ADVANCED AND CONTEMPORARY STUDIES IN AGRICULTURE, FOREST AND WATER ISSUES

Editors
Prof. Dr. İbrahim CENGİZLER
Assoc. Prof. Selçuk DUMAN

DUVAR

ADVANCED AND CONTEMPORARY STUDIES IN AGRICULTURE, FOREST AND WATER ISSUES

Editors

Prof. Dr. İbrahim CENGİZLER

Assoc. Prof. Selçuk DUMAN

ADVANCED AND CONTEMPORARY STUDIES IN AGRICULTURE, FOREST AND WATER ISSUES
Editors: Prof. Dr. İbrahim CENGİZLER, Assoc. Prof. Selçuk DUMAN

Editor in chief: Berkan Balpetek
Cover and Page Design: Duvar Design
Printing : December -2023
Publisher Certificate No: 49837
ISBN: 978-625-6643-40-6

853 Sokak No:13 P.10 Kemeraltı-Konak/İzmir
Tel: 0 232 484 88 68

www.duvaryayinlari.com
duvarkitabevi@gmail.com

TABLE OF CONTENTS

Chapter 1

Afforestation To Struggle Wind Erosion

Endam ÖZKAYA[1]

1. INTRODUCTION

Soil is the one of basic requirements of life for all living things is an indispensable natural resource. Just as all living things need air and water, they need soil just as much. There are many reasons why soil is so active in the life of living things. These; It can be counted as providing a living environment for living things, regulating the climate, providing food, fiber, fuel and raw materials for many sectors, controlling the risk of flood and flood, playing an active role in the carbon and nitrogen cycle. It directly or indirectly affects people and other living things in many issues such as the regulation of social life. With the transition of societies to settle life, civilizations and cultures were formed, technology developed and agricultural activities began to increase. People have started to cultivate the land for purposes such as access to healthy food, feed for animals and trade. However, the methods used in tillage have remained primitive with the development of technology over time and have begun to cause the soil structure to be negatively affected and the fertile layers to be damaged. Thus, the structure and texture of the soils began to be damaged, causing unpredictable climatic conditions. However, it would be wrong to say that there is only human influence in soil degradation. The natural climatic conditions to which the soil is exposed can be listed as natural factors affecting soil degradation in situations beyond human influence and control, such as topographic and geological structure.

Incorrect tillage methods, excessive irrigation and fertilizer use, or on the contrary, the use of less water and fertilizer than necessary, unplanned construction, etc. They are natural factors that cause soil degradation and negatively affect soil fertility in disasters such as flood and overflow disasters, drought risk and erosion. A well-nourished fertile soil becomes resistant to all kinds of damage (1). While floods and flood disasters have many negative effects such as carrying the fertile layers of the soil, turning it into mud, making it difficult to work, decreasing the oxygen rate of the soil and causing the accumulation of toxic substances, drought is caused by the lack of precipitation

[1] Kilis 7 Aralik University, Graduate School of Natural and Applied Sciences,
Department of Horticulture,Kilis/TURKEY
*corresponding author: endamozkaya44@gmail.com, Orcid no:0009 0000 2616 0633

due to the effect of the climate, thus reducing the moisture level, barrenness and salinity of the soil. It is a natural disaster that causes the plant life to increase and cause it to become a state that does not allow plant life. Erosion, on the other hand, can be defined as the process of erosion of the fertile layer of the soil and accumulation by moving from one place to another with the effect of precipitation waters or wind, which can occur due to human influence as well as natural processes. Erosion caused by human action is called accelerated erosion, while erosion that occurs as a result of natural processes without human influence is called geological erosion. While accelerated erosion occurs rapidly and more dangerously than geological erosion in sloping areas with heavy rainfall, geological erosion occurs much more slowly. The two forces that activate erosion are water and wind. The transport of the soil as a result of excessive precipitation is called water erosion, and the transport by strong winds is called wind erosion. Water erosion occurs when the fertile layer slides in the direction of the surface flow, as a result of excessive rainfall in slope areas, which cannot withstand the gravity as a result of the soil's absorption capacity. Wind erosion, on the other hand, has less bearing capacity compared to water erosion, but it occurs as a result of soil being transported and piled up in another area as a result of strong winds.(URL-1)

In this study, wind erosion, which is one of the erosion types that has a negative effect on soil structure and fertility, is discussed. The definition of wind erosion, its situation and effects in the world and in Turkey, and the importance of afforestation in combating wind erosion are mentioned.

2. WIND EROSION

Wind erosion is the movement of soil particles with the effect of the wind and their accumulation in another place. Wind erosion occurs as a result of the breaking of the resistance power of the soil to erosion by the effect of strong winds. With the force of the wind, the topsoil material is transported in the form of dust clouds in the direction of the wind blowing direction and this top material accumulates in places where there is no vegetation, causing small hills to form.(URL-1) Wind erosion affects precipitation, wind force, soil structure, texture, organic matter content. and the roughness of the surface, vegetation, the intensity of agricultural activities, depending on the interaction of methods used in agriculture (URL-1). It is a natural disaster that causes the loss of fertile layers of the soil by transport and desertification with the dune masses it brings. While wind erosion causes the soil to lose its properties in the areas where it starts, it also negatively affects the lands it passes over in the form of dust clouds during transportation. When its power decreases, it leaves this dust cloud

on the land and changes the soil structure of this land it is transported to. Irregular precipitation regime, high temperature differences, high average summer temperatures and the excessive evaporation that it brings are conditions that trigger wind erosion (2). Wind erosion occurs in flat lands with loose and fine soil, where no precautions are taken against the strong effects of the wind. Although arid and semi-arid areas are sensitive areas for wind erosion, soils poor in organic matter, areas with excessive and free grazing, areas with excessive tillage, bare areas without vegetation, light soils with high sand content in terms of structure, excessive evaporation or Clay soils with low moisture content as a result of excessive tillage are areas with high wind erosion sensitivity, erosion triggering and severe exposure. The formation of crust on the soil surface, aggregation, sufficient soil and air humidity are the conditions that have a reducing effect on wind erosion. Wind erosion can occur in different areas such as forests, deserts and farmland. It is usually formed by the movement of the soil by three different movements. These are drifting, jumping and hanging movements. The suspended movement, also called suspension, is the movement of soil particles smaller than 0.1mm suspended in the air in the form of a dust cloud, while the jumping movement is the movement that causes the 0.05-0.5mm-sized particles that are too large to be suspended in the air to be carried by jumping. Drifting is the motion of pushing and rolling soil particles 0.5-2.0mm in size by the force of the wind. Soil particles carried by wind erosion are carried by 3%-38% suspension, 7%-25% jumping, 55%-72% drifting movement.(URL-9) Therefore, wind erosion sweeps the fertile surface of the soil as a result of these movements, accumulates in hilly or pitted areas, pollutes the air and causes reduced visibility. It starts by rolling the soil particles in the direction of the breeze with light winds and then turns into dust storms with the intensification of the wind (URL-3).

2.1. CAUSES OF WIND EROSION

The effect of humans and natural factors on the formation of wind erosion is great. The main reasons that trigger the formation of this erosion are;

- Thinning of the structure of the soil by over-processing,
- Allowing animals to graze freely in pastures and meadows, and damage to ground cover and shrub plants in these areas,
- Deforestation and destruction of existing vegetation,
- Leaving the soil uncovered in fallow practices in agricultural areas,
- Agricultural soils with insufficient amount of organic matter and exposing these soils to excessive tillage,

• Plowing the soil only by turning it upside down with mechanical tillers and plowing without making large cuts,

• Plowing in strong wind periods,

• Traffic with heavy-duty vehicles on the agricultural land and the soil crumbling and turning into dust with this pressure,

• Burning of stubble fields,

• Low precipitation regime and high summer temperatures in arid areas and low moisture content of the soil due to excessive evaporation (2).

2.2. FACTORS AFFECTING WIND EROSION

2.2.1. Climate

Climatic factors affecting wind erosion; precipitation regime, temperature averages and temperature differences, wind, humidity and air density. The fact that the precipitation is less than normal throughout the year and triggers drought by bringing with it high summer temperatures will reduce the resistance of the soil that is not saturated with water and moisture in these areas to the abrasive forces of the wind, and if it is more than normal in sloping areas, it will cause wind erosion along with the surface flow. Wind, on the other hand, is the breeze that occurs as a result of the displacement of the air by interacting with the ground surface, and when it gets stronger, it is the main factor that causes wind erosion by activating the soil surface. Features of wind affecting erosion; velocity, direction, duration and turbulence. The soil, which loses its moisture with drought, becomes prone to wind erosion with the effect of these characteristics. Having an appropriate level of soil moisture will ensure that soil particles adhere to each other with the effect of cohesion and will be less affected by erosion. Again, freezing and thawing events that occur on the soil surface due to the effect of climate are also conditions that make the soil prone to wind erosion (URL-9).

2.2.2. Soil

Soil properties affecting wind erosion; soil structure, texture, grain density, bulk weight, organic matter content, moisture content and surface roughness. Wind erosion is almost inevitable in flat and bare lands with sandy, loose, fine-grained and dry soils. The looser and lighter the soil, the lower its resistance to the abrasive effects of the wind. Since the soil has a moisture-binding feature, we can say that clay soils with appropriate moisture content are the soils with the most suitable structure in preventing wind erosion. However, intensive tillage may decompose the particles in these soils and cause a decrease in resistance to erosion. In addition, the higher the particle density of the soil, the

less likely the wind will affect this soil negatively. Tillage also affects resistance to erosion. Over-cultivated soils become resistant to erosion (3;4). The organic matter content of the soil also affects its resistance to erosion. Organic materials cause soil particles to aggregate and bind to each other, thus increasing resistance to wind erosion. The roughness of the soil surface makes it difficult for the wind to sweep the top layer of the soil, and the wind cannot move freely as in flat areas and constantly encounters obstacles. Thus, leaving the soil surface rough prevents wind erosion and prevents the loss of nutrients from the soil (URL-9).

2.2.3. Vegetation

The frequency, length, type and seasonal distribution of vegetation are the characteristics that play an important role in combating wind erosion. Because a land covered with vegetation is resistant to wind erosion. Plants reduce wind speed and trap soil particles. They act as a shield against the wind in areas exposed to strong winds. Thus, they save agricultural lands from exposure to erosion and contribute to the fertility of the soil and the preservation of the quality and quantity of the products. The wind curtain application used in agricultural lands is the most important method of combating wind erosion in this regard. Because applications using live plants suitable for local conditions are more effective and sustainable than applications using inanimate cover (URL-9).

2.2.4. Human İmpact

In addition to climate, soil and vegetation, another factor that creates erosion and causes it to increase is of course human. Mistakes made by people in tillage, ignoring the practices that will ensure its sustainability, unplanned construction and non-purpose land use is activities that increase the risk of accelerated erosion. With excessive tillage methods, both the creation of traffic density in agricultural lands, the crumbling and separation of soil particles with excessive ploughing, excessive use of water and fertilizer or on the contrary, the use of less water and fertilizer, occupation of the lands to be used for agricultural purposes with construction and agricultural land towards the slopes. Applications such as the tendency to build up, intensive crop cultivation and exploitation of organic matter in the soil for profit, not covering the soil surface with appropriate covers in fallow applications, allowing free grazing, opening the afforestation areas for construction are applications that cause wind erosion to occur with human influence.

3. WIND EROSION IN THE WORLD AND IN TURKEY

3.1. Wind Erosion on Earth

Wind erosion is the process of transporting and accumulating soils as a result of the interaction of the wind and the topsoil in areas with arid and semi-arid climatic conditions. Wind erosion poses a significant threat in deserts, in areas with large coastal dunes, and in areas with light-textured soils with high sand content. Almost 40% of the world's population is exposed to the adverse effects of the arid climate. Wind erosion is a natural phenomenon that poses a risk in these regions where there is drought, and it causes economic, environmental and social damages in the areas where it occurs. Although there are many countries in the world that have been exposed to wind erosion from time to time, wind erosion, which is called the 'Dust Bowl', which affected the Canadian meadows and the USA in 1930, can be given as an important example that causes great losses. This natural event, caused by winds reaching 100 km/h, caused serious damage to agriculture and ecology and caused tens of thousands of people to migrate. Experts explained the reasons for dust bowl as excessive and wrong agricultural activities, overgrazing of animals and drought. This event has been called one of the worst ecological disasters caused by wind erosion in history. The same region was exposed to dust storms 14 times in 1932 and 38 times in 1933. It is known that serious dust storms were experienced again in the 1950s (URL-4).

Fig.-1: ABD Dust Bowl Wind Erosion-1930 (URL-5)

Again, the share of the wind in the erosion experienced in the Sahel Belt in Africa in 1968-1973 is quite large. became in need of food aid. This process directly or indirectly affected the population of approximately 50 million people (URL-7). With the desertification brought about by erosions caused by water and wind; Africa, the Middle East, Australia, Southwest China, western parts of South America and our country are at risk. According to UNCCD data, 70% of arid areas have already been damaged by water and wind erosion. With the effect of water and wind, approximately 24 billion tons of topsoil layers are lost in these areas every year. The top layer of the soil is rich in organic matter

content and is the most important layer on which agricultural activities are generally dependent. The disappearance of this layer brings with it social, economic and environmental disasters. This condition affects approximately 1.2 billion people. While approximately 135 million of this population are at serious risk, 10 million of them are forced to migrate due to health and economic problems (9)

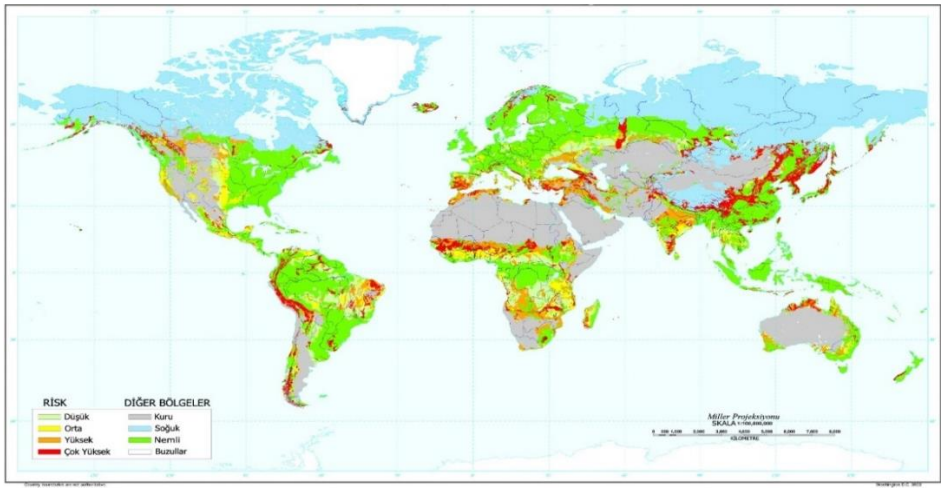


Fig.2: Distribution of Wind Erosion Risk in the World (URL-6)

Today, in areas exposed to wind erosion from time to time, different methods of struggle are used in accordance with the severity of erosion, the way it is transported and the geography it affects. Generally, with the destruction of vegetation, the direct contact of the wind with the soil surface has brought along large wind erosion events and desertification. The people living in these areas affected by erosion have been directed to afforestation activities as well as economic and psychological support. Afforestation is the most economical and sustainable application in the fight against erosion, due to many other features of plants such as collecting dust, filtering the air, contributing to soil organic matter. Therefore, in the Dust Bowl disaster in South America, the public was first encouraged to afforestation, dead trees were removed and new ones were planted. Likewise, in the erosion disaster in Africa, against dust storms coming from the Sahara Desert, it is 15 kilometers wide, 7,775 meters across the border lengths of Djibouti, Eritrea, Ethiopia, Sudan, Chad, Nigeria, Mali, Senegal, Burkina Faso and Mauritania to the Sahara Desert. Projects have been carried out to create a green wall up to a kilometer long (URL-7)

Fig.3: Africa/Sahel Belt Wind Erosion and Green Wall Project (URL-7)

3.2. Wind Erosion in Turkey

Due to the geography it is in, Turkey has different climate types including humid, semi-humid, arid, semi-arid and even extremely arid and desert belts. Faces danger. This danger shows its effect much more during the year in the Central Anatolia and Southeastern Anatolia regions (7). These areas exposed to the negative effects of drought and erosion due to human influence and climate change are gradually increasing. Wind erosion is a serious problem in our country from time to time, and it causes the formation of large sand dunes that cause soil degradation, do not allow agriculture, and affect social life significantly. As a result of wind erosion, land sand dunes on approximately 500,000 hectares of land in the provinces of Konya, Kayseri, Niğde, Iğdır and Manisa in Turkey; On the Mediterranean, Black Sea and Aegean coasts, beach dunes were formed on an area of 29.000 hectares. While land dunes are mobile sand dunes formed in streams and stream beds in areas far from the sea, beach dunes are dunes formed by the movement of fine sand to the beach by waves and wind in areas where streams flow in areas close to the sea. The removal of vegetation in these areas and the intensive and continuous cultivation of soil caused the soil to lose its fertility. Thus, with the effect of strong winds, fertile soils were replaced by sand dunesTürkiye is in a position with ecosystems sensitive to water and wind erosion. In the world wind erosion risk distribution map (FIGURE-2) Central Anatolia is indicated as one of the areas most exposed to wind erosion in the world. As a matter of fact, the severe wind erosion experienced in Konya/Karapınar in the Central Anatolia Region in the 1960s is an important proof of this situation. The removal of the existing vegetation, the plowing of pastures, the use of excessive processing methods that harm soil fertility in agriculture in order to gain profit, and the deficiencies in irrigation have caused the soil surface of this area to be eroded by the effect of strong winds and to form large land dunes. Konya is the place where wind erosion is the main land degradation problem and 69.22% (322 474 ha) of the danger affecting 465 913 hectares of land across the country occurs within the borders of this province (10). Another important wind erosion site in our country is

located in Iğdır/Aralık. Iğdır / December, which is a microclimate area with semi-arid climatic conditions, has 13,554 hectares of land dunes after Konya, and is the second largest area exposed to wind erosion in our country. Iğdır/Aralık, which has sandy, loamy, low water holding capacity, insufficient organic matter and plant nutrients, is in a region exposed to strong winds and unsuitable for agriculture (5). Areas such as Manisa/Akselendi Plain and Kayseri/Sultansazlığı, Develibatisi are also examples of land dune formations under the influence of the wind (URL-9).

3.2.1 Wind Erosion and Combat Studies in Konya/Karapınar Region

Karapinar; It is a district of Konya with a surface area of 2675 km2 and a population of 42,259. It is surrounded by Konya Plain in the north and west, Karacadağ in the east, Andıklı, Small and Big Katran Hills in the south. The district lies between 37.50-38 east longitude and 33.10-34.10 north latitude. It is at an altitude of 1026 m above sea level. (2) The district, which is located in the Central Anatolia region and has an arid continental climate, is in the region that receives the least rainfall in Turkey. The annual average precipitation is 275 mm. The average temperature is 11 °C and the prevailing wind direction is North-Northeast. The annual average wind speed is 3.5 m/s. The winds that cause erosion are blowing from the South-Southwest direction and the wind speed in the district can sometimes reach up to 110 km/h. It is possible to encounter alluvial, colluvial, sierozem and regosol soil groups in the lands of the district, which was exposed to severe wind erosion in 1960. In the lands of the district where wind erosion is observed, it is generally light in the upper soils; It has a loamy and sandy surface. When the profile depth is examined, clayey heavy soil structure is observed. While the soils of the district are rich in lime and potassium, they are quite poor in terms of organic matter and phosphorus content. 1 030 000 decares of the district, which has 1 595 000 decares of agricultural land, has been destroyed as a result of wind erosion. The district, which consists of 43,000 decares of black sand; covered by dust clouds, dunes were formed and agricultural lands were at risk of losing their productivity. The resulting sandstorms left the people of the district in a difficult situation economically and socially. The lands of the people who made their living from agricultural activities were damaged and people had to migrate due to these dust storms. Dust clouds caused health problems, reduced visibility and even caused the highway connections to the district to be closed by sandstorms (URL-8).

The Karapınar region is an old lake bed, and as this lake dries up over time, the dune beds at its base have come to the surface. The fact that sea shells are

occasionally found on the territory of the region confirms this view. These dunes, which came to the surface, mixed with agricultural lands with the effect of strong winds and caused a decrease in soil fertility. In addition, its continental climate, which is exposed to extreme summer temperatures, makes the region vulnerable to wind erosion. The pastures have been destroyed as a result of widespread ovine breeding in the district, grazing from the bottom and overgrazing, and the removal of plants such as geven, tapir and mullein, which are not consumed by animals but have soil-holding properties. The fact that the agricultural lands exposed to excessive tillage are under the influence of strong winds has also made the district lands vulnerable to wind erosion. The first struggle with this wind erosion experienced in Karapınar was started in 1962 by the General Directorate of TOPRAKSU, one of the units forming the General Directorate of Rural Services (KHGM). Initially, an area of 160,000 decares was surrounded by wire fences and tried to be protected. Later, KHGM started to carry out control, protection, production and research activities under the name of Research Substation. The first reclamation works were carried out on the 43.000 decares of land, which was determined to be sensitive to erosion in the first degree, located in the southwest of the district, 7 km from the Karapınar district. This place has become a complete desert and the vegetation has been destroyed. Crescent-shaped dunes with a height of 40-45 meters, a width of 50-60 meters and a length of 250-300 meters were formed on the land. Since the interaction of the wind with these dune dunes may cause greater erosion, studies have been started in this area primarily. Many physical and cultural precautions have been taken in this area. Curtains 1.5-2 m high were formed from the reeds. The speed of the wind was tried to be broken by leaving 12-20m distances between these curtains. After these curtains were installed, the spaces between them were grazed. Thus, one-to-one contact of the wind with the soil surface is cut off. In the grazing study, heat and drought resistant plants such as sand rye and grass weed were used. After the grazing work was completed, afforestation studies were carried out that completely restricted the soil movement. In the afforestation work, plants such as maple, ash, acacia, oleaster, which are suitable for the local, were used (URL-8).

Fig.4: Konya/Karapınar Reed Screening Application-1962(URL-11)

As a result of all these studies, agricultural activities have started to be carried out on an area of 20 thousand decares with the strip-like planting method in Konya Karapınar today. The area of 15 thousand decares, which has turned into a dune area, has been turned into pasture and every year pine, cedar and so on. Coniferous trees continue to be planted. About 700 thousand almond trees have been planted and maintained on Ketir Hill, which is under the influence of erosion. An area of 43 thousand decares consisting of dune hills has been made forested with afforestation works. While the area of 40 thousand decares under protection has been turned into a pasture area covered with vegetation, an area of 6 thousand decares has been separated as vineyard-garden area and controlled agriculture has begun. It is proof that planting has important effects in stopping erosion.

4. METHODS OF PROTECTION AGAINST WIND EROSION

Fight against wind erosion; It can be achieved by controlling the wind speed at the surface and the properties of the soil. In order to control soil properties, soil infiltration should be increased, evaporation should be reduced, and plants and organisms that use excess water should be removed from the soil. This contributes to soil moisture and prevents the wind from easily sweeping and carrying the soil. Because, moist soil particles are tightly attached to each other and are less affected by strong winds. Therefore, it is recommended as a very important application, especially in arid and semi-arid areas, which are sensitive to wind erosion, immediately after the spring rains, as it will increase the adhesion of the particles to each other, which will form aggregates and clods with high volume in the soil (URL-12). In order to control the wind speed on the surface, it can be done with plants, correct soil cultivation practices and some mechanical measures. Herbal measures; These are the measures taken by growing agricultural products with binding properties in the soil, using a strip-like planting arrangement, and installing wind curtains. Thus, while contributing to soil moisture with vegetative measures, a physical barrier is

created against the wind. With the use of the right tillage methods, cuts are created in the soil and the surface roughness is increased, so that the soil aggregates and its sensitivity to the wind are reduced. By using normal plows instead of disc plows in processing, the crumbling of the soil is prevented. Because; disc plows are causes ploughing by scattering the soil, which reduces the resistance against the wind. Wind curtains are another herbal precaution method. This method is to surround fertile soil with trees and shrubs that act as shields against wind erosion. Thus, fertile soils, the products grown are protected from dust and snow storms, and the loss of soil moisture is reduced. In addition, thanks to the plants used, the soil is beneficial in terms of organic matter. Another important measure against wind erosion is mechanical measures. Artificial wind curtains can be given as an example of this precaution method. It is a temporary method against sand dune movements in the first stage of erosion with the artificial screening method. Dune mobility is stopped with reed, wood, plastic fences, and then by grazing and afforestation between these curtains, definite and permanent measures are taken against erosion.(URL-12)

4.1. The Importance of Afforestation in Combating Wind Erosion

The common point of all these wind erosion disasters in the world and in our country is undoubtedly the destruction of vegetation. With the disappearance of vegetation, areas that are already sensitive in terms of climate and topography turn into dune areas that are completely unsuitable for agriculture and production due to the strong winds. Therefore, the first measures taken in all these events are the initiation of artificial screening and afforestation, apart from economic and social measures. Screening can be done with living or non-living material. In areas subject to severe wind erosion, reed, wood, plastic fence etc. Temporary measures are taken to break the speed of the wind with inanimate materials. Afterwards, grazing and afforestation works are started. These grazing and afforestation studies initiated using live plants are definite and permanent solutions in the long term. Afforestation using locally suitable plant species is the most economical and sustainable method in combating wind erosion. Windbreaks, also called windbreaks, are afforestation methods in the fight against wind erosion and are considered an effective method in preventing wind erosion by preventing the loss of moisture content of the soil, the scavenging of the fertile layer, the reduction or transport of soil organic matter. Preferring perennial plants that are resistant to drought and strong winds, suitable for the local area, have a long root depth, can grow quickly, can branch from the bottom, and reach a certain height and crown diameter, are preferred,

because they provide less maintenance and less energy consumption in the long term, wind curtains, combating wind erosion It is the most effective and sustainable method. These curtains made of trees are placed perpendicular to the prevailing wind direction, so that they serve as counter-shields in strong winds. The height of the plants to be used in 10-15 years and the distances between them should be well planned. In curtain systems to be installed in two or more rows, the row spacing is 4.5m; There should be a maximum distance of 2.4m above the row. These dimensions are general measurements. In such planning, the crop pattern of the land, the tools and equipment used in tillage, the size of the parcels, the irrigation systems used and their management should be taken into consideration. Thus, the distances between the curtains are well adjusted and the risk of erosion is minimized without interrupting any work. Windscreens can be somewhat costly and take a long time to install. However, when considered in the long term, it saves energy, causes an increase in soil organic matter, and increases the productivity of the land it protects by 10%-20%. Thus, in a few years, the cost of its installation is amortized. It is very important to make the right planning and design in order to ensure their sustainability. It can be installed as a single or double row according to the need, or it can be built using trees or bushes. This completely depends on the slope, height and wind speed of the land on which it is established (8).

Windbreak curtains are facilities consisting of trees, shrubs and bushes that are established in long and narrow strips to control the wind. It ensures the protection of the soil, water and the products grown on the land where it is established. It absorbs the speed of the wind and reduces the carrier effect it will create on the soil surface. It will protect the land from heavy snowfall and blizzards, as well as help snow accumulation and soil moisture. It prevents the seeds of the crops grown on the land where it is established from being carried by the wind, thus increasing the yield obtained from the unit area. It prevents the deterioration of the physical structure of the products in the ripening period due to the effect of the wind. It protects agricultural areas and residential areas from dune movement, thus providing healthier areas for the continuation of activities. It also protects water resources from the negative effects of dune movement. Thus, access to healthy water is facilitated and it saves the energy to be used for water purification. Trees used in wind curtains can protect areas 10-15 times their own height. Thus, it prevents noise and increases visibility, which is narrowed by dust clouds. In addition, since plants have the ability to filter the air, it provides cleaner air and environment for humans and animals (URL-12).

Fig.5: Example of Wind Curtains (URL-22)

Rainwater harvesting practices also protect the soil against erosion (11;12). Especially mulch applications provide protection by keeping the soil surface covered and reducing the power of the wind (13).

5. CONCLUSION AND RECOMMENDATIONS

Soil is one of the basic necessities of life for humans and is a non-renewable natural resource. Therefore, the soil should be protected from all kinds of natural disasters and calamities, as well as from human intervention. People cannot control these natural disasters and disasters, but they can take some measures to minimize the negative effects they may create. Erosion can be caused by natural factors as well as by human influence, and if it cannot be controlled, it can turn into a natural disaster that seriously threatens both soil and human health. The two forces that trigger erosion are water and wind. Erosion caused by water is the type of erosion that is more destructive and has great effects in our country, while wind erosion is less common than water. However, this does not mean that it does not have negative effects. Areas exposed to wind erosion, where strong winds are effective, unfortunately turn into unhealthy, arid and desert areas unsuitable for agricultural activities and settlement. Therefore, ensuring sustainability in natural resources, continuity of soil and food security, and erosion control practices for a healthy environment are of great importance.

wind erosion; Excessive and untimely agricultural processing and crumbling of the soil as a result of mechanical tools, not covering the soil with any cover in fallow applications in agricultural areas, allowing free grazing in pastures and meadows, deforestation and destruction of natural vegetation, natural characteristics of the soil (structure, texture, organic matter). It is a natural phenomenon that has a dangerously destructive effect in areas exposed to strong winds that are flat and close to straight, which occur due to erosion sensitivity in terms of its content, etc. In order not to endanger the soil and the living things living in the soil, necessary precautions should be taken in advance in areas

prone to wind erosion. Many different methods are used to combat wind erosion. These; using this right tillage methods, taking mechanical and vegetative measures, and taking measures to protect and increase soil moisture. The implementation of these measures at the appropriate time with the right planning will increase the resistance of the soil to the negative effects of the wind. Mechanical measures, which are among the methods of struggle, have the feature of stopping wind erosion, but they do not offer a definitive solution in the long run. Vegetative measures and afforestation method with wind curtains is an effective method that provides economic, ecological and social contributions when planned with an understanding of sustainability in the long term. Windbreaks are facilities consisting of trees, shrubs and shrubs established in long and narrow strips in order to control the wind, which ensure the protection of soil, water and the products grown on the land where they are established. They absorb the speed of the wind and reduce the carrier effect it will create on the soil surface. Windscreens using locally suitable plant species require less maintenance and cost, contribute to soil organic matter and moisture, act as a shield against dust storms and filter the air. Thus, energy savings are achieved and the efficiency obtained from the unit area increases. Thus, while protecting the soil, it contributes to its productivity and sustainability. In line with all these measures, another important issue is the monitoring and evaluation of this whole process. Within the scope of combating wind erosion, it is of great importance to monitor and evaluate each stage. The development of the methods applied in the struggle should be monitored and the success situation should be evaluated continuously. Thus, the process of re-adaptation of people and other living things living in areas subject to erosion is facilitated and improvement works are accelerated.

REFERENCES

(1) Gokcen, I. S., and Kuzucu, M. (2023). Soil quality and fertility in vineyards of Kilis province of Turkey, the northwest of “fertile crescent”. Emirates Journal of Food and Agriculture. 2023. 35(7), p: 657-665 doi: 10.9755/ejfa.2023.v35.i7.3116

(2) Karaoglu, M. (2018). The Importance of Vegetation in Wind Erosion.-T.C. Iğdır University, Iğdır Faculty of Agriculture, Department of Soil Science and Plant Nutrition- Review article/Review article/ Journal of Agriculture 1(2), 49-60, 2018 /12 p.

(3) Kuzucu, M., & Dökmen, F. (2015). The Effects of Tillage on Soil Water Content in Dry Areas. Agriculture and Agricultural Science Procedia, 4, 126-132.

(4) Kuzucu, M. (2019). Effects of soil tillage methods and organic fertilization on yield and soil organic matter in sloping olive orchards of Kilis. Fresenius Environmental Bulletin, 28(1), 446-451.

(5) Karaoglu, M. (2018). Wind Erosion Studies in Iğdır-December.- T.C. Iğdır University, Iğdır Faculty of Agriculture, Department of Soil Science and Plant Nutrition/Review article/ Journal of Agriculture 1(2), 25-38, 2018

(6) Karaoglu, M. (2018). Wind Erosion.- T.C. Iğdır University, Iğdır Faculty of Agriculture, Department of Soil Science and Plant Nutrition/Review article/Review article/ Journal of Agriculture 1(2), 11-24, 2018

(7) Özkaya, E. & Kuzucu, M. and Gökçen, İ.S. (2023). “Sustainable Soil Management in Dry Areas” / Agriculture, Forestry and Fisheries Book in a Globalizing World, ISBN: 978-625-6945-39-5 Editor: Prof. Dr. Alaeddin BOBAT/ Part:2, p.29-50.

(8) Ministry of Agriculture and Forestry / General Directorate of Combating Desertification and Erosion (2019). National Strategy and Action Plan to Combat Desertification 2019-2030/ 128 p.

(9) Mevlana Development Agency Project Name Tr52-11-Td01/74 (2012) Combating Erosion And Afforestation Master Plan/ 12 P.

(10) Ministry Of Agriculture And Forestry / General Directorate Of Combating Desertification And Erosion (2021). 'Preparation Of National Wind Erosion Risk Map' Project, National Dynamic Wind Erosion Model And Monitoring System (Udremis)/8 P.

(11) Kuzucu, M. (2017). Effects Of Water Harvesting Techniques And Using Humic Acid On Soil Moisture, Plant Evaporation, Growth And Yield In Pistachio Orchards In Southeastern Of Turkey. Fresenius Environmental Bulletin, 26(12), 7521-7528.

(12) Kuzucu, M., Dökmen, F., & Güneş, A. (2016). Effects Of Climate Change On Agriculture Production Under Rain-Fed Condition. International Journal Of Electronics Mechanical And Mechatronics Engineering, 6(1), 1057-1065.

(13) Yazar, A., Kuzucu, M., Celik, I., Sezen, S. M., & Jacobsen, S. E. (2014). Water Harvesting For Improved Water Productivity In Dry Environments Of The Mediterranean Region Case Study: Pistachio In Turkey. Journal Of Agronomy And Crop Science, 200(5), 361-370.

URL-1: https://topraktema.org/kategoriler/yok-olan-toprak/nas%C4%B1l-yok-ollu/erozyon/ Access Date:10.04.2023

URL-2: https://topraktema.org/topragin-islevleri/ Access Date:10.04.2023

URL-3: https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/wind-erosion/Access Date:30.03.2023

URL-4: https://www.softschools.com/facts/us_history/dust_bowl_facts/814/Access Date:30.03.2023

URL-5: https://www.nationalgeographic.com/travel/article/141229-dust-bowl-grapes-of-wrath-drought-migrants-family-trip11 Accessed:30.03.2023

URL-6:https://tr.wikipedia.org/wiki/Dosya:Rüzgâr_eroziyon_risk_dağımı.jpg/ Accessed: 30.03.2023

URL-7: https://www.yesilist.com/afrikanin-mucadelesi-sahra-colune-karsi-orulen-yesil-duvar/ Access Date:30.03.2023

URL-8: https://arastirma.tarimorman.gov.tr/konyatopraksu/Menu/13/Tarihcemiz/ Access Date:30.03.2023

URL-9: https://ktu.edu.tr/dosyalar/havzaamenajmani_05ae4.pdf /Access Date:30.03.2023

URL10: https://acikders.ankara.edu.tr/pluginfile.php/135144/mod_resource/content/0/8.%20Hafta.pdf/ Accessed on:10.04.2023

URL-11:https://www.memleket.com.tr/ruzgar-erosyonyla-collesen-saha-agaclandirilarak-yeniden-kazanildi-1548751h.html/Access Date:11.04.2023

URL-12: https://ktu.edu.tr/dosyalar/havzaamenajmani_c565a.pdf /Access Date:07.04.2023

URL-13: https://dkm.org.tr/uploads/yayinlar/1585519247049.pdf /Access Date:12.04.2023

Chapter 2

Exploring the Potential of Phase Change Materials in Wood-Based Applications: A Comprehensive Review

Ahmet CAN[1]

Abstract − The interesting field of phase change materials (PCMs) and their numerous uses is explored in this review paper, with a special emphasis on how PCMs can be used in conjunction with wood-based materials. The classification of PCMs, their innate characteristics, and their many applications are only a few of the subjects that are covered in this article. Additionally, it emphasizes the ground-breaking method of microencapsulation as a successful way to improve PCM performance, particularly in minimizing washing-related problems. The paper then examines the use of PCMs in wood, clarifying the benefits and difficulties of this symbiotic interaction. The paper highlights the growing interest in using wood as a substrate for PCM integration and the distinctive advantages it offers by looking at existing literature studies. Wood is a desirable option for PCM integration due to its intrinsic porosity, thermal stability, and renewable nature, offering potential for a variety of applications. The essay highlights the benefits of wood-based PCMs, such as enhanced energy efficiency, thermal management, and sustainable design, through careful examination. It also highlights how wood-based PCMs could help create eco-friendly structures, effective thermal energy storage systems, and cutting-edge thermal management techniques. Researchers, engineers, and business executives interested in the developing subject of phase change materials and its integration with wood-based materials may find this comprehensive compilation to be a valuable resource. It offers insights into the subject's potential, analyzes present trends and obstacles, and gives a full understanding of the subject. It gives readers a complete overview of the field, discusses current issues and trends, and sheds light on how wood-based PCM applications can develop in the future.

Keywords − Phase Change Materials, wood, energy storage

[1] Department of Forest Industrial Engineering, Faculty of Forestry, Bartin University, Bartın, Turkey

Odun Esaslı Uygulamalarda Faz Değiştiren Malzemelerin Potansiyelinin Araştırılması: Kapsamlı Bir İnceleme

Öz − Faz değiştiren malzemelerin (PCM'ler) ilgi çekici alanı ve bunların sayısız kullanımları bu inceleme makalesinde incelenmekte olup, PCM'lerin ahşap bazlı malzemelerle birlikte nasıl kullanılabileceğine özel bir vurgu yapılmaktadır. PCM'lerin sınıflandırılması, doğuştan gelen özellikleri ve birçok uygulaması bu makalede ele alınan konulardan sadece birkaçıdır. Ek olarak, çığır açan mikrokapsülleme yönteminin, özellikle yıkamayla ilgili sorunları en aza indirmede PCM performansını artırmanın başarılı bir yolu olduğunu vurguluyor. Makale daha sonra PCM'lerin ahşapta kullanımını inceleyerek bu simbiyotik etkileşimin faydalarını ve zorluklarını açıklığa kavuşturuyor. Makale, mevcut literatür çalışmalarına bakarak ahşabın PCM entegrasyonu için bir alt tabaka olarak kullanılmasına yönelik artan ilgiyi ve sunduğu ayırt edici avantajları vurgulamaktadır. Ahşap, çeşitli uygulamalar için potansiyel sunan, kendine özgü gözenekliliği, termal stabilitesi ve yenilenebilir doğası nedeniyle PCM entegrasyonu için arzu edilen bir seçenektir. Makale, dikkatli bir inceleme yoluyla ahşap bazlı PCM'lerin gelişmiş enerji verimliliği, termal yönetim ve sürdürülebilir tasarım gibi faydalarını vurgulamaktadır. Ayrıca ahşap bazlı PCM'lerin çevre dostu yapılar, etkili termal enerji depolama sistemleri ve son teknoloji termal yönetim teknikleri oluşturmaya nasıl yardımcı olabileceğini de vurgulamaktadır. Faz değiştiren malzemelerin geliştirilmesi ve ahşap bazlı malzemelerle entegrasyonu konusuyla ilgilenen araştırmacılar, mühendisler ve şirket yöneticileri bu kapsamlı derlemeyi değerli bir kaynak olarak görebilirler. Konunun gelecekteki potansiyeline dair öngörüler sunar, mevcut eğilimleri ve engelleri analiz eder ve konunun tam olarak anlaşılmasını sağlar. Okuyuculara alana ilişkin eksiksiz bir genel bakış sunar, güncel sorunları ve eğilimleri tartışır ve ahşap tabanlı PCM uygulamalarının gelecekte nasıl gelişebileceğine ışık tutar.

1. Introduction

With the world's economic growth, energy consumption has surged significantly, with fossil fuels accounting for 81 percent of the market. However, using fossil fuels has a significant negative impact on the environment and the economy since it results in the release of dangerous gases into the atmosphere, which makes people more concerned about the environment. In addition, fossil fuels are running out, thus we need to find other energy sources to fulfill the rising demand. Solar, wind, and geothermal energy are examples of renewable energy sources

that have the potential to meet the world's energy demands in a way that is environmentally responsible and sustainable. A research by Jacobson et al. (2015) found that switching to only renewable energy sources by the year 2050 is both technically and financially possible and will greatly reduce greenhouse gas emissions and air pollution, as well as generate employment and save lives (Memon, 2014; Jacobson et al. 2015).

The subject of thermal energy storage (TES) is quickly expanding as a result of the rising significance of energy efficiency and the requirement to use non-renewable energy sources more effectively. Since TES enables the collecting and storage of thermal energy from widely dispersed sources like solar radiation, geothermal energy, and industrial waste heat, it offers a practical solution to the issue of energy storage. The usage of TES systems can reduce the need for non-renewable energy sources and increase energy efficiency by storing thermal energy during times of low demand and releasing it during times of high need. Additionally, by storing excess heat during the day and releasing it at night, TES systems can be employed to offer thermal comfort in buildings (Verdier et al. 2014).

Thermal energy storage (TES) can enhance the overall effectiveness and dispatch ability of applications related to renewable energy generation. According to a study by Zhai et al. (2019), revealed that TES can decrease the variability and spread of renewable energy sources, such as solar and wind power, by storing excess energy during periods of low demand and disbursing it during high demand. The integration of renewable energy resources into various TES systems can decarbonize the energy sector by decreasing its dependence on non-renewable energy sources and increasing energy efficiency. Furthermore, thermal comfort can be provided in buildings through the use of TES systems, which reduces the need for air conditioning and heating systems and enhances energy efficiency. Therefore, the integration of renewable energy resources with TES systems is a viable strategy to decarbonize the energy sector and enhance the overall effectiveness and dispatch ability of various renewable power applications (Powell et al. 2016; Sarbu and Sebarchievici, 2018)

Energy consumption has become one of the most pressing concerns in today's society due to the rapid growth rate of metropolitan areas and increasing comfort standards. The over-usage of energy from non-renewable sources has major environmental consequences, making the utilization of renewable energy sources a preferred option. According to a study by Jacobson et al. (2015), transitioning to 100% renewable energy sources by 2050 is technically and economically feasible, and would significantly reduce greenhouse gas emissions and air pollution,

while also creating jobs and saving lives. Renewable energy sources, such as solar, wind, and geothermal energy, have the potential to provide a sustainable and environmentally friendly solution to the world's energy needs. In addition, the integration of renewable energy resources with thermal energy storage (TES) systems can help to decarbonize the energy sector by reducing the reliance on non-renewable energy sources and improving energy efficiency (Jacobson et al. 2015; Hussain et al. 2017).

Thermal energy storage (TES) systems can be utilized to reserve spare energy and connect the demand-supply space by providing the highest demand of power if energy output exceeds energy consumption. TES systems can store excess thermal energy during periods of low demand and release it during periods of high demand, thereby improving the overall effectiveness and dispatch ability of renewable energy applications. In addition, TES systems can be used to provide thermal comfort in buildings by storing excess heat during the day and releasing it at night, reducing the need for air conditioning and heating systems (Zhao et al. 2017; Yang and Garimella, 2013).

Energy engineers and scientists are working towards achieving a more consistent, reliable, efficient, and continuous energy supply from renewable sources, while also meeting the growing demand for energy. The importance of implementing corrective actions to combat global warming has been emphasized, and integrating renewables into energy systems, as well as the development of energy storage technologies, are important fields of current Research. The integration of renewable energy resources with thermal energy storage (TES) systems can help to decarbonize the energy sector by reducing the reliance on non-renewable energy sources and improving energy efficiency (Kenisarin and Mahkamov, 2007; Ahmed et al. 2017).

Phase change materials (PCMs) are used to store thermal energy in the form of latent heat. This means that when the PCM changes phase, it absorbs or releases a large amount of heat without changing temperature. This makes PCMs ideal for applications where temperature stability is important, such as in building insulation, solar thermal collectors, and personal care products.

Traditional PCMs are often in the form of a bulk material, which can be difficult to handle and can leak if the container is damaged. Microencapsulated PCMs are a solution to these problems. In microencapsulated PCMs, the PCM is encased in a tiny capsule made of a material that is impermeable to the PCM. This prevents the PCM from leaking and makes it easier to handle.

Microencapsulated PCMs have a number of advantages over traditional PCMs. They are more stable, easier to handle, and have a higher thermal conductivity. This makes them ideal for a wider range of applications.

Here are some of the benefits of microencapsulated PCMs:

- They are more stable than traditional PCMs. This is because the PCM is encased in a capsule, which prevents it from coming into contact with the environment.
- They are easier to handle than traditional PCMs. This is because the capsules are small and lightweight, and they can be easily transported and stored.
- They have a higher thermal conductivity than traditional PCMs. This means that they can transfer heat more easily, which makes them more efficient for thermal energy storage.

Microencapsulated PCMs are a promising new technology for thermal energy storage. They have a number of advantages over traditional PCMs, and they are becoming increasingly popular for a wide range of applications heat (Schossig et al. 2005).

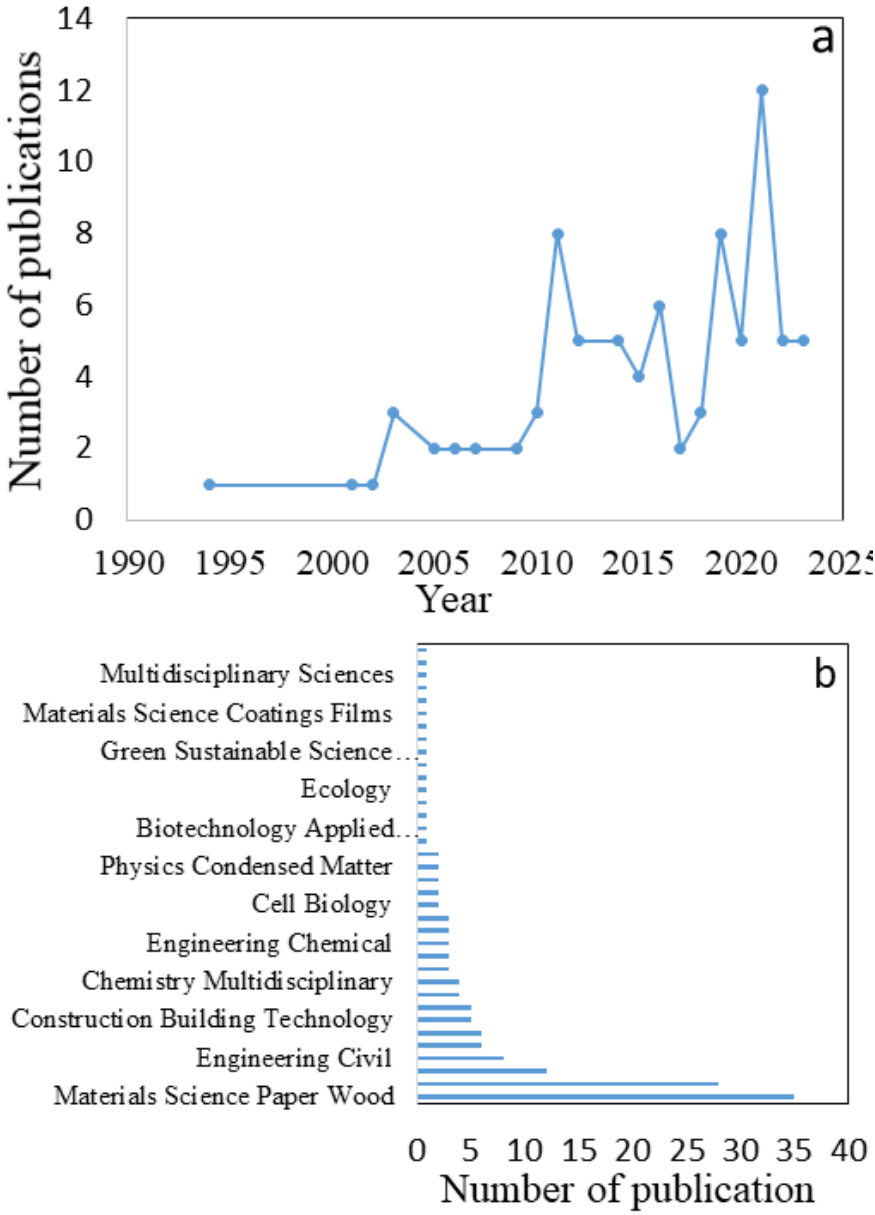


Fig. 1. Analysis of recent literature available on PCMs via web of Science. a) number of publications per year; b)distribution of number of publication under different sections

In recent years, studies on phase change materials and wood impregnation have increased. The number of articles made by years as a result of searching the words "wood" and "phase change substance" together in the web of science page

are given in figure 1a. Several promising PCMs impregnated wood have been reported in recent literature. The number of publication on PCMs impregnated wood have grown exponentially during last few years (Fig. 1a, b).

2 Phase change materials

2.1 Definition

Thermal energy storage (TES) systems, including the use of Phase Change Materials (PCMs), have gained significant attention in research and development over the past 30 years. PCMs are materials that can absorb or release a large amount of energy in the form of latent heat during phase transitions, such as solid-liquid or liquid-gas transitions.

TES systems are crucial for addressing the challenge of maintaining a balance between energy demands and energy supply, especially in the context of sustainable and efficient energy systems. While thermal energy is abundant in nature, it is intermittent, and there is a need for energy storage solutions to bridge the gap between energy production and consumption, particularly during periods when the primary energy source is not available or insufficient, such as when the sun sets in the case of solar energy.

By utilizing PCMs, TES systems can store thermal energy during times of excess or low-cost energy production, such as during daylight hours when solar energy is abundant. The stored energy can then be released when needed, such as during nighttime or periods of increased energy demand. This helps to optimize energy utilization, improve energy efficiency, and reduce the reliance on conventional fossil fuels, thereby contributing to a more sustainable energy system.

2.2 Basics in the phase change mechanism, systems, and analysis

During a phase transition, phase change materials (PCMs) store and release energy as latent heat. There are three stages to this process: liquid-gas, solid-liquid, and solid-solid. But only phase transitions from solid to liquid matter for building envelopes. A PCM undergoes an endothermic process in which heat causes its molecular bonds to weaken and the material absorbs energy. The PCM undergoes a phase transition from solid to liquid as a result. The PCM regains its solid state and releases its energy when the temperature drops (Sharma et al. 2009; Kuznik et al. 2011; Pielichowska and Pielichowski, 2014; Kalnæs and Jelle, 2015; Sharma et al. 2015).

2.2.1 Energy conversion mechanism

The Energy Conversion Mechanism refers to the process of converting one form of energy into another form of energy (Dobrota and Pašti 2020). There are

various methods of energy conversion, including electrochemical energy conversion systems such as batteries, fuel cells, and supercapacitors (Dunbar et al., 1992), wireless energy transfer and conversion (Kawasaki, 2013), and wind energy conversion systems (Wu et al. 2011). In addition, there are several energy conversion devices based on piezoelectricity, such as fiber-based energy conversion devices for human-body energy harvesting (Huang et al. 2020). Furthermore, there are intrinsic energy conversion mechanisms that exist between thermal energy and mechanical work in the telescopic motions of double-walled carbon nanotubes (Guo et al. 2018).

2.2.2 Energy storage system mechanism

Building energy storage systems can use phase change materials (PCMs) for both passive and active energy storage. PCMs are integrated into building components in passive systems, where they absorb energy when the outside temperature rises to a melting point or higher and release it when the temperature drops. PCMs in active systems are designed to store energy in independent collectors during times of low demand and release it again during times of high demand. Solar energy is typically stored by this system during the day and released at night when there is a greater need for energy (Kenisarin and Mahkamov, 2016).

2.2.3 Available analytical methods of energy and chemical behavior of PCM

Phase change materials (PCMs) have been thermally analyzed using a variety of techniques, such as guarded hot plates, T-history techniques, differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA) (Su et al. 2015). The most popular technique for figuring out PCM thermo-physical properties like latent heat of fusion and melting temperature is DSC (Sharma et al. 2009; Kuznik et al. 2011; Kalnæs and Jelle, 2015; Sharma et al. 2015). DSC, however, is limited to the analysis of uniformly sized test samples of PCMs (Li and Fang, 2010; Eddhahak-Ouni et al. 2013; Su et al. 2015)

The melting temperature, supercooling degree, heat of fusion, specific heat, and thermal conductivity of multiple PCMs can all be simultaneously examined using the T-history method (Li and Fang, 2010; Eddhahak-Ouni et al. 2013; Su et al. 2015; Can et al. 2023). PCM-based energy-saving systems' thermal conductivity is examined using the guarded hot plate method (Li and Fang, 2010; Eddhahak-Ouni et al. 2013; Su et al. 2015). PCMs' thermal stability is assessed using TGA (Su et al. 2015). Particle size distribution and material morphology are evaluated using scanning electron microscopy (SEM) (Su et al. 2015; Kittusamy et al. 2022). For examining the chemical stability and compatibility of the materials,

techniques such as X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) are available (Su et al. 2015; Kittusamy et al. 2022;Xi et al. 2022).

3 Properties and Selection criteria of PCMs

PCM, which stands for Phase Change Material, is a type of material that can undergo reversible phase transitions between solid and liquid states, typically with a change in temperature. PCM selection criteria may vary depending on the specific application and requirements, but here are some common factors to consider when selecting a PCM (Zalba et al. 2003; Sarı and Kaygusuz, 2014; Cabeza et al. 2017).

Temperature range: Determine the desired temperature range for the PCM to operate within. Different PCMs have specific melting and freezing points, and it's crucial to choose a PCM that matches the desired temperature range for effective thermal energy storage or thermal management.

Thermal properties: Evaluate the specific heat capacity and latent heat of the PCM. The specific heat capacity determines how much energy the PCM can absorb or release per unit mass, while the latent heat refers to the amount of energy absorbed or released during the phase transition. Higher specific heat and latent heat values generally indicate better energy storage capabilities.

Thermal conductivity: Consider the thermal conductivity of the PCM, which affects how efficiently it can transfer heat. Depending on the application, you may require a PCM with high or low thermal conductivity.

Compatibility: Assess the compatibility of the PCM with the materials and systems it will be used with. This includes considerations such as chemical compatibility, potential reactions with other materials, and whether the PCM can be easily integrated into the existing system or infrastructure.

Cycle life and reliability: Evaluate the durability and reliability of the PCM over repeated thermal cycles. Some PCMs may degrade or exhibit reduced performance over time, so it's important to choose a PCM with a suitable cycle life for the intended application. Cost-effectiveness: Consider the cost of the PCM and its overall cost-effectiveness in relation to the desired application. This includes factors such as the initial cost, maintenance requirements, and potential energy savings or benefits offered by the PCM.

Safety and environmental impact: Assess the safety aspects and environmental impact of the PCM. Some PCMs may pose risks in terms of flammability, toxicity, or environmental hazards. It is crucial to select a PCM that is safe to handle, non-toxic, and environmentally friendly.

These selection criteria help determine the most suitable PCM for a specific application, whether it's for thermal energy storage systems, building insulation, temperature regulation in electronics, or other thermal management applications.

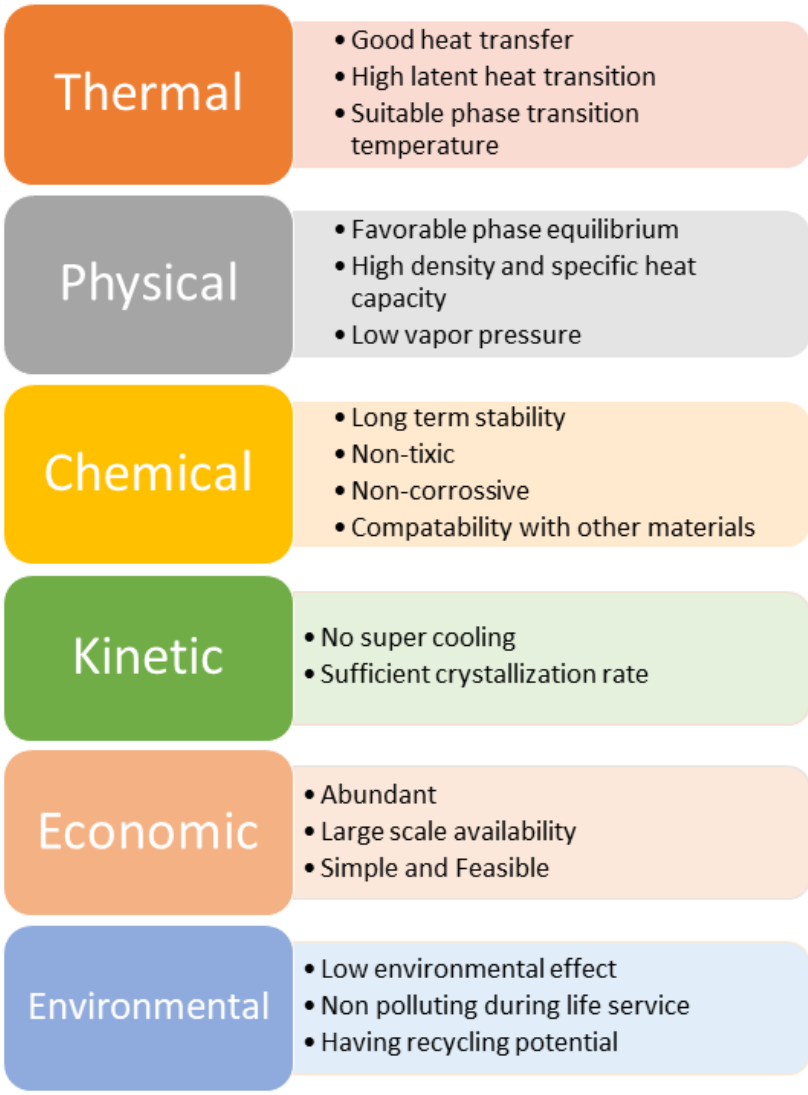


Fig. 2. PCM selection criteria.

4. Classification of PCMs

PCMs can be categorized into different types based on their form of heat storage, including solid-solid, solid-liquid, liquid-gas, and solid-gas PCMs. Among these, solid-liquid PCMs offer advantages such as low cost, high latent heat of

phase transition, and a wide range of phase transition temperatures. They can be further classified into inorganic and organic PCMs.

4.1 Inorganic phase change materials

Inorganic phase change materials (PCMs) are a type of PCM that consists of non-organic substances. Unlike organic PCMs, which are typically composed of carbon and hydrogen-based compounds, inorganic PCMs are made up of elements other than carbon and hydrogen. Inorganic PCMs offer unique properties and advantages for thermal energy storage applications (Tatsidjodoung et al. 2013; Xie et al. 2017).

Some common examples of inorganic PCMs include:

Salt Hydrates: These are compounds that contain water molecules bound within their crystal structure. They exhibit high latent heat capacity and can store and release thermal energy effectively. Salt hydrates like sodium sulfate decahydrate (Glauber's salt) and magnesium sulfate heptahydrate (Epsom salt) are commonly used in TES systems.

Metal Alloys: Certain metal alloys exhibit solid-solid phase transitions with significant latent heat storage capacity. Examples include alloys based on gallium, indium, and tin. These materials can undergo reversible phase changes near room temperature and are being explored for various thermal management applications.

Inorganic Salt Mixtures: Mixtures of different salts can create eutectic compositions that have desirable melting and solidification temperatures. For example, a eutectic mixture of sodium nitrate and potassium nitrate (also known as solar salt) is commonly used in concentrated solar power plants for TES.

Inorganic PCMs offer advantages such as high thermal conductivity, excellent thermal stability, and resistance to degradation or decomposition over repeated phase change cycles. They are often more suitable for high-temperature applications compared to organic PCMs. However, they may have challenges such as lower phase change enthalpy and potential issues related to corrosion or supercooling.

4.2 Organic phase change materials

Research has demonstrated that OPCMs can be a useful tool for storing and releasing solar energy for indoor heating when added to building materials. However, areas like Canada and the Nordic countries that receive little sunlight during the winter may find this pattern unsuitable. In these areas, storing solar energy during the day and releasing it at night may not be as practical as using OPCMs

to regulate indoor temperature fluctuations in residential buildings. Thus, it appears more promising to use OPCMs in building materials for thermal regulation in cold climate countries where biomaterials are highly sought after than to use them for solar energy storage.

According to Kalnaes and Jelle (2015), in order to ensure passive housing standards in cold climates, building constructions use a lot of insulation materials to minimize the amount of heat loads that are transferred between indoor and outdoor temperatures. They also observed that excess energy is stored and released when the interior temperature drops in a building that has phase change materials (PCMs) incorporated into it. This occurs when the building's internal thermal mass increases. By controlling temperature variations, energy is used more effectively. As a result, using PCMs in building construction can be a useful strategy to raise energy efficiency and lower heating loads in chilly regions.

A number of factors, including physical, thermal, chemical, and kinetic properties, should be taken into account when choosing a PCM that is appropriate for use in building applications. Other factors including cost, availability, safety, compatibility, and dependability must also be considered in addition to these guidelines. The latent heat of fusion and operating temperature are important considerations when selecting a suitable phase change material. A PCM that is deemed suitable should possess a large latent heat of fusion and fit within the working temperature range. To choose the best PCM for a particular building application, it is crucial to carefully assess and compare various PCMs based on these parameters and other pertinent factors (Pasupathy et al. 2008; Agyenim et al. 2010; Baetens et al. 2010; Pielichowska and Pielichowska, 2014; Kalnaes and Jelle, 2015; Konuklu et al. 2015; Sharma et al. 2015; Souayfane et al. 2016; Nazir et al. 2019).

According to the research findings supplied, there are two types of organic phase change materials (OPCMs): par-affins and non-paraffins. Although they are not bio-based, paraffins and polyethylene glycols are commonly used as standards (Sharma et al. 2009; Baetens et al. 2010; Sarier and Onder, 2012; Souayfane et al. 2016; Guo et al. 2018;). Conversely, non-paraffin BPCMs come from raw materials like animal fat and vegetable oils (Sharma et al. 2009; Jeong et al. 2013; Yu et al. 2014; Jeong et al. 2014). These materials are less flammable, exhibit high latent heat, lack super cooling and phase separation, and maintain their chemical and thermal stability over extended periods of time (Agyenim et al. 2010; Jeong et al. 2013; Yu et al. 2014; Jeong et al. 2014). The hypothesis that OPCMs can be incorporated into a variety of construction materials is supported by the study's findings (Pasupathy et al. 2008; Sharma et al. 2009; Kalnaes and Jelle, 2015; Souayfane et al. 2016; Guo et al. 2018). Furthermore, non-paraffin

BPCMs made from raw materials like animal fat and vegetable oils are chemically and thermally stable over a long period of time (Sharma et al. 2009; Jeong et al. 2013; Yu et al. 2014; Jeong et al. 2014). As a result, they provide a sustainable and environmentally beneficial substitute for conventional building materials.

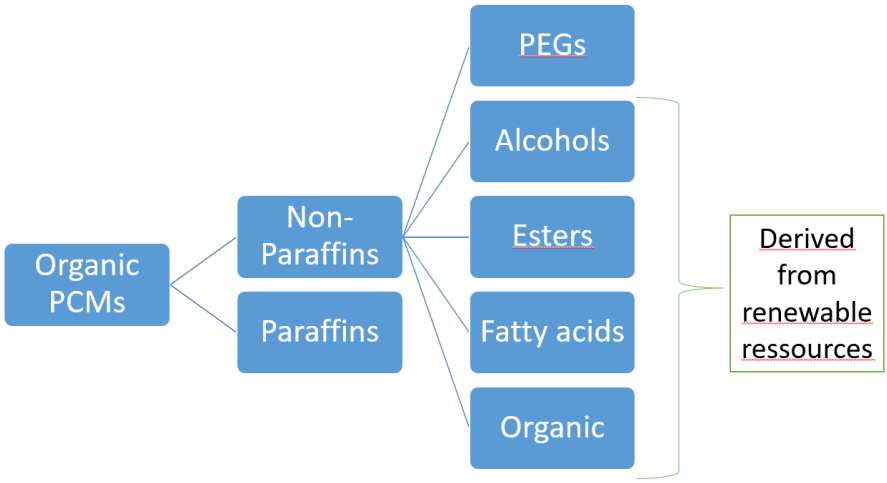


Fig. 3. Diagram of organic phase change materials (PCMs) classification

3.1. Paraffins

By using latent heat energy storage techniques, paraffins and commercial paraffin waxes, which are derived from crude oil, have been widely utilized to store solar energy. The research results that have been provided indicate that paraffins are cheap, non-toxic, non-reactive, and do not corrode metals. They also have a high latent heat storage capacity. After many cycles, they maintain their stable properties, exhibit good thermal and chemical reliability, and are less prone to phase segregation and supercooling. These materials do, however, have a moderate thermal energy storage density; however, their low thermal conductivity is by far their greatest disadvantage (Baetens et al. 2010; Sharma et al. 2015; Gulfam et al. 2019).

Depending on the carbon number, paraffins can withstand temperatures across a broad range. The melting temperature would increase with the average length of the hydrocarbon chain. Liquid paraffins have carbon chains with fewer than fifteen carbons. The melting and heat of fusion temperatures rise as the number of carbon chains increases (Baetens et al. 2010; Sarier and Onder, 2012; Sharma et al. 2015).

Therefore, based on the research results, it can be concluded that paraffins are a suitable material for storing solar energy due to their high latent heat storage

capacity, stability, and low cost. However, their low thermal conductivity is a significant drawback. The melting temperature and heat of fusion of paraffins increase with an increase in the number of carbon chains (Sarier and Onder, 2012; Pielichowska and Pielichowski, 2014).

3.2 Polyethylene Glycols

Since polyethylene glycol (PEG) is made from crude oil, it is not bio-based; rather, it is derived from a dimethyl ether chain. Because of its chemical makeup and properties, PEG is soluble in both water and organic solvents. Grades including 400, 600, 1000, 3400, 10,000, 20,000, 35,000, 100,000, and 1,000,000 are available for PEGs (Sharma et al. 2015). Because polyethylene glycols (PEGs) are non-flammable, non-toxic, and non-corrosive, they have been extensively used and researched as possible materials for use as phase change materials (PCMs).

These materials have a high degree of crystallinity, a large heat of fusion ranging from 117 to 174 kJ/kg, and a melting temperature that varies from 4 to 70°C depending on the molecular weight. The heat of fusion and melting point of a polymer increase as its molecular weight does. Because of their stability and lack of toxicity, PEGs are a good material to use as PCMs. PEGs' melting and fusion temperatures can be changed by changing their molecular weight (Sharma et al. 2015; Souayfane et al. 2016).

3.3. Polyols

Polyols are classified as medium-temperature (90-200 ºC) PCMs and can be further subdivided into sugar alcohols, poly-alcohols, and glycols (Sharma et al. 2015). In their investigation of various substances, such as sugar alcohol, for use as PCM, Kaizawa et al. discovered that erythritol has a significant latent heat of fusion of 344 kJ/kg. It is a promising PCM material for medium-to-high temperature applications because of its 117 °C melting point. Erythritol's high latent heat of fusion and promising melting point make it a suitable material for use as a PCM (Kaizawa et al. 2007). Alcohols are a great PCM, but because of supercooling at lower temperatures and volume expansion during phase transition, their use in construction applications is restricted. When choosing a PCM for building applications, these constraints need to be taken into account (Elefsiniotis et al. 2013; Jiang et al. 2014; Sharma et al. 2015).

3.4. Fatty Acids

Compounds that have the general formula CH3(CH2)2nCOOH are found in both plant and animal sources. The six groups that comprise the most commonly

used fatty acids are caprylic, capric, lauric, myristic, palmitic, and stearic. Thus, it can be inferred from the research findings that fatty acids, which come from both plant and animal sources, are a suitable material for use as PCM. Six groups comprise the most widely used fatty acids: caprylic, capric, lauric, myristic, palmic, and stearic (Pasupathy et al. 2008; Kalnaes and Jelle, 2015)

The special and superior properties of fatty acids include congruent melting, good thermal and chemical stabilities, non-toxicity, biodegradability, and a melting temperature range that, when combined or esterified, is appropriate for use in construction (Yu et al. 2014; Jeong et al. 2014; Gulfam et al. 2019). Because of their special and superior qualities, fatty acids are therefore a good material to use as PCM, according to the research findings. When combined or esterified, they have a melting temperature range appropriate for building applications, a congruent melting point, good chemical and thermal stabilities, and are non-toxic and biodegradable (Pasupathy et al. 2008; Kalnaes and Jelle, 2015; Souayfane et al. 2016).

Recently, researchers have focused on fatty acids as possible BPCMs for low-to-medium energy storage applications. Fatty acids are exceptional because they melt congruently, have good chemical and thermal stabilities, are non-toxic, biodegradable, and, when combined or esterified, have a melting temperature range that is appropriate for use in construction. Fatty acids are therefore a promising material for use as BPCMs for low-to-medium energy storage applications, according to the research findings. They are a good substitute for conventional PCMs due to their exceptional qualities and distinctive features (Rozanna et al. 2005; Sole et al. 2014; Yuan et al. 2014)

Fatty acids and their binary mixtures as BPCMs for thermal energy storage have been the subject of reviews by Yuan et al. (2014) and Rozanna et al. (2005). According to Yuan et al. (2014), only the thermal behavior of saturated fatty acids has been studied in this research. Finding a pure fatty acid with a phase transition temperature in the right range for thermal energy storage applications is challenging, according to the study's findings. Nonetheless, it has been discovered that binary mixtures of fatty acids have a phase transition temperature range that is appropriate for thermal energy storage applications. The use of fatty acids and their binary mixtures as PCMs for thermal energy storage was also reviewed by Rozanna et al (2005). It was discovered that fatty acid binary mixtures have been demonstrated to have superior thermal properties than pure fatty acids. Fatty acid derivatives as potential PCMs were studied by Feldman et al (1986; 1995). Butyl stearate, vinyl stearate, methyl palmitate and methyl stearate (Feldman et al. 1995), and mixtures of ethoxylated linear alcohols (Feldman et al. 1986) were

among the substances examined in the study. According to the study, these materials have melting points between 10 and 43 °C with latent heats of 100 to 140 kJ/kg and, in the later study, between 23 and 27°C with a latent heat of fusion of 180 kJ/kg (Feldman et al. 1986; Feldman et al. 1995). Therefore, based on the research results, it can be concluded that while pure fatty acids may not have a suitable phase transition temperature range for thermal energy storage applications, binary mixtures of fatty acids have been found to have a suitable range.

In order to develop a phase change material (PCM) for solar energy storage applications, Lin et al. (2018) investigated the thermal and chemical characteristics of a combination of expanded graphite, polyvinyl butyral, and palmitic acid. They discovered that the mixture could be used for solar energy storage because it had a phase transition temperature that was marginally lower than that of pure palmitic acid. Despite the lack of physical or chemical interactions, the mixture also integrated into a stable chemical and crystalline mixture.

Here is a summary of the key findings from the study:

- The mixture of palmitic acid, polyvinyl butyral, and expanded graphite had a phase transition temperature of 56-59°C, which is suitable for solar energy storage applications.
- The mixture was stable chemically and crystalline, with no physical or chemical interactions observed.
- The mixture had a high latent heat of fusion, which means that it can store a lot of energy per unit mass.
- The mixture was non-toxic and environmentally friendly.

Based on these findings, the authors concluded that the mixture of palmitic acid, polyvinyl butyral, and expanded graphite is a promising PCM for solar energy storage applications (Lin et al. 2018).

Sharma et al. (2016) studied the thermal and chemical stability of three organic phase change materials (OPCMs) including paraffin wax, palmitic acids, and myristic acids for 1500 melting/freezing cycles. They used DSC and FTIR to measure the thermo-physical properties of the PCMs before and after the thermal cycling. The authors found that all three PCMs showed gradual changes in their thermo-physical properties after the thermal cycling. However, the changes were not significant and the PCMs remained stable for up to 1500 melting/freezing cycles. The authors also found that the melting temperature of the two fatty acids (palmitic and myristic acids) decreased after 500 thermal cycles, while the melting temperature of paraffin wax increased. This is because the fatty acids are more susceptible to oxidation than paraffin wax. Based on these findings, the authors concluded that paraffin wax, palmitic acids, and myristic acids are all suitable for thermal energy storage applications. However, paraffin wax may be a better

choice for applications where long-term thermal stability is required.

4.3 Eutectic phase change materials

Eutectic phase change materials (PCMs) are a specific type of PCM that exhibit a eutectic composition. In a eutectic mixture, the individual components melt and solidify at a lower temperature than either of the pure components alone. This characteristic allows for a well-defined melting and solidification temperature, making eutectic PCMs particularly useful for thermal energy storage applications. Eutectic PCMs are typically composed of two or more pure substances, such as salts, metals, or organic compounds, combined in specific ratios. The eutectic composition provides a unique combination of properties for efficient thermal energy storage (Kahwaji and White, 2018; Zeng et al. 2018).

Eutectic PCMs have a well-defined melting point and solidification point, which means they undergo phase transitions at a specific temperature. During the phase change, the eutectic PCM absorbs or releases a significant amount of latent heat, making it an effective medium for thermal energy storage.

Eutectic PCMs generally have high phase change enthalpy, which refers to the amount of energy absorbed or released during the phase transition. The high enthalpy enables the storage of a large amount of thermal energy in a relatively small volume or mass of the PCM.

The thermal conductivity of eutectic PCMs is an important property as it affects the efficiency of heat transfer during the charging and discharging processes. Optimizing the thermal conductivity of eutectic PCMs can enhance the overall performance of thermal energy storage systems.

Eutectic PCMs find applications in various fields, including building and construction, electronics cooling, thermal management of batteries, solar thermal energy storage, and waste heat recovery. They offer advantages such as high energy storage density, temperature stability, and repeatability of the phase change process.

5 Incorporation of PCM in Lignocellulose Materials

The incorporation of phase change materials (PCMs) in lignocellulosic materials can offer several advantages and potential applications. Lignocellulosic materials, such as wood or biomass, are renewable and sustainable resources, making them an attractive option for incorporating PCMs for thermal energy storage.

Here are some potential benefits and considerations:

1. Thermal Energy Storage: PCMs can absorb and release large amounts of thermal energy during the phase change process, which can help regulate temper-

ature fluctuations in buildings. By incorporating PCMs into lignocellulosic materials, such as wood composites or insulation boards, these materials can act as thermal storage layers, enhancing the energy efficiency of buildings.

2. Enhanced Thermal Properties: Lignocellulosic materials already possess inherent thermal properties, such as low thermal conductivity. By incorporating PCMs, the thermal properties of these materials can be further enhanced, allowing for better insulation and temperature regulation.

3. Sustainable Solution: The use of lignocellulosic materials as a matrix for PCM incorporation aligns with sustainable and eco-friendly practices. By utilizing renewable resources, the overall environmental impact of thermal energy storage systems can be reduced.

4. Compatibility and Integration: One important consideration is the compatibility between the PCM and the lignocellulosic matrix. It is crucial to ensure proper impregnation or encapsulation of the PCM within the material to maintain its integrity and prevent leakage during phase transitions. Additionally, the manufacturing process should be optimized to achieve a uniform distribution of the PCM within the lignocellulosic material.

5. Application-specific Considerations: The choice of PCM and lignocellulosic material should be based on the specific application requirements, such as desired phase change temperature range, latent heat capacity, durability, and fire resistance.

Overall, the incorporation of phase change materials in lignocellulosic materials holds promise for energy-efficient and sustainable building applications. Ongoing research and development in this area are focused on optimizing the integration process, improving material performance, and exploring new combinations of PCMs and lignocellulosic matrices to further enhance thermal energy storage capabilities.

The use of wood flour as a matrix to encapsulate fatty acids, such as lauric acid (LA), myristic acid (MA), hexadecanoic acid (HA), and stearic acid (SA), was investigated by Liang et al. (2018) in their study. Through physical interaction, the researchers were able to fill the pores in the wood and retain the acids, preventing any leakage from being seen. In contrast to pure fatty acids, it was observed that the resulting combinations or composites showed lower phase transition temperatures and latent heat of fusion. This finding suggests that the incorporation of wood-flour as a matrix may have influenced the thermal properties of the fatty acids. It's important to consider that the thermal properties of the final composite can be influenced by various factors, including the interaction between the matrix and the encapsulated material. In this case, the wood-flour matrix may have affected the heat transfer characteristics and thermal behavior of the fatty

acids, resulting in a decrease in phase transition temperature and latent heat of fusion.

The study conducted by Mathis et al. (2018) focused on exploring the potential use of red oak and sugar maple for impregnated floors, specifically for micro-encapsulation of a PCM (Phase Change Material) known as Nextek29. The PCM used in the study was derived from agricultural resources, although its specific composition was not disclosed. The reported findings indicated a significant enhancement in thermal storage capacity for impregnated red oak compared to untreated red oak. The impregnated wood demonstrated a 77% increase in thermal storage capacity, suggesting that the incorporation of the PCM resulted in improved thermal energy storage capabilities. In terms of application, the impregnated wood was found to receive and store solar energy effectively within a specific working temperature range of 28 to 31 degrees Celsius. This implies that the impregnated wood can absorb and release thermal energy within this temperature range, making it suitable for flooring applications. Additionally, the authors reported that sugar maple exhibited a lower thermal mass compared to red oak. This suggests that the sugar maple, even when impregnated with PCM, may have a relatively lower capacity for storing thermal energy compared to red oak. Overall, the study highlights the potential of using red oak as an impregnated floor material for micro-encapsulated PCM, leading to improved thermal storage capacity. However, it also suggests that different wood species, such as sugar maple, may exhibit varying thermal properties and should be carefully considered based on the specific requirements of the application.

The study mentioned involved the incorporation of a blend of lauric and capric acids as a binary PCM (Phase Change Material) into decorative wood-based panels, specifically medium density fiberboards (MDF) (Mathis et al. 2019). Initially, the PCM was encapsulated in plastic pouches, and then these pouches were integrated into grooved MDF panels. The researchers concluded that the wood panels filled with the PCM demonstrated a suitable phase transition temperature of 22.2 °C and a latent heat of fusion of 57.1 J/g. These properties make the composite material well-suited for building applications, particularly in passive systems where PCM can play a role in thermal energy storage. The significance of this finding lies in the fact that the phase transition temperature and latent heat of fusion of the composite align well with the requirements of passive systems in buildings. Passive systems aim to optimize energy efficiency by utilizing materials and design strategies that naturally regulate temperature and reduce the reliance on active heating or cooling. By incorporating the binary PCM into MDF panels, the composite material can effectively absorb and release thermal energy

within the specified temperature range, contributing to the overall energy performance of the building. This study highlights the potential of using wood-based panels, such as MDF, as a carrier for PCM integration, offering a viable solution for passive thermal energy storage in building applications.

The study conducted by Yang et al. (2019) focused on delignified and carbonized wood samples that were impregnated with lauric acid (LA). The resulting composite material exhibited characteristics of a lightweight, highly porous material. One notable finding from the study was the significant encapsulation ratio of more than 80%. This indicates that the lauric acid was successfully impregnated and encapsulated within the wood samples, with a high level of retention and minimal leakage. Additionally, the composite material demonstrated a latent heat of 178 J/g. The latent heat of fusion refers to the amount of heat absorbed or released during a phase transition, in this case, the transition of the lauric acid between solid and liquid phases. A latent heat value of 178 J/g indicates a substantial heat storage capacity for the composite material.

The study conducted by Li et al. (2009) focused on investigating the potential use of a composite material consisting of paraffin, high-density polyethylene (HDPE), and wood flour as a stable form of phase change material (PCM). The researchers also explored its application as a thermal storage layer in an electric floor heating system. The resulting composite material exhibited several desirable properties for building applications. Firstly, it achieved a suitable phase change temperature range of 20 to 30 degrees Celsius. This means that the composite can undergo a phase transition within this temperature range, allowing it to absorb or release thermal energy effectively, which is important for thermal regulation in buildings. Additionally, the composite demonstrated a high latent heat of fusion, indicating a significant capacity for storing and releasing thermal energy during the phase change process. This property is crucial for efficient thermal energy storage systems. Moreover, the composite exhibited good thermal conductivity, which means it can efficiently transfer heat. This property is important for ensuring the uniform distribution of thermal energy within the composite and facilitating heat transfer to or from the surrounding environment.

The study conducted by Ma et al. (2019) focused on exploring the use of delignified cedar wood impregnated with a eutectic mixture of capric acid-palmitic acid (PA) as a thermal energy storage system. The thermal analysis of the composite revealed important findings. The composite exhibited a latent heat of fusion of 94 J/g, indicating a significant capacity for storing thermal energy during the phase change process. The phase change temperature of the composite was reported to be 23 degrees Celsius, indicating the temperature range at which the composite undergoes the phase transition.

The study conducted by Guo et al. (2016) focused on the incorporation of micro-encapsulated dodecanol as a phase change material (PCM) into a composite material consisting of wood flour and high-density polyethylene (HDPE). The researchers utilized a pre-polymer modified by polyethylene glycol as the matrix material for micro-encapsulating the PCM. The composite material was prepared through a hot-compression process, combining the micro-encapsulated PCM with the wood flour/HDPE matrix. The thermal properties of the composite were analyzed, revealing important findings. The melting temperature of the composite material was reported to be 27.2 degrees Celsius. This temperature represents the point at which the PCM transitions from a solid to a liquid phase, absorbing thermal energy in the process. The freezing temperature of the composite, which corresponds to the PCM transitioning from a liquid to a solid phase, was found to be 11.3 degrees Celsius.

The study conducted by Amini et al. (2022) focused on impregnating Scotch pine wood samples with capric acid at a concentration of 80%. The researchers measured the retention value, which refers to the amount of impregnated substance retained by the wood, and reported a retention value of 267 kg/m^3 for the impregnated wood samples. Additionally, the study measured the latent heat of the impregnated wood samples. At the aforementioned retention level of 267 kg/m^3 and with capric acid as the impregnating substance, a latent heat of 70.5 J/g was obtained. Latent heat refers to the amount of heat absorbed or released during the phase change process of the material.

Can and Zigon's (2022) study concentrated on using n-heptadecane as a phase change material (PCM) to impregnate spruce sapwood. The purpose of the study was to assess the n-heptadecane-impregnated wood's decay resistance qualities and thermal energy storage (TES) attributes. A range of characterisation methods, such as FTIR (Fourier-transform infrared spectroscopy), TGA (thermogravimetry), DSC (differential scanning calorimetry), and XRD analysis, were utilized to examine the phase change characteristics of the wood impregnated with n-heptadecane. The DSC analysis yielded results that indicated the n-heptadecane-impregnated wood performed moderately well in terms of heat storage and release during the phase change process. However, specific details about the performance, such as the phase change enthalpy or temperature, were not mentioned in the provided information. The study highlights the potential of using n-heptadecane-impregnated spruce sapwood as a TES material. The findings suggest that the impregnated wood has the capability to store and release thermal energy, although the extent of its performance was not explicitly specified. Further analysis and investigation using the mentioned characterization techniques could provide

a more comprehensive understanding of the phase change properties of the n-heptadecane-impregnated wood.

Can et al. (2023) investigated the biological characteristics, hygroscopicity, and thermal performance of three distinct commercial phase change materials (PCMs) after impregnating sapwood from Oriental spruce trees. The morphology and characteristics of the PCM-impregnated wood were examined using a variety of characterization methods, including differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FT-IR), thermogravimetric analysis (TGA), and scanning electron microscopy (SEM). DSC analysis supported the results, which showed that the PCM-impregnated wood performed poorly in terms of heat storage and release during phase change processes. Nonetheless, at the operating temperatures, the PCMs showed outstanding thermal stability. With a phase change temperature of 21.49 °C and a phase change enthalpy of 40.34 J/g, PCM1W demonstrated the most satisfactory results of all the samples. The study also assessed the wood impregnated with PCM's resistance to biological assaults. The PCMs were discovered to be resistant to fungi that demolish wood. Following a 96-hour water absorption test, the wood samples' water absorption dropped by 28%, and their tangential swelling dropped by 75%. Experiments conducted on a lab scale showed how resistant the PCM material is to biological assaults. To validate these results, additional large-scale pilot studies are still needed.

Thermal properties of the MPCM and microcapsule-impregnated poplar wood (MPCMW) were analyzed using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC). The MPCM demonstrated excellent thermal stability at the working temperature range. Among the samples, MPCM2 and MPCM3 exhibited the most satisfying results with phase change enthalpies of 98.85 J/g and 135.1 J/g, and phase change temperatures of 58.29 °C and 60.76 °C, respectively, which are within the medium-temperature zone suitable for building applications. Poplar wood samples were then impregnated with the MPCM using a vacuum-pressure process, resulting in approximately 15% weight gain. The impregnation process did not significantly alter the chemical structure and crystallinity ratios of the wood samples, as confirmed by FTIR and XRD analyses. TGA analysis revealed that thermal decomposition occurred in two stages, and the MPCMW samples began to decompose at 200 °C. The MPCMW samples exhibited latent heat storage ranging from 30.8 J/g to 82.62 J/g within the temperature range of 59.70 °C to 61.73 °C. These samples also demonstrated great durability, maintaining a latent heat of 40-50 J/g even after undergoing 50 heating-cooling cycles. Furthermore, the thermal conductivity enhancements of

the MPCMW samples were approximately 40% higher than the reported values for untreated poplar wood (Can, 2023).

6. Advantages of Wood-based PCMs

The utilization of wood as a support material for PCMs offers several advantages. First, wood is a naturally grown capillary porous material with natural channels known as capillaries (Li et al. 2022). This unique structure allows for the preparation of composite materials through capillary adsorption (Zhai et al. 2009). Second, wood is a sustainable and renewable resource, making it an environmentally friendly choice for thermal energy storage applications (Can, 2023).

Wood-based PCMs have been found to have superior thermal insulation performance compared to traditional building materials such as steel, glass, and cement (Li et al. 2023). The thermal insulation performance of wood is 400 times that of steel and 16 times that of concrete (Li et al. 2023). Lightweight timber-framed buildings, which utilize wood-based PCMs, have shown potential in greatly reducing heating and cooling costs over the lifespan of residential units (Soares et al. 2017). Additionally, timber-structured buildings have been found to be more energy-efficient compared to light-framed and concrete-structured buildings (Li et al. 2022).

The impregnation of wood with PCMs allows for the regulation of indoor temperatures, reducing the need for artificial heating and cooling systems. This passive utilization of solar energy contributes to lower energy consumption and reduced costs in buildings. Furthermore, wood-based PCMs can provide a more homogeneous temperature distribution within buildings, enhancing thermal comfort and improving overall energy efficiency (Xia et al. 2021).

7. Advancements in Wood-based PCMs

Recent developments in wood-based PCMs have focused on improving their thermal stability, latent heat of phase transition, and leakage prevention during the phase change process. Researchers have explored innovative approaches to enhance the performance of wood-based PCMs, leading to promising results.

For example, Xu et al. developed PCMs by mixing silica sol and PEG and pressing them into wood. The resulting PCES-Wood showed good thermal stability and excellent thermal latent heat. The silica network formed inside the wood prevented the leakage of PCMs during phase change (Xu et al. 2020). Yang et al. (2018) reported the development of thermochromic delignified wood composed of a thermochromic compound and delignified wood. This composite material reduced heat flow and had a suitable phase change temperature, enabling it to maintain the internal temperature for a longer duration than pristine wood.

These advancements in wood-based PCMs have opened up new possibilities for their practical applications in the building industry. By utilizing renewable and recyclable biomass media as support materials, form-stable PCMs based on wood offer a sustainable and efficient solution for thermal energy storage. The transmittance of energy storage wood for sunlight transmission and utilization has also been explored, further enhancing the versatility and potential applications of wood-based PCMs (He et al. 2023; Li et al. 2023).

8. Electrothermal Conversion of PCES-Wood

In addition to its thermal storage capabilities, PCES-Wood has also shown potential for electrothermal conversion. This means that it can convert electrical energy into thermal energy and vice versa. This property opens up possibilities for utilizing PCES-Wood in various applications, including heating systems, temperature regulation, and energy-efficient devices.

The electrothermal conversion of PCES-Wood relies on its unique properties, such as its high thermal conductivity and electrical resistivity. These properties allow for efficient heat transfer and electrical conduction, enabling the conversion of electrical energy into heat and vice versa. By integrating PCES-Wood into heating systems, the efficiency and performance of these systems can be significantly improved, leading to energy savings and reduced environmental impact (Li et al. 2023).

9. Photothermal Conversion of PCES-Wood

In addition to electrothermal conversion, PCES-Wood has also demonstrated potential for photothermal conversion. This means that it can convert solar energy into thermal energy, offering opportunities for sustainable and renewable energy utilization.

The photothermal conversion of PCES-Wood relies on its ability to absorb and convert sunlight into heat. This property is enhanced by the incorporation of light-absorbing materials or coatings onto the surface of the PCES-Wood. These materials or coatings can enhance the absorption of sunlight and increase the efficiency of photothermal conversion. By harnessing solar energy through PCES-Wood, buildings can reduce their reliance on traditional energy sources and contribute to a more sustainable and environmentally friendly future (Li et al. 2023).

10. Challenges and Future Research Directions

While wood-based PCMs offer numerous advantages and innovative applications, there are still challenges to overcome and areas for further research. One of the main challenges is the leakage problem during the phase change transition

process. Ensuring the encapsulation of PCMs within the wood matrix is crucial for preventing leakage and maximizing the performance of wood-based PCMs. Ongoing research is focused on developing effective encapsulation techniques and enhancing the thermal conductivity of PCES-Wood to address this challenge (He at al. 2023).

Future research directions in wood-based PCMs include exploring new and sustainable sources of biomass media as support materials, investigating the scalability and cost-effectiveness of PCES-Wood production, and optimizing the performance and durability of PCES-Wood in various applications. Additionally, advancements in nanotechnology and materials science may offer new opportunities for further improving the properties and performance of wood-based PCMs (Li et al. 2023; He et al. 2023).

11. Conclusion

Phase change material-impregnated wood offers a promising solution for thermal energy storage in the building industry. By utilizing wood as a support material for PCMs, buildings can benefit from passive solar energy utilization and improved temperature regulation. Wood-based PCMs have shown superior thermal insulation performance, energy efficiency, and sustainability compared to traditional building materials. Recent advancements in wood-based PCMs have focused on enhancing their thermal stability, latent heat of phase transition, and electrothermal and photothermal conversion capabilities.

However, challenges remain, particularly regarding the leakage problem during the phase change transition process. Ongoing research is dedicated to developing effective encapsulation techniques and improving the thermal conductivity of PCES-Wood. Future research directions include exploring sustainable biomass media, optimizing production scalability and cost-effectiveness, and further enhancing the performance and durability of wood-based PCMs.

Overall, wood-based PCMs offer a sustainable and efficient solution for thermal energy storage in buildings, contributing to energy savings, improved thermal comfort, and reduced environmental impact. Continued research and development in this field will pave the way for the widespread adoption and application of wood-based PCMs in the building industry.

Author Contributions

Ahmet Can: Contributed the laboratory studies

Conflict of Interest

The authors declared no conflict of interest.

References

1. Jacobson, M.Z., Delucchi, M.A., Bazouin, G., Bauer, Z.A., Heavey, C.C., Fisher, E., Yeskoo, T. W. (2015). 100% clean and renewable wind, water, and sunlight (WWS) all-sector energy roadmaps for the 50 United States. Energy & Environmental Science, 8(7), 2093-2117.
2. Memon S.A. (2014). Phase change materials integrated in building walls: A state of the art review. Renew Sustain Energy Rev 31(C):870–906. https://doi.org/10.1016/J.RSER.2013.12.042
3. Verdier D., Ferrière A., Falcoz Q., Siros F., Couturier R. (2014). Experimentation of a high temperature thermal energy storage prototype using phase change materials for the thermal protection of a pressurized air solar receiver. Energy Proc 49:1044– 1053.
4. Zhai, M., Huang, G., Liu, L., Zhang, X. (2019). Ecological network analysis of an energy metabolism system based on input-output tables: Model development and case study for Guangdong. Journal of cleaner production, 227, 434-446.
5. Powell, K.M., Kim, J.S., Cole, W.J., Kapoor, K., Mojica, J.L., Hedengren, J.D., Edgar, T. F. (2016). Thermal energy storage to minimize cost and improve efficiency of a polygeneration district energy system in a real-time electricity market. Energy, 113, 52-63.
6. Sarbu I., Sebarchievici C. (2018). A Comprehensive review of thermal energy storage. Sustain 10(1):191.
7. Hussain A., Arif S.M., Aslam M., Hussain A., Arif S.M., Aslam M. (2017). Emerging renewable and sustainable energy technologies: State of the art. Renew Sustain Energy Rev. 71(C):12–28.
8. Zhao, B. C., Cheng, M. S., Liu, C., Dai, Z. M. (2017). Cyclic thermal characterization of a molten-salt packed-bed thermal energy storage for concentrating solar power. Applied Energy, 195, 761-773.
9. Yang, Z., Garimella, S.V. (2013). Cyclic operation of moltensalt thermal energy storage in thermoclines for solar power plants. CTRC Res Publ 103:256–265. https://doi.org/10. 1016/j.apenergy.2012.09.043
10. Ahmed, S. F., Khalid, M., Rashmi, W., Chan, A., Shahbaz, K. (2017). Recent progress in solar thermal energy storage using nanomaterials. Renewable and Sustainable Energy Reviews, 67, 450-460.
11. Kenisarin, M., Mahkamov, K. (2007). Solar energy storage using phase change materials. Renew Sustain Energy Rev 11(9):1913– 1965.
12. Schossig, P., Henning, H.M., Gschwander, S., Haussmann, T. (2005). Micro-encapsulated phase-change materials integrated into construction materials. Sol Energy Mater Sol Cells 89(2–3):297– 306.

13. Kuznik, F., David, D.;,Johannes, K., Roux, J.J. (2011). Areview on phase change materials integrated in building walls. Renew. Sustain. Energy Rev. 15, 379–391.
14. Kalnæs, S.E., Jelle, B. (2015). Phase change materials and products for building applications: A state-of-the-art review and future research opportunities. Energy Build. 94, 150–176.
15. Sharma, A., Tyagi, V., Chen, C., Buddhi, D. (2009). Review on thermal energy storage with phase change materials and applications. Renew. Sustain. Energy Rev. 13, 318–345.
16. Sharma, R., Ganesan, P.B., Tyagi, V., Metselaar, H.S.C., Sandaran, S.(2015) Developments in organic solid–liquid phase change materials and their applications in thermal energy storage. Energy Convers. Manag. 95, 193–228.
17. Pielichowska, K., Pielichowski, K. (2014). Phase change materials for thermal energy storage. Prog. Mater. Sci. 2014, 65, 67–123.
18. Dobrota, A.S., Pašti, I. A. (2020). Chemisorption as the essential step in electrochemical energy conversion. Journal of Electrochemical Science and Engineering, 10(2), 141-159.
19. Dunbar, W. R., Lior, N., & Gaggioli, R. A. (1992). The component equations of energy and exergy.
20. Kawasaki, S. (2013, May). The green energy harvesting winds by the RF/microwave power transmission. In 2013 IEEE Wireless Power Transfer (WPT) (pp. 111-114). IEEE.
21. Wu, B., Lang, Y., Zargari, N., & Kouro, S. (2011). Fundamentals of wind evergy conversion system control.
22. Huang, L., Lin, S., Xu, Z., Zhou, H., Duan, J., Hu, B., Zhou, J. (2020). Fiber-based energy conversion devices for human-body energy harvesting. Advanced Materials, 32(5), 1902034.
23. Guo, Z., Zhang, H., Li, J., Leng, J., Zhang, Y., Chang, T. (2018). An intrinsic energy conversion mechanism via telescopic extension and retraction of concentric carbon nanotubes. Nanoscale, 10(10), 4897-4903.
24. Kenisarin, M.M., Mahkamov, K. (2016). Passive thermal control in residential buildings using phase change materials. Renew. Sustain. Energy Rev. 55, 371–398.
25. Su, W., Darkwa, J., Kokogiannakis, G. (2015). Review of solid–liquid phase change materials and their encapsulation technologies. Renewable and Sustainable Energy Reviews, 48, 373-391.
26. Eddhahak-Ouni, A., Drissi, S., Colin, J., & Neji, J. (2013, March). Analysis by differential scanning calorimetry of concrete modified with

microencapsulated phase change materials. In 2013 international renewable and sustainable energy conference (IRSEC) (pp. 337-342). IEEE.
27. Li, H., Fang, G. Y. (2010). Experimental investigation on the characteristics of polyethylene glycol/cement composites as thermal energy storage materials. Chemical engineering & technology, 33(10), 1650-1654.
28. Can, A., Lee, S. H., Antov, P., Abd Ghani, M. A. (2023). Phase-Change-Material-Impregnated Wood for Potential Energy-Saving Building Materials. Forests, 14(3), 514.
29. Kittusamy, R.K., Rajagopal, V., Felix, P.G. (2022). Preparation and Thermal Characterization of Nanographene-Enhanced Fatty Acid-Based Solid-Liquid Organic Phase Change Material Composites for Thermal Energy Storage. Strojniški vestnik-Journal of Mechanical Engineering, 68(7-8), 461-470.
30. Xi, S., Bu, Z., Kong, G., Cao, Y., & Yu, W. (2022). Perspectives on the Application of Phase Change Energy Storage in Building Energy Efficiency. ES Energy Environ.
31. Zalba, B., Marín, J. M., Cabeza, L. F., & Mehling, H. (2003). Review on thermal energy storage with phase change: materials, heat transfer analysis and applications. Applied Thermal Engineering, 23(3), 251-283.
32. Sarı, A., & Kaygusuz, K. (2014). A review of phase change materials for solar thermal energy storage applications. Renewable and Sustainable Energy Reviews, 31, 974-982.
33. Cabeza, L. F., Castell, A., Barreneche, C., de Gracia, A., Fernández, A. I., Farid, M. M. (2017). Phase change materials for energy storage in buildings: A review. Renewable and Sustainable Energy Reviews, 68, 1154-1179.
34. Tatsidjodoung, P. Le Pierrès, N. and Luo, L. (2013). A review of potential materials for thermal energy storage in building applications, Renew. Sustain. Energy Rev., vol. 18, 327–349.
35. Xie, N. Huang, Z. Luo, Z. Gao, X. Fang, Y. and Zhang, Z. (2017). Inorganic salt hydrate for thermal energy storage, Appl. Sci., 7(12).
36. Kalnæs, S.E.; Jelle, B. (2015). Phase change materials and products for building applications: A state-of-the-art review and future research opportunities. Energy Build. 94, 150–176
37. Pasupathy, A., Velraj, R. Seeniraj, R. (2008). Phase change material-based building architecture for thermal management in residential and commercial establishments. Renew. Sustain. Energy Rev. 12, 39–64
38. Souayfane, F., Fardoun, F., Biwole, P.H. (2016). Phase change materials

(PCM) for cooling applications in buildings: A review. Energy Build. 129, 396–431.
39. Agyenim, F., Hewitt, N.J., Eames, P., Smyth, M. (2010). A review of materials, heat transfer and phase change problem formulation for latent heat thermal energy storage systems (LHTESS). Renew. Sustain. Energy Rev. 14, 615–628.
40. Nazir, H.,, Batool, M., Osorio, F.J.B., Isaza-Ruiz, M., Xu, X., Vignarooban, K., Phelan, P., Inamuddin; Kannan, A.N.M. (2019). Recent developments in phase change materials for energy storage applications: A review. Int. J. Heat Mass Transf. 129, 491–523.
41. Konuklu, Y.; Ostry, M.; Paksoy, H.; Charvát, P. (2015). Review on using microencapsulated phase change materials (PCM) in building applications. Energy Build. 106, 134–155.
42. Baetens, R., Jelle, B., Gustavsen, A. (2010). Phase change materials for building applications: A state-of-the-art review. Energy Build. 42, 1361–1368.
43. Sarier, N., Onder, E. (2012). Organic phase change materials and their textile applications: An overview. Thermochim. Acta, 540, 7–60.
44. Jeong, S.G., Chung, O., Yu, S., Kim, S., Kim, S. (2013). Improvement of the thermal properties of Bio-based PCM using exfoliated graphite nanoplatelets. Sol. Energy Mater. Sol. Cells 2013, 117, 87–92.
45. Yu, S., Jeong, S.G., Chung, O., Kim, S. (2014). Bio-based PCM/carbon nanomaterials composites with enhanced thermal conductivity. Sol. Energy Mater. Sol. Cells 2014, 120, 549–554.
46. Jeong, S.G., Lee, J.H., Seo, J., Kim, S. (2014). Thermal performance evaluation of Bio-based shape stabilized PCM with boron nitride for energy saving. Int. J. Heat Mass Transf. 2014, 71, 245–250.
47. Gulfam, R., Zhang, P., Meng, Z. (2019). Advanced thermal systems driven by paraffin-based phase change materials—A review. Appl. Energy, 238, 582–611.
48. Kaizawa, A., Maruoka, N., Kawai, A., Kamano, H., Jozuka, T., Senda, T., Akiyama, T. (2007). Thermophysical and heat transfer properties of phase change material candidate for waste heat transportation system. Heat Mass Transf. 44, 763–769.
49. Jiang, Y.; Hussain, H.; Kressler, J. Poly(vinyl alcohol) Cryogel Formation Using Biocompatible Ice Nucleating Agents. Macromol. Mater. Eng. 2014, 300, 181–190.
50. Elefsiniotis, A., Becker, T., Schmid, U. (2013). Thermoelectric Energy Harvesting Using Phase Change Materials (PCMs) in High Temperature

Environments in Aircraft. J. Electron. Mater. 43, 1809–1814.
51. Solé, A., Neumann, H., Niedermaier, S., Martorell, I., Schossig, P., Cabeza, L.F. (2014). Stability of sugar alcohols as PCM for thermal energy storage. Sol. Energy Mater. Sol. Cells 126, 125–134.
52. Yuan, Y., Zhang, N., Tao, W., Cao, X., He, Y. (2014). Fatty acids as phase change materials: A review. Renew. Sustain. Energy Rev. 29, 482–498.
53. Rozanna, D., Chuah, T.G., Salmiah, A., Choong, T.S.Y., Sa'Ari, M. (2005). Fatty Acids as Phase Change Materials (PCMs) for Thermal Energy Storage: A Review. Int. J. Green Energy 1, 495–513.
54. Feldman, D., Shapiro, M., Banu, D. (1986). Organic phase change materials for thermal energy storage. Sol. Energy Mater. 13, 1–10.
55. Feldman, D., Banu, D., Hawes, D. (1995). Development and application of organic phase change mixtures in thermal storage gypsum wallboard. Sol. Energy Mater. Sol. Cells 36, 147–157.
56. Lin, Y., Zhu, C., Alva, G., Fang, G. (2018). Palmitic acid/polyvinyl butyral/expanded graphite composites as form-stable phase change materials for solar thermal energy storage. Appl. Energy 228, 1801–1809.
57. Sharma, R.K., Ganesan, P.B., Tyagi, V.V. (2016). Long-term thermal and chemical reliability study of different organic phase change materials for thermal energy storage applications. J. Therm. Anal. Calorim. 124, 1357–1366.
58. Kahwaji, S., White, M. A. (2018). Prediction of the properties of eutectic fatty acid phase change materials. Thermochimica Acta, 660, 94-100.
59. Zeng, J. L., Chen, Y. H., Shu, L., Yu, L. P., Zhu, L., Song, L. B., Cao, Z., Sun, L. X. (2018). Preparation and thermal properties of exfoliated graphite/erythritol/mannitol eutectic composite as form-stable phase change material for thermal energy storage. Solar Energy Materials and Solar Cells, 178, 84-90.
60. Liang, J., Zhimeng, L., Ye, Y., Yanjun, W., Jingxin, L., Changlin, Z. (2018). Fabrication and characterization of fatty acid/wood-flour composites as novel form-stable phase change materials for thermal energy storage. Energy Build. 171, 88–99.
61. Mathis, D., Blanchet, P., Landry, V., Lagière, P. (2018). Impregnation ofWood with Microencapsulated Bio-Based Phase Change Materials for High Thermal Mass Engineered Wood Flooring. Appl. Sci. 8, 2696.
62. Mathis, D., Blanchet, P., Landry, V., Lagiere, P. (2019). Thermal characterization of bio-based phase changing materials in decorative wood-based panels for thermal energy storage. Green Energy Environ. 4, 56–65.

63. Yang, Z., Deng, Y., Li, J.(2019). Preparation of porous carbonized woods impregnated with lauric acid as shape-stable composite phase change materials. Appl. Therm. Eng. 150, 967–976.
64. Li, J., Xue, P., He, H., Ding, W., Han, J. (2009). Preparation and application e
ects of a novel form-stable phase change material as the thermal storage layer of an electric floor heating system. Energy Build. 2009, 41, 871–880.
65. Ma, L., Wang, Q., Li, L. (2019). Delignified wood/capric acid-palmitic acid mixture stable-form phase change material for thermal storage. Sol. Energy Mater. Sol. Cells 2019, 194, 215–221.
66. Guo, X., Cao, J., Peng, Y., Liu, R. (2016). Incorporation of microencapsulated dodecanol into wood flour/high-density polyethylene composite as a phase change material for thermal energy storage. Mater. Des. 89, 1325–1334.
67. Amini, M.H.M., Temiz, A., Hekimoglu, G., Demirel, G.K., Sarı, A. (2022). Properties of Scots pine wood impregnated with capric acid for potential energy saving building material. Holzforschung 76, 744–753.
68. Can, A., Žigon, J. (2022). n-Heptadecane-Impregnated Wood as a Potential Material for Energy-Saving Buildings. Forests, 13(12), 2137.
69. Can, A., Ergun, M. E., Özlüsoylu, İ. (2023). Properties of oak wood incorporating microencapsulated phase change material. BioResources, 18(3), 6068.
70. Can, A. (2023). Preparation, characterization, and thermal properties of microencapsulated palmitic acid with ethyl cellulose shell as phase change material impregnated wood. Journal of Energy Storage, 66, 107382.
71. Li, Y., Wang, B., Zhang, W., Zhao, J., Fang, X., Sun, J., Xia, R., Guo, H., Liu, Y. (2022). Processing wood into a phase change material with high solar-thermal conversion efficiency by introducing stable polyethylene glycol-based energy storage polymer. Energy, 254, 124206.
72. Li, Y., Zhang, W., Sun, J., Fang, X., Wang, B., Li, F., Zhang, D., Guo, H., Liu, Y. (2023). A route of polyethylene glycol-based phase change heat storage wood with AlN as the thermal conductive filler. Wood Science and Technology, 1-23.
73. Soares, N., Santos, P., Gervásio, H., Costa, J. J., & Da Silva, L. S. (2017). Energy efficiency and thermal performance of lightweight steel-framed (LSF) construction: A review. Renewable and Sustainable Energy Reviews, 78, 194-209.
74. Xia, R., Zhang, W., Yang, Y., Zhao, J., Liu, Y., & Guo, H. (2021). Transparent wood with phase change heat storage as novel green energy storage composites for building energy conservation. Journal of Cleaner

Production, 296, 126598.
75. Xu, J., Yang, T., Xu, X., Guo, X., & Cao, J. (2020). Processing solid wood into a composite phase change material for thermal energy storage by introducing silica-stabilized polyethylene glycol. Composites Part A: Applied Science and Manufacturing, 139, 106098.
76. Yang, H., Wang, Y., Yu, Q., Cao, G., Yang, R., Ke, J., Di, X., Liu, F., Zhang, W., Wang, C. (2018). Composite phase change materials with good reversible thermochromic ability in delignified wood substrate for thermal energy storage. Applied energy, 212, 455-464.
77. He, S., Zhao, X., Wang, E. Q., Chen, G. S., Chen, P. Y., Hu, L. (2023). Engineered Wood: Sustainable Technologies and Applications. Annual Review of Materials Research, 53.

Chapter 3

An Overvıew On Dısaster Of The Century And The Impact On Agrıculture

Asuman Büyükkılıç Yanardağ[1]
İbrahim Halil Yanardağ[2]

Abstract:

Earthquakes are known to have various effects on agriculture. Depending on their magnitude, earthquakes cause delays in agricultural activities and damage to production resources. It is known that each of the 10 provinces affected by the earthquake we experienced in February 2023, are provinces with very high agricultural potential. Adana, Şanlıurfa, Diyarbakır, Malatya, Kahramanmaraş, Hatay, Malatya, Kahramanmaraş, and Diyarbakır, which account for about 15 percent of the total agricultural land in Turkey, are also located in the earthquake zone. The earthquake zone also accounts for 20 percent of Turkey's crop production and 15 percent of livestock production. In these 11 earthquake-affected provinces, there are 2.6 million hectares of field crops, including cereals and other crops. This corresponds to approximately 15.5 percent of Turkey's crop production. The earthquakes that hit Turkey have caused significant damage to agriculture and food security. The earthquakes caused cracks, fissures and collapses in fields, making it difficult to use agricultural land. Agricultural irrigation systems were also damaged. As Turkey is an earthquake-prone country, we need to get used to living with earthquakes. Therefore, some measures need to be taken to protect agricultural areas and at the same time to ensure sustainability.

Keywords: Disaster, century. effects, agriculture

Malatya Turgut Özal University, Agriculture Faculty,
Soil Science and Plant Nutrition Department.
Alacakapı Mah. Kırkgöz Cad. No:70 P.K. 44210 Battalgazi / Malatya/Turkey
[1] Orchid Asuman Büyükkılıç Yanardağ: 0000-0003-3236-2022
[2] Orchid İbrahim Halil Yanardağ: 0000-0003-2558-9600
*corresponding author email: buyukasuman@gmail.com

Introduction

Disaster of the Century

On February 6, 2023, two earthquakes centered in Pazarcık and Elbistan occurred when we experienced the disaster of the century (Fig.1). Afterwards, thousands of large and small aftershocks occurred. These earthquakes, which were very close to the surface, were very different from the major earthquakes that occur in the world. The differences of the earthquakes which, occurred at a depth very close to the earth's surface. This increased its destructiveness a lot. These earthquakes caused the Anatolian peninsula to shift 3 meters to the west, which is also created some problems on the lands. Some of these were rifts and depressions in the agriultural area (Fig. 2).

Kaynak: The Telegraph

Fig. 1. On February 6, where two major earthquakes occurred and the plates in the region.

As we all know, earthquakes are natural disasters that can cause significant damage to human life and the environment. The soil quality and fertility of a region can be affected by earthquakes. Soil contamination is becoming an

increasing post-earthquake problem that can have a negative impact on food security and human health (UNEP., 2020). Soil pollution can reduce crop yields due to toxic levels of contaminants. It can make these crops unsafe for consumption by animals and humans. The main anthropogenic sources of soil pollution are chemicals used in industrial activities or produced as by-products, household waste, municipal waste (including wastewater); livestock, agricultural chemicals, and petroleum derivatives (FAO., 2021). Post-earthquake construction and demolition wastes, i.e. excavations, have also become sources of pollution.

Fig.2. Rifts in the lands after the 6 February earthquake (AA., 2023)

Soil pollution can lead to the extinction of both plants and animals, cause the emergence of new pests and diseases and change the balance of ecosystems. It also allows the spread of antimicrobial resistant bacteria and genes (EC., 2023 and FAO., 2021). For all these reasons, soil pollution caused by earthquakes has become a very important issue after major earthquakes. Earthquakes affecting the soil, of course, affect agriculture, especially sustainable agriculture and food.

Effects of Earthquake on Agriculture:

Today, it is a known fact that earthquakes have various effects on agriculture. Depending on their magnitude, earthquakes cause damage to production resources and delays in agricultural activities (Fig. 3). Cracks, landslides, and fractures in the land due to earthquakes make the use of agricultural land more difficult. Not only land but also agricultural irrigation systems can be damaged. Migration due to earthquakes also has negative effects on agricultural production (Yavuz., 2023). Earthquakes can also have negative impacts on crop and animal production activities, such as stopping or delaying agricultural production activities, loss of crops, stored inputs and livestock (UNEP., 2020, EPA., 2023 and FAO., 2015).

Depending on their magnitude, earthquakes can cause different effects such as damage to production resources and difficulty in accessing these resources. Due to earthquakes, cracks, landslides, landslides, cracks and fractures that occur in lands where agriculture is intensive make it difficult to use agricultural lands. Sometimes they prevent it. In addition, agricultural lands, irrigation pipes and sometimes irrigation canals can also be damaged by all these effects. Migration due to all these negative conditions caused by earthquakes can disrupt agricultural production (Yavuz., 2023).

In earthquakes that occur during the production period, animal and plant production activities are also severely damaged. These damages can be in the form of loss of products and inputs or animal wastage during both production activities and harvesting. Distortions in the land can cause harvest loss as well as making harvesting difficult. Feed shortages can also occur when animal feed is destroyed by earthquakes. Long/short-term power outages and lack of access to fuel during energy-demanding animal and crop production processes can also cause significant losses.

Fig. 3. After the February 6 earthquake, huge cracks in a field in Hatay (Sergen Sezgin/AA, 24 Şubat 2023)

All these negative effects of earthquakes on agriculture can lead to decreases in animal and plant production. Most importantly, decreases in product quality can push prices to very high levels. Earthquake disruptions that may occur at many stages of the food supply chain may lead to both loss of agricultural products and higher food prices. These developments can push up food inflation first and then general inflation.

It is a known fact that each of the 10 provinces affected by the earthquake we experienced in February 2023 are provinces with very high agricultural potential. Adana, Şanlıurfa, Diyarbakır, Malatya, Kahramanmaraş, Hatay, Malatya, Kahramanmaraş, and Diyarbakır, which account for about 15 percent of the total agricultural land in Turkey, are also located in the earthquake zone (Fig.4). The earthquake zone also accounts for 20 percent of Turkey's crop production and 15 percent of livestock production. In these 11 earthquake-affected provinces, there are 2.6 million hectares of field crops, including cereals and other crops. This corresponds to approximately 15.5 percent of Turkey's crop production (Yavuz., 2023).

The magnitude of all these impacts depends on various factors, such as the magnitude of the earthquake. For example, the earthquakes that hit Turkey in February 2023 caused significant damage to agriculture and food security. The earthquakes caused cracks, fissures and subsidence in fields, making it difficult to use agricultural land (Fig. 4). Agricultural irrigation systems were also damaged.

Fig. 4. February 6 earthquake ruptures in agricultural areas (Anonymous., 2023)

Effects of Earthquakes on Soil Quality and Productivity

Earthquakes can have various impacts on soil, agriculture, soil quality and soil fertility. For example, earthquakes directly affect the soil, causing soil liquefaction, the process by which saturated soil temporarily loses its strength and behaves like a liquid. This can cause buildings and infrastructure to sink or topple. The severity of soil liquefaction depends on factors such as the type of soil and the intensity of the earthquake. Earthquakes indirectly affect agriculture. They can disrupt agricultural activities by damaging crops, irrigation systems and storage facilities.

The extent of damage depends on factors such as the proximity of the epicenter, the magnitude of the earthquake and the resilience of agricultural infrastructure. Earthquakes also indirectly affect soil quality. Earthquakes can affect soil quality by changing the physical, chemical and biological properties of soil. They can change the aggregate stability of soils. For example, seismic shaking can cause compaction, which reduces soil porosity, affecting water infiltration and root growth. In addition, earthquakes can introduce new materials into the soil through landslides or ground fractures. Earthquakes can affect soil fertility by disrupting nutrient cycling processes (C, N, etc.). Seismic tremors can lead to the loss of topsoil, which contains organic matter and nutrients essential for plant growth. Furthermore, earthquakes can alter soil pH and nutrient availability, potentially affecting crop productivity.

The specific effects of earthquakes on soil, agriculture, soil quality and soil fertility can vary depending on factors such as the magnitude of the earthquake, the depth of seismic activity and local geological conditions.

Suggestions

Since Turkey is an earthquake-prone country, we need to get used to living with earthquakes (Fig. 5). Therefore, some measures need to be taken to protect agricultural areas and at the same time ensure sustainability. By increasing crop diversity, we can minimize crop losses and thus control food security. Another measure is to design irrigation systems with flexible pipes and connection points. This can help prevent damage during earthquakes. Developing emergency response plans and conducting drills can help farmers respond effectively during earthquakes. Training farm workers on safety protocols, evacuation routes and first aid procedures is crucial to minimize injuries and ensure a coordinated response (FEMA., 2021). Implementing soil conservation practices such as tillage, terracing and cover cropping can improve soil stability and reduce the risk of erosion triggered by seismic events. Maintaining healthy soil structure through the addition of organic matter and proper nutrient management also contributes to long-term soil resilience (W.B., 2016). It is important that farmers are aware

of earthquake risks in their area and collaborate with local authorities, agricultural extension services and disaster management agencies to implement appropriate mitigation strategies.

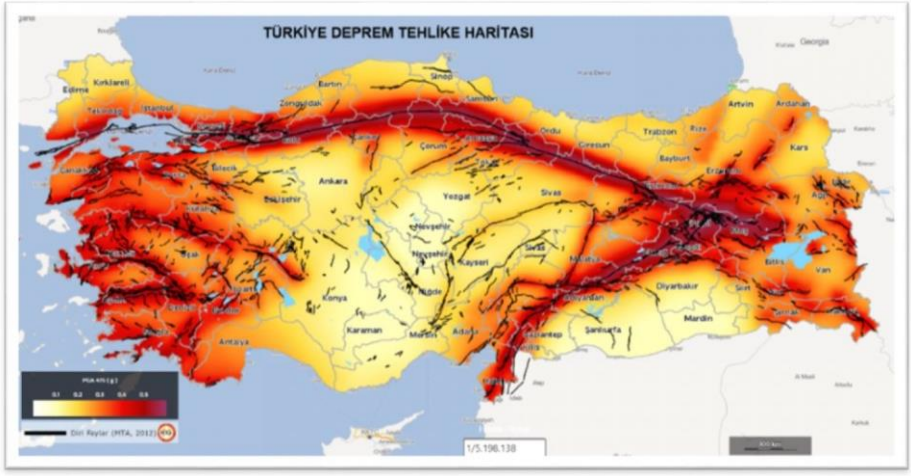


Fig. 5. Earthquake map of Turkey (AFAD, 2018).

Conclusions

It is a known that earthquakes can have various effects on agriculture. Depending on their magnitude, earthquakes cause delays in agricultural activities and damage to production resources. Since Turkey is an earthquake-prone country, we need to get used to living with earthquakes. Therefore, some measures should be taken to protect agricultural areas and at the same time to ensure sustainability. If we count a few of them; By increasing crop diversity, food security can be controlled. Flexible pipes can be used for irrigation to prevent damage during earthquakes. Conducting emergency drills can help farmers respond effectively during an earthquake. Implementing soil conservation practices can improve soil stability and reduce the risk of erosion triggered by seismic events. The addition of organic matter can maintain soil structure while also ensuring long-term soil resilience. It is important for farmers to cooperate with local authorities, agricultural extension services and disaster management agencies on earthquake preparedness.

References

1. AFAD., 2018. https://tdth.afad.gov.tr/
2. AA., 2023. https://www.aa.com.tr/tr/asrin-felaketi/depremler-kirsal-mahalledeki-arazide-cokuntu-ve-yukselmeler-olusturdu/2859335
3. EC., 2023. https://environment.ec.europa.eu/topics/soil-and-land/soil-health_en
4. EPA., 2023. Agriculture and Natural Events and Disasters | US EPA
5. FAO., 2015. FAO - News Article: Nepal Earthquake's impact on food security and agriculture likely very high
6. FAO., 2021. https://www.fao.org/global-soil-partnership/areas-of-work/soil-pollution/en
7. FEMA., 2021. https://www.fema.gov/press-release/20210318/tips-reduce-earthquake-damage
8. UNEP., 2020. https://www.unep.org/news-and-stories/story/soil-pollution-risk-our-health-and-food-security
9. Yavuz., F., 2023. How Turkey's Earthquake Affected the Agriculture and Food Security, 7 March 2013. Poltics Today, Daily Newspaper. https://politicstoday.org/turkey-earthquake-agriculture-food-security/
10. W.B., 2016. World Bank, The İstanbul Seismic Risk Mitigation Project. https://www.worldbank.org/en/country/turkey/brief/the-istanbul-seismic-risk-mitigation-project

Chapter 4

Economıc Value And Usage Areas Of Algae

Ayşe GÜNDOĞDU[1]
Saniye TÜRK ÇULHA[2]

Abstract

Algae, which are used in many fields today, are living organisms that show diversity with many classifications within themselves. Algae are evaluated in two groups: microalgae and macroalgae. Microalgae form the first link of the food chain and are called primary producers. They vary from small single-celled species to complex multicellular structures. Marine flora consists of algae and seagrass. Algae are important in terms of maintaining the CO_2 - O_2 balance in their environment, providing places for nutrition, reproduction, shelter, and protection of aquatic organisms, and creating balance between organisms in the aquatic environment. They are ecologically important for many vertebrate and invertebrate species, as they lay eggs, hide their larvae, and provide shelter from their enemies. In addition to forming the first link of the food chain as they are primary producers, some species have indicator properties in the environment. It is known that algae have been used by people for a long time, especially in the fields of food, medicine, and cosmetics. Substances such as alginic acid obtained from brown algae, agar obtained from red algae, and some types of microalgae (*Spirulina, Chlorella*, etc.) are used in many branches of industry today.

Keywords: Microalgae, macroalgae, algae use, chemical content, nutrients.

Introductıon

Algae is one of the organisms that have a very important role in the ecosystem and they live in quite different environments. Algae can live in a wide range of environments on Earth, from the poles to hot water sources, from freshwater to salt water. They can grow in seas and lakes at depths of 100 m below the surface or with lower light intensity, and under high pressure. Studies show that an important part of the algae such as 70% ecologically, is watery areas. Thanks to

[1] 1- Prof. Dr. Sinop üniversitesi, Su Ürünleri Fakültesi, Akliman, Temel Bilimler Bölümü, aysegundogdu57@hotmail.com, ORCID No: 0000-0003-1323-1003
2- Doç. Dr. İzmir Katip Çelebi Üniversitesi, Su Ürünleri Fakültesi, Temel Bilimler Bölümü, trksanye@gmail.com ORCID No: 0000-0003-0380-0858

the pigments in their structure, they convert CO_2 and H_2O into organic substances with the effect of light, thus increasing the nutritional value and dissolved O_2 ratio in the aquatic environment. For this reason, they have a very important role in the functioning and continuity of the aquatic ecosystem. Because of this role, they form the first link in the food chain and are called primary producers. Algae contain and produce polysaccharides, proteins, fats, fatty acids, essential amino acids, minerals, vitamins, and bioactive molecules (Ak et al., 2022:26).

Studies on marine algae and their usage possibilities have been carried out for many years. In 2700 BC, King Shen Nung is known as the first person to use algae. After Christ (AD), marine algae became of great importance in the field of medicine and as a nutrient in China, Japan, and Korea. Algae were first used as a colorant in the cosmetics industry in the Roman Empire, during the time of Virgil and Heros. The oldest known usage area of algae is fertilizer making, and it was mostly used in the Far East (Cirik, 1981:28; Kaba and Çağlak, 2006:31). In addition, agar, carrageenan, and alginate are the most important substances obtained from algae (Cirik, 1981:28). Agar is the first red algae product produced in the Far East and has been recently recognized in Europe. Carrageenan, which is a product obtained from red algae such as agar, has been used on European coasts for many years as a thickener for marmalades and similar works. However, in recent years, the usage areas and importance of Carrageenan obtained by extraction have increased a lot (Jensen, 1966:31). Besides red algae, brown algae are also of great value. Alginic acid and alginates are the most important products obtained from brown algae. The discovery of alginic acid and its usability as a raw material in modern industry emerged in 1897 as a result of the work of E.C.C. Stanford, who was born in Sussex. The production of alginic acid and alginates in the USA started in 1929 and developed as an industry branch (Myklestad, 1963:32; Kaba and Çağlak, 2006:31). “Seaweeds” or “sea vegetables” are commonly known as macroalgae (Paiva et al., 2017:33), which have been used by humans for generations as food, soil conditioner, or fertilizer. Today, in the main market of Asia, macroalgae are used as food, fertilizer, phycocolloid [general name of colloids (agar and alginate etc.) extracted from algae], and cosmetic components. Despite this, macroalgae are still considered “underutilized” resources (Milledge and Harvey, 2016:32) and their industrial production is not at the expected levels (Barka and Blecker, 2016:27; Sasa et al., 2020:33).

Algae are used in almost every field of industry. Due to the fact that they can be cultivated throughout the year, can be produced in areas that are not suitable for agriculture, and are the systems that use water and solar energy most efficiently, studies on biomass production to be used in energy sources and

different areas (water treatment, as fertilizer) are noteworthy in recent years. Because of their valuable metabolites and pigments in their cells, they are also consumed as antioxidants, thanks to their natural food dye, food support and immune-boosting properties. In addition, they are used in animal feed, fertilizer, aquaculture, alcohol industry, paper and rubber industry, paint and textile industry, pharmaceutical and cosmetic industry, and wastewater treatment due to their high metal binding capacity. The algae, which are cultured both in the natural environment and in laboratory conditions, have great importance in the economy. In recent years, the potential of microalgae in the production of biofuels, which is a renewable and non-toxic energy source, has also been mentioned (Ak et al., 2022:26).

1. Chemical Content of Algae

Algae are primary producers in the marine ecosystem. They have a very important place with the acids, alkaloids, amines, cellulose, enzymes, glycosides, trace elements (Ga, Zn, Ni, Co, Fe, Mn, Ca, Cr, B, Na, Mg, Al, F, K) and inorganic minerals, lipids, sterols, steroids, fatty acids, phenolic components (shikimic acid, shikimate, phenylpropanoid, phenolic acid, coumarin, lignan, flavonoid, anthocyanin, tannin, quinone), phytohormones (auxin, gibberellin), pigments, proteins, peptides, amino acids, vitamins (C, B12, H, folic acid, nicotinic acid, pantothenic acid, B1, B2, E, K) and volatile components (acetic, acrylic, butyric, formic, myristic, palmitic acid, aldehyde, alcohol, terpenes and phenols) they contain (Lewis, 1962:32; McCourt, 1995:32; Brownlee et al., 2005:27; Al-Saif et al., 2014:26).

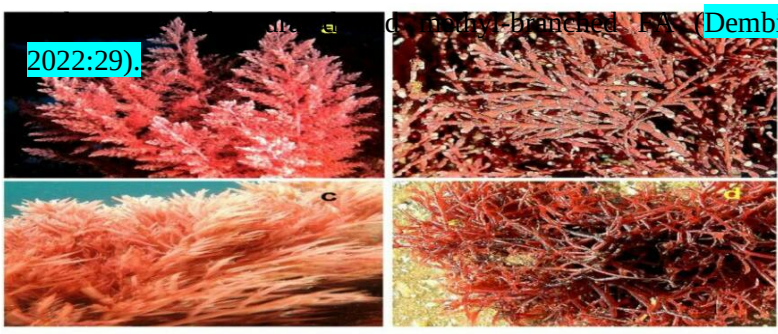
In a study, the presence of stigmasterol, hexadecanoic acid, and decortinon was detected in the green algae *Codium elongatum*. β-sitosterol was detected in another green alga, *Enteromorpha intestinalis*. Saturated and unsaturated fatty acids were isolated from red algae *Botrocladia leptopoda* varieties. The presence of cholesterol and different new metabolites has been shown in the brown alga *Iyengaria stellata* (Ali et al., 1999:26). In another study, the presence of fatty acids, steroids, carotenoids, polysaccharides, lectins, mycosporin-like amino acids, halogenated compounds, polyketides, and toxins in algae was emphasized (Cardozo et al., 2007:27; Aktar and Cebe, 2010:26).

Algae are organisms of commercial importance due to their ability to produce different chemical and biological compounds. They show diversity from small unicellular species to complex multicellular structures. They are also the most important primary producers of biomass and one of the most valuable groups for organisms (Gezici et al., 2012:30). Thanks to the valuable metabolites they store in the cell, algae can be used as food support and health protection, animal feed,

fertilizer due to their soil structure improvement properties, natural food dye, cosmetics industry, and wastewater treatment thanks to their metal binding abilities (Gökpınar et al., 2013:30).

The most commonly used algae for economic purposes are Brown algae (*Phaeophyta, Fucophyta),* red algae (Rhodophyta), and green algae (Chlorophyta), (Figure 1-3.). The most cultivated macroalgae are *Macrocystis, Palaria, Laminaria, Alaria, Sargassum, Undaria, Gracilaria, Gelidium, Gelidella, Gigartina, Kappaphcus, Eucheuma, Chondrus, Porphyra, Iridaea, Hypnea, Acanthophora, Agardhiella, Plocamium, Monostroma, Ulva* and *Enteromorpha* are economic species belonging to the genus (Sukatar and Şenkardeşler, 2001:33). Microalgae contain high energy thanks to fatty acids such as oleic acid (C18:1) and palmitoleic acid (C16:1), which are more than 80% in amount. For this reason, it is very convenient to turn microlags into fuel. Gasification, pyrolysis, and transesterification methods can be given as examples of the methods used to convert microalgae to biodiesel. Fatty acid compositions are of primary importance in the production of biodiesel by microorganisms (Eliçin et al., 2009:30).

Figure 1: Marine brown algae: (a) *Fucus vesiculosus*; (b) *Laminaria digitata*; (c) *Padina pavonica*; and (d) *Undaria pinnatifida* contain a



c finely-branched. I.V. (Dembitsky, 2022:29).

Figure 2: Marine red algae: (a) *Asparagopsis taxiformis* (b)*Corallina officinalis* (c) *Porphyra umbilicalis* (d) *Gracilaria verrucosa* (Dembitsky, 2022:29).

Figure 3. Green algae belonging to the genus Codium: (a) *C. capitatum*; (b) *C. dwarkense*; (c) *C. taylorii*; and (d) *Codium* sp. live in different zones of the world's oceans and contain different types of saturated and methyl-branched FA (Dembitsky, 2022:29).

2. Classification of Algae

Algae are generally classified into two groups, macroalgae and microalgae according to their size, while on the other hand, they are classified differently as brown, red, green algae and cyanobacteria according to the pigments they contain (Ak and Cirik, 2017:26; Alçay et al., 2017:26). It is known that 104 species of blue-green algae, 380 species of red algae, 144 species of brown algae and 141 species of green algae are distributed in the seas of our country (Taşkın et al., 2004:33; Durucan and Turna, 2011:29). Macroalgae, are a distinct group of multicellular, fast-growing, large-sized, (Khan et al., 2018:31) plant-like protists that can be seen with the naked eye, and are classified as brown (*Phaeophyta*), green (*Chlorophyta*), and red algae (*Rhodophyta*). Their colors are due to the different pigments they contain (Villarruel-López et al., 2017:34; Øverland et al., 2019:33). Macroalgae, which are generally found in the zones close to the coast (El-Gamal, 2010:29) and vary between 1-2 cm and 40-50 m in size depending on the species, are vegetative organisms that form the nutrition, shelter, and breeding environment for aquatic creatures (Ak and Cirik, 2017:26).

Microalgae are microscopic creatures and can be prokaryotic like cyanobacteria (*Chloroxybacteria*) or eukaryotic like green algae (*Chlorophyta*) (Khan et al., 2018:31). Microalgae can multiply rapidly and survive even under adverse conditions thanks to their unicellular or simple multicellular structures (Mata et al., 2010:32; Elcik and Çakmakcı, 2017:29). Microalgae, about 3-10 μm in diameter or length, are bio compounds with high nutritional value and therapeutic functions such as lipids, proteins, carbohydrates, pigments, and

polymers. They are autotrophic microorganisms that use light energy and inorganic nutrients such as carbon dioxide, nitrogen, and phosphorus to synthesize and develop these compounds (De Morais et al., 2015:28).

Microalgae are present as phytoplankton both near the coast and in the deep zones. Phytoplankton are composed of organisms such as diatoms, dinoflagellates, green and yellow-brown flagellates, and blue-green algae (*Cynanophyceae*), (El Gamal, 2010:29). In general, microalgae are classified as red, green, brown, and blue-green algae according to the pigments they contain (Dineshkumar et al., 2017:29). The only group within the microalgae classes that includes prokaryotic organisms is the blue-green algae. Blue-green algae are classified by bacteriologists in the Cyanobacteria division since their cells do not have nuclei and plastid walls, do not have mitochondria, Golgi apparatus, and vacuoles, and gender is not seen (Ak and Cirik, 2017:26). This group of algae is of great importance for humans and animals in terms of the proteins, carbohydrates, lipids, vitamins, enzymes, and other bioactive compounds (antibiotics, algicides, toxins, pharmaceutically active compounds, and plant growth regulators) they synthesize (Demiriz, 2008:28; Sasa, et al., 2020:33). In the generally valid classification system, algae are divided into seven sections in the non-flowering plants (Symptomatic plants-Cryptogamae) branch (Güner and Aysel, 1989:31; Güner, 1994:31):

A- *Cyanophyta* (Blue-Green Algae): Blue-green algae can live both in water and on land. Algae living in water are either free-swimming or cling to a place, depending on their condition. Although the members of this section are usually unicellular, simple or pseudo-branched filamentous types can also be found that form colonies. Some species of blue-green algae living in stagnant waters become abundant in certain seasons and years, causing coloration of the waters. The resulting colors are usually wine red or violet red.

B- *Euglenophyta* (Whiplash Algae): They are single-celled organisms that are naked or surrounded by a special wall. They usually swim freely. There is one class and two orders of flagellated algae that live in fresh, brackish, and moist environments. When abundant in water, *E. sanguinia* species change the color of the water to red.

C- *Pyrrophyta* (Fire color Algae): They are two flagellated algae that can be single-celled colonies or branched filamentous. They usually live in the seas, although some can live in fresh and brackish waters. The most important team in the department is *Dinophycales*. Most of the genera in this order live in the seas and form the food of fish. When the *Gymnodinium brevis* species included in these grow too much, they can cause the death of

the fish. Species belonging to the genus *Peridinium* cause a luminescent phenomenon called yakomoz in the seas.

D- *Chrysophyta* (Golden Algae): This section, which has a wide distribution area and is represented by many species, is systematically divided into three classes. The largest class of golden algae is Bacillariophyceae. This class is also divided into two groups according to cell structure. Diatoms living in fresh, brackish, salty waters and humid environments are single-celled and can form colonies. Its cells consist of two interlocking box covers, one small and the other large.

E- *Chlorophyta* (Green Algae): It is a section containing green plants with a single-celled, threadlike, ribbon-shaped structure that differ in shape and size. Its walls are composed of pectin and cellulose. They have a wide distribution area in nature. 90% live in fresh water and 10% live in the sea. Some species form a group of plants called lichens together with fungi.

F- *Phaeophyta* (Brown Algae): They mostly live in the seas. It has filamentous, leafy, densely branched, tree-like forms. Cells are mononuclear. Their walls are made of cellulose and pectin. Some species are very rich in alginate substances. Brown algae, which is a single class, are divided into three subclasses.

G- *Rhodophyta* (Red Algae): It is the most developed part of algae. Most of them have thallus which are multi-row, filamentous, densely branched, or large-surfaced fleshy structures. In many species, cell walls are composed of an outer mucilage-like pectin layer and an inner cellulose layer. In some groups, for example, in the class *Corallinaceae*, they look like stones because they accumulate abundant calcium carbonate on their cell walls.

3. Macroalgae and Microalgae consumed as food

Nori or Mor Laver (*Porphyra* spp.): Sushi is the most common use of nori. Sushi is a typical Japanese dish, served on a nori plate with sour and boiled rice with some sugar and vinegar, sauce on top, and usually, slices of various types of raw fish, wrapped in a roll and cut 3-4 cm thick. In another method, nori is cooked for a short time and then cut into small pieces and sprinkled over boiled rice or noodles. In addition, tsukudani aonori, which is preserved by boiling in soy sauce, is known as a luxurious dish (Kaba and Çağlak, 2006:31). Another use of nori is in rice sandwiches called onigiri. Nori is used as a raw material for jam and wine, and the products are called nori jam or nori wine. In China, nori is used to make soups and to prepare spicy foods by frying them in hot oil (Oğur, 2016:32).

Aonori or Green Laver (*Monostroma* spp. and *Enteromorpha* spp.): Another macroalgae used as human food, Aonori is the trade name for a mixture

of various green seaweeds such as sea lettuce (Ulva) or true green laver (Enteromorpha) and Monostrama. Among these green algae, *Monostrama latissimum* and *Enteromorpha prolifera* are grown for commercial purposes in Japan today (Oğur, 2016:32). These algae contain 20-26% protein and 19-23% mineral substances. Enteromorpha's sodium content is lower than others, but its calcium and iron content is higher. They are rich in B group vitamins, especially B group vitamins are in higher value in Enteromorpha (Yamamota, 1982:34; Kaba and Çağlak, 2006:31).

Kombu or Haidai (*Laminaria japonica*): Kombu is the Japanese name for dried seaweed derived from a mixture of the *Laminaria* species. These include *L. longissima, L. japonica, L. angustata, L. coriacea and L. ochotensis*. Recently, kombu has been considered as an energy source and its cultivation has been done successfully. 32% of the kombu obtained in China is used as raw material in alginate production (Nisizawa, 1985:32). Konbu is rich in minerals, vitamins, amino acid (especially ascorbic acid and glutamic acid) content, and EPA (Eicosapentaenoic acid) ratio (20-25%), (Fujiwara, 1984:30). Suboshi kombu, obtained from Laminaria angustata, is boiled with soy sauce and some spices. In making chopped kombu, suboshi konbu is chopped into strips and dipped in soy sauce to obtain konbu pickle. Sliced kombu is the process of softening suboshi konbu obtained from Laminaria japonica by soaking it in vinegar and slicing it with a knife. Roll kombu is the suboshi konbu obtained from Laminaria angustata and Laminaria longissima cut into rectangles and wrapped in paper rolls (Chapman and Chapman, 1980:28; Oğur, 2016:32).

Wakame, quandai-cai (*Undaria pinnatifida*): In Japan, wakame products are mostly made from *Undaria pinnatifida*. Wakame is a sea vegetable or edible seaweed. In Japan, salted wakame is used as a thickener in various soups and stews. It can also be consumed fresh, in the form of a raw salad by mixing it with soy sauce, or boiled and added with vinegar, sugar, and soy sauce. Sliced wakame is mechanically cut into small pieces and dried in the dryer. The cut leaves are classified into uniform sizes, packaged in plastic films, and made ready for sale (Nisizawa, 1985:32).

The amount of Fe, Mg, and Cu in wakame is higher than in konbu and hizik. The Ca and P contents are relatively high in haiboshi and sliced wakame, while the Na content is high in yudoshi-enzo wakame. In terms of amino acid content, the amount of alanine, glycine, proline and serine is higher than aspartic and glutamic acid. The presence of these amino acids creates the unique flavor of wakame. Suboshi wakame is rich in vitamin content and has almost the same amount of vitamins in unprocessed leaves. Haiboshi wakame is also relatively rich in vitamins. However, in other processed products a significant portion of

the vitamins are lost. In contrast to konbu and hiziki, palmitic and oleic acids constitute a significant portion of the fatty acid content of the total oil in wakame (Nisizawa, 1985:32; Kaba and Çağlak, 2006:31).

Hiziki (Hizikia fusiformis): Hiziki is a typical nutrient derived from macroalgae used as human food in Japan and is made from *Hizikia fusiformis*. Boiled hiziki is cut into small pieces (about 5 cm) and dried in the sun again, the product is called "hoshi hiziki". Hoshi hiziki is boiled or roasted and mixed with pureed soybeans and some vegetables (especially carrots). It is then sweetened with soy sauce and sugar, cooked, and offered for sale. Another area of use is to use the water obtained by boiling hoshi hizik in water, called dashi, in making meals or soups. Additionally, hoshi hiziki is boiled with the addition of soy sauce, sugar, and rice wine, and this mixture is served with boiled rice. Although there is a loss of vitamins during the boiling of hoshi hiki, its niacin content is relatively high and its total lipid content is low. In addition, it is rich in mineral substances, especially Fe and Cu content (Nisizawa, 1985:32; Kaba and Çağlak, 2006:31).

Mozuku (*Cladosiphon okamuranus*): Mozuku is a brown seaweed harvested from the natural population of the southern island of Japan, which has a more tropical climate. Harvested seaweed must be protected from the sun and is stored to dry for approximately 15 days. It is put on the market after cleaning and 20-25% salting. It is sold wet and salted in packages ranging from 250 g to 18 kg. It is washed to remove salt, drained, and used as a fresh vegetable, eaten with soy sauce and in seaweed salad (McHugh, 2003:32; Oğur, 2016:32).

Seagrass or green caviar (*Caulerpa lentillifera*): The genus *Caulerpa* has many species, but *Caulerpa lentillifera* and *C. racemosa* are the most popular edibles. Both have a grape-like appearance and are used as fresh salads.

Dulse (*Palmaria palmata*): Dulse is a type of red algae with leathery leaves. Dulse is a good source of minerals, iron content is very high, and contains all trace elements necessary for human nutrition. Its vitamin content is even higher than a vegetable like spinach.

Irish moss or carrageenan moss (*Chondrus crispus*): This moss is not eaten as is, but as a result of its carrageenan content, it is used for its thickening power when boiled in water. This seaweed is used in seaweed salad, as sashimi garnishes, and as a soup ingredient. *Chondrus crispus* is an industrial source of carrageenan, often used as a thickener and stabilizer in dairy products such as ice cream and processed foods including lunch meat. It can also be used as a thickener in pressed fabric and for clarification in beer or wine.

Winged Kelp (*Alaria esculenta*): In Ireland, Scotland (United Kingdom), and Iceland are eaten both fresh and cooked. It has the best protein among the Kelps and is rich in trace metals and vitamins, especially in terms of niacin.

Ogo, Ogonori or Sea Moss (*Gracilaria* spp.): Gracilaria is used as food in Japanese, Hawai and Philippine cuisine.

Callophyllis variegata: The demand for edible seaweed in Chile has increased and *Callophyllis variegata* ("Carola") is one of the most popular. This red seaweed has a high commercial value.

Microalgae have rich protein, carbohydrate, and fatty acid content. These organisms, which have high nutritional value, are the most important source of macronutrients, vitamins, and trace elements for aquatic animals. The main ingredient in the composition of microalgae is crude protein. It is also noteworthy that microalgae are rich in vitamins, especially the high amount of vitamin B12. Protein-rich microbial algae contain abundant mineral substances such as K, Na, Mg, Ca, P, S, and Fe. The ratio of these mineral substances varies more or less depending on the seasons. The amount of nucleic acids these algae contain is also at values that cannot be neglected. A culture of microalgae in open fields is only possible in the warm months or when certain temperatures are reached (Atay, 1978:27).

Spirulina is a rich micronutrient and a source of antioxidants, amino acids, vitamins, and minerals (Figure 4). Spirulina contains 65% protein, more protein than any other natural nutrient, and the digestibility of protein is high. It has a fat content of 15-20% and a high rate of polyunsaturated fatty acids. Spirulina has rich thiamine, niacin, riboflavin, and beta-carotene content, and is also the richest source of herbal vitamin B12 in nature. It has a high absorption rate of Fe, and rich Ca content (Kaba and Çağlak, 2006:31). The features that make chlorella and spirulina important in human and animal nutrition are that they contain long-chain polyunsaturated fatty acids, natural phenolic compounds with antioxidant properties, sterols, protein at a higher rate of 50% and essential amino acids (Vaz et al., 2016:34; Andrade et al., 2018:26). Table 1 shows microalgations recommended to be used in human consumption (Borowitzka, 1998:27; Alçay et al., 2017:26).

Table 1. Microalgies used for human consumption or recommended (Figure 5-7).

Algae	Sources
***Cyanobacteria* (Blue-green algae)**	
Spirulina platensis	USA, Thailand, China, Taiwan, India etc. cultured in their country.
Spirulina maxima	USA, Thailand, China, Taiwan, India etc. cultured in their country.
Nostoc commune	Collected from the field.
Aphanizomenon flos-aqua	Collected from the field (USA, Lake Klamath).

Chlorophyta	
Chlorella spp.	It was cultured in Taiwan and Japan.
Dunelialla salina (beta karoten için)	It was cultured in Australia, Israel and the United States.
Scenedesmus sp.	Czechoslovakia and experimentally cultivated.
Haemotococcus pluvialis (for astaxanthin)	It is only experimentally cultural.

Figure 4: *Spirulina platensis*. (http://www.hashmidawakhana.co.in/spirulina-platensis.html). (Bilal and Altiner, 2020:27)

Figure 5: *Nostoc commune*. (Anonymous 2023a.:26)

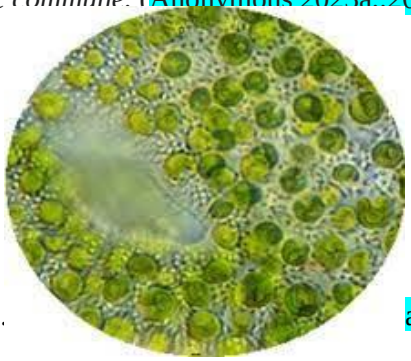


Figure 6: *Chlorella* sp. and Ashraf, 2018:33)

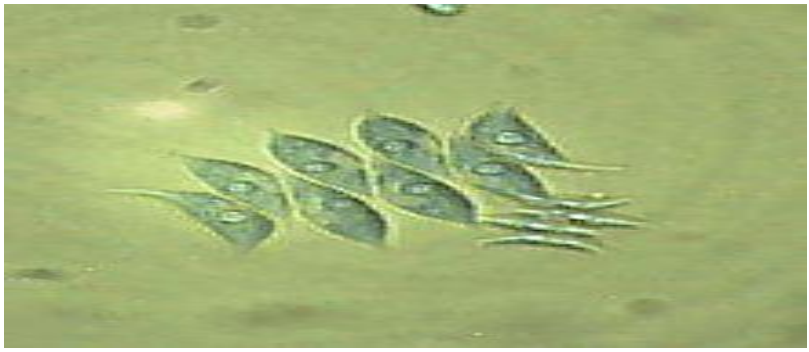


Figure 7. *Scenedesmus acuminatus* (Anonymous (2023b.:26).

5. Nutritional Content of Algae

It is known that algae are very rich in carbohydrates, proteins, lipids, fatty acids, glycerol, natural pigments (beta-carotene, astaxanthin, xanthophyll, phycobilin) and amino acids (Durmaz et al, 2002:29). In addition, it has been determined by many researchers that they contain bioactive substances with antibacterial, antifungal, and antiviral properties, such as minerals, vitamins, polysaccharide,s and polyphenols (Chandini et al., 2008:28). Algae is a rich source of antioxidant vitamins and pigments, as well as polyunsaturated fatty acids *(*Gökpınar et al., 2001:30; Oğur, 2016:32).

Algae are sources of protein, amino acids, carbohydrates, fats, oils, fatty acids, polysaccharides, minerals, and vitamins (Lahaye, 1991:31; Darcy-Vrillon, 1993:28 ; Burtin, 2003:27). For example, 100 g of Porphyra or Palmaria meets all of the daily human needs for vitamins A, B2, and B12 and 67% of the vitamin C requirement (Chapman, 1970:28). Vitamin A is abundant in Ulva, Laminaria, Undaria, Sargassum, and Codium species. In comparison, algae are as rich in vitamin A as cabbage (Cirik and Cirik, 2004:28). Carotene amounts have been detected in some of the algae distributed in the Mediterranean and Black Sea. Cystoseira species of Adriatic origin contain 66-111 mg/kg^{-1} carotene in dry matter, Sargassum vulgare 71 mg/kg$^{-1,}$ and *Cystoseira barbata* of Black Sea origin 120 mg/kg^{-1} (Atay, 1984:27).

Algae are rich in vitamin C. In studies, vitamin C contents of Ulva, Enteromorpha, Alaria, Undaria, Laminaria, Sargassum, Undaria, Porphyra, Wildemannia, and Gigartina were determined as 3-135 mg/100g-1 (dry weight), (Chapman, 1970:28). Brown algae contain higher amounts of vitamin E than green and red algae. Among brown macroalgae, the highest amount of vitamin E was determined as 200-600 mg tocopherol/kg-1 (dry weight) in the Fucus and Ascophyllum species. Red algae and green algae contain only alpha tocopherols, while brown algae contain alpha, beta, and gamma tocopherols (Burtin, 2003:27).

Brown algae contain higher amounts of vitamin E than green and red algae. Among brown macroalgae, the highest amount of vitamin E was determined as 200-600 mg tocopherol/kg-1 (dry weight) in the Fucus and Ascophyllum species. Red algae and green algae contain only alpha tocopherols, while brown algae contain alpha, beta, and gamma tocopherols (Venugopal, 2009:34; Caf, 2014:27).

Protein amounts of algae vary from species to species. In Spirulina, a microalgae, this ratio is 70% in dry matter, while 30-40% in red algae, 20% in green algae, and 10-11% in brown algae. The oil content of algae is low, ranging between 1-5%. Despite this, it has been reported that the essential fatty acids it contains are much higher than other land plants (Givens, 1997:30). The amount of protein in Porphyra species is equal to soybeans, 3 times richer than wheat, 6 times richer than rice, and 1.7 times richer than beef (Ünal, 1988:34). Algae can be considered a good prebiotic source due to their 75% fiber content and high content of polysaccharides such as alginic acid, laminarin, phycocyanin, phycoerythrin, carrageenan (O'Sullivan et al., 2010:32). Prebiotics are fermentable, non-digestible carbohydrates that increase some microorganisms in the intestine, facilitate the colonization of non-enteropathogens and positively affect human or animal health (Kaleli, 2007:31; İnanç et al., 2005:31).

Algae are usually found in oceans, rivers, freshwater lakes, streams, streams, arctic lakes, puddles, etc., They can live in a wide range of areas in aquatic and semi-aquatic environments, are autotrophic and photosynthetic organisms (Yüksel, 2009:34; Alçay et al., 2017:26). Thanks to the pigments in their structure, algae convert carbon dioxide and water into carbohydrates under the influence of light, increasing the nutritional value of the aquatic environment and providing a food source for many aquatic creatures, as well as increasing the dissolved oxygen rate in the water (Duan, 2013:29). In addition, algae are very important in terms of protecting the integrity of the entire ecosystem, as they produce two-thirds of the photosynthetic carbon needed by the whole world (Oğur, 2016:32; Sasa, et al., 2020:33).

6. Algae used in bioplastic production

Algae, which is the best raw material for polymers obtained from natural polysaccharides or carbon-containing sugars, has a very high potential as a renewable biomass source in bioplastic production with these features. The main element used in bioplastic production is polysaccharides. Common polysaccharides found in marine algae are floridean starch, agar, and alginates. For example; green algae contain sulfuric acid polysaccharides, sulfate galactans and xylans, while brown algae contain alginic acid, fucoidan (sulfate fucose), laminarin (β-1,3 glucan), and sargasan; It contains red algae agar, carrageenans,

floridean starch (amylopectin-like glucan), and water-soluble sulfate galactan (Özdemir and Erkmen, 2013:33).

7. Algae used as a source of Diatomite

"Diatomite" which has a wide range of uses ranging from filtration to filler to refractories, is a sediment consisting of fossilized siliceous shells of single-celled microscopic algae called diatoms. Usage areas;

- As a filter aid in all kinds of filtration processes.
- As an additive in concrete production, in the production of paint, toothpaste, rubber, plastic, medicine, cosmetics, paper, matches, polish, glaze, cleaning agents, and similar products,
- As a catalyst carrier in chemical reactions, as an absorbent in liquids and dynamite,
- As a source of silica, in the preparation of many chemical substances, as a medium-strength abrasive, as a mechanical insecticide, in the production of cat litter, and as an insulation material,
- Due to its extremely low heat, sound, and electrical conductivity, it is used in the form of powder or plates in the production of insulation materials.
- It has wide application areas in the production of light building materials and refractory materials and generally as ceramic raw material (Özbey and Atamer, 1987:33; Çetin and Taş, 2012:28).

8. Microalgae used as a pigment source

Today, many microalgae species are used in biotechnological studies for industrial purposes due to their high protein, beta-carotene, unsaturated fatty acids, vitamins, and pigment contents. Pigment-producing microalgae have produced β-Carotene, Astaxanthin, Phycocyanin, Xanthophyll, and Phycoerythrin.

- ***β-Carotene:*** Rhodophyto from red algae contains α and β-Carotene, Chloromonodophyta contains Diadinoxanthin, Hetereoxanthin, and Vaucheriaxanthin, and Chlorophta is characterized by Acetylenic carotenoids.
- ***Astaxanthin:*** Astaxanthin is a carotenoid obtained from microalgae, has high commercial value, and has positive effects on human health due to its strong antioxidant properties. It is widely used in preserving the colors of tropical ornamental fish and coloring the egg yolks of poultry.
- ***Phycoerythrin:*** *Porphyridium*, a red microalgae genus, is a source of biochemicals with nutritional and therapeutic properties, and it is reported

that the algae genus contains polysaccharides with antiviral and anti-inflammatory effects, long-chain unsaturated fatty acids, and pigments and fluorescents such as Zeaxanthin. These water-soluble pigments are used as natural colorants in foods and are also used in cosmetics and pharmaceuticals. Red phycoerythrin gives some specific properties to foods due to its yellow fluorescence. For this purpose, it is used in lollipops, alcoholic and non-alcoholic drinks.

- ***Porphyridium-Phycocyanin:*** It is a blue pigment obtained from the red alga *Porphyridium aeugineum*. The most important phycocyanin is C-*phycocyanin*.
- ***Lutein:*** Lutein gives foods a bright yellow color as a color pigment. Functional foods; Ready soup, alcoholic beverage, biscuit, sauce, cake, confectionery, and fruit juice sectors are the food sectors that use Lutein (Çelikel et al., 2006:28; Duru and Yılmaz, 2013:29).

9. Microalgae and biofuel technology

Due to their particular properties, microalgae can play an essential function globally in the manufacturing of excessive value-introduced merchandise, foods, feeds, fertilizers, polymers, and biofuels, further to a few different environmental properties consisting of wastewater bioremediation and carbon dioxide mitigation (Ferreira et al., 2019:30). Microalgae are microorganisms that contain carbohydrates, proteins, lipids, and vitamins. In general, microalgae can contain approximately 15-77% oil, depending on the species. Compared to other oil crops, their high oil content and fast growth efficiency make microalgae attractive for biodiesel and biogas production. Production of these fuels from microalgae has the potential to meet the increasing global energy need and to contribute to the prevention of global warming at least partially by converting excess carbon dioxide in the atmosphere into efficient products through photosynthesis (Ulukardeşler and Ulusoy, 2012:33). In addition to its capacity for the manufacturing of biofuels, microalgae can develop in numerous environments which include saltwater and wastewater, saving arable land and freshwater for meal crops. They develop quickly and efficiently, yield extra biofuel consistent with vicinity than land plants, and assist lessen greenhouse gases with the aid of using CO_2 from the air or commercial emissions (Abreu et al., 2023:26).

10. Use of algae as nanofibers

Because algae have a high carbon content and may be used to make biofuels, bioplastics, and health supplements, they are a desirable feedstock. Algae or algal extracts are inexpensive, sustainable, renewable, and show promise for creating value-added biocomposite materials with antibacterial, anticancer, medicinal,

and restorative qualities (Karaduman et al., 2022:31). Algae are famous for his or her cappotential to accumulate ions of heavy metals and restructure them into extra bendy forms (Nowicka, 2022:32). The production of nanomaterials from a wide variety of algal substances has proven to be among the most current and novel areas of biochemical study due to their ability to reduce metal ions (El-Refaey ve Salem, 2023:29). Among various algae, the most extensively studied algae for the biosynthesis of NPs are brown, red, blue-green, blue-green, micro, and macro-green algae (Chaudhary et al., 2020:28). Due to the antimicrobial residences of the microalgae-derived bioactive pigments (Janarthanan and Senthil Kumar., 2018:31), it's miles very critical to research their capacity use in numerous packages, extra in particular inside the formation of antimicrobial nanofiber-primarily based totally materials, for packages in textiles, food-packaging, etc., (Martins et al., 2023:32). Due to the biosorption properties of algae, it is possible to use them as biological biosorbents in wastewater treatment systems (Gündoğdu and Türk Çulha, 2023:30). Water filtering applications for the elimination of nutrients, organic contaminants, and heavy metals from wastewater are another area in which algae are used (Karaduman et al., 2018:31; Carlsson et al., 2007:27). Microalgae are specifically used in the production of biofuels due to their high lipid and carbohydrate content (Karaduman et al., 2018:31; Saad et al., 2019:33), as well as in the cultivation of aquatic organisms like fish, crustaceans, and mollusks (Hasan and Rina, 2009:31) this is because of their lipid content. Relevant studies on algal fibers containing different macroalgae species are included in the review prepared by Karaduman et al., (2022:31).

11. Harmful Effects of Algae

The seas contain numerous single-celled algae called phytoplankton. Some of these small organisms multiply in the water arm and cause various effects in the ecosystem. As a result of the proliferation of these small organisms, strong toxin production, change in water quality or reddish effects, it causes a wide range of effects, from water color change, foam formation and fish death (death or diseases of whales, marine mammals and other marine animals) to pollution of beaches. In addition, it affects the larval forms as well as the adult forms of many marine organisms, toxins can be carried through the food chain and the negative effects on the ecosystem may extend to humans (Anderson et al., 2001:26; Aydın and Uzar, 2009:27).

Many organisms can interact with microalgae through direct cell-cell interaction, with microalgal toxins both secreted from the cell surface and causing mechanical damage when infiltrated into the organism's skin and gills. Some

diatom species, for example; *Chaetoceros concavicornis, C. convolutus*, *Skeletonema costatum*, and *Rhizosolenia chunii seta*, cause death due to the mechanical effect that weakens the respiration seen in fish and crustacean gills, thanks to their spines and protrusions. For example; Cyanobacterial filaments or colonies have been shown to reduce the feeding rate of cladoceres by inhibiting their filtering movements and causing them to reject nutrients. For example; It has been proven that saxitoxin is detected by copepods in the environment and acts as a feeding deterrent (Aydın and Uzar, 2009:27).

Macroalgae also pose some safety risks. They may contain excessive amounts of heavy metals such as As, Cd, Cr, Ni, V, Hg, Pb, and some anti-nutritional factors, radioactive isotope, dioxin, pesticide, kainic acid, and lectin, phlorotannin, phytic acid, trypsin, amylase inhibitor. For these reasons, it is reported that caution should be exercised in passing the necessary tests on macroalgae, especially before their use for food and feed purposes (Garcia-Vaquero and Hayes, 2016:30; Circuncisão et al., 2018:28; Sasa, et al., 2020:33). On the other hand, these species can be harmful to humans and wild animals because they have the ability to produce cyanotoxins (Rücker et al., 2007:33; Dumlupınar, 2012:29), and they can lead to the death of any living creature that drinks water containing these toxins. Therefore, they are species that need to be careful (Demiriz, 2008:28). Cyanobacterial toxins are chemically divided into two groups: cytotoxin and biotoxin. Cytotoxins damage the cell structure by disrupting the permeability and integrity of the cell membrane, thus causing gastrointestinal diseases (Ilieva et al., 2019:31). Biotoxins are physiologically divided into three groups: neurotoxins that affect the nervous system, hepatotoxins that affect the liver, and dermatotoxins that have an irritating effect (Dumlupınar, 2012:29). On the other hand, it is also been reported that cyanobacterial toxins have an anticancer effect (Zanchett and Oliveira-Filho, 2013:34) and can show cytotoxic activity against cancer cells (Guedes et al., 2013:30; Sasa et al., 2020:33).

Conclusıon

Considering the potential applications of algae, not only the promotion of microalgae production but also the conversion of macroalgae into high value-added products and bringing them into the economy is an issue that needs attention. Algae, which offer new opportunities to meet the needs of sustainable production and a developing economy, need to be integrated with interdisciplinary approaches such as chemistry, materials science, and biomedical engineering and used in many research areas. Considering the scarcity of usable water, increasing pollution threatening the world, and the gradual decrease in

food stocks, it is of great importance to make algae easily usable in many fields. However, economic and technological challenges need to be overcome and market concerns need to be addressed in order to reap the full benefits of these products. One of the main barriers is the high cost associated with large-scale cultivation of microalgae, and the focus should be on cost-effectiveness to achieve wider market pervade.

References

Abreu, A.P., Martins, R. and Nunes J., (2023). Emerging Applications of Chlorella sp. and Spirulina (Arthrospira) sp. *Bioengineering*, 10(8), 955.

Ak, İ. and Cirik, S. (2017). Mavi-Yeşil algler (siyanobakteriler) ve termalizm. *Su Ürünleri Dergisi*, 34(2): 227-233.

Ak, İ., Koru, E., Türker, G., Çankırıgil, E.C. and Dereli, M.G., (2022). Biochemical compounds of algae: sustainable energy sources for biofuel production, Editor: El-Sheekh, M. and El-Fatah Abomohra, ABD, *Handbook of Algal Biofuels, Elsevier*, (pp. 700), 57-78.

Aktar, S. and Cebe, G.E. (2010). General Specifications, Using Areas of Algae And Their Importance on Pharmacy. *Journal of Faculty of Pharmacy of Ankara University*, 39 (3), 237-264.

Alçay, A.Ü., Bostan, K., Dinçel, E. and Varlık, C. (2017). Alg-lerin insan gıdası olarak kullanımı. *Aydın Gastronomy*, 1(1), 47-59.

Ali, M.S., Ahmad V.U., Mazhar F. and Usmanghani K., 1999. Some chemical constituents from marine algae of Karachi coast (Arabian sea), *Turkish Journal of Chemistry*, 23, 181-183.

Al-Saif, S.S.A., Abdel-Raouf, N., El-Wazanani, H.A. and Aref, I.A. (2014). Antibacterial substances from marine algae isolated from Jeddah coast of Red Sea, Saudi Arabia, *Saudi Journal of Biological Sciences*, 21(1), 57-64.

Anderson, M.D., Andersen, P., Bricelj, V.M., Cullen, J.J. and Rensel, J.E.J. (2001). Monitoring and Management Strategies for HAB in Coastal Waters, IOC Technical Series No:59, Paris, 280p,

Andrade, L.M., Andrade, C.J., Dias, M., Nascimento, C.A.O. and Mendes, M.A. (2018). Chlorella and Spirulina Microalgae as Sources of Functional Foods, Nutraceuticals, and Food Supplements; an Overview. *MOJ Food Processing and Technology*, 6(2), 00144.

Anonymous (2023a.). Wikipedia. *Nostoc commune.* The free encyclopedia. https://en.wikipedia.org/wiki/Nostoc_commune

Anonymous (2023b). Wikipedia. *Scenedesmus acuminatus.* The free encyclopedia.
https://en.wikipedia.org/wiki/Scenedesmus_acuminatus

Atay, D. (1978). *Deniz yosunları ve değerlendirme araçları*. Ankara Üniversitesi Ziraat Fakültesi Yayınları, Başbakanlık Basımevi, Ankara.

Atay, D., (1984). *Bitkisel Su Ürünleri Üretim Tekniği*, Ankara Üniversitesi Ziraat Fakültesi Yayınları.

Aydın, H. and Uza, S., (2009). Marine Microalgae Biotoxins and Their Effects. *Celal Bayar University Journal of Science*, 5(1), 87 – 100.

Barka, A. and Blecker, C. (2016). Microalgae as a potential source of single-cell proteins. A review. *Biotechnology, Agronomy, Society and Environment*, 20(3), 427-436.

Bilal, T. and Altiner A. 2020. Effect of Spirulina platensis on Some Serum Markers, Performance Metrics, Brownlee, and Organ Weights, in Rats Fed

with Hydrogenated Vegetable Oil and/or Cholesterol. *Veterinary Medicine and Public Health Journal*, 1(2),60-69.

Borowitzka, M. A. (1998). Algae as food. In Microbiology of fermented foods. Springer, US.

Brownlee, I.A., Allen, A., Pearson, J.P., Dettmar, P.W., Havler, M.E., Atherton, M.R. and Onsøyen, E. (2005). Alginate as a source of dietary fiber, *Critical Reviews of Food Science and Nutrition*, 45, 497-510.

Burtin, P. (2003). Nutritional value of seaweeds, *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 2, 498–503.

Caf, F. (2014). Ekonomik Değeri olan Bazı Alg Türlerinden Elde Edilen Ekstrelerin Biyokimyasal Analizi ve Saccharomyces cerevisiae Kültüründe Besinsel Değerinin Ölçülmesi. Fırat Üniversitesi Fen Bilimleri Enstitüsü Biyoloji Anabilim Dalı, Doktora Tezi, Elazığ, 100s.

Cardozo, K.H.M., Guaratini, T., Barros, M.P., Falcão, V.R., Tonon, A.P., Lopes, N.P., Campos, S., Torres, M.A., Souza, A.O., Colepicolo, P. and Pinto, E. (2007). Metabolites from algae with economical impact, *Comparative Biochemistry and Physiology*, Part C, 146, 60-78.

Carlsson, A.S., Van Beilen, J.B., Möller, R. and Clayton, D. (2007). *Micro and macroalgae*: utility for industrial applications. Outputs from the EPOBIO project, 82.

Chandini, S.K., Ganesan, P., Suresh, P.V., and Bhaskar, N. (2008). Seaweeds as a source of nutritionally beneficial compounds: A review. *Journal of Food Science and Technology*, 45(1), 1-13.

Chapman, V.J. (1970). *Seaweeds and their uses*, Methuen and Co. Ltd. 304.

Chapman, V.J. and Chapman, D.J. (1980). Seaweeds and their uses. Chapman and Hall, London, 334p. doi: 10.1007/978-94-009-5806-7

Chaudhary, R., Nawaz, K., Khan, A.K., Hano, C., Abbasi, B.H. and Anjum, S. (2020). An overview of the algae-mediated biosynthesis of nanoparticles and their biomedical applications. *Biomolecules*, 10(11), 1498.

Circuncisão, A.R., Catarino, M.D., Cardoso, S.M. and Silva, A.M.S. (2018). Minerals from macroalgae origin: health benefits and risks for consumers. *Marine Drugs*, 16(11), 400-429.

Cirik, S. and Cirik, S. (2004). Su Bitkileri (Deniz Bitkilerinin Biyolojisi, Ekolojisi Yetiştirme Teknikleri), Ege Üniversitesi Su Ürünleri Fakültesi Yayınları No:58.

Cirik, Ş. 1981. Algae in Turkish sea and their means of evaluation, (in Turkish). Çevre haberleri, Boğaziçi Üniversitesi yayınları, İstanbul, (9), 65-68.

Çelikel, N., Kınık, Ö., Gönç, S. and Kavas, G. (2006). Mikroalglerin Gıdalarda Renk Verici Madde (Pigment) Kaynagı Olarak Kullanımı, Türkiye 9. Gıda Kongresi; 24-26 Mayıs 2006, Bolu, 447-450.

Çetin, M. and Taş, B. (2012). Biyolojik Orjinli Tek Doğal Mineral: Diyatomit. *Tübav Bilim Dergisi*, 5(2), 28-46.

Darcy-Vrillon, B., (1993). Nutritional aspects of the developing use of marine macroalgae for the human food industry, *International Journal of Food Sciences and Nutrition*, 44, 23-35.

De Morais, M.G., Vaz, B.S., De Morais, E.G. and Costa, J.A.V. (2015). Biologically active metabolites synthesized by microalgae. *Biomed Research International.* (4), 835761. https://doi.org/10.1155/2015/835761

Demiriz, T. (2008). Bazı alglerin antibakteriyel etkileri (Yüksek Lisans Tezi). Ankara Üniversitesi Fen Bilimleri Enstitüsü, Biyoloji Anabilim Dalı, Ankara, 60 s.

Dembitsky, V. 2022. Hydrobiological Aspects of Saturated, Methyl-Branched, and Cyclic Fatty Acids derived from Aquatic Ecosystems: Origin, Distribution, and Biological Activity. *Hydrobiology*, *1*(1), 89-110; https://doi.org/10.3390/hydrobiology1010007

Dineshkumar, R., Narendran, R., Jayasingam, P. and Sampathku-mar, P. (2017). Cultivation and chemical composition of microalgae *Chlorella vulgaris* and its antibacterial activity against human pathogens. *Journal of Aquaculture and Ma-rine Biology*, 5(3), 00119. https://doi.org/10.15406/jamb.2017.05.00119

Duan, E. (2013). Bazı deniz makroalglerinden (Ulva sp. Cysto-seria sp.) fermente sıvı organik gübre üretimi ve taze fa-sulye (Phaseolus vulgaris) verimine etkisinin belirlenmesi (Yüksek Lisans Tezi). Giresun Üniversitesi Fen Bilimleri Enstitüsü, Biyoloji Anabilim Dalı, Giresun, 64s.

Dumlupınar, Y.M. (2012). İzmir ilinde gelişen bazı mavi-yeşil alglerin (Cyanophyta: Cyanobacteria) izolasyonu ve kültürü (Yüksek Lisans Tezi). Ege Üniversitesi Fen Bilimleri Ensti-tüsü, Biyoloji Anabilim Dalı, İzmir, 48s.

Durmaz, Y., Işık, O., Bandarrra, N.M., Cirik, S., Turan, G., and Gökpınar, Ş. (2002). *Porphyridium cruentum* (Rhodophyceae) yağ asitleri kompozisyonuna kurutma yöntemlerinin etkisi. *Ege Journal of Fisheries and Aquatic Sciences*, 19(1-2), 189-195.

Duru, M.D. and Yılmaz, H.K. (2013). Mikroalglerin Pigment Kaynağı Olarak Balık Yemlerinde Kullanımı, *Türk Bilimsel Derlemeler Dergisi* 6 (2), 112-118.

Durucan, F. and Turna, İ.İ. (2011). The Macrobenthic Marine Algae of West Coast of Antalya (Antalya – Kalkan) [Antalya Batı Kıyılarının (Antalya – Kalkan) Makrobentik Deniz Algleri]. *SDU Journal of Science (E-Journal)*, 6 (2), 91-98.

El-Gamal, A.A. (2010). Biological importance of marine algae. *Saudi Pharmaceutical Journal*, 18(1), 1-25.

El-Refaey, A.A. and Salem, S.S. (2023). Algae materials for bionanopesticides: nanoparticles and composites. *Algae Materials*. Academic Press, Elsevier, 219–230. https://doi.org/10.1016/B978-0-443-18816-9.00004-6

Elcik, H. and Çakmakçı, M. (2017). Mikroalg üretimi ve mikroalg-lerden biyoyakıt eldesi. *Gazi Üniversitesi Mühendislik Mi-marlık Fakültesi Dergisi*, 32(3), 795-820.

Eliçin, A.K., Kılıçkan, A. and Avcıoğlu, A.O. (2009). Mikroalglerden Biyodizel Üretimi. 25. tarımsal mekanizasyon ulusal kongresi, 01-03 ekim Isparta, 101-107.

Fujiwara, M. (1984). Purification and chemical and physical characterization of an antitumour polysaccharide from seaweed, Sargassum fulvellum. *Carbohydrate Research*, 125, 97-106.

Ferreira, A., Ribeiro, B., Ferreira, A.F., Tavares, M.L., Vladic, J., Vidović, S. and Gouveia, L. (2019). Scenedesmus obliquus microalga-based biorefinery–from brewery effluent to bioactive compounds, biofuels and biofertilizers–aiming at a circular bioeconomy. *Biofuels, Bioproducts and Biorefining*, 13(5), 1169-1186.

Garcia-Vaquero, M. and Hayes, M. (2016). Red and green macro-algae for fish and animal feed and human functional food development. *Food Reviews International*, 32(1), 15-45.

Gezici, M., Eliçin, K. and Gürhan, R. (2012). Biyoyakıt Amaçlı Mikroalg Üretim İçin Bazı Yetiştirme Parametrelerinin Belirlenmesi, *Tarım Makinaları Bilimi dergisi*, 8(2), 223-231.

Givens, D.I. (1997). Sources of N-3 Polyunsaturated Fatty Acids Additional to Fish Oil for livestock diets, New Meats Congress, Bristol- England.

Gökpınar, Ş., Göksan, T., and Durmaz, Y. (2001). PUFA kaynağı olarak mikroalgler, XI. Ulusal Su Ürünleri Sempozyumu, Hatay, 4-6 Eylül, Cilt II, s. 779-785.

Gökpınar, Ş., Işık, O., Göksan, T., Durmaz, Y., Uslu, Y., Ak, B., Önalan, S.K. and Akdoğan, P. (2013). Algal Biyoteknoloji Çalışmaları, *Yunus Araştırma Bülteni*, 4, 21-26.

Gündoğdu, A. and Türk Çulha, S., (2023). Duvar Publishing. Editör. Prof. Dr. Alaeddin Bobat. *The Use of Algae in Removal of Heavy Metal Ions from Wastewater*, Vol. VIII (pp. 10-- 130), İzmir.

Guedes, E.A.C., da Silva, T.G., Aguiar, J.S., de Barros, L.D., Pinotti, L.M. and Sant'Ana, A.E.G. (2013). Cytotoxic activity of marine algae against cancerous cells. *Brazilian Journal of Pharmacognosy*, 23(4), 668-673.

Güner, H. ve Aysel V. (1989). Tohumsuz Bitkiler Sistematiği (Algler), I. Cilt, Ege Üniversitesi Fen Fakültesi Kitaplar Serisi No: 108, Ege Üniversitesi Basımevi Bornova/İzmir.

Güner, H. (1994). İlkel Su Bitkileri Algler. *Bilim ve Teknik*- Tübitak, 72-77.

Hasan, M. R. and Rina, C. (2009). Use of algae and aquatic macrophytes as feed in small-scale aquaculture: a review (No. 531). Food and Agriculture Organization of the United Nations (FAO).

Ilieva, V., Kondeva-Burdina, M., Georgieva, T. and Pavlova, V. (2019). Toxicity of cyanobacteria. Organotropy of cyanotoxins and toxicodynamics of cyanotoxins by species. Pharmacia, 66(3), 91-97.

İnanç, N., Sahin, H. and Çiçek, B., (2005). Probiyotik ve Prebiyotiklerin Sağlık Üzerine Etkileri, *Erciyes Tıp Dergisi (Erciyes Medical Journal*), 27, 122-127.

Janarthanan, M. and Senthil Kumar, M. (2018). The properties of bioactive substances obtained from seaweeds and their applications in textile industries. *Journal of Industrial Textiles*, 48(1), 361-401.

Jensen, A. (1966). Carotenoids of norwegian brown seaweeds and seaweed meals. Norwegian institute of seaweed recearch, report No: 31, 1-138.

Kaba, N. and Çağlak, E. (2006). The usage of sea algae in human nutrition (Deniz Alglerinin İnsan Beslenmesinde Kullanılması) *Ege University Journal of Fisheries and Aquatic Sciences*. 23 (1/2), 243-246.

Kaleli, İ. (2007). Probiyotiklerin etki mekanizması, Ankem Dergisi, 21, 238-242.

Karaduman F.R., Türk Çulha S. and Horzum Polat N. (2018). Algae biosorbents for heavy metal polluted waters. *International Ecology Symposium*, 843p.

Karaduman, F.R., Çulha, S.T., and Horzum, N. (2022). Algal nanofibers: Current status and recent developments. Materials Today Communications, 104248.

Khan, M.I., Shin, J.H. and Kim, J.D. (2018). The promising future of microalgae: current status, challenges, and optimization of a sustainable and renewable industry for biofuels, feed, and other products. *Microbial Cell Factories*, 17, 36. https://doi.org/10.1186/s12934-018-0879-x

Lahaye, M. (1991). Marine algae as sources of fibers: Determination of soluble and insoluble dietary fiber contents in some, sea vegetables. *Journal of Science and Food Agriculture*, 54, 587–594.

Lewis, E.J. (1962). Gonzales E A, The protein, peptide and free amino acid contents of some species of marine algae from Bombay, *Annals of Botany*, 261, 301-316.

Mata, T.M., Martins, A.A. and Caetano, N.S. (2010). Microalgae for biodiesel production and other applications: a review. *Renewable and Sustainable (2023). Energy Reviews*, 14(1), 217-232.

Martins, R, Mouro. C, Pontes. R, Nunes. J. and Gouveia. I. (2023). Natural Deep Eutectic Solvent Extraction of Bioactive Pigments from *Spirulina platensis* and Electrospinning Ability Assessment. *Polymers.* 15(6),1574. https://doi.org/10.3390/polym15061574

McCourt, R.M. (1995). Green algae phylogeny. *Trends in Ecology and Evolution*, 10, 159-163.

McHugh, D.J. (2003). A guide to the seaweed industry. *FAO Fisheries Technical Paper*, No. 441, Rome, 105 p.

Milledge, J.J. and Harvey, P.J. (2016). Potential process 'hurdles' in the use of macroalgae as feedstock for biofuel production in the British Isles. *Journal of Chemical Technology and Biotechnology*, 91, 2221-2234.

Myklestad, S. (1963). Experiments with seaweed as a supplemental fertilizer. Bergaman pres, London, 432- 438.

Nisizawa, K. (1985). Preparation and marketing of seaweeds as foods. Chapter 4. http://www.fao.org/docrep/X5822E/x5822e06.htm.

Nowicka, B. (2022). Heavy metal induced stress in eukaryotic algae mechanisms of heavy metal toxicity and tolerance with particular emphasis on oxidative stress in exposed cells and the role of antioxidant response. *Environmental Science and Pollution Research*, 29(12), 16860–16911.

O'Sullivan, L., Murphy, B., McLoughlin, P., Duggan, P., Lawlor, P.G., Hughes, H. and Gardiner, G.E. (2010). Prebiotics from marine macroalgae for human and animal health applications, *Marine Drugs*, 8, 2038-2064.

Oğur, S. (2016). Kurutulmuş alglerin besin değeri ve gıda olarak kullanımı. *Ege Üniversitesi Su Ürünleri Dergisi*, 33(1), 67-79.

Øverland, M., Mydland, L.T. and Skrede, A. (2019). Marine macroalgae as sources of protein and bioactive compounds in feed for monogastric animals. *Journal of the Science of Food and Agriculture*, 99, 13-24.

Özbey, G. and Atamer, N. (1987). "Kizelgur (Diatomit) Hakkında Bazı Bilgiler". 10. Türkiye Madencilik Bilimsel Teknik Kongresi, 493-502. Ankara.

Özdemir, N. and Erkmen, J. (2013). Yenilenebilir biyoplastik üretiminde alglerin kullanımı. *Karadeniz Fen Bilimleri Dergsisi*, 3(8), 89-104.

Paiva, L., Lima, E., Neto, A.I., Marcone, M. and Baptista, J. (2017). Nutritional and functional bioactivity value of selected Azo-rean macroalgae: *Ulva compressa*, *Ulva rigida*, *Gelidium microdon*, and *Pterocladiella capillacea*. *Journal of Food Science*, 82(7), 1757-1764.

Randrianarison, G. and Ashraf, M.A. (2018). Microalgae Plant (Chlorella Sp.) for Wastewater Treatment and Energy Production. *Ekoloji*, 27(106), 1455-1465.

Rücker, J., Stüken, A., Nixdorf, B., Fastner, J., Chorus, I. and Wiedner, C. (2007). Concentrations of particulate and dis-solved cylindrospermopsin in 21 Aphanizomenon-domina-ted temperate lakes. *Toxicon*, 50(6), 800-809.

Saad, M.G., Dosoky, N.S., Zoromba, M.S. and Shafik, H.M. (2019). Algal biofuels: current status and key challenges. *Energies*, 12(10), 1920.

Sasa, A., Şentürk, F., Üstündağ, Y. and Erem, F. (2020). Use of Algae as Foods or Food Ingredients and Their Effects on Health. *International Journal of Engineering, Design and Technology*, 2(2), 97-110.

Sukatar, A. ve Şenkardeşler, A. (2001). Türkiye'de Makroskobik Alglerin Kültür Olanakları ve *Gracilaria gracilis* (Stackhouse) Stentoft, Irvine et Farnham, *Enteremorpha intestinalis* (L.) Nees ile E. prolifera (O.F. Müller) J. Ag. Türlerinin Kültürü. *Ege Üniversitesi Su Ürünleri Dergisi*, 18(1), 33-51.

Taşkın, E., Öztürk, M. and Kurt, O. (2004). Marine algae of the bay of Iskenderun (Northeastern Mediterranean): Cyanophyceae and Chlorophyceae. Süleyman Demirel Üniversitesi, *Eğirdir Su Ürünleri Fakültesi Dergisi*, 1 (11), 77-83, Isparta

Ulukardeşler, A.H. and Ulusoy, Y. (2012). 3. Nesil Biyoyakıt Teknolojisi Olan Alglerin Türkiye'de Üretilebilirlik Potansiyeli, Onuncu Ulusal Kimya Mühendisliği Kongresi, 3-6 Eylül 2012, Koç Üniversitesi, İstanbul, 1-6.

Ünal, A. (1988). Önemli besin kaynağı deniz algleri. Ankara Eczacı Odası Bülteni. 10-6.

Vaz, B.S., Moreira, J.B., Morais, M.G. and Costa, J.A.V. (2016). Microalgae as a new source of bioactive compounds in food supplements *Current Opinion in Food Science*, 7, 73-77.

Venugopal, V. (2009). Marine Products for Healthcare. CRC Pres Taylor and Francis Group. Printed in the United States of America on acid free paper. 527p. USA.

Villarruel-López, A., Ascencio, F. and Nuño, K. (2017). Microalgae, a potential natural functional food source – a review. *Polish Journal of Food and Nutrition Sciences*, 67(4), 251-263.

Yamamoto, I. 1982. Antitumour activity of crude extracts from edible marine algae against L-1210 leukemia. Bot. mar., (25: 455-7.

Yüksel, K. (2009). İzmir ili ve çevresinde bulunan termal su-larda gelişen bazı termofilik mavi-yeşil alglerin (siyanobak- terilerin) izolasyonu ve moleküler yöntemlerle tayini (Yük-sek Lisans Tezi). Ege Üniversitesi Fen Bilimleri Enstitüsü, Biyoloji Anabilim Dalı, İzmir, 82s.

Zanchett, G. and Oliveira-Filho, E.C. (2013). Cyanobacteria and Cyanotoxins: From Impacts on Aquatic Ecosystems and Human Health to Anticarcinogenic Effects. *Toxins*, 5, 1896-1917.

Chapter 5

New Frontıers In Agrıculture, Forest And Water Issues

Importance Of L-Tryptophan In Crayfısh Reproduction

Ayşe Gül HARLIOĞLU[1]
Muzaffer Mustafa HARLIOĞLU[2]

Introductıon

Crayfish are one of the most important keystone animals in aquatic ecosystems There are approximately 600 crayfish species, of which only 15 are of economic importance. Therefore, they are reproduced. Their reproduction is carried out for two main purposes. The first of these is the incubation of the egg-laid females and the obtaining of the offspring, and the other is the growth of these offspring until they reach the size that will be stocked into natural waters. Along with these, there has been an increase in the number of juveniles obtained in some species in recent years, and their efforts to grow them with extensive stocking until they reach the market size (Ackefors and Lindqvist, 1994:58; Skurdal and Taugbol, 2002:451; Perez et al., 1997:7; Savolainen et al., 2004:238; Yu et al., 2020:2; Dong et al., 2022:2; Harlıoğlu and Farhadi, 2022:238). On the other hand, in some countries such as France, Italy, Belgium and Germany, production and breeding of *Pontastacus leptodactylus* is done by extensively or semi-intensively methods. In parallel with these studies, studies on feeding of crayfish were also needed and basic researches such as preparation of feeds especially for crayfish nutritional requirements were started (Ackefors, 1998:65; Wickins and Lee, 2002:71; Köksal, 1988:370; Doğukan et al., 2021:570).

Although around 600 species of crayfish are found naturally in the continents except Africa and the Antarctic continent approximately 10-15 of these species are economically important. In addition to being an important source of protein, being extremely tasty and expensive has caused crayfish to become one of the luxury aquatic products and to increase the production of

[1] 1 Prof. Dr.; Fırat Üniversitesi, Su Ürünleri Fakültesi, Yetiştiricilik ABD, Elazığ/ Türkiye, aharlioglu@firat.edu.tr ORCID No: https://orcid.org/0000-0001-9478-6419
2 Prof. Dr.;Fırat Üniversitesi, Su Ürünleri Fakültesi, Yetiştiricilik ABD, Elazığ/ Türkiye, mharlioglu@firat.edu.tr ORCID No: https://orcid.org/0000-0001-8288-0571

crayfish, especially in Europe and America. At the beginning of the studies aimed at increasing the crayfish production are the efforts to protect the natural crayfish species and increase their yield, prohibit the stocking of non-native crayfish species and prevent disease transmission, and the reproduction of crayfish in culture conditions (McClain, 2020:261; Li et al., 2022:2; Yeh and Li, 2022:233).

Cannibalism is one of the most important factors affecting survival in crayfish, especially in cultural conditions. For this reason, efforts are being made to improve the aquaculture efficiency by increasing the survival rate by decreasing the aggressive behaviors and cannibalism of the crayfish (Holdich et al., 1995:47; He et al., 2021a:2; He et al., 2021b:3). These studies include L-tryptophan, which is one of the 20 amino acids that make up proteins, added to the diets of crayfish and other decapods, and aims to increase productivity in aquaculture by reducing aggression in this animals (Harlıoğlu et al., 2014:734; Yang et al., 2019:1008; Zhang et al., 2019:159; Hou et al., 2023:2). For this reason, the importance of L-tryptophan in crayfish reproduction is reviewed in the present study. In addition, the importance of L-tryptophan in the reproduction of some other decapods (i.e., lobster, crab), which are systematically close relatives of the crayfish, was also discussed.

In some countries where crayfish farming is carried out; attempts have been made to reduce cannibalism by controlling some environmental factors such as light regime, increasing the number of shelters in the environment, control of stock intensity and size heterogeneity (Harlıoğlu and Farhadi 2017:3; Farhadi et al., 2014:287). In later studies, investigations have been carried out aiming to decrease the aggressiveness and cannibalistic properties of the crayfish (Harlıoğlu et al., 2014:734).

Cannıbalısm In Crayfısh

The cannibalistic behavior of the crayfish is an important factor that determines its survival rate in natural and cultural conditions (Wickins and Lee 2002:16; Skurdal and Taugbol 2002:19; Harlıoğlu and Farhadi 2017:1990). Although aggressiveness and cannibalism can be controlled to some extent by arrangements such as shelter increase, nutrient abundance, stock intensity, size gridding it is known that even under ideal conditions, the cannibalistic characteristics of crayfish can occur (Holdich 1993:308; Lodge et al., 2000:22; Harlıoğlu et al. 2014:734). Especially in the sensitive period of shell change (molting), this feature is more evident. The newly changed shell is vulnerable to attack because it does not harden immediately. Higher mortality rates are reported in the juvenile stages in intensive farming trials, which leads to

cannibalism (Savolainen et al. 2004:338). Therefore, in the intensive culture of crayfish, the main problem is the nature of aggressive behavior and cannibalism. It has been researched by many investigators that juvenile deaths at high level are due to direct cannibalism or that crayfish are the most sensitive and that the stress of the shell change is the cause of the physiological complication (Taugbøl and Skurdal 1992:412; He et al., 2021a:2; He et al., 2021b:2).

The cannibalistic behavior of crayfish and economically inadequate production of individuals in separate compartments are the most important factors affecting crayfish culture studies. It has also started to prepare pellets for nutritional needs of crayfish. For this reason, studies on crayfish cultures today are mainly based on the production of crayfish juveniles in controlled conditions and on the basis of stocking these juveniles in natural environments or in artificial ponds of different sizes and shapes (Köksal 1988:370; Perez et al. 1997:7) so that the produced juveniles are fed to the marketing size in small pools it does not make it very economical (Wickins and Lee 2002:75).

In recent years, intensive systems have been developed that include individual compartments designed to reduce the frequency of individual encounter and cannibalism. However, these studies have shown that individual compartments, not being economical, can make a difference not only in the prevention of cannibalism but also in growth and development (Manor et al. 2002:264; Harlıoğlu and Farhadi, 2017:1990; McClain, 2020:261; He et al., 2021a:2; He et al., 2021b:2).

L-Tryptophan

L-tryptophan ($C_{11}H_{12}N_2O_2$) is a basic essential amino acid that living organisms can not produce by itself and a precursor of 5-hydroxytryptamine, 5-HT. Amino acids are the building blocks of the protein that keep life alive. Since living organisms can not produce L-tryptophan, they provide this substance by eating L-tryptophan-containing foods or by taking L-tryptophan supplements (Leathwood 1987:150; Nagaraju, 2011:4; Sahu et al., 2020:2412). There is a need for vitamin B6 in order for L-tryptophan to function effectively. Other elements that support L-tryptophan are vitamin C, vitamin B9 (folate) and magnesium.

L-tryptophan is a vital element for neurotransmitters such as serotonin and melatonin. Such chemical carriers carry nerves in living organisms from one cell to another. It is known that these carriers can not perform brain functions properly when they are not in sufficient quantity. In addition, L-tryptophan is used to form vitamin B3, also known as Niacin. Niasin is also known to help

reduce depression in humans. In addition, in mammals and birds fed with L-tryptophan-supplemented feeds, 5-HT synthesis was increased (Leathwood 1987:150; Fernstrom and Wurtman 1971:150; Denbow et al. 1993:716) and aggressiveness was reduced (Chamberlain et al. 1987:504; Shea et al. 1991:589; Cleare and Bond 1995:73; Savory et al. 1999:580).

The Importance Of L-Tryptophan In The Culture Of Crayfish And Other Decapods

The relationship between amin serotonin [5-hydroxytryptamine creatinine sulfate complex (5HT)] level and crayfish aggressiveness is very complex. It is known that the effect of 5-HT in the nervous system varies and this effect varies relying on the dose, period and route of administration (Teshiba et al. 2001:2524; Edwards et al. 2002:361; Panksepp et al. 2003:361; Harlıoğlu et al., 2020:634). These differences most likely reflect the occurrence of multiple receptor subtypes that are different, with respect to location, movement in the nervous system, and pharmacology of 5-HT. The presence of different receptor subtypes has also been supported by studies. The data obtained from replicated receptors is important in terms of physiological and behavioral studies for the identification of receptor subtypes in the transfer of known genetic information in the molecular structure (Edwards et al. 2002:362; Panksepp et al. 2003:361; Harlıoğlu and Farhadi, 2017:1984).

Effects of dietary tryptophan on the aggresiveness behavior, development, and survival of juvenile crab (*Scylla serrata*) and crayfish (*P. leptodactylus*) were investigated by Laranja et al. (2010:84) and Harlıoğlu et al. (2014:733), respectively. They found that the aggressive actions of *S. serrata* and *P. leptodactylus* was inhibited significantly, and rearing ratio (i.e., promoted growth and low mortality ration) was enhanced significantly by raising tryptophan levels to 1.00 % in their diets.

It was found that 5-HT reduced the desire for subordinate animals to withdraw and increased their aggressive behavior (Peeke et al. 2000:575), but they found no sign that exogenous 5-HT increased aggressive behavior in juvenile lobster *Homarus americanus*. On the other hand, Peeke et al. (2000:575) reported that 5-HT reduces competition for dominance and shelter space between animals. In addition, Tierney and Mangiamele (2001:757) also examined the effect of 5-HT injection in crayfish (*Procambarus clarkii*) and observed that when 5-HT was injected at low concentrations, individuals had a small effect on body posture and slowed down in their movements. Moreover, in another study, a higher effect of this substance on crayfish was observed when applied at moderate concentrations; a posture twisted in the crayfish was

observed (Livingstone et al. 1980:76). Furthermore, when the dose is further increased; it has been determined that there is more flexibility in the crayfish exposed. However, it was reported that 5-HT significantly reduced aggressive behaviors in *P. clarkii* (Livingstone et al. 1980:77).

Doernberg et al. (2001:91) found that continuous reduction in 5-HT levels (5,7-DHT produced by injection of neurotoxin) leads to an increase in the time that juvenile lobster pairs discriminate in fight. However, the same manipulation did not cause any effect in cannibalistic behavior in crayfish (*Orconectes rusticus*) (Panksepp et al. 2003:362). Panksepp et al. (2003:360) also found that injecting 5-HT in a relatively slow fashion quickly boosted the fight intensity, while injecting it quickly found that it increased the fight intensity slowly. It has been reported that in crab (*Carcinus maenas*), endogenous amine levels (5-HT, DA, and octopamine) alter cannibalistic behavior and are higher in winners when compared to loser (Sneddon et al. 2000:538).

Changes in posture and behavior of some crustaceans such as lobster and crayfish have been observed after the injection of 5-HT. This posture change usually consists of a rising edge on the substrate with the abdomen, and the walking legs beneath the body are twisted. However, the twisting behaviors of amphibians *Gammarus lacustris*, crab *C. maenas* (Bevengut and Clarac, 1982:24) and Australian crayfish *Cherax destructor* (McRae, 1996:294) after the injection of serotonin have been described (Helluy and Holmes, 1990:1215). On the other hand, in some studies, aggressive behaviors increased when exogenous 5-HT was given to the individuals. For example; in the case of *Munida quadrispina* lobster, aggressive behaviors are reported to act when exogenous 5-HT is given to individuals (Antonsen and Paul, 1997:502). In addition, Huber et al. (1997:5939) and Huber and Delago (1998:573) reported aggression in 5-HT injected crayfish (*Astacus astacus*) and lobsters (*H. americanus*).

In a research on the the cheliped regeneration in a crab species (*Eriocheir sinensis*) through melatonin, serotonin and dopamine supplementation to the diet Zhang et al. (2019:1) found that L-tryptophan significantly promoted the cheliped regeneration ratio over two weeks ($P < .05$). They also fopund that the activities of digestive enzymes in the crab were enormously increased by the inclusion of 0.53% or 0.70% L- tryptophan ($P < 0.05$) to the diet. Moreower, the melatonin amount of eyestalks and muscle promoted significantly ($P < 0.05$) in *E. sinensis*. Therefore, Zhang et al. (2019:1) concluded that dietary inclusion of L- tryptophan may increase cheliped regeneration by governing regeneration-related gene expression and hepatopancreatic digestion in this species, that can

be attained by predominanting melatonin amounts and the binding of 5-HT and dopamin to related receptors.

Yang et al (2019:1007) investigated the effect of suplementary L-tryptophan to the diet for a month on the immune system, gut microbiota, bacterial challenge and survival rate of the crab *E. sinensis*. They found that the dietary L-tryptophan significantly increases the survival rate, abundance and diversification of the gut microbiota. They also found that the dietary L-tryptophan improved the immunity of this species. The results of Yang et al (2019:1007) showed that the optimum dietary dosage is 0.47% or 0.73% L-tryptophan supplementation. However, in another investigation, *E. sinensis* was fed with the diets for 30 days containing 3.6, 4.7, 7.3 and 10.5 g L-tryptophan /kg dry matter, respectively by Zhang et al. (2021:1602). At the end of the experimet it was concluded that the addition of L-tryptophan to the diet of *E. sinensis* is useful for growth and can considerably increase the activities of digestive enzyme and food intake probably by interfering 5- HT and mandatoring to its associated receptors (Zhang et al., 2021:2).

The beneficial effects of suplementary L-tryptophan on the molting performance in juvenile shrinp *Litopenaeus vannamei* was also investigated for 30 days by Sun et al. (2015:235). The survival and growth rate were significantly improved by the levels of dietary tryptophan, and the best results were provided at 0.60 % supplementation. It was found that feed conversion ratio was importantly reduced in the shrimp as dietary tryptophan level raised.

In addition to decapod species the effectiveness of L-tryptophan if fish species has also been investigated in many investigations (Sahu et al., 2020:2412). It was observed that many of the increased serotonergic activity in the brain have been shown to prevent aggressive behaviors in the vertebrates. For example, Winberg and Nilsson (1993:598) and Young (1996:314) reported that in teleosts they inhibit aggressive behavior in the cichlid, *Aequidens pulcher* and knifefish, *Apteronotus leptorhynchus* species injected from the cortex of serotonin (5-hydroxytryptamine) (Munro, 1986:258; Maler and Ellis, 1987:76). On the other hand, it has been stated that dietary L-tryptophan supplementation is effective in controlling aggression in some fish, including some fish species important for aquaculture, such as rainbow trout (Winberg et al., 2001:3868), grouper (Hseu et al., 2003:1) and Atlantic code fish (Höglund et al., 2005:525). For example, Johnston et al. (1990) found that 5-HT and 5-HIAA (a significant metabolite of serotonin in the vertebrates) increased rainbow trout fed to feeds containing high levels of L-tryptophophan and they reported that the 5-HT synthesis rate may depend on the availability of L-tryptophan. Therefore, Zhang (2018:158) stated that one of the native

compounds, L-tryptophan, can be improved to eliminate aggressive behaviour in aquatic animals without harmful effects.

The effects of dietary L-tryptophan (0.36%, basal diet-control group, 0.47%, 0.73% and 1.05% respectively) and melatonin for 30 days on the serum glucose level and antioxidant capacity in the hepatopancreas of the crab *E.sinensis* were determined by Xu et al. (2018:91). It was found that different the levels of L-tryptophan did not an important effect on the amount of serum glucose, and its level was about (4.62±0.20) mmol/L. On the other hand, 0.73% L-tryptophan supplementation to the diet caused a significant improvement at the capacity of as superoxide dismutase (82.86±1.07) U/mL. At the end of the experiment Xu et al. (2018:91) concluded that 0.73% dietary L-tryptophan is able to promote the antioxidant capacity of *E. sinensis*, but the reaction on the serum glucose level are not clear.

Conclusıon

In conclusion, this review indicates that there are only a few published studies on the importance of L-tryptophan in crayfish and other decapod crustaceans reproduction (i.e., exclusively in aggression control and mitigate cannibalistic behavior). Investigation findings suggest that L-tryptophan, especially in diets, has positive effects on reducing the aggression of crayfish and other decapods, preventing mortality, and increasing the yield and productivity of these animals by increasing brain 5-HT concentration. However, no studies published on the effects of L-tryptophan on juvenile crayfish rearing. Whereas, when mature crayfish are compared with shell changes (molting) once a year, juvenile crayfish change their shells 5-7 times in their first year. Therefore, in addition to studies on adults, more research should be conducted on the importance of L-tryptophan in the lives of juvenile crayfish (ie, determination of dosage and ratio to mitigate cannibalistic behavior).

References

Ackefors, H. (1998). The culture and capture crayfish fisheries in Europe. *World Aquacult*. 29(2), 18–24; 64–67.

Ackefors, H., and Lindqvist O.V. (1994). Cultivation of freshwater crayfishes in Europe, In: Freshwater Crayfish Aquaculture in North America, Europe, and Australia, Families Astacidae, *Cambaridae and Parastacidae* (ed. by J. V. Huner), 1; 57-62.

Antonsen, B.L., and Paul D.H. (1997). Serotonin and octopamine elicit stereotypical agonistic behaviors in the squat lobster *Munida quadrispina* (Anomura, Galatheidae). *J. Comp. Physiol.* 181A, 501– 510.

Bevengut, M., and Clarac, F. (1982). Controle de la posture du crabe *Carcinus maenas* par des amines biogenes. *C. R. Acad. Sci. Paris* 295, 23– 28.

Chamberlain, B., Ervin, F.R., Pihl, R.O., and Young, S.N. (1987). The effect of raising or lowering tryptophan levels on aggression in vervet monkeys. *Pharmacol. Biochem. Behav*. 28, 503–510.

Cleare, A.J. and Bond, A.J. (1995). The effect of tryptophan depletion and enhancement on subjective and behavioral aggression in normal-male subjects. *Psychopharmacology* 118, 72-81.

Denbow, D.M., Hobbs, F.C., Hylet, R.M., Graham, P.P., and Potter, L.M. (1993). Supplemental dietary L-tryptophan effects on growth, meat quality, and brain catecholamine and indoleamine concentrations in Turkey. *Br. Poult. Sci*. 34, 715– 724.

Doğukan, K., Ercüment, G., Güroy, D., Dinçer, S., Yılmaz, B. H., and Yavuzcan, H. (2021). Evaluation of biofloc technology for *Astacus leptodactylus*: Effect of different stocking densities on production performance and physiological responses. *Acta Aquatica Turcica*, *17*(4), 569-579.

Doernberg, S.B., Cromarty, S.I., Heinrich, R., Beltz, B.S., and Kravitz, E.A. (2001). Agonistic behavior in native juvenile lobsters depleted of serotonin by 5,7-dihydroxytryptamine. *J Comp Physiol* A. 187, 91–103.

Dong, Y., Jia, R., Hou, Y., Diao, W., Li, B, and Zhu, J. (2022). Effects of stocking density on the growth performance, mitophagy, endocytosis and metabolism of *Cherax quadricarinatus* in integrated rice–crayfish farming systems. *Front. Physiol. 13:1040712. doi: 10.3389/fphys.2022.1040712.*

Edwards, D.H., Yeh, S.H., Musolf, B.E., Antonsen, B.L., and Krasne, F.B. (2002). Metamodulation of the crayfish escape circuit. *Brain Behav. Evol.* 60, 360– 369.

Farhadi, A., Gardner, C. and Kochanian, P. (2014). Reducing cannibalism of narrow clawed crayfish *Astacus leptodactylus* Eschscholtz 1823 through management of photoperiod and stocking density. *Asian Fisheries Science*, 27(4), 286-296.

Fernstrom, J.D., Wurtman, R.J. (1971). Brain serotonin content: physiological dependence on plasma tryptophan levels. *Science* 173, 149– 152.

Harlıoğlu, M.M., and Farhadi, A. (2017). Factors affecting the reproductive efficiency in crayfish: implications for aquaculture. *Aquaculture Research*. 48, 1983–1997. DOI: 10.1111/are.13263.

Harlıoğlu, M.M., and Farhadi, A. (2022). Androgenic hormones in crustacean aquaculture: a review. *Turkish Journal of Zoology* 46, 237-248

Harlıoğlu, M.M., Farhadi, A., and Harlıoğlu, A.G., (2020). Roles of Neurotransmitters in Decapod Reproduction. *Thalassas: An International Journal of Marine Sciences* 36: 633–639 https://doi.org/10.1007/s41208-020-00202-2

Harlıoğlu, M.M., Harlıoğlu, A.G., Mişe Yonar, S., and Çakmak, Duran. T. (2014). Effects of dietary L-tryptophan on the agonistic behavior, growth, and survival of freshwater crayfish *Astacus leptodactylus* Eschscholtz. *Aquaculture International*. 22, 733-748.

He, M., Liu, F., and Wang, F. (2021a). Resource utilization, competition and cannibalism of the red swamp crayfish *Procambarus clarkii* in integrated rice-crayfish culture without artificial diets. *Aquaculture Reports* 20, 100644.

He, M., Liu, F., and Wang, F. (2021b). Quantitative analysis of density dependent resource utilization, cannibalism, and competition of the red swamp crayfish (*Procambarus clarkii)* in rice-crayfish cocultures without supplementary food. *Aquaculture*, 543(31-35), 736966.

Helluy, S., and Holmes, J.C. (1990). Serotonin, octopamine, and the clinging induced by the parasite *Polymorphus paradoxus* (Acanthocephala) in *Gammarus lacustris* (Crustacea). *Can. J. Zool.* 68(6), 1214–1220.

Holdich, D.M. (1993). A review of astaciculture freshwater crayfish farming. *Aquatic Living Reseurces* 6(3), 307-317.

Holdich, D.M., Reader, J.P., Rogers, W.D., and Harlıoğlu, M.M. (1995). Interactions between three species of crayfish, *Austropotamobius pallipes*, *Astacus leptodactylus* and *Pacifasacus leniusculus*. *Freshwater Crayfish* 10, 46-56.

Hou, M., Pang, Y., Niu, C., Zhang, D., Zhang, Y., Liu, Z., Song, Y., Shi, A., Chen, Q., Zhang, J., Cheng, Y., and Yang, X. (2023). Effects of Dietary L-TRP on Immunity, Antioxidant Capacity and Intestinal Microbiota of

the Chinese Mitten Crab (*Eriocheir sinensis*) in Pond Culture. *Metabolites* 13, 1. https://doi.org/10.3390/metabo1301000. 17 pages

Hseu, J.R., Lu, F.I., Su, H.M., Wang, L.S., Tsai, C.L., and Hwang, P.P. (2003). Effect of exogenous tryptophan on cannibalism, survival and growth in juvenile grouper, *Epinephelus coioides*. Aquaculture 1-12.

Höglund, E., Bakke, M.J., Øverli, Ø., Winberg, S., and Nilsson, G.E. (2005). Suppression of aggressive behaviour in juvenile Atlantic cod (*Gadus morhua*) by L-tryptophan supplementation. *Aquaculture* 249, 525-531.

Huber, R., Smith, K., Delago, A., Isaksson, K., and Kravitz, E.A. (1997). Serotonin and aggressive motivation in crustaceans: altering the decision to retreat. *Proc. Natl. Acad. Sci.* U. S. A. 94, 5939–5942.

Huber, R, and Delago, A. (1998). Serotonin alters decisions to withdraw in fighting crayfish, *Astacus astacus*: the motivational concept revisited. *J. Comp. Physiol.* 182A, 573– 583.

Johnston, W.L., Atkinson, J.L., Hilton, J.W., and Were, K.E. (1990). Effect of dietary tryptophan on plasma and brain tryptophan, brain serotonin, and brain 5-hydroxyindoleacetic acid in rainbow trout. *Journal of Nutrition and Biochemistry* 1, 49-54.

Köksal, G. (1988). *Astacus leptodactylus* in Europe. In: Freshwater Crayfish: Biology, Management and Exploitation (eds D.M. Holdich and R.S. Lowery), Croom Helm, London and Timber Press, Oregon, 365-400.

Laranja, Jr. J.L.Q., Quinitio, E.T., Catacutan, Mae, R., and Relicardo, M.C. (2010). Effects of dietary l-tryptophan on the agonistic behavior, growth and survival of juvenile mud crab *Scylla serrata*. *Aquaculture* 310(1–2), 84–90.

Leathwood, P.D. (1987). Tryptophan availability and serotonin synthesis. Proc. Nutr. Soc. 46, 143–156. Fernstrom, J.D., Wurtman, R.J., 1971. Brain serotonin content: physiological dependence on plasma tryptophan levels. *Science* 173, 149– 152.

Li, P.,Wu, G., Li, Y., Hu, C., Ge, L., Zheng, X., and Lv, W. (2022). Long-term rice-crayfish-turtle co-culture maintains high crop yields by improving soil health and increasing soil microbial community stability. *Geoderma*, 413, 115745.

Livingstone, M.S., Harris-Warrick, R.M., and Kravitz, E.A. (1980). Serotonin and octopamine produce opposite postures in lobsters. *Science* 208, 76–79.

Lodge, D., Taylor, C., Holdich,, D.M., and Skurdal, J. (2000). Reducing impacts of exotic crayfish introductions: new policies needed. *Fisheries* 25(8), 21-23.

Manor, R., Segev, R., Leibovitz, M.P., Aflalo, E.D., and Sagi, A. (2002). Intensification of redclaw crayfish *Cherax quadricarinatus* culture II. growout in a seperate cell system. *Aquacultural Engineering*, 26, 263-276.

Maler, L.,and Ellis, W.G. (1987). Inter-male aggressive signals in weakly electric fish are modulated by monoamines. *Behav. Brain. Res.* 25, 75–81.

McClain, W.R. (2020). Crayfish aquaculture. *Fisheries and Aquaculture*, Oxford University Press. New York, 9, 260-284.

McRae, T. (1996). On the postural effects induced in female *Cherax destructor* (Clark) by serotonin and octopamine. *Freshwater Crayfish* 11, 293– 298.

Munro, A.D. (1986). Effects of melatonin, serotonin, and naloxone on aggression in isolated cichlid fish (*Aequiidens pulcher*). *J. Pineal Res.* 3, 257–262.

Nagaraju, G.P.C. (2011). Reproductive regulators in decapod crustaceans: an overview. *Journal of Experimental Biology*, *214*(1), 3-16.

Panksepp, J.B., Yue, Z., Drerup, C., and Huber, R. (2003). Amine neurochemistry and aggression in crayfish. *Microsc. Res. Tech.* 60, 360–368.

Peeke, H.V.S., Blank, G.S., Figler, M.H., and Chang, E.S. (2000). Effects of exogenous serotonin on a motor behavior and shelter competition in juvenile lobster (*Homarus americanus*). *Journal of Comparative Physiology* A 186, 575-582.

Perez, J.R., Carral, J.M., Celada, M., Saez-Royuela, M., and Sierra, A. (1997). Current status of astaciculture production and commercial situation of crayfish in Europe. *Aquacult. Europe*, 22(1), 6-13.

Sahu, S., Ngasotter, S., Mog, M., Tesia, S., Sharma, S., and Waikhom, B.D.D. (2020). A review on physiological, behavioral and metabolic role of dietary tryptophan in fish. *IJCS*, 8(3), 2411-2417.

Savolainen, R., Ruohonen, K., and Railo, E. (2004). Effect of stocking density on growth, survival and cheliped injuries of stage 2 juvenile signal crayfish *Pasifastacus leniusculus* Dana. *Aquaculture*, 236, 237-248.

Savory, C.J., Mann, J.S., and Macleod, M.G. (1999). Incidence of pecking damage in growing bantams in relation to food form, group size, stocking density, dietary tryptophan concentrations and dietary protein source. *Br. Poult. Sci.* 40, 579–584.

Shea, M.M., Douglass, L.W., and Mench, J.A. (1991). The interaction of dominance status and supplemental tryptophan on aggression in *Gallus domesticus* males. *Pharmacol. Biochem. Behav*. 38, 587–591.

Skurdal, J., and Taugbol, T. (2002). Astacus, biology of freshwater crayfish, In D.M. holdich (ed), Chapter: 12, Blackwell Science Ltd., 674 p.

Sneddon, L.U., and Taylor, A.C., Huntingford, F.A., and Watson, D.G. (2000). Agonistic behaviour and biogenic amines in shore crabs *Carcinus maenas*. *The Journal of Experimental Biology* 203, 537-545.

Sun, Y.P., Guan, L.Z., Xiong, J.H., Xi, Q.Y., and Zhang, Y.L. (2015). Effects of L-tryptophan-supplemented dietary (0.12, 0.24, 0.36, 0.48 and 0.60 %, respectively) on growth performance and 5-HT and GABA levels in juvenile *Litopenaeus vannamei*. *Aquaculture international*, 23, 235-251.

Taugbøl, T., and Skurdal, J. (1992). Growth, mortality and molting rate of noble crayfish, *Astacus astacus* L., juveniles in aquaculture experiments. *Aquaculture and Fisheries Management*, 23, 411-420.

Teshiba, T., Shamsian, A., Yashar, B., Yeh, S.R., Edwards, D.H., and Krasne, F.B. (2001). Dual and opposing modulatory effects of serotonin on crayfish lateral giant escape command neurons. *J. Neurosci.* 21, 4523–4529.

Tierney, A.J., and Mangiamele, L.A. (2001). Effects of serotonin and serotonin analogs on posture and agonistic behavior in crayfish. *J Comp Physiol* A 187, 757–767.

Wickins, J.F., and Lee, DO'C. (2002). Crustacean Farming: Ranching and Culture, Blackwell Science, 446p.

Winberg, S., and Nilsson, GE. (1993). Roles of brain monoamine neurotransmitters in agonistic behaviour and stress reactions, with particular reference to fish. *Comp. Biochem. Physiol., C* 106, 597– 614.

Winberg, S., Øverli, Ø., and Lepage, O. (2001). Suppression of aggression in rainbow trout (*Oncorhynchus mykiss*) by dietary L-tryptophan. *The Journal of Experimental Biology*. 204, 3867-3876.

Xu, M., Zhang, J., Huang, G., Zhang, C., Cheng, Y., and Yang, X. (2018). Effects of L-tryptophan and melatonin on the serum glucose level and antioxidant capacity in the hepatopancreas of Chinese mitten crab (*Eriocheir sinensis*). *Journal of Fisheries of China*, 42(1), 91-99.

Yang, X., Xu, M., Huang, G., Zhang, C., Pang, Y., and Cheng, Y. (2019). Effect of dietary L-tryptophan on the survival, immune response and gut microbiota of the Chinese mitten crab, *Eriocheir sinensis*. *Fish & shellfish immunology*, 84, 1007-1017.

Yeh, E. T., and Li, F. (2022). Of Crayfish, Rice, and Anxiety: Agricultural Modernization in Chongzhou, Sichuan. *Global Food History*, 8(3), 232-253.

Young, S.N. (1996). Behavioral effects of dietary neurotransmitter precursor: basic and clinical aspects. *Neurosci. Biobehav. Rev.* 20, 313– 323.

Yu, J., Xiong, M., Ye, S., Li, W., Xiong, F., Liu, J., and Zhang, T. (2020). Effects of stocking density and artificial macrophyte shelter on survival, growth and molting of juvenile red swamp crayfish (*Procambarus clarkii*) under experimental conditions. *Aquaculture* 521, 735001.https://doi.org/10.1016/j.aquaculture.2020.735001

Zhang, J. (2018). Modulation of growth performance and nonspecific immunity of red swamp crayfish *Procambarus clarkii* upon dietary fulvic acid supplementation. *Fish and Shellfish Immunology,* 83, 158-161.

Zhang, C., Zhang, Q., Song, X., Pang, Y., Song, Y., Wang, Y., .. and Yang, X. (2019). L-tryptophan promotes the cheliped regeneration of Chinese mitten crab (*Eriocheir sinensis*) through melatonin, serotonin and dopamine involvement. *Aquaculture*, 511, 734205.

Zhang, C., Zhang, J., Huang, G., Xu, M., Cheng, Y., and Yang, X. (2021). Effects of dietary L-tryptophan supplementation on growth performance, food intake, digestive enzyme activity and serotonin (5-HT) levels in juvenile Chinese mitten crab (*Eriocheir sinensis*). *Aquaculture Nutrition*, 27(5), 1602-1611.

Chapter 6

Effects of Internal Exposure to *Vibrio harveyi* on Histopathological Changes in

Mediterranean Mussel (*Mytilus galloprovincialis* Lamarck, 1819)

Berin Zeynep BALKAYA [1,1]
Mert GÜRKAN [1]
İbrahim Ender KÜNİLİ [2]

Abstract

The Mediterranean mussel (*Mytilus galloprovincialis*) is a species distributed along the shores of Turkey, and it holds economic importance due to its consumption as food by humans. Additionally, this mussel is used as an indicator organism in various biological studies because of its feeding characteristics through filtration. *Vibrio harveyi* is a pathogenic bacterial species that naturally occurs in marine environments and its quantity in water can vary depending on climatic conditions. In this study, the effects of injecting 100 µl of *V. harveyi* suspension (10^7 cfu/ml) into the post-adductor muscles of mussels after 24 hours were histopathologically examined in the gill and digestive gland tissues of the mussels. No deaths were observed in the control and treatment groups at the end of the study. Focal consolidations in the gills and dilations in vascular diameters were observed in mussels exposed to the bacteria. In digestive gland sections, epithelial damage, hyperplasia, hypertrophy, and an increase in the amount of lipofuscin aggregates were detected. When all findings were evaluated together, it was concluded that exposure to *V. harveyi* has adverse effects on the health of mussels.

Keywords: *Mytilus galloprovincialis*, *Vibrio harveyi*, mussel, histology, bacteria

Introduction

Bivalve molluscs are valuable seafood products that are increasingly in demand all over the world due to their nutritional properties and unique flavours. For this demand, aquaculture activities and wild fisheries are increasing every

[1] Faculty of Science, Biology Department, Çanakkale Onsekiz Mart University
[2] Faculty of Marine Science and Technology, Department of Fishing and Processing Technology, Çanakkale Onsekiz Mart University

year. However, sustainable production of economic species is directly related to the quality of seawater, which is shaped by physical, chemical, and biological factors. In parallel with the global climate change, there are some changes in seawater quality and characteristics due to the increasing seawater temperature. These include the migration of microorganisms to different seas with favourable temperatures and the changes in the natural seawater microflora. These changes in the microflora of seawater in terms of numbers and species directly affect bivalve molluscs such as mussels, which feed by filtering water non-selectively.

The natural microflora of seawater is constituted by the changing composition of Vibrio, Pseudomonas, Acinetobacter, Moraxella, Aeromonas, Micrococcus and Bacillus genera. Among these, Vibrio species such as *V. alginolyticus, V. anguillarum, V. furnissii, V. parahaemolyticus, V. tapetis* and *V. harveyi* species are widely distributed in marine environments and gaining spaces in new areas in parallel with climate changes that are pathogens causes vibriosis in both fish and shellfish (Yang et al., 2005; Wu et al., 1995). This pathogenicity is a major cause of mortality in marine aquaculture animals, including molluscs (Austin and Zhang, 2006; Travers et al., 2012). Vibriosis-related pathologies in bivalves have been reported since the 1960s. However, these effects have increased dramatically in recent years (Battistini et al., 2020; Künili et al., 2021).

Mytilus galloprovincialis (Mediterranean mussel), which has a wide distribution in the Mediterranean, is one the most important economic bivalve species for Mediterranean countries. This species is not only a good bioindicator in marine ecotoxicology (Li et al., 2012), but also frequently used in immunological studies of marine aquaculture animals due to its sensitivity to pathogens (Costa et al., 2009; Cellura et al., 2006). Mussels are routinely used as bioindicators in ecotoxicological studies (Cappello et al., 2017a, 2017b; Giannetto et al., 2015, 2017; Maisano et al., 2017) and since they feed by filtration, they accumulate excessive amounts of bacteria in their bodies. Mussels have an effective hormonal and cellular defence mechanism against bacterial infection (Canesi and Pruzzo, 2016). In bivalves, bacteria such as Vibrio may show pathogenicity directly by acting on tissues or indirectly by affecting physiological functioning due to their difficulty in excretion by filtration (Yang et al., 2005; Çolakoglu et al., 2014). Therefore, the adversely affected physiological performance of the organism may be change in bioaccumulation characteristics and in some cases may even cause the death of the host. Moreover, considering food web relationships and zoonosis potent of the bacterial agents such as Vibrio spp., from the lower form of sea organisms to humans that consume mussels are also potentially at risk (Travers et al., 2015).

For this reason, it is important to identify the mortality potent of pathogens by different ways including examination of histopathological changes and death rate at different levels of the pathogen presence. This study was carried out on *M. galloprovincialis* to investigate the effects of internal and external exposure to *V. harveyi* at high concentrations. *V. harveyi* was the model pathogen since it was isolated as current Vibriosis agent in *Pinna nobilis* (an endemic bivalve mollusc for the Mediterranean) mass mortality event (Künili et al., 2021) and *M. galloprovincialis* was the model host since their population decreasing along the *P. nobilis* natural beds.

MATERIAL And METHODS

M. galloprovincialis samples used in the study (Fig. 1a) were obtained from a mussel farm in Çanakkale. Mussel specimens were brought to the laboratory alive under suitable environmental conditions and adapted to the environment with 10 mussels in each glass aquarium for 5 days before the application started (Fig. 1b). During this period, the mussels were exposed to seasonal photoperiod. A total of 60 mussels were used in the study. During the experiments, 1/3 of the seawater in the glass aquaria was changed daily, the bottom was cleaned, and the water was aerated routinely.

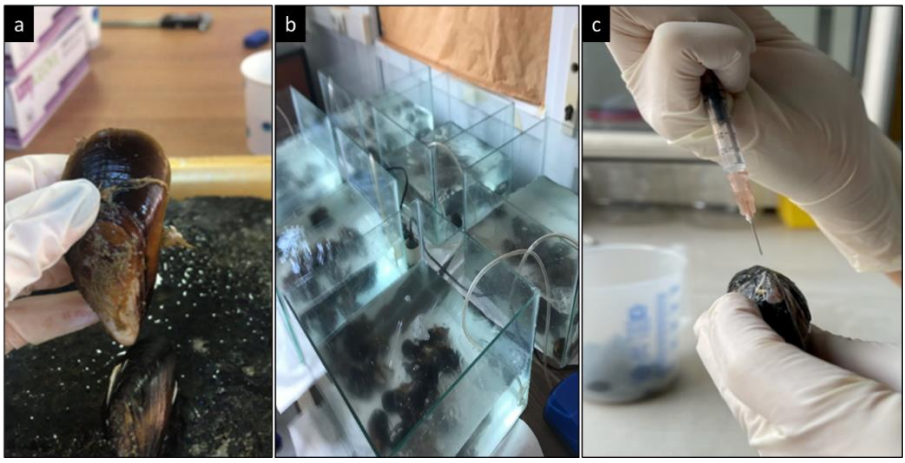


Figure 1. Animal material and experimental setup, a. *M. galloprovincialis*, b. Experimental setup, c. *V. harveyi* injection to the mussel

Bacterial preparation

V. harveyi, which was previously isolated from *Pinna nobilis* and identified by 16S rRNA gene amplification, was obtained from Dr. İbrahim Ender Künili (Genbank Accession No: MW259975, MW259976). Lyophilised bacterial strains were resuscitated in Nutrient Broth (Merck) containing 2.5% NaCl for 24 hours

at 30°C. The recovered strains were transferred to petri dishes containing 2.5% NaCl and Plate Count Agar (Merck) medium. The transferred petri dishes were incubated at 30°C for 20 hours. The young cultures grown on the petri dishes were transferred to test tubes containing 9 ml of 2.5% NaCl and peptone water. The amount of suspended bacterial cells was adjusted to 10^7 cfu/ml using a McFarland densitometer (BioSan).

Internal Exposure

The 10^7 cfu/ml suspension was resuspended in phosphate buffered saline (PBS) (pH 7.4) in a lower volume (1 ml) and at the same concentration. 100 µL of the new suspension was injected into the adductor muscle (PAM) of mussels (Fig. 1c). In order to distinguish the effect of PBS from the effect of bacterial injection, only 100 µL of PBS was injected into the mussels in the control group. Mussels were dissected at 24 h after bacterial treatment. 100 µL bacterial suspension (10^7 cfu/ml) was injected into the mussels and the mortality rate at the end of 24^{th} hour was determined.

Histopathological Examination

Gill and digestive glands of control and treatment group mussels were placed in Davidson's fixative. Fixation was completed at room temperature for 24 hours. Then, the tissues were gradually passed through ethanol series for dehydration and embedded in paraffin block. The tissues were cut with a Leica microtome at a thickness of 5 µm. The sections were stained with Haematoxylin & Eosin (Wilson and Gamble 2002). Histological findings were photographed using a CX31 Olympus light microscope equipped with a digital camera using DP2-BSW software.

Results And Discussion

The data obtained at 24 hours after the treatments were scored between 10 (very good) and 1 (very bad) for external and internal appearance, 0 (none) and 5 (too much) for histopathological changes, and the findings of other analyses were compared by determining the values and summarised in Table 1. No mortality was detected in the control and treatment groups.

Table 1. Level of *V. harveyi*, survival rate, external and internal appearance, and histopathological changes of mussel samples according to contamination load and treatment method after 24h.

Trial groups	**Examination Scoring**

	V. harveyi load *(cfu/g)*	***Alive ratio*** *(%)*	(For morphological view; 10: very good 1: very bad, For histopathological changes; 0: none, 5: maximum)		
			External appearance	*Interior appearance*	*Histopathological changes*
Injection Control (PBS)	-	100	10	9	1
10^7 cfu/ml injection	2.1 x 10^4	100	10	6	3

There was no change was detected in the external appearance of the mussels in all experimental groups. In the internal appearance of the mussels, obvious changes in tissue integrity, organ shape and colour were observed due to bacterial exposure (Fig. 2).

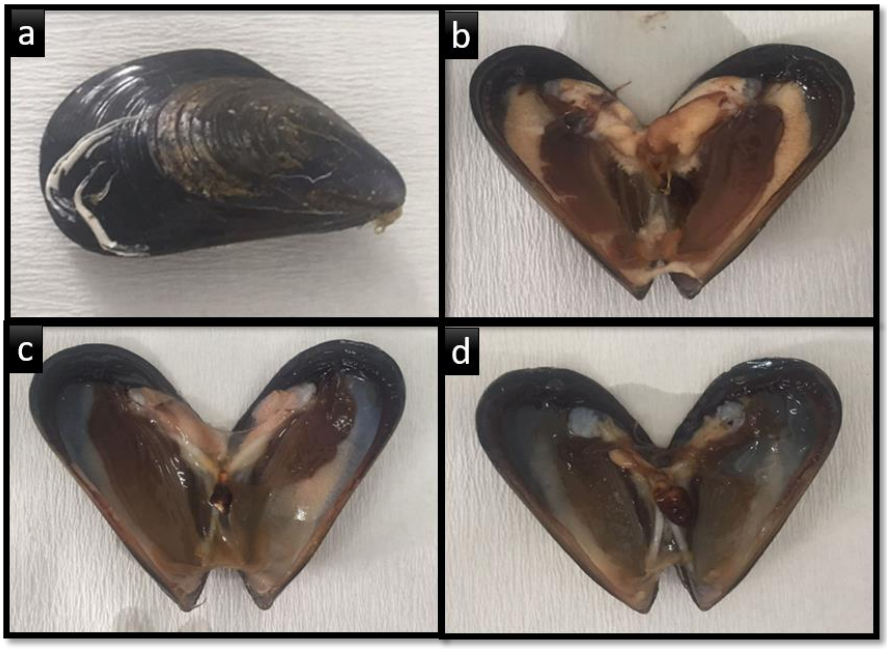


Figure 2. Mussel samples used in the experiments, a. External view of the samples used in the experiments, b. Internal view of the control group mussel, c. Internal view of the PBS group mussel, d. Internal view of the mussel injected with 10^7 cfu/ml *V. harveyi*

Injection of *V. harveyi* into the samples decreased the examination score by 3 points compared to the control group, and $2.1x10^4$ cfu/g bacteria were detected in total mussel tissues in microbiological analysis results.

No significant histopathological findings were found in the gill sections of control and PBS treated mussels. However, lamellar fusion and epithelial damage

and enlargement of the central vein were detected in the gills of mussels treated with *V. harveyi* (Fig. 3).

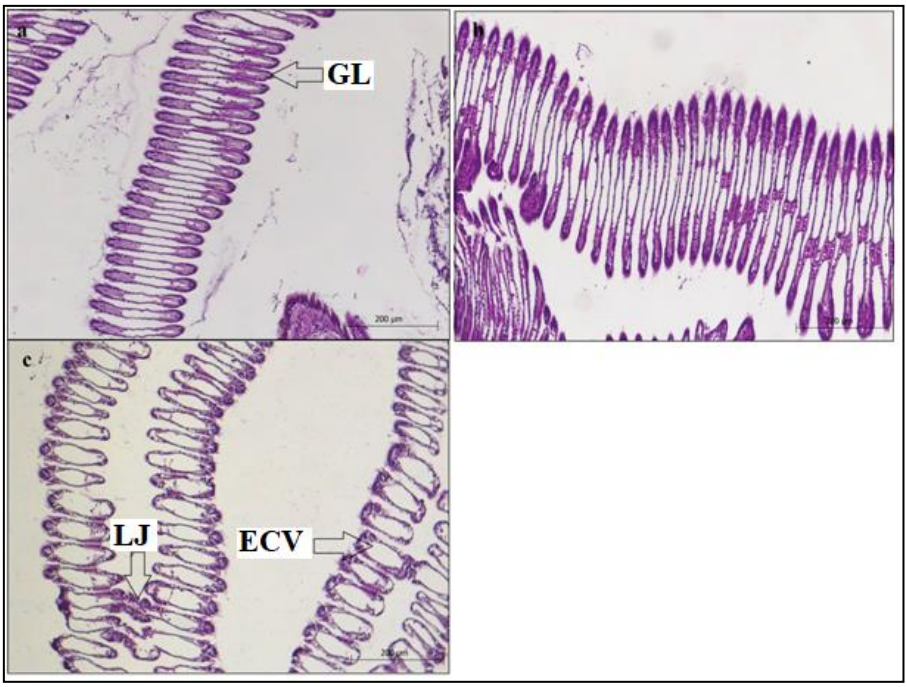


Figure 3. *M. galloprovincialis* gill sections, a. Control group, b. PBS group, c. 10^7 cfu/ml *V. harveyi* injection group, H&E, (GL: Gill lamella, ECV: Enlarged central vein, LJ: Lamellar junction).

No significant histopathological findings were found in the digestive gland sections of control and PBS treated mussels. However, an increase in lipofuscin aggregate, focal haemocyte infiltrations, hypertrophy, epithelial deformations were detected in the digestive gland sections of mussels treated with *V. harveyi* in the post-adductor muscle (Fig. 4).

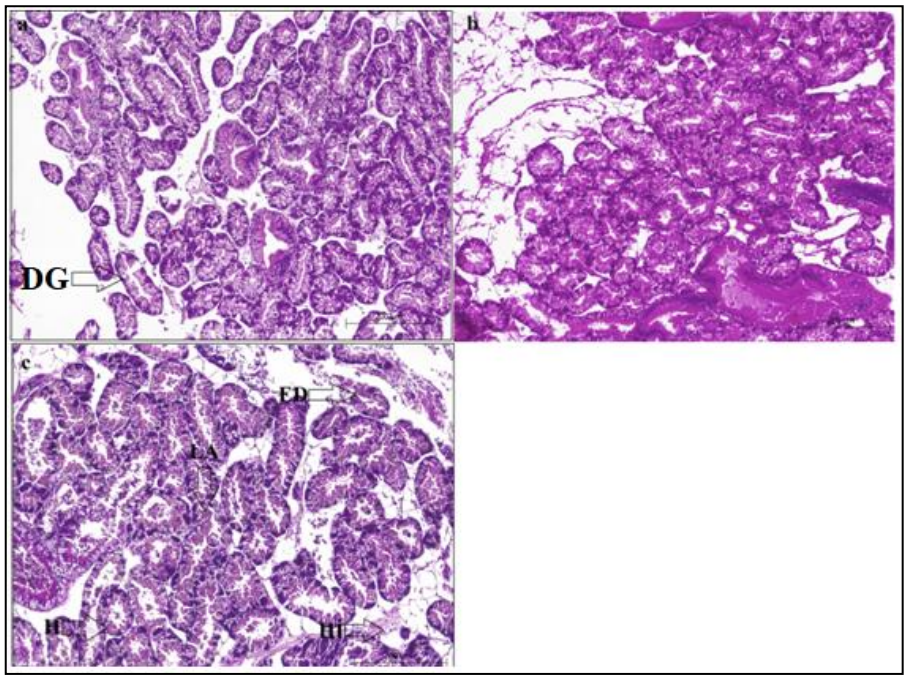


Figure 4. *M. galloprovincialis* digestive gland sections, a. Control group, b. PBS group, c. 10^7 cfu/ml *V. harveyi* injection group, H&E, (DG: Digestive gland, ED: Epithelial deformation, LA: Lipofuscin aggregate, HI: Haemocyte infiltration, H: Hypertrophy).

Liu et al. (2014) reported that *Vibrio harveyi* infection in *M. galloprovincialis* is sex-specific and causes wide variety of metabolic responses. Parisi et al. (2019) investigated the responses induced in haemolymph and posterior adductor muscle (PAM) after bacterial infection with *Vibrio splendidus* in *M. galloprovincialis* samples in vivo. The number of viable intra hemocyte bacteria increased after the first hour after injection, suggesting that an intense phagocytosis occurred as a result of this event, and 24 h clearance was observed. As a result of these observations in the mussel, significant morphological changes in the volume of muscle fibres were observed and muscle tissue organisation was found to improve after 48 hours. Intensive cell cycle activity was observed in PAM after infection with haemocyte infiltration. The results showed that haemolymph is the system responsible for physiological adaptations to maintain homeostasis and immunity against stressful factors such as pathogenicity in mussels.

Battistini et al. (2020) conducted microbiological, parasitological and histological analyses of mussels (*M, galloprovincialis*) from the Gulf of La Spezia in order to see more clearly how human activity and the presence of potentially pathogenic microorganisms affect their health status. In general,

despite the presence of pathogenic microorganisms to which the mussels were exposed, mortality rates were not examined and histological examination did not reveal any significant results.

Künili et al. (2021) examined the tissue damage and oxidative stress effects caused by the protozoan (*H. pinnae*), which causes mass mortality in *P. nobilis* samples and has recently been observed in the Dardanelles, as well as the deaths observed by co-infection of *V. harveyi*, *V. corallilyticus, V. tubiashii*, *V. mediterranei*, and *V. hispanicus* pathogens. It was reported that the integrated infection of *H. pinnae* protozoon with Vibrio caused mass mortality and therefore *P. nobilis* population was negatively affected.

Declines in the populations of marine bivalves and even mass mortalities of some species distributed in the Mediterranean and the Aegean have been reported. It is reported that there are many different reasons for these declines and mass extinctions (climate change, anthropogenic pressure, bacterial, virus, protozoan infection, prey-predator relationships). As stated in the literature summary; *V. harveyi* infection, which may occur naturally, has the potential to cause minimum physiological disorders and maximum mortality in mussels. In addition, there is no study investigating the histopathological changes that may occur in the gill and digestive gland tissues of *M. galloprovincialis* samples as a result of this infection. The natural presence of the bacterium, whose histopathological effects will be evaluated within the scope of the proposed project, in seawater increases the risk factor significantly. There is always the potential for the density of this bacterium to increase as a result of changes in climatic data and/or changes in inputs in seawater. Since *M. galloprovincialis*, which is preferred as animal material, is fed by filtration, it has the potential to directly accumulate bacterial changes in water. Since this species is consumed as food by humans and has an important role in the food web, it is thought to have a high impact potential.

Conclusion

Considering all these, we believe that the identification of the pathologies that *V. harveyi* infection may cause in mussels will allow basic inferences to be made about these global declines.

Acknowledgments

This study was supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) (2209-A Project).

References

Austin B, Zhang XH., 2006. *Vibrio harveyi*: A significant pathogen of marine vertebrates and invertebrates. Lett Appl Microbiol; 43(2):119-124.

Battistini, R., Varello, K., Listorti, V., Zambon, M., Arcangeli, G., Bozzetta, E., … Serracca, L., 2020. Microbiological and Histological Analysis for the Evaluation of Farmed Mussels *(Mytilus galloprovincialis)* Health Status, in Coastal Areas of Italy. Pathogens, 9(5), 395.

Canesi, L., Pruzzo, C., 2016. In: Ballarin, L., Cammarata, M. (Eds.), Specificity of innate immunity in bivalves: A lesson from bacteria. Elsevier Inc, pp. 79-91 Lessons in immunity: from single-cell organisms to mammals.

Cappello, T., Maisano, M., Mauceri, A., Fasulo, S., 2017a. 1H NMR-based metabolomics investigation on the effects of petrochemical contamination in posterior adductor muscles of caged mussel *Mytilus galloprovincialis*. Ecotoxicol Environ Saf; 142: 417-422.

Cappello, T., Fernandes, D., Maisano, M., Casano, A., Bonastre, M., Bebianno, M.J., Mauceri, A., Fasulo, S., Porte, C., 2017b. Sex steroids and metabolic responses in mussels *Mytilus galloprovincialis* exposed to drospirenone. Ecotoxicol Environ Saf; 143: 166-172.

Cellura C, Toubiana M, Parrinello N, Roch P., 2006. HSP70 gene expression in *Mytilus galloprovincialis* hemocytes is triggered by moderate heat shock and *Vibrio anguillarum*, but not by *V. splendidus* or *Micrococcus lysodeikticus*. Dev Comp Immunol; 30: 984-997.

Çolakoğlu, F. A., Çardak, M., Çolakoglu, S., Künili, I. E., 2014. Depuration Times of *Donax trunculus* and *Tapes decussatus*. Brazilian Journal of Microbiology, 45, 1017-1022.

Costa MM, Prado-Alvarez M, Gestal C, Li H, Roch P, Novoa B, et al., 2009. Functional and molecular immune response of Mediterranean mussel (*Mytilus galloprovincialis*) haemocytes against pathogen-associated molecular patterns and bacteria. Fish Shellfish Immunol; 26:515-523.

Giannetto, A., Maisano, M., Cappello, T., Oliva, S., Parrino, V., Natalotto, A., De Marco, G., Barberi, C., Romeo, O., Mauceri, A., Fasulo, S., 2015. Hypoxia-inducible factor α and Hif-prolyl hydroxylase characterization and gene expression in short-time airexposed *Mytilus galloprovincialis*. Mar. Biotechnol; 17: 768–781.

Giannetto, A., Maisano, M., Cappello, T., Oliva, S., Parrino, V., Natalotto, A., De Marco, G., Fasulo, S., 2017. Effects of oxygen availability on oxidative stress biomarkers in the Mediterranean mussel *Mytilus galloprovincialis*. Mar. Biotechnol; 19: 614-626.

Künili, İ.E., Gürkan, S.E., Aksu, A., Turgay, E., Çakır, F., Gürkan, M., Altınağaç,

U., 2021. Mass mortality in endangered fan mussels *Pinna nobilis* (Linnaeus 1758) caused by co-infection of *Haplosporidium pinnae* and multiple *Vibrio* infection in Çanakkale Strait, Turkey, Biomarkers; 26(5): 450-461.

Li A, Ma J, Cao J, McCarron P., 2012. Toxins in mussels (*Mytilus galloprovincialis*) associated with diarrhetic shellfish poisoning episodes in China. Toxicon; 60:420e5.

Liu X, Sun H, Wang Y, Ma M, Zhang Y., 2014. Gender-specific metabolic responses in hepatopancreas of mussel *Mytilus galloprovincialis* challenged by *Vibrio harveyi*. Fish Shellfish Immunol; 40(2):407-13.

Maisano, M., Cappello, T., Natalotto, A., Vitale, V., Parrino, V., Giannetto, A., Oliva, S., Mancini, G., Cappello, S., Mauceri, A., Fasulo, S., 2017. Effects of petrochemical contamination on caged marine mussels using a multi-biomarker approach: histological changes, neurotoxicity and hypoxic stress. Mar. Environ. Res; 128: 114-123.

Parisi, M.G., Maisano, M., Cappello, T., Oliva, S., Mauceri, A., Toubiana, M., Cammarata, M., 2019. Responses of marine mussel *Mytilus galloprovincialis* (Bivalvia: Mytilidae) after infection with the pathogen *Vibrio splendidus*. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology; 221:1-9.

Travers M-A, Le Goic N, Huchette S, Koken M, Paillard C., 2012. Summer immune depression associated with increased susceptibility of the European abalone, *Haliotis tuberculata* to *Vibrio harveyi* infection. Fish Shellfish Immunol; 32:170e7.

Travers, M.A., Miller, K.B., Roque, A., Friedman, C.S., 2015. Bacterial diseases in marine bivalves. J. Invertebr Pathol; 131: 11-31.

Wilson, I. and Gamble, M., 2002. The hematoxylins and eosin. Theory and practice of histological techniques. 5th ed. London, UK: Churchill Livingston, 125-138

Wu X, Pan J, Jian J., 1995. Advances in studies on shellfish diseases: on microbial diseases of shellfish. Mar Sci Bull;14: 82-91.

Yang S, Wang Y, Dong S., 2005. Progress of research on vibriosis in marine cultured fish (In Chinese). Mar Fish Res; 26:75-83.

Chapter 7

Environmental Impact Assessment Of Laying Hen Production Systems Through Life Cycle Assessment

Büşra YAYLI[1]
İlker KILIÇ[2]

1. Introduction

Egg production is easy and economical, the protein content is high, and the fat content is low despite being an animal protein. The vast consumption area can be consumed quickly and is offered to the consumer at a more affordable price than other animal-derived proteins in retail sales. For these reasons, the increasing demand for eggs has played an active role in developing the egg poultry sector. Developments such as the widespread use of industrial egg poultry and automation in the poultry house have also significantly accelerated the realized production potential.

China is the largest producer of chicken eggs in the world, providing 36.4% alone in 2021. In the same year, 6.8% was supplied by America, 7.5% by India and 7% by Indonesia. Turkey supplies approx.1.2% of the world's egg production with 1 243 633 tons of eggs, ranking it 10th. In the world of egg export, after the Netherlands (351 224 tons), Turkey ranks second with 221 215 tons [1]. In the first ten months of 2023, 16 million 975 thousand eggs were produced. In the January-October period, chicken egg production increased by 4.0% compared to the same period of the previous year [2]. According to 2021 data, 121 302 869 laying hens and 4975 commercial laying hen houses in Turkey. In the same period, 19 billion 788 million eggs were produced in the commercial egg sector, and 239 eggs were produced per person [3]. Turkey is a significant producer and exporter with its egg potential. Today, the technical and technological developments in the egg industry have progressed at the same level as in European countries. As the egg is one of the essential export products and its consumption increases, the production potential mostly made by intensive enterprises also increases the amount of waste to be generated.

Along with the increase in egg production, waste and emissions such as manure, urine, and gas outputs appear in addition to the product obtained. In

[1] Research Assistant.; Bursa Uludag University Faculty of Agriculture Department of Biosystems Engineering. busrayayli@uludag.edu.tr ORCID No: 0000-0002-0198-3550
[2] Prof. Dr.; Bursa Uludag University Faculty of Agriculture Department of Biosystems Engineering. ikilic@uludag.edu.tr ORCID No: 0000-0003-0087-6718

cases where these cannot be controlled within the enterprise, they affect the employees' efficiency, animal welfare, and health. At the same time, if they reach the environment, they cause various environmental problems. To develop prevention and control strategies against ecological effects, it is essential first to determine which effects they cause and their effect sizes. Life cycle assessment, a holistic system to assess the environmental performance of products or services, is a reliable analysis used for multiple purposes. Life cycle assessment evaluates ecological impacts by qualitatively and quantitatively defining the use of raw materials, energy requirements, emissions, and wastes released to the environment throughout the life cycle of a product, process, or activity [4].

2. Environmental Effects of Laying Hens Productions

Consumption of resources and raw materials such as feed production, water, and land use throughout the egg production process (cradle-to-grave); The coal, fuel, and electricity consumptions used in the operating process; and the manure and urine from chickens are the main factors causing environmental problems. The overall environmental impacts caused by pollutants from laying poultry can be described as follows:

Climate change: It causes climate change with the emissions of greenhouse gases that cause global warming (especially CO_2, CH_4, and N2O, which are the most critical greenhouse gases) to the atmosphere. It is expressed in kg CO_2, which is the equivalent of CH_4 and N_2O gases, according to the emission factors determined by the IPPC. For a 100-year timeline, methane (CH_4) has an estimated global warming potential of 27-30 times CO_2, and nitrous oxide (N_2O) has 273 times that of CO_2 [5]. The concept of carbon footprint is also an effective method to determine the impact of a product or service on climate change and uses these equivalences in calculations.

Energy use: In egg farming, energy use includes a significant share before production, during the production period, and in the stages after production. Diesel fuel use, coal use, and electricity consumption of machinery, tools, and equipment used during production in the poultry house are evaluated in energy use. Energy uses are usually expressed in MJ.

Water use: In the rearing of layer hens, the amount of water used to grow the product is the stage of feed production that causes the most water consumption. In addition, the water consumed by chickens in the poultry house and the water used for cleaning are evaluated within the water use. The water consumed is calculated as m^3, ton, or liter. The concept of water footprint has emerged to determine the water consumption and the extent of pollution in the water in the formation of production or product.

Acidification and eutrophication: The most crucial gas emission in poultry farming originates from ammonia (NH_3). NH_3 gas emission causes acidification and eutrophication [6, 7]. Acidification is the emission of gases that harm the environment by reacting with other compounds such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and ammonia (NH_3) arising from various sources in the air and returning to the surfaces as acid rain [8, 9, 10]. In acidification, the reference gas is expressed in terms of SO_2 The primary sources of eutrophication are emissions of NO_3^- (nitrate) and PO_4^{-3} (phosphate) in water and NH_3 (ammonia) in air. Eutrophication can measures be measured by reference gases NO_3^- or PO_4^{-3} equivalents.

Nitrification and denitrification: N gas in nitrogenous compounds in the air is first converted to NH_4 by bacteria and released into the soil. Bacteria in the soil first convert NH_4 (ammonium) to NO_2 (nitrite) and then to NO_3 (nitrate), and this is called nitrification. NO_3 leaks from the soil, leaching with surface waters and underground drinking water, causing NO_3 accumulation. The process of reducing NO_3 to N gas by microorganisms is called denitrification. NO_3, gaseous by denitrification, causes environmental effects such as the greenhouse effect, global warming, acid rain, and ozone degradation.

Land use: In general, as in all aquaculture, while most land use is realized in feed production in laying hen farming, the operation structure established on a specific land also causes land use. The m^2 equivalence is used as the reference unit.

3. Life Cycle Assessment (LCA)

The rapid increase in consumption and the increasing population over time, the decrease in resources, the concern of being unable to meet future needs, and the potential environmental effects it creates have revealed the concept of life cycle analysis in which ecological sustainability is evaluated. Life cycle analysis is an all-purpose analysis that enables the calculation, evaluation, and reporting of the effects, risks, and their interactions throughout the entire life cycle of an activity or product. In various studies, the definition of life cycle analysis has been made:

Guinee [11], stated that life cycle assessment is a generally accepted method for evaluating the environmental impacts of a product throughout its life cycle.

According to Baumann and Arvidsson [12], life cycle assessment is a systematic methodology that deals with the material and energy flows used in processes such as raw material input, production, use, and waste generation related to a product or process and their environmental impacts.

According to Gulli [13], Life cycle assessment is a quantitative analysis that can be used with other models to identify and evaluate potential environmental impacts during the life cycle of a process or product, to improve production methods, and to predict the behavior of various production cycles, including agricultural production.

According to the International Organization for Standardization (ISO), life cycle assessment is the collection of inputs and outputs throughout the life cycle of a product system and the assessment of its potential environmental impacts.

The life cycle assessment methodology has been standardized with ISO 14040:2006 and ISO 14044:2006, a series of environmental management standards created by the International Organization for Standardization [14].

The phases within which a product, service, or process's life cycle analysis will be presented with four different approaches: 'cradle to grave,' 'cradle to gate,' 'cradle to cradle,' and 'gate to gate.'

According to ISO standards, life cycle analysis consists of four stages. These;

- Definition of aim and scope
- Inventory analysis
- Impact assessment
- Interpretation

3.1. Definition of Aim and Scope

The first stage of life cycle analysis is defining the aim and scope. The aim and scope of the product, service, or process to be analyzed should be clearly stated. While LCA analysis can be applied for short-term studies, it can also be used for long-term studies. The target public to which the research results will be presented may vary. Factors such as working time, target audience, and databases suitable for the study influence choosing the LCA type. The available database is selected for the data and standards used in the study. The database chosen may change depending on the geographical region where the study is conducted, the content, and the purpose of the study.

The defined functional unit is taken as a basis in the life cycle assessment while limiting the scope. A reference is an operating unit that reveals the environmental effects of a production system or a service. Wiedemann and McGahan [15] stated that the definition of an available unit is "a reference unit that enables the comparison of inputs and outputs in production and different system operations in a similar structure." The functional unit is determined by considering the environmental impact categories and the aim of the research. [16, 17].

The production or process must be limited while estimating in the life cycle assessment. In determining the system boundaries, which stages and processes of the life cycle of the product or service will be included, which will be excluded, and their justifications are taken into account [18].

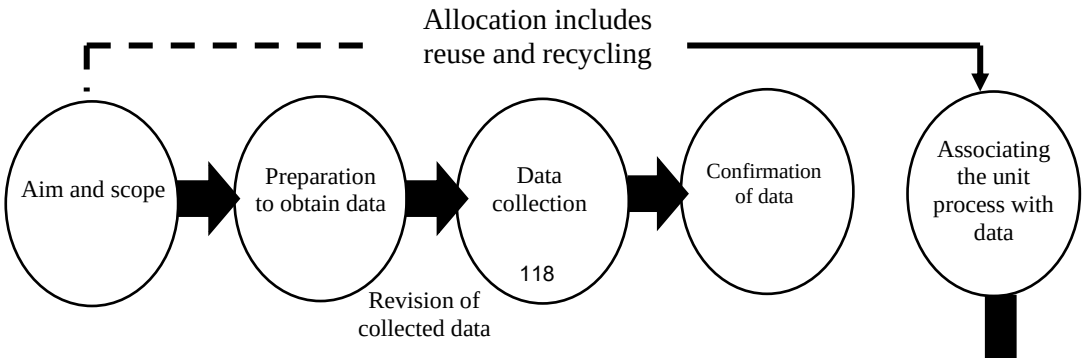
3.2. Life Cycle Inventory

In the inventory analysis phase, which is the third part of the life cycle analysis, the limits and product system of the work whose purpose and scope are determined are defined. The life cycle Inventory step includes data on raw material inputs, resource use, energy requirements, liquid and solid waste, atmospheric emissions, and leakage to aquatic environments. Additionally, it aims to collect qualitative and quantitative data, to express the product outputs as a result of production numerically, to obtain and evaluate all the data-related data, and to determine the calculation procedures. The inventory phase of the life cycle is the primary phase for analyzing the method. The data's details, accuracy, and consistency directly affect the accuracy of the results in determining the impact categories and the results for the future stages. In the ISO-14044:2006 standard, the formation steps of inventory analysis are specified as obtaining the data, calculating the data, and distributing the data (allocation) (Figure 1).

3.2.1. Obtaining Data

Data collection is the most challenging and long-time phase of life cycle analysis. Qualitative or quantitative data collected, measured, calculated, or estimated for each process of inputs and outputs at the working system boundaries are obtained. Local or global sources are used if data cannot be accepted or reached. The main headings in which the data can be classified can be listed as follows:

- energy inputs, raw material inputs, auxiliary inputs, and other physical inputs
- products, by-products and wastes
- air, water, and soil emissions
- other environmental degradations



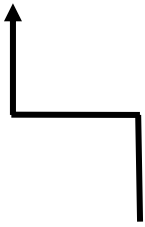


Figure 2. Flow chart of life cycle inventory assessment

3.2.2. Calculation of Data

At this stage of the inventory analysis, the calculation methods should be clearly stated, and the same calculation procedures should be applied consistently throughout the study. Data needs to be validated to ensure data quality in computation. Validation of data is related to being consistent with each other and making comparative analysis. Calculations of inputs and outputs should be made by creating flow charts in unit processes, considering the study's unit function. Based on its purpose, system boundaries can be revised according to the sensitivity analysis of essential inputs and outputs in processing data obtained in life cycle analysis.

3.2.3. Allocation

This stage includes data distribution to the relevant processes. Distribution should be avoided if the unit process is split into two or more sub-stages, by-products are produced, and the production process is expanding. Suppose data allocation cannot be avoided in the production process. In that case, it must be distributed in a way that reflects the fundamental physical relationship between different products or functions. If the physical connection between the development or processes cannot be established in the distribution, it is done by

decoupling it with other relationships. For example, the economic value of the products is allocated among the by-products in proportion.

3.3. Life Cycle Impact Assessment

As stated in ISO [14], since life cycle assessment is a relative approach based on unit function, it differs from other techniques such as environmental performance assessment, environmental impact assessment, and risk assessment in this respect. At this stage of the life cycle analysis, the potential effects of the inventory data collected for system inputs (raw material, energy, water, and resource uses) and system outputs (product, waste, by-products) on humans and ecology are evaluated. There are some compulsory and optional elements to carry out an impact assessment. Required factors include defining impact categories and category indicators, impact classification (classification), and characterization.

3.3.1. Identification of impact categories and indicators

In the life cycle assessment, impact categories indicate environmental problems (climate change, acidification, eutrophication) related to the production system or process examined to reflect the purpose and scope of the work done (Table 1). Each impact category has a specific environmental mechanism, and impact indicators vary according to the types defined within these ecological mechanisms.

Table 1. Environmental Impact Categories and Units

Impact Category	Unit
Climate Change	kg CO_2 eq
Ozone Depletion	kg CFC-11 eq
Terrestrial Acidification	kg SO_2 eq
Freshwater Eutrophication	kg P eq
Marine Eutrophication	kg N eq
Human Toxicity	kg 1,4-DB eq
Photochemical Oxidation Formation	kg NMVOC
Particulate Matter Formation	kg PM10 eq
Terrestrial Ecotoxicity	kg 1,4-DB eq
Freshwater Ecotoxicity	kg 1,4-DB eq
Marine Ecotoxicity	kg 1,4-DB eq
Ionizing Radiation	kBq U235 eq
Agricultural Land Use	m^2a

Urban Area Use	m^2a
Natural Area Transformation	m^2
Water Consumption	m^3
Metal Consumption	kg FE eq
Fossil Consumption	kg oil eq

3.3.2. Impact classification

Classifications are grouped by associating the determined impact categories and indicators with the data collected during the life cycle inventory analysis. For example, SO_2 (sulfur dioxide) gas emissions cause acidification. Therefore, SO_2 is classified in the acidification effect category.

3.3.3. Characterization

Whichever data obtained in the inventory analysis contributes to the same impact category, these data are multiplied by specific coefficients and converted into a standard unit, revealing the total impact of that impact category. The characterization stage enables comparison between inventories within the same impact category. E.g., CO_2, CH_4, and N_2O are the most important greenhouse gases that cause climate change. Calculating the effects of these gases on climate change in kg CO_2 equivalents over the standard unit characterizes their impact on climate change.

After the compulsory stages in the life cycle impact assessment are carried out, optional steps can also be carried out within the scope of the study on the inventory data. These stages are normalization, grouping, weighting, and data quality analysis [14].

3.3.4. Normalization

An inventory analysis tool eliminates the units by dividing the impact indicators by a selected reference value and comparing them between different impact categories [19]. For the reference to be determined, reference values such as the sum of inputs and outputs for a specific area globally, regionally, nationally, or locally, the sum of inputs and outputs per capita for one particular area, and the information and outcomes of the alternative scenario presented to the product system can be selected.

3.3.5. Grouping

Impact categories within the defined purpose and scope of the work are assigned to one or more predefined groups. The grouping stage provides ease of

interpretation and evaluation of impact categories for studies to be carried out in certain areas. For example, when examining the chemicals of a service that cause environmental pollution in the aquatic environment, grouping them as water emissions provides ease of monitoring and evaluating the impact category.

3.3.6. Weighting

At this stage of the life cycle analysis, different impact categories are graded according to their values using numerical values. Weighting the impact categories with the weighting process reveals which class has a more significant impact. The same indicators or normalized indicator results can differ depending on the country, region, organization, or society where the weighting process is performed.

3.3.7. Data quality analysis

Additional information and techniques may be needed to understand better and demonstrate the importance, uncertainty, and sensitivity of inventory analysis results. Different analyses are used to reveal the accuracy of the data to carry out the purpose and scope of life cycle analysis. Gravity Analysis is applied to identify the data that contributes the most to the result. Uncertainty Analysis is applied to reveal uncertainties in data and calculations. Sensitivity Analysis is used to decide how changes in data and methodological choices affect the inventory results.

3.4. Life Cycle Interpretation

Interpretation is the final stage of life cycle analysis. The data, findings, and results obtained in the inventory analysis and impact assessment step are evaluated by the purpose and scope of the study and suggestions presented. Regarding the purpose of the study, interpretations should be made using the definitions of system functions, functional units, and system boundaries, using the data obtained and within the limitations determined by sensitivity analysis. There are some points to be considered in the interpretation phase of an LCA study [14]:

• According to the findings obtained from the inventory analysis and impact assessment phase, it is necessary to determine and emphasize the critical issues that affect the study.

• The evaluation should involve the subject and ensure the results are sensitive and consistent.

• In the interpretation phase, the final work should be concluded, and the precautions and limitations that can be taken for the current situation should be put forward.

4. Standardization of Life Cycle Assessment

The environmental concept of life cycle assessment (LCA) was developed from the idea of a detailed environmental assessment of products in Europe and the USA in the late 1960s and early 1970s [20]. The Society of Environmental Toxicology and Chemistry (SETAC) published the first guideline for life cycle assessment in 1993, describing the procedures for life cycle assessment. In the international standards developed and accepted in the late 1990s, recommendations and requirements were put forward for various methodological issues that should have been included in the directive published by SETAC [21].

Another organization working on life cycle analysis is UNEP (United Nations Environment Development). In 1996, a guiding guide was published titled "Life Cycle Assessment: What it is, and what to do about it." SETAC and UNEP are currently working in collaboration with the Lifecycle Initiative. This cooperation ensures that the public interest is a scientifically provided global forum by establishing a consensus (governments, companies, scientific organizations, and non-governmental organizations).

The first national standard on life cycle assessment was established by ISO on May 15, 1997, with the title "ISO-14040: Environmental management - Life cycle assessment - Principles and framework". This standard explains the general framework, principles, and requirements for carrying out and reporting life cycle assessment studies and specifies relevant definitions. However, this published standard needs to mention a detailed structuring of the life cycle assessment. To under-definition the methodology and eliminate the deficiencies, new standards were established that clarified the stages of the lifecycle review.

These standards are "ISO 14041:1998 Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis", "ISO 14042:2000 Environmental management - Life cycle assessment - Life cycle impact assessment", and "ISO 14043:2000 Environmental management - Life ISO 14040 standard has been developed by creating "cycle assessment - Life cycle interpretation" titles. ISO 14041, ISO 14042, and ISO 14043 standards were cancelled in 2007. It was revised as "ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework" in 2007 and the standards titled "ISO 14044:2006 Environmental management — Life cycle

assessment — Requirements and guidelines" entered into force as the last standard published up to date. In the year 2018, the standard ISO 14044 Environmental Management - life cycle assessment - requirements and guidelines - Amendment 1", and by 2020, "Environmental Management-life cycle assessment - requirements and guidelines - Amendment 2" headers with improvements have been made, but yet are not provided with free access. It is applied based on ISO 14040 and 14044 standards in every study on life cycle assessment conducted nationally or internationally. Other ISO standards that can help in the life cycle analysis and the standards published by the Turkish Standards Institute (TSE) based on the ISO 14040 standard are given in Table 2.

Table 2. ISO and TSE standards related to life cycle assessment

Standards	Current Status
ISO 14040:1997 Environmental managament – Life cycle assessment – Principles and framework	Withdrawn
ISO 14041:1998 Environmental management - Life cycle assessment - Goal and scope definition and inventory analysis	Withdrawn
ISO 14042:2000 Environmental management - Life cycle assessment - Life cycle impact assessment	Withdrawn
ISO 14043:2000 Environmental management - Life cycle assessment-Life cycle interpretation	Withdrawn
ISO/TR 14049:2000 Environmental management-Life cycle assessment- Examples of application of ISO 14041 to goal and scope definition and inventory analysis	Withdrawn
ISO 14040: 2006 Environmental management - Life cycle assessment - Principles and framework	Current
ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines	Current
ISO 14044:2006 / Amd 1: 2017 Environmental management — Life cycle assessment — Requirements and guidelines — Amendment 1	Current
ISO 14044:2006 / Amd 2: 2020 Environmental management — Life cycle assessment — Requirements and guidelines — Amendment 2	Current
ISO 14045:2012 Environmental management - Eco-efficiency assessment of product systems -Principles, requirements and guidelines	Current
ISO/TR 14047:2012 Environmental management- Life cycle assessment- Illustrative examples on how to apply ISO 14044 to impact assessment situations	Current
ISO/TS 14048:2002 Environmental management -- Life cycle assessment -- Data documentation format	Current
ISO 14049:2012 Environmental management - Life cycle assessment - Illustrative examples on how to apply ISO 14044 to goal and scope definition and inventory analysis	Current
TS EN ISO 14041:2003 Environmental management- Life cycle assesment- Goal and scope definition and inventor analysis	Withdrawn
TS EN ISO 14042:2002 Environmental management- Life cycle assessment- Life	Withdrawn

cycle impact assessment	
TS EN ISO 14043:2003 Environmental management - Life cycle assessment - Life cycle interpretation	Withdrawn
TS EN ISO 14040:2007 Environmental management – Life cycle assessment – Principles and framework	Current
TS EN ISO 14044/A1: Environmental management – Life cycle assessment – Requirements and guidance-Amendment 1	Current
TS EN ISO 14044/A2: Environmental management - Life cycle assessment - Requirements and guidelines - Amendment 2	Current

5. Life Cycle Analysis (LCA) Software

There is a lot of computer software used in life cycle assessment studies. The most widely used software is Simapro and GaBi.

5.1. SimaPro Software

SimaPro software was developed in 1990 by PRe Consulting, a Dutch company. This software makes a comprehensive environmental assessment of products or services, and their environmental performance is evaluated. SimaPro provides the determination and definition of the sustainability targets of the products or services for which their ecological performance is determined, as well as sustainable product development and analysis. It is software widely used in over 80 countries by many international and local industrial organizations, consultancy companies, academia, and research centers such as Unilever, Heineken, and BASF [22] SimaPro software has an integrated structure of various databases and various applications for impact assessment analysis. These evaluations are as follows [23]:

Monitoring corporate and product sustainability performance

Carbon footprint assessment

Water footprint assessment

Product design and eco-design

Environmental product declaration

Environmental reporting

Determination of key performance indicators

Simapro has a rich library with international databases in computer software. New databases can be included as versions are updated. Simapro contains various databases:

Agri-footprint

Ecoinvent

European and Danish Input/Output database

Industry data library: PlasticsEurope, ERASM, World Steel

US Life Cycle Inventory database
AGRIBALYSE
Environmental Footprint database
EXIOBASE
Quantis World Food LCA Database
DATASMART LCI package
ESU World Food LCA database
IDEA Japanese Inventory database
Social hotspots database
WEEE LCI database

5.2. GaBi Software

GaBi, another software used for life cycle analysis, was developed by the German company Thinkstep firm. The life cycle inventory data of the GaBi program, which has been used for more than 25 years, is produced by ISO 14044, ISO 14064, and ISO 14025 standards. It offers alternative scenarios by evaluating the effects on the environment to determine the production, waste, distribution, and recycling stages of a product or system and its sustainability from the perspective of the life cycle. The GaBi program covers automotive, building and construction, chemicals and petroleum, consumer products, education, electronics, food and agriculture, food and beverage, textiles, and energy; it is applied in many industrial areas [24].

5.3. Umberto Software

Umberto life cycle assessment software developed by the German company IFU Hamburg. Umberto is an all-purpose software with resource efficiency and process optimization that enables the calculation of life cycle analysis. With this software, the LCA analysis provides the most comprehensive integrated cost analysis to increase environmental effectiveness and reveal the climatic effects by determining the CO_2 balance of products or companies by calculating the environmental impacts throughout the product's life cycle [25].

5.4. OpenLCA Software

OpenLCA, another life cycle analysis program, is a free and open-access LCA software that emerged in 2006 due to discussions by Andreas Ciroth, Michael Srocka, and Jutta Hildenbrand. It has been managed by a company named GreenDelta, located in Berlin, since its inception [26].

6. LCA studies on Egg Production

Studies on LCA predict the potential environmental impacts of the egg production process and integrate improvement and control methods into the process. Inputs such as feed, electricity and water consumption, and land use were considered in the LCA application in egg production. Feed production, laying hen activities, manure management, transportation, and retailing processes have significantly benefited LCA-applied egg production systems [27, 28, 29, 30, 31]. When the studies are examined, the feed production process is where the most emissions originate in egg production. Climate change is the hotspot among environmental problems in the egg production process.

De Vries and De Boer [32], examined the production of chicken, beef, eggs, milk, and pig meat to compare the environmental impacts of different livestock farms in their study. They stated that the differences between ecological effects were affected by feed efficiency, enteric CH_4 emission rates in monogastric and ruminant animals, and reproduction rates. The study shows that egg production generally causes less environmental impact than other livestock.

Dekker et al. [33], conducted a study in the Netherlands to compare the ecological effects per 1 kg of eggs produced using life cycle assessment between single and multi-layer cage systems, free-range systems, and organic systems. It has been determined that global warming potential, energy use, phosphorus use, nitrogen, and phosphorus supplements have the lowest environmental impact in free-range systems and organic farming systems. Land use, nitrogen, and phosphorus deficiency were the weakest in battery cage systems. It was shown that the system in which acidification has the most minor effect was multi-layer battery cage systems.

Leinonen et al. [34], in a study they conducted in England, evaluated the environmental effects of 1 kilogram of egg with life cycle analysis from four different egg production systems: battery cage systems, free-run systems, free-range systems, and organic systems. As a result of the study, the number of chickens required for 1 kg egg production is the highest in organic production systems and the lowest in battery cage systems. Similarly, the feed consumption per chicken was highest in organic production systems and lowest in caged systems. It is stated that these general differences in production also affect the differences in environmental effects between systems. Feed production, processing, and transportation account for 54-75% of energy use and 64-72% of the global warming potential of systems. While electricity consumption (ventilation, automatic feeding, and lighting) creates the second most significant impact on energy use, gas and fuel use constitute 7-14% of the total energy use.

It has been stated that the most critical contributor to acidification and eutrophication potential are caused by manure.

Pelletier et al. [28], in a study conducted in the Midwestern United States, determined the carbon footprint by evaluating greenhouse gas emissions along the intensive egg production and supply chain with life cycle analysis. According to the study results, feed production and use significantly contributed to the supply process emissions. They stated that feed production constitutes the largest share of emissions in egg production.

The potential environmental impacts of a laying hen farm in Bursa were evaluated by Kilic and Karaman [35], through life cycle analysis. The study obtained 3.3 kg/day of feed and 3.52 kg of water consumed per viol egg produced, 1.08 m^2 of land use, and 2.64 kg of manure was released. As a result of the study, they concluded that the gas that contributes the most to acidification and eutrophication is NH_3, and the gas that contributes the most to global warming is CH_4.

In a study in Iran, Ghasempour and Ahmadi [31], examined the environmental effects of 1 kg egg production from 1000 chicks for 420 days. As a result of the analysis, it has been determined that the energy input for 1 kg egg production is 30/09 MJ and 4/07 kg CO_2 equivalent, creating a global warming potential, and the information that causes the environmental impact is from the feed.

In a study by Pelletier [36], five laying hen breeding systems (battery cage system, enriched cage system, free-range system, free-run system, and organic system) operating in Canada were applied in egg production and their environmental effects on the life cycle. Compared with the analysis. As a result of the data and evaluations obtained in the life cycle inventory and impact assessment stages, non-organic systems showed very similar environmental performance. It has been observed that the use of resources and emissions in organic egg production are lower in organic farming systems compared to other systems.

Abín et al. [37], conducted a study in Spain that determined the environmental effects of an intensive farm with 55.000 laying hens through life cycle analysis using the Simapro program. According to the study's results, the most severe environmental impact was natural area transformation, followed by terrestrial toxicity and aquatic ecotoxicity. While feed production is the most important source of adverse environmental effects, the exchange process of newly arrived chickens and old ones creates less impact. They stated that its contribution to reducing the environmental impacts of urban land use and metal consumption resulting from the change of laying hens is remarkable.

Estrada-Gonzalez et al. [38], focused on an eco-efficient approach to life cycle analysis with a door-to-door approach in a semi-technological egg production farm. The study revealed 5.58 kg CO_2/kg of egg emission per egg produced, indicating that the climate change category is a hotspot in egg production. They stated that implementing an eco-efficient plan focusing on energy use could result in a 49.5% reduction in total energy consumption and a 56.3% savings in environmental impacts.

7. Conclusion

Considering the world's population growth rate and our country, the need for protein from animal products will increase, and a deficit will occur. In order to close this gap, there will be an increase in industrial enterprises that produce more eggs per unit area. This change in cultivation systems also brings environmental effects. In order to achieve sustainable production, environmental impacts must be predicted, and necessary precautions must be taken. When the studies in the literature are examined, it has been seen that the environmental effects of egg poultry production systems can be predicted successfully. Therefore, as a result of the study, it was concluded that the life cycle assessment method is beneficial in determining the environmental impacts of egg poultry production systems.

References

[1] FAO, (2021). Food and Agriculture Organization of the United Nations, *Crops and livestock products*. Retrieved October 13, 2023, from https://www.fao.org/faostat/en/

[2] TUIK, (2023). Turkish Statistical Institute, *Livestock Statistics*. Retrieved October 13, 2023, from https://data.tuik.gov.tr/Bulten/Index?p=Kumes-Hayvanciligi-Uretimi-Ekim-2023-49416

[3] YUM-BİR, (2021). *Yumurta Üreticileri Merkez Birliği, Yumurta Tavukçuluğu Verileri.* Retrieved November, 14, 2023, from https://www.yum-bir.org/UserFiles/File/Veri-2021.pdf

[4] Berlin, J. (2002). Environmental life cycle assessment (LCA) of Swedish semi-hard cheese. *International Dairy Journal*, 12, 939-953.

[5] EPA, (2023). United States Environmental Protection Agency, *Greenhouse gas emissions: understanding global warming potentials.* Retrived November 16, 2023, from https://www.epa.gov/ghgemissions/understanding-global-warming-potentials#:%7E:text=Methane%20(CH4)%20is%20estimated,uses%20a%20different%20value

[6] Cowling, E. B., Erisman, J. W., Smeulders, S. M., Holman, S. C., & Nicholson, B.M. (1998). Optimizing air quality management in Europe and North America: justification for integrated management of both oxidized and reduced forms of nitrogen. *Environmental Pollution,* 102, 599–608.

[7] Mollenhorst, H., & De Boer, I. J. M. (2004). Identifying sustainability issues using participatory SWOT analysis: A case study of egg production in the Netherlands. *Outlook on Agriculture*, 33, 267-276.

[8] Audsley, A., Alber, S., Clift, R., Cowell, S., Crettaz, R., Gaillard, G., Hausheer, J., Jolliet, O., Kleijin, R., Mortensen, B., Pearce, D., Roger, E., Teulon, H., Weidema, B., & Van Zeijts, H. (1997). *Harmonisation of environmental life cycle assessment for agriculture*. Final Report, Concerted Action AIR3-CT94-2028. European Commission, DG VI Agriculture, 139(1).

[9] Basset-Mens, & C., Werf, VDHMG. (2003). Environmental assessment of contrasting pig farming systems in France. *Life Cycle Assessment in the Agri-food Sector Proceedings from the 4th International Conference,* 6-8 October, 2003, Bygholm, Denmark.

[10] Kilic, I., & Amet, B. (2017). Estimation of Carbon Footprint of a Dairy Cattle Operation: Bursa Case Study. *Journal of Agricultural Faculty of Gaziosmanpasa University*, 34(Supplementary Issue), 134-142.

[11] Guinée, J. B. (2002). *Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards*. Institute for Environmental Sciences, The Netherlands.

[12] Baumann, H., & Arvidsson, R. (2015). *Life Cycle Assessment (LCA): Encyclopedia of Polymeric* Berlin, Germany.

[13] Gulli, A. (2017). *A Comparative Analysis of Feed and Environmental Factors on Broiler Growth in the United States*. Master's Thesis, University of Arkansas, Bachelor of Science in Chemistry, USA.

[14] ISO, (2006). International Organization for Standardization, ISO-14044:2006, *Environmental Management - Life Cycle Assessment - Reguirement and Guidelines*. Retrieved October 10, 2023, from https://www.iso.org/standard/38498.html#:~:text=ISO%2014044%3A2006%20specifies%20requirements,and%20critical%20review%20of%20the

[15] Wiedemann, S., & McGahan, E., (2011). *Environmental Assessment of an Egg Production Supply Chain Using Life Cycle Assessment*. Australian Egg Corporation Limited, Sydney. Retrieved from December 1, 2023, from http://www.freeranger.com.au/uploads/7/4/2/0/7420102/aecl_carbon_footprint.pdf

[16] De Boer, I. J. M. (2003). Environmental impact assessment of conventional and organic milk production. *Livestock Production Science*, 80, 69–77.

[17] Thomassen, M. (2003). *Life cycle assessment at commercial organic dairy farms. Comparison of three methodologies: LCA, ecological footprint-analysis and an adjusted nutrient balance*, Master's Thesis, Animal Production Systems Group, Wageningen University, The Netherlands.

[18] Tillman, A. M., Ekvall, T., Baumann, H., & Rydberg, T. (1993). Choice of system boundaries in life cycle assessment. *Journal of Clean Production*, 2, 21-29.

[19] Demirer, G. N., (2011). *Yaşam Döngüsü Analizi*, Sürdürülebilir Üretim ve Tüketim Yayınları-I. Retrieved October 14, 2023, from https://rec.org.tr/wp-content/uploads/2017/02/yda.pdf

[20] Hunt, R. G., & Franklin, W. E. (1996). LCA - How it came about - Personal reflections on the origin and the development of LCA in the USA. *The International Journal of Life Cycle Assessment*, 1(1), 4-7.

[21] Russell, A., Ekvall, T., & Baumann, H. (2005). Life cycle assessment - introduction and overview. *Journal of Cleaner Production*, 13(13), 1207-1210.

[22]Metsims, (2005). Retrieved November 18, 2023, from https://www.metsims.com/tr/

[23] Simapro, (2021). *About SimaPro*. Retrieved November 18, 2023, from https://simapro.com/about/

[24] Sphera, (2021). Retrieved November 18, 2023, from http://www.gabi-software.com/turkey/index/

[25] iPoint, (2021). *Umberto-know the flow*. Retrieved October 19, 2023, from https://www.ifu.com/en/

[26] openLCA, (2021). *Why we started the development of openLCA*. Retrieved November 19, 2023, from http://www.openlca.org/

[27] Li, Y., Allacker, K., Feng, H., Heidari, M. D., & Pelletier, N. (2021). Net zero energy barns for industrial egg production: An effective sustainable intensification strategy?. *Journal of Cleaner Production*, 316, 128014.

[28] Pelletier, N., Ibarburu, M., & Xin, H. (2013). A carbon footprint analysis of egg production and processing supply chains in the Midwestern United States. *Journal of Cleaner Production*, 54, 108-114.

[29] Xin, H., Gates, R. S., Green, A. R., Mitloehner, F. M., Moore, P. A., & Wathes, C. M. (2011). Environmental impacts and sustainability of egg production systems. *Poultry Science*, 90 (1), 263–277.

[30] Xin, H., Gates, R. S., Green, A. R., Mitloehner, F. M., Moore, P. A., Wathes, C. M., Moore Jr., P. A., & Wathes, C. M. (2011). Environmental impacts and sustainability of egg production systems. *Poultry Science*, 90 (1), 263–277.

[31] Ghasempour, A., & Ahmadi, E. (2016). Assessment of environment impacts of egg production chain using life cycle assessment. Journal of Environmental Management, 183, 980–987.

[32] De Vries, M., & De Boer, I. J. M. (2010). Comparing environmental impacts for livestock products: A review of life cycle assessment. *Livestock Science*, 128, 1-11.

[33] Dekker, S. E. M., De Boer, I. J. M., Vermeij, I., Aarnik, A. J. A., & Groot Koerkamp, P. W. G. (2011). Ecological and economic evaluation of Dutch egg production systems. *Livestock Science*, 139, 109-121.

[34] Leinonen, I., Williams, A. G., Wiseman, J., Guy, J., & Kyriazakis I. (2012). Predicting the environmental impact of chicken systems in the United Kingdom through a life cycle assessment: Egg production systems. *Poultry Science*, 91, 26-40.

[35] Kilic, I., & Karaman, S. (2014). Life cycle assessment of a laying hen farm. *Mediterranean Agricultural Sciences*, 27(2), 107-112.

[36] Pelletier, N. (2017). Life cycle assessment of Canadian egg products, with differentiation by hen housing system type. *Journal of Cleaner Production*, 152, 167-180.

[37] Abín, R., Laca, A., Laca, A., & Díaz, M. (2018). Environmental assesment of intensive egg production: A Spanish case study. *Journal of Cleaner Production*, 179, 160-168.

[38] Estrada-Gonzalez, I. E., Taboada-González, P. A., Guerrero-Garcia-Rojas, H., & Marquez-Benavides, L. (2020). Decreasing the Environmental Impact in an Egg-Producing Farm through the Application of LCA and Lean Tools. *Applied Sciences*, 10(4), 1352.

Chapter 8

ENVIRONMENTAL BIOTECHNOLOGY PROCESSES IN THE TREATMENT OF LIVESTOCK WASTES

***Büşra YAYLI*[1]**
***İlker KILIÇ*[2]**

1. Introduction

Organic wastes generated from various activities are thrown into the environment, stored, incinerated, or used inefficiently without an effective transformation process. As a result, waste cannot be thoroughly degraded and threatens the environment, ecosystem, and human health, although it has an essential place in national economies. Uncontrolled storage and decomposition of waste lead to the formation of gases such as CH_4 and CO_2, which are harmful to human health; odor, flies, and pathogens are formed, and the hygiene conditions of the environment deteriorate. Nitrate accumulation resulting from decomposition can cause deterioration of soil structure and microbiology and pose a threat to humans and other living things through vegetable and fruit consumption and drinking water as a result of nitrate mixing with surface and groundwater [1, 2].

Due to the increase in the world population, the livestock sector has grown and caused the accumulation and formation of animal waste that causes environmental pollution in developed and developing countries. These wastes are very harmful to the environment and difficult to dispose of. In recent years, environmental waste caused by livestock and animal waste has become one of the most critical environmental problems. Manure, wet organic, and animal wastes are non-resident pollution sources from the livestock industry. It reaches surface waters or groundwater, deteriorating the water quality and making it unusable [3].

Livestock industry waste can also be used in fertilizer and feed production areas. Thus, the evaluation of wastes in the livestock industry both reduces environmental pollution and ensures economic recovery of these wastes. However, applying waste directly to agricultural fields or streams without any

[1]Research Assistant.; Bursa Uludag University Faculty of Agriculture Department of Biosystems Engineering. busrayayli@uludag.edu.tr ORCID No: 0000-0002-0198-3550

[2]Prof. Dr.; Bursa Uludag University Faculty of Agriculture Department of Biosystems Engineering. ikilic@uludag.edu.tr ORCID No: 0000-0003-0087-6718

fermentation process negatively affects the product productivity of the soil as well as environmental pollution [3].

Nitrate accumulation resulting from decomposition can cause deterioration of soil structure and microbiology and threaten humans and other living things through vegetable and fruit consumption and drinking water due to nitrate mixing with surface and groundwater. Biotechnological methods find an essential area of use in the evaluation and elimination of wastes at the point of environmental protection.

Biotechnology has recently enabled modern tools and approaches in various fields such as agriculture, food, healthcare, and environmental protection. Suppose there is not a very serious pollution burden in treating hazardous wastes and controlling pollution. In that case, applying environmental biotechnology techniques using living organisms can offer solutions. This paper examines environmental biotechnological applications that can be applied in evaluating, removing, and treating farm animal manure.

2. Uses Areas of Environmental Biotechnology in Livestock Wastes Treatment

2.1. Treatment of wastes

Excessive nutrient accumulation occurs in soils where unreasonable or excessive fertilizer is applied. This situation causes heavy metal pollution in the ground, creating a toxic effect on living things in the ecosystem. At the same time, it disrupts the soil's flora and affects the soil's biological and biochemical reactions. Thanks to bioremediation methods, highly toxic pollutants are transformed into less harmful forms thanks to the metabolic activities of microbes (such as transformation, mineralization, and immobilization) [4]. Bioremediation is a process that includes the capacity to clean the environment by removing pollutants in water and soil through degradation, detoxification, and retention by macro and microorganisms such as plants, bacteria, earthworms, and fungi [5]. Bioremediation is a more permanent method because pollutants do not transform from one phase to another but are changed into harmless end products such as carbon dioxide and water through biological activities.

In bioremediation methods, two approaches, in-situ and ex-situ, are based on transporting or removing wastes to a different location for pollutant removal. In in-situ application, the contaminated material is cleaned on-site. Bioventing, biostimulation, biodegradation, biosparging, and bio-augmentation are in-situ methods. In the ex-situ process, pollutant removal is carried out by physically removing the contaminated material from its location. Land farming,

composting, bioreactors, and soil biopiles are examples of ex-situ bioremediation methods. The ex-situ bioremediation method, the remediation technologies that cannot be applied in the soil environment, gives faster and more effective results than the in-situ method [6].

The bioremediation method is called phytoremediation if plants are used to remove pollutants in soil and water. If plants are used to remove heavy metals from the soil with the phytoremediation method, the plants must be removed from the soil. Plants and macro and micro creatures are used in bioremediation applications. In the studies conducted, it is thought to be a valuable alternative for the treatment of heavy metal pollution in the soil, with its features such as accumulating heavy metals in the tissues of earthworms, contributing to the development of plants by increasing plant nutritional elements in the soil, providing aeration of the soil and supporting microbial activity [7]. However, there needs to be more information on how and by which methods the heavy metals in earthworms can be removed from the soil since heavy metals in their bodies can be mixed back into the soil after they die. There is a need for further research on this subject.

Microorganisms are also used in the bioremediation method. Microorganisms are transferred to the soil, and conditions are controlled to optimize their metabolic activity and growth. Environmental factors such as temperature, pH, and inorganic nutrients such as nitrogen and phosphorus are modified for optimization. With another method, by looking at the microorganismic structure of the soil, microorganisms transfer nutrients to the area where waste is in the soil. Thus, microorganisms existing in the soil are activated. Creatures such as fungi and bacteria are also microorganisms used in bioremediation. Thanks to mycelial structure and fungal enzymatic systems, fungi are more suitable for the bioremediation method. Thanks to their biochemical capacities and morphologies, fungi play an essential role as decomposers, including organisms in soil and water [8].

In cases of excessive pollutant loads, natural microorganisms may be unable to clean pollutants. In such cases, studies are being conducted on genetically modified microorganisms (GEMs).

2.2. Biyoenergy Products From Livestock Wastes

2.2.1. Biomass

The world's most important energy source is oil, but as oil reserves gradually decrease, alternative energy sources have become even more critical. Biomass is all organic materials of plant and animal origin that are not fossils. Biomass energy is obtained from all natural materials of animal and plant origin, the

main components of which are carbohydrate compounds. Biomass production from animal waste can be converted into liquid and gaseous fuels due to biotransformation processes, and it can also be used for heating and electricity generation. An economic study of the energy that can be obtained should be conducted when agricultural biomass resources are characterized to determine their chemical and physical properties. If the feasibility and operation of the process are economical, biofuel can be produced by applying thermochemical methods to agricultural biomass. If the techno-economic evaluation is not applicable due to the examination, it can be used in applications such as compost, animal feed, soil improver, and natural fertilizer [9].

In addition, minimizing gas emissions from animal waste, pathogens, microorganisms associated with waste, and odor supports its conversion into useful energy sources and helps reduce environmental impacts. It will be achieved by increasing the energy production from biomass by applying advanced technologies to convert electricity, liquid, gas, or unprocessed solid fuels from raw biomass into suitable energy carriers [10].

As the number and weight of animals increase, the amount of waste generated also increases, which is related to the biomass energy potential. Since biomass resources of animal origin are generally rich in CH_4 and CO_2, biogas production involving anaerobic digestion is prioritized. The products resulting from biogas production are also converted and used for electricity and heat generation, as valuable fertilizer, and even as biofuel.

Physical, biochemical, and thermochemical processes can be used in biomass conversion processes. Physical methods such as grinding, drying, pelletizing, and accumulation can be applied in bioconversion [11]. Applying physical techniques before thermochemical or biochemical processes increases the applicability of biomass.

Thermochemical conversion processes to convert biomass into products are gasification, pyrolysis, and combustion. The most commonly used chemical processes in biomass conversion are combustion, gasification, pyrolysis, fermentation, and transesterification [12].

The combustion process is applied to convert the chemical energy in biomass into mechanical, electrical, or heat energy. Materials with more than 50% moisture content are not preferred because they must be dried before combustion. Especially since the moisture content of animal manure is usually more than 50%, the combustion process is not applied. It is also undesirable because it creates problems in terms of low energy efficiency and air pollution.

The gasification process is applied to obtain gas from carbon-containing materials to produce fuel. It is carried out by heating the biomass in the

anaerobic environment at 700-1000ºC. With the gasification technique from biomass, a gaseous fuel can be obtained with a high efficiency to be used in oil-fired turbines that provide power and heat. Using gas fuel obtained by gasification of biomass can be expanded by making small arrangements in places where natural gas is used [13].

Pyrolysis of biomass is a thermochemical process carried out in the absence of oxygen and at high temperatures to break down organic molecules to obtain gas. The classical working range of pyrolysis is between 300-600ºC. It can be realized in 3 ways according to the change of these temperatures and heating rates: slow, fast, and flash. The most well-known pyrolysis process is biochar production, which is realized by slow pyrolysis. The main objective of fast pyrolysis is to obtain a high amount of liquid from biomass. Flash pyrolysis occurs at very high temperatures within milliseconds compared to other pyrolysis types.

Bioethanol and biogas are produced as a result of the fermentation of biomass in an oxygen-free environment. Since the transesterification process produces biodiesel from biomass, this process is examined under biofuel.

2.2.2. Biogas

Biogas, a clean energy source, is obtained due to the anaerobic treatment of some specially grown plants, agricultural, and organic wastes, especially animal manure, with suitable bacteria [2]. In parallel with the interest in energy recovery from waste, interest in anaerobic biotechnology has also increased. Biogas production is the breakdown of organic substances containing biodegradable substances under anaerobic conditions by successive multistage reactions [14]. Biogas applications, which have significant advantages, especially in regions with intensive agricultural production, attract considerable interest in agriculture waste management worldwide due to their environmental and economic benefits. After biogas production in biogas plants, the remaining organic wastes can be used in agriculture as high-quality fertilizer by composting [15].

Biogas production is based on the formation of methane gas (CH_4) and carbon dioxide (CO_2) as the end product as a result of the breakdown of organic matter [16]. One m^3 of biogas provides a heat value in the range of 4700-5700 kcal and has the equivalent of 0.62 liters of kerosene, 1.46 kg of charcoal, 3.47 kg of wood, 0.43 kg of butane gas, 12.3 kg of dung and 4.70 kWh of electrical energy [17].

Biogas production factors include temperature, pH, organic matter loading rate, MRS (microorganism retention time), C/N, toxicity, and hydraulic feeding

time [18]. Depending on the operating temperature in biogas plants, the hydraulic waiting time varies between 20 and 120 days. The C/N ratio in wastes producing biogas from animal manure varies between 15/1 and 30/1. If the C/N ratio provides 15/1 to 30/1, there is no need to adjust the livestock manure separately. C/N calculations are always based on dry matter. The optimum C/N ratio can be achieved by mixing different organic substances. Mineral ions, heavy metals, and detergents have a toxic effect by inhibiting the growth of microorganisms in anaerobic treatment. While small amounts of mineral ions (sodium, potassium, calcium, magnesium, ammonium, and sulfur) improve the growth of bacteria, heavy metals create a toxic effect [18].

Biogas production occurs in 3 stages: Fermentation and hydrolysis, acetic acid formation, and methane formation (Figure 1). During the fermentation and hydrolysis phase, the first phase of biogas production, bacterial groups called fermentation and hydrolysis bacteria break down carbohydrates, proteins, and fats, the three essential elements of organic matter. Organic substances transform into CO_2, acetic acid, and soluble volatile organic substances. Since most volatile organic substances in the last group are volatile fatty acids, this stage is called the formation phase of volatile fatty acids. In the acetic acid formation stage, acetogenic (acid-forming) bacterial groups, which are released as a result of the first stage and convert volatile fatty acids into acetic acid, are activated, and some acetogenic bacteria convert volatile fatty acids into acetic acid and hydrogen. Another group of acetogenic bacteria uses the released carbon dioxide and hydrogen to form acetic acid. However, the acetic acid formed this way is less than the first pathway. In the methane formation stage, methane-forming bacteria use CO_2 and H_2 to produce methane (CH_4) and water (H_2O). In contrast, another group of methane-forming bacteria uses the acetic acid released from the second stage to produce CH_4 and CO_2. Of all the methane produced, 30 percent is made in the first pathway and 70 percent in the second.

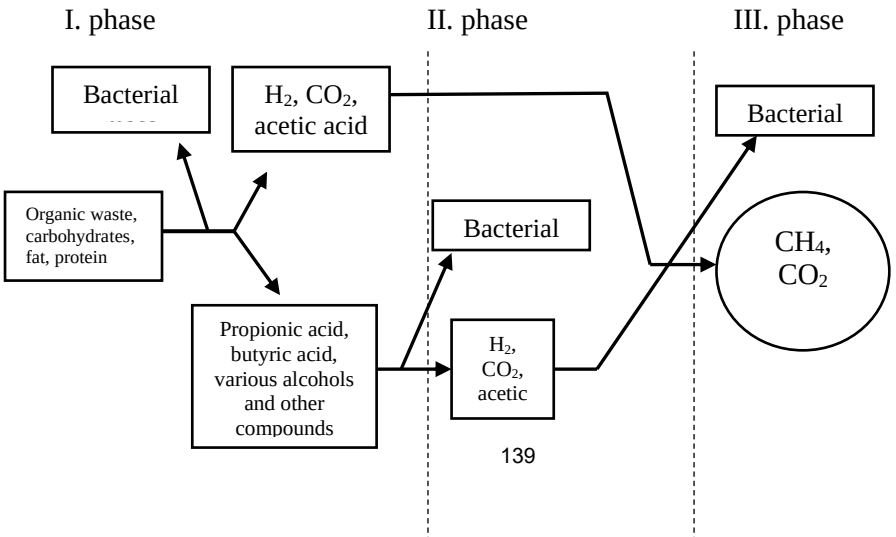


Figure 1. Biogas production stages [3]

Qi et al. [19], examined a biogas system in Northern China where pig manure and vegetable waste were used together and found that there was a decrease in the emissions of air pollutants such as H_2S, SO_2, NO_2, NH_3, CO, and C_2H_4 released into the atmosphere with the use of the system, and also that manure and vegetable waste were released into the atmosphere. It has been determined that harmonious service provides a 32.4% increase in efficiency.

White et al. [20], conducted a study on a small-scale biogas system in cattle farms in Ontario. They found that the system could produce 120 MW of electricity and that changes in the feedstock used in biogas production affected the biogas yield between 10-80%.

In the study conducted by Kurt [15], the animal fertilizer production results of Düzce province were examined, and the annual animal manure production amount was 369,421.188 tons, the biomass calorific value was 10,266.95 TEP (ton equivalent oil), the biogas amount was 10,323,786 m^3, and the biomass and bioenergy potential. It has been determined that research and development studies on energy production from biomass should be disseminated, and technological designs should be made.

2.2.3. Composting

The composting process is the biological decomposition of organic materials under aerobic or anaerobic conditions into CO_2 and H_2O together with a humus-like substance that is harmless to health [21, 22]. The compost material should have high biodegradability and organic matter content, contain ideal concentrations of trace nutrients that plants can benefit from, and be free from harmful substances. The moisture content of the compost produced should be 65%, nitrogen content should be 1.8-2%, and pH value should be around 7. Since the organic matter in the compost increases the soil's maximum water-holding capacity, it prevents soil erosion by ensuring that the earth absorbs water in high amounts of rainfall [22]. The composting process aims to convert biodegradable organic materials into stable end products and reduce waste volume, eliminating undesirable organisms such as pathogens and fly eggs that may be present in solid waste, eliminating existing or potential odor problems, maintaining maximum macronutrient (N, P, K) and micronutrient (Zn) content, obtain products that have fertilizer value and can be used as soil conditioners [23].

Different methods are applied in composting, windrow composting, passively aerated piles, aerated static piles, and composting in reactors. Composting is faster than mixing the heap because the composting process is faster when plenty of air reaches the microorganisms. During composting in reactors, it should be ensured that the raw material continues to be in contact with oxygen. The most essential difference between open field and bioreactor composting is the use of enzymes in bioreactors. The most important advantage of this method, known as enzymatic composting, is that it saves time.

Aerobic composting is an odorless process and is widely preferred in compost production. It has advantages such as short fermentation time and elimination of pathogenic microorganisms and disadvantages such as the need for continuous oxygen supply and moisture control. There must be enough oxygen to provide aerobic conditions for decomposition without creating an odor problem. Anaerobic composting is a process that takes a long time to complete and may require external heat in some cases. Bad odor formation is observed. Biogas can be obtained as a by-product during anaerobic conversion [24].

Common factors affecting composting in all forms are grain structure, C/N ratio, pH, temperature, aeration, and water content [25]. Moisture is essential for the growth and reproduction of microorganisms in the compost. The moisture content is approximately 40-45% in the lower range. The upper range is determined by keeping the pores open so oxygen can reach the microorganisms. The optimal pH of the bacteria used in composting is 6-8. When the environment starts to warm up during the process, the pH drops to 4 - 5 with the organic acids secreted by the bacteria. With the transition to the thermophilic phase, the pH value of the environment increases again to 8.

Microorganisms used in composting feed on organic materials. Heat is generated during this activity. The increase in temperature in the environment also causes pathogenic organisms to die. For pathogen removal, the compost temperature must be above 60°C for 2 or 3 days [25]. Breaking down solid wastes with small grain structures provides more surface area for microorganism activity. In this case, the reaction time can be shortened. The optimum C/N ratio for composting is between 25-35. If this ratio exceeds 35, biological activity slows down, and the duration of the process is prolonged. If it is below 25, ammonia is released, and microorganisms are damaged.

2.2.4. Biodiesel

Biofuel can be converted from biomass of plant and animal origin and is the only renewable energy source that can be converted into liquid biofuels such as

ethanol and biodiesel. It is an environmentally safe fuel that can be used in various diesel engines and generally without any modification to the machines, offering an alternative to fossil fuels. Similar processes are followed to obtain biodiesel from animal waste and vegetable waste. Pork, beef, and poultry solid fats and oils are animal-derived materials that can be converted into biodiesel.

Compared to traditional fuels, interest in using agricultural products has started to increase due to their advantages, such as being both renewable and having lower environmental emission rates. Esterification and transesterification methods are used in biodiesel production. Non-toxic and biodegradable biodiesel is produced by combining animal fat, vegetable oil, or recycled cooking oil with methanol or ethanol using the transesterification process.

In biodiesel production in the transesterification process of animal-derived biomass, fat-based triglycerides consist of three fatty acids attached to a glycerol moiety. The triglycerides in the reaction react with alcohols such as methanol or ethanol and a catalyst to produce esters and glycerol at the end of the three-step response (Figure 2) [26, 27]. Although acidic catalysts, essential catalysts, or enzymes can be used in transesterification, important catalysts are generally used [28]. Animal fats, which are subjected to the process before the transesterification process, provide efficiency during the process by filtering impurities. Transesterification is the most widely used process in biodiesel production and is considered the best option because this process is relatively simple compared to other methods.

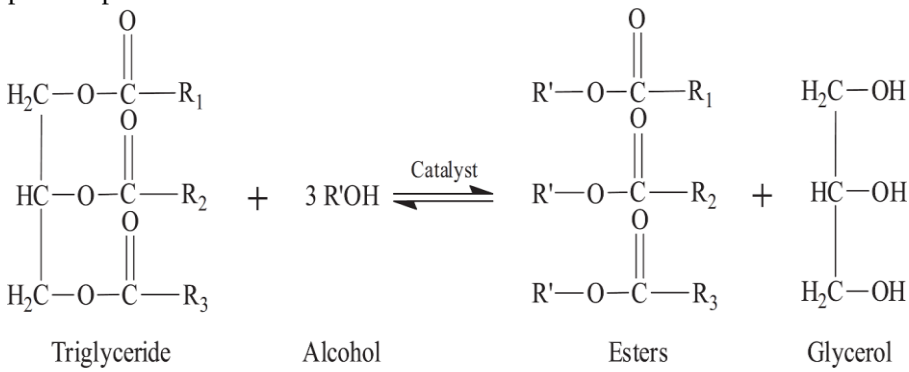


Figure 2. Transesterification Reaction [27]

The type and amount of oils used as raw material sources in biodiesel production are essential. Because the types and ratios of fatty acids in the oil used show the fuel quality of the biodiesel produced, saturated and unsaturated fatty acids can affect the cetane number of biodiesel. Since the cetane number of

saturated fatty acids is higher, it has better ignition properties. The viscosity of biodiesel can also be related to the length of the fatty acid. Short chain lengths reduce viscosity and provide good fuel flow in cold weather.

Biodiesel production is a preferable alternative for recycling animal wastes into valuable products without contributing to environmental pollution, especially in cases where proper disposal cannot be provided. In addition, considering the significant impact of animal wastes on greenhouse gas emissions, the mitigation effect of climate change effects through conversion is substantial. However, it may lead to additional resources and energy consumption in case of incorrect practices or insufficient care in collecting, storing, and disposing of animal wastes. During and after the biodiesel production process, by-products and by-products may cause negative impacts on water and soil pollution when the process is not controlled correctly.

2.3. Biosensor Applications

Biosensors are another biotechnology used to determine environmental pollution and control environmental conditions. Thanks to the developed biosensors, it is possible to detect waste and predict pollution in the ecosystem.

The main field of study in developing biosensors is the perception and response of living things to changes in the ecological system. Living things must perceive changes in their environment and adapt to change to continue their lives. This sensing mechanism has formed the basis for developing biosensors (in artificial conditions) in the laboratory [29, 30].

In biosensors used in the agricultural field, animal and plant cells are used as recognizers. Biosensors in agriculture can generally be used to measure pesticide use, artificial fertilizer, foul odor, and plant and animal diseases [31]. One of the biosensors used in agriculture is the electronic nose. An electronic nose is a smart device that detects and identifies volatile compounds and odors that mimic the human nose. There are various studies on the use of electronic noses in agricultural applications. Some of the studies include the detection of Salmonella enteric pathogen in poultry manure, the use of maturity detection in fruits, the determination of the freshness of beef, the collection and classification of aroma signals from wheat of different ages [32, 33, 34]. Electronic noses monitor and analyze the odors emitted into the atmosphere from animal waste and waste management systems from animal housing facilities. Determination of pathogens and microorganisms in animal-derived fertilizer content will help ensure quality and safety in production.

Thanks to biosensor technologies, enzymes, microorganisms, and antibodies are used to detect heavy metals, pathogens, toxins (aflatoxins), and organic

pollutants created by animal waste. In enzyme-based biosensors, enzymes catalyze the reaction by selecting the relevant substrate among thousands of chemicals. If adverse conditions occur in the responses, it may cause the enzyme activity to deteriorate and the determination to fail.

Antibody-based biosensors (Immunosensors) are biosensors using antibodies as receptors. Antibodies are protein-structured substances that immune system cells produce against foreign organisms such as viruses, bacteria, or their protein products. The most crucial advantage of antibody-based biosensors is that they are immunogenic. The most critical benefit is that the target must not be purified before detection. Immunosensors can be developed to determine hormones, drugs, viruses, bacteria, and pesticides.

Living organisms such as bacteria, algae, and fungi have a high potential for use in biosensors. Microbial biosensors must be able to establish a specific connection between the biological structure and the measurable signal, and particular forms with selectivity towards the target analyte must be used. Microorganism-based biosensors are advantageous compared to enzyme-based biosensors because they are created using living cells, are easy to obtain, are cheaper, provide more stability than enzymes, and have intracellular sensing mechanisms.

Different microbial sensors have been developed today for the detection of environmental pollutants such as heavy metals, toxic gases, drugs, endocrine disruptors, and physicochemical parameters such as biochemical oxygen demand, which determines how fast the oxygen present in water is used by microorganisms in water [35]. In addition, some cold-adapted organisms are widely used in the food industry to prevent microbial contamination and increase the preservation of cell tissues by freezing and preserving the texture and flavor of frozen foods [36].

4. Conclusion

Reducing waste generation is of great importance in solving the environmental problems that are increasing globally today. Considering the pressure of the livestock sector on the environment, technological methods to be used in this field have essential advantages in protecting both the environment and human health. Animal manure and animal wastes generated in animal production facilities cause air, water, and soil pollution in production areas. Treatment of these wastes by technological methods is essential for environmental health. The application of biotechnological processes in agriculture is very economically and environmentally significant.

In this study, the main methods used in treating animal wastes were examined, the studies carried out worldwide were reviewed, and it was determined that the biotechnological techniques applied in treating animal wastes have high removal efficiency. The studies to be used in this field have the potential to be used successfully.

References

[1] Yu, H. W., Samani, Z., Hanson, A., & Smith, G. (2002). Energy recovery from grass using two-phase anaerobic digestion. *Waste Management*, 22, 1-5.

[2] Deviren, H., İlkılıç, C., & Aydın, S. (2017). Usable Materials in the Production Biogas and Using Fields of Biogas. *Batman University Journal of Life Sciences*, 7 (2/2), 79-89.

[3] Şenol, H., Elibol, E. A., Açıkel, Ü., & Şenol, M. (2017). Potential of producing biogas and electric energy from poultry animals in Turkey. 2016. *BEU Journal of Science*, 6(1), 1-11.

[4] Gangola, S., Joshi, S., Kumar, S., & Pandey, S. C. (2019). *Comparative analysis of fungal and bacterial enzymes in biodegradation of xenobiotic compounds*. Smart bioremediation technologies (pp. 169-189). Academic Press.

[5] Ojuederie, O. B., & Babalola, O. O. (2017). Microbial and plant-assisted bioremediation of heavy metal polluted environments: A review. International Journal of Environmental Research Public Health, 14, 1–26.

[6] Baker, K. H., & Herson, D. S. (1994). *Bioremediation.* McGraw – Hill, New York.

[7] Kara, E., Taciroğlu, B., & Sak, T. (2016). Using Earthworms to Remove Heavy Metal in Soil. *KSU Journal of Natural Sciences*, 19(2), 201-207.

[8] Deshmukh R., Khardenavis A. A., & Purohit H. J. (2016). Diverse metabolic capacities of fungi for bioremediation. *Indian journal of microbiology*, 56(3), 247-264.

[9] Saleem, M. (2022). Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source. *Heliyon*, 8(1), e08905.

[10] Rosillo-Calle, F., De Groot, P., Hemstock, S. L., & Woods, J. (Eds.). (2015). *The biomass assessment handbook: Energy for a sustainable environment*. Routledge.

[11] Üçgül, İ., & Akgül, G. (2010). Biomass Technology. Journal of YEKARUM, 1(1), 3-11.

[12] Noor, S., Latif, A., & Jan, M. (2011). Overview of biomass conversion technologies. *Science Vision*, 16.

[13] Mutlu, N., Tolay, M., Karaca, C., & Öztürk, H. H. (2019). Developments in Biomass Gasification Technology. *Journal of Agricultural Machinery Science*, 15(2), 53-59.

[14] Bayrak, E. H., Yokuş, S. K. & Pehlivan, E. (2014). Biogas production from sludge of sewage treatment plant in Turkey. *Electronic Journal of Occupational Improvement and Research*, 2(1), 84-93.

[15] Kurt, A. (2021). Evaluation of biogas and compost availability potential of agricultural and animal origin in Duzce province. *Journal of Yalvac Academy*, 6(1), 14-26.

[16] Yüksekdağ, M., Gökpınar, S. & Yelmen, B. (2020). Treatment Sludges and Disposal Applications in Wastewater Treatment Plants. *European Journal of Science and Technology*, (18), 895-904.

[17] Çelikkaya, H. (2016). *Biyogaz.* Fırat Kalkınma Ajansı. Retrieved December 2, 2023, from https://fka.gov.tr/sharepoint/userfiles/Icerik_Dosya_Ekleri/FKA_ARASTIRMA_RAPORLARI/BİYOGAZ.pdf

[18] Gülen, J. & Çeşmeli, Ç. (2012). General knowledge about biogas and usage areas of by products. *Erzincan Journal of Science and Technology*, 5(1), 65-84.

[19] Qi, X., Zhang, S., Wang, Y., & Weng, R. (2005). Advantageous of the integrated pig biogas- vegetable greenhouse system in North China. *Ecological Engineering*, 34, 175-185.

[20] White, A. J., Kirk, D. W., & Graydon, J. W. (2011). Analysis of small-scale biogas utilization systems on Ontario cattle farms. *Renewable Energy*, 36(3), 1019-1025.

[21] Epstein, E. (1997). *The Science of composting*. Technomic Publising Co. Inc, USA, 383-415.

[22] Orkun, M. O., Güngör, E. B. Ö. & Erdin, E. (2011). Investigation of compost application respect of potential soil pollution. K*atı Atık ve Çevre*, 83, 60-67.

[23] Öztürk, İ., Arıkan, O., Altınbaş, M., Alp, K., & Güven, H. (2016). Katı Atık Geri Dönüşüm ve Arıtma Teknolojileri. *Union of Municipalities of Turkey. Retrieved November 8, 2023, from https://www.researchgate.net/publication/320549122_Kati_Atik_Geri_Donusum_ve_Aritma_Teknolojileri_El_Kitabi*

[24] Ogejo, J. A. (2018). *Compost Bedded Pack Dairy Barns*. Virginia State University. Retrieved November 10, 2023, from https://digitalpubs.ext.vt.edu/vcedigitalpubs/7988474469263459/MobilePagedReplica.action?pm=2&folio=1#pg1

[25] Dudu, Ü. & Nazilli, G. E. (2018). Compositing of Organic Solid Wastes with Biotechnological Methods in Aerobic Conditions. *Turkish Journal of Scientific Reviews*, 11(2), 47-50.

[26] Baskar, G., Kalavathy, G., Aiswarya, R., & Selvakumari, I. A. (2019). *Advances in bio-oil extraction from nonedible oil seeds and algal*

biomass. In Advances in eco-fuels for a sustainable environment (pp. 187-210). Woodhead Publishing.

[27] Pereira, C. O., Portilho, M. F., Henriques, C. A., & Zotin, F. M. (2014). $SnSO_4$ as catalyst for simultaneous transesterification and esterification of acid soybean oil. J*ournal of the Brazilian Chemical Society*, 25, 2409-2416.

[28] Dunford, N. T. (2007). *Biodiesel production techniques.* Oklahoma Cooperative Extension Service.

[29] Malhotra, S., Verma, A., Tyagi, N., & Kumar, V. (2017). Biosensors: principle, types and applications. *International Journal of Advance Research and Innovative Ideas In Education*, 3(2), 3639-3644.

[30] Tüylek, Z., (2021). Biosensor and Biochip Applications in Biotechnology. *International Journal of Life Sciences and Biotechnology*, 4(3), 468-490.

[31] Boz, B., Paylan, İ. C., Kizmaz, M. Z., & Erkan, S. (2017). Biosensors and Their Using Areas in Agriculture. *Agricultural Machinery Science*, 13(3), 141-148.

[32] Balasubramanian, S., Panigrahi, S., Louge, C. M., Marchello, M., Doetkott, C., Gu, H., Sherwood, J., & Nolan, L. (2005). Spoilage identification of beef using an electronic nose system. *Transactions of the ASAE*, 47(5), 1625-1633.

[33] Zhang, H., & Wang, J. (2008). Identification of stored-grain age using electronic nose by ANN. *American Society of Agricultural and Biological Engineers*, 24(2), 227-231.

[34] Kızıl, Ü., Genç, L., Genç, T. T., Rahman, S., & Khaitsa, M. L. (2015). E-nose identification of Salmonella enterica in poultry manure. *British Poultry science*, 56(2), 149-156.

[35] Gupta N., Renugopalakrishnan V., Liepmann D., Paulmurugan R., & Malhotra, B.D. (2019). Cell-based biosensors: recent trends, challenges and future perspectives. *Biosensors and Bioelectronics*, 141(1), 111435.

[36] Kırkıncı, S. F., Maraklı, S., Aksoy, H .M., Özçimen, D., & Kaya, Y., (2021). Antarctica: A review of Life Sciences and Biotechnology Researches. *International Journal of Life Sciences and Biotechnology*, 4(1), 158-177.

Chapter 9

Facility Location Problems: A Case Study In The Furniture Industry

***Celal GÜNGÖR*[1]**

Abstract

The furniture industry plays an important role in Turkey's economy. The selection of a facility location should be consistent with the objectives of minimizing operating costs, ensuring fast delivery of products to customers, and maximizing overall profitability as an outcome. In this study, a hypothetical problem was created to explain how linear programming can help solve facility location selection problems. Euclidean distances are calculated to recommend the minimum total distances with the aim of minimizing transportation costs from facilities to distributors. The IBM ILOG CPLEX Optimization Studio (v.22.1.1.0) software was used for the analyses. Based on the geographical coordinates of 6 alternative locations and 12 distributors, 3 locations (Kayseri, Bursa, and Ankara) were selected as the locations for the facilities. The minimum total distance was calculated to be approximately 4,800 km total distance for facilities and distributors. The model also satisfies several constraints; for example, each distributor has been assigned a location whose supply capacity is greater than its demand.

Keywords: Furniture industry, Linear Programming, Optimization

Introduction

With an export value of 4.227 million dollars, the Turkish furniture industry ranks eleventh among the countries that export furniture worldwide (Sanayi Genel Müdürlüğü, 2022). Türkiye's share of global furniture exports is 1.74%. The industry is also growing steadily, recording growth of 79.1% from 2017 to 2021. Furniture imports, on the other hand, amounted to 563 million dollars in 2021. Comparing the export and import figures, it is clear that the furniture industry makes a significant positive contribution to the Turkish economy.

While the furniture industry in Türkiye is predominantly composed of independent and small-scale furniture workshops that operating with traditional

[1]Dr. Öğr. Üyesi; İzmir Kâtip Çelebi Üniversitesi, Orman Fakültesi, Orman Endüstri Mühendisliği Bölümü, celalgungor53@hotmail.com ORCID No: 0000-0001-9882-6393

methods and rely heavily on craftsmanship, manufacturing household items mainly for the domestic market and often on the basis of small orders, the number of medium and large-scale enterprises has increased in recent years (Ticaret Bakanlığı, 2021).

According Turkish Statistical Institute (2021)'s data from 2020, there were 39,338 enterprises with 209,190 employees in the furniture industry. In addition, the number of employees in the retail sector is estimated at 100,000 (TÜİK, 2021). The number of employees and enterprises in the furniture industry for 2020 are presented in Table 1.

Table 1: The Number of Employees and Enterprises in the Furniture Industry for 2020 (NACE REV.2 Code:31), (TÜİK, 2021)

	Number of Employees	Number of Enterprises
Manufacture of furniture	209.190	39.338
Micro	79.604	36.258
Small	51.713	2.537
Medium	47.790	496
Large	30.083	47
Manufacturing	4.308.474	409.482
Total in Türkiye	15.952.817	3.304.088

As far as exports are concerned, the furniture industry is becoming increasingly important in Türkiye. Looking at the last five years, it can be seen that the export figures of the furniture industry (classified under International Trade Classification Code 82 for furniture; and SITC, Rev. 4 for bed sets, bed headboards, and cushions) have increased consistently every year (TÜİK, 2021).

The selection of a facility location involves choosing the geographical location where the facility will operate. There are many factors that influence the choice of a facility location (Kobu, 2006; Üçüncü, 2003). The selection of a facility location should serve objectives such as conducting operations at the lowest cost, delivering products to customers as quickly as possible, and achieving the highest profitability. This is because the choice of a location is one of the critical factors that determine the success and longevity of the facility (Üçüncü, 2003). When choosing a facility location, it is important that is close to production resources such as raw materials, energy, and labor. The raw materials required for production should be available in sufficient quantity and of good quality. The supply of raw materials should not only meet current needs, but also have the potential to meet future needs. Similarly, the labor

potential, the quality of the labor force, and the wage level in the region are also decisive factors when choosing the location of the facility. The quality of the workforce and their living conditions in the social and cultural environment have a direct impact on the potential of the workforce, so the social and cultural environment of the chosen location is of great importance. Factors such as the availability of energy and water supply facilities, the quantity and quality of these resources, the possibilities for the disposal and recycling of operational waste, transportation, communication and other infrastructure facilities are important factors that must be taken into account when selecting a facility location. The availability of services such as security and finance and the presence of supporting entities for the facility's activities, are also important. In addition to production factors mentioned here, it is also important that the location of the facility is close to the markets where the goods and services produced are to be offered. While proximity to raw materials and quick delivery of products to the market offer many advantages to ensure uninterrupted production, the main advantage of the facility's location is that transportation costs are covered at the lowest cost. Transportation costs are cost elements that do not contribute to the sales value of the product. Other factors that influence the choice of the location of a facility are the amount of land and construction costs, the existence of government policies such as incentives or tax exemptions, the geographical and topographical location of the site and the climatic characteristics. Climatic conditions should be taken into account when choosing a location, as they affect both the heating and cooling costs of the workplace and the durability and protection of raw materials, semi-finished and finished products.

When selecting a facility location, it is essential to compare the costs associated with the alternatives over a specific period. Various quantitative analysis methods are used for this purpose. Some common methods for solving facility location problems can be roughly divided into the following categories (Güngör, 2002; Kobu, 2006; Taha, 2003; Üçüncü, 2003; Winston, 2022):

- Mathematical Programming Models: These models use mathematical optimization techniques to find the optimal solution to the facility location problem. The two most common types of mathematical programming models are:
  - Integer Linear Programming (ILP): Models the facility location problem as a linear programming problem with integer constraints.
  - Mixed-Integer Linear Programming (MILP): Extends ILP by allowing both integer and continuous decision variables.

- Heuristic Methods: Heuristic methods are approximation algorithms that can be used to find good solutions to facility location problems in a relatively short time. Some common heuristic methods include:
  - Greedy Algorithms: Make locally optimal choices at each step to find a near-optimal solution.
  - Metaheuristic Algorithms: Iterative methods that guide other heuristics, such as Genetic Algorithms, Simulated Annealing, Tabu Search, and Ant Colony Optimization
  - Variable Neighborhood Search (VNS): Systematically explores different neighborhoods to improve the solution.
- Network Optimization Models: These models use network optimization techniques to find the optimal solution to a facility location problem. Common network optimization models include:
  - Minimum Spanning Tree (MST): Finds the minimum spanning tree of a graph, i.e., a subset of the edges that connects all nodes/locations in the graph with the lowest total edge weight.
  - Maximal Covering Location Problem (MCLP): Finds the optimal location for a given number of facilities to maximize the number of demand points that can be covered within a certain distance. It establishes a balance between demand point coverage and a limited number of facilities.
- Clustering Methods: Clustering methods can be used to group demand points into clusters based on their similarity. Once the demand points have been clustered, the facility location problem can be solved by locating a facility in each cluster. Some common clustering methods include:
  - K-Means: Divides the data into a given number of clusters by minimizing the sum of squared distances of each data point to the centroid of its cluster. It divides the data into k clusters based on similarity.
  - Hierarchical Clustering: Builds a hierarchy of clusters by iteratively merging or splitting them.
- Simulation Models: Simulation models can be used to evaluate the impact of uncertainties on location decisions. Some common simulation methods include:
  - Monte Carlo Simulation: Generates random scenarios to evaluate the impact of uncertainty on facility location decisions.
- Geographic Information System (GIS):

- Spatial Analysis: Utilizes GIS software to analyze spatial relationships, accessibility, and suitability of locations for facility location.
- Hub Location Problems: Hub location problems are a special class of facility location problems involving the location of hub facilities and the assignment of demand points to hub facilities.
- p-Median Problem: Determines the optimal location of p facilities to minimize the sum of the distances to the demand points.
- p-Center Problem: Similar to p-median but minimizes the maximum distance to each demand point.
- Multi-Objective Optimization: Multi-objective optimization methods can be used to solve facility location problems with multiple objectives, such as minimizing cost and maximizing service quality.
- Goal Programming: Balances multiple objectives, such as minimizing costs and maximizing service levels.
- Auction-Based Approaches: Auction-based approaches can be used to allocate demand points to facilities in an efficient manner.
- Auction Mechanisms: Agents bid for the right to serve specific demand points, resulting in efficient allocation.
- Efficiency Analysis/Data Envelopment Analysis (DEA): Evaluates the relative efficiency of facilities based on multiple input and output factors.

The choice of method depends on the specific characteristics of the facility location problem, including the number of facilities to be located, the number of demand points, the nature of objective function or cost structure, and the presence of constraints.

In this study, an example will be used to explain how a linear programming can be employed to solve a facility location problem. The example is a modified version of Gültekin (2021)'s tutorial. In this example, Euclidean distances will be calculated to suggest the minimal distances in total to minimize transportation costs from facilities to depots and to customers.

Application

Definition of the problem

A company group wants to establish 3 furniture manufacturing facilities in Türkiye with supply capacities of 1,000, 1,400, and 1,800 pieces of furniture per day. There are 6 alternative locations for these 3 facilities. The geographical coordinates of these candidate locations are shown in Table 2. Each location has a different distribution capacity per day, namely 1,710, 1,150, 1,100, 570,

1,420, and 990 furniture, respectively. This means that a facility can be assigned to a location for which it has a larger capacity.

Tablo 2: Geographical Coordinates and Capacities of Candidate Locations

City	Location	N	E	Cap.
İstanbul	Sınırlı Sorumlu İstanbul Kerestecileri Sanayi Sitesi İşletme Kooperatifi	41°07′	28°78′	1,710
Ankara	Elmadağ Mobilyacılar İhtisas Organize Sanayi Bölgesi	39°93′	33°28′	1,150
Bursa	İnegöl Mobilya ve Ağaç İşleri İhtisas Organize Sanayi Bölgesi	40°15′	29°53′	1,100
Kayseri	Kayseri Organize Sanayi Bölgesi	38°73′	35°37′	570
İzmir	Torbalı Karma ve Mobilya Organize Sanayi Bölgesi	38°09′	27°33′	1,420
Sakarya	Kaynarca Mobilya İhtisas Organize Sanayi Bölgesi	41°02′	30°28′	990

N: Latitude, E: Longitude, Cap: Distribution Capacity

Three furniture manufacturing facilities will supply the finished products to 12 regional distributors, whose their geographical coordinates are given in Table 3. The alternative locations of the facilities and distributors are presented in a map in Figure 1. It should be noted that one distributor will be supplied by a single facility.

Tablo 3: Geographical Coordinates of Distributor

City	Latitude (N)	Longitude (E)
Edirne	41°67′	26°55′
Eskişehir	39°76′	30°52′
Denizli	37°78′	29°09′
Antalya	36°89′	30°71′
Konya	37°87′	32°49′
Kastamonu	41°37′	33°77′
Gaziantep	37°06′	37°37′
Sivas	39°75′	37°01′
Rize	41°02′	40°51′
Diyarbakır	37°92′	40°21′
Erzurum	39°90′	41°26′
Van	38°50′	43°37′

Figure 1: Locations of Alternative Facilities and Distributors

The objective of the problem is to locate these facilities and assign distributors to these facilities in order to minimize the total Euclidean distance between the facilities and their assigned distributors.

Model parameters

Parameters and Sets:

- **NDistributor**: Number of distributors.
- **NFacilities**: Number of facilities.
- **NCandidate**: Number of candidate locations.

Decision Variables:

- **y[j][k]**: Binary variable indicating whether facility **j** is located at candidate location **k**.
- **x[i][j]**: Binary variable indicating whether distributor **i** is assigned to facility **j**.
- **z[i][j][k]**: Binary variable indicating whether distributor **i** is assigned to facility **j** located at candidate location **k**.

Objective Function:

The objective is to minimize the total distance between distributors and candidate locations, weighted by the assignment variables.

Constraints:

1. Each distributor must be assigned to exactly one facility.
2. Each facility must be assigned to exactly one candidate location.
3. Each candidate location can have at most one facility.

4. Binary variables **z** are constrained based on the assignment of facilities and candidate locations.
5. Constraints to ensure that if **z[i][j][k]** is 1, then **x[i][j]** and **y[j][k]** must also be 1.
6. A constraint linking binary variable y to parameter A, stating that y[j][k] cannot be 1 if A[j][k] is 0.

Notes:

1. The minimize statement defines the objective function using the Euclidean distance between depots and candidate locations.
2. Various mathematical functions like **sqrt** and **pow** are used to calculate distances.

Procedures For The Optimization Process:

The "execute" section, which is used for procedural logic that runs before the optimization process. This block of code initializes the 2D array **A** based on some conditions involving the arrays **SupplyCapacity** and **CandidateCapacity**. Let's break it down into two sections:

The first part:

- **for (var j in Facilities)**: It iterates over each element **j** in the set **Facilities**.
- **for (var k in Candidate)**: It iterates over each element **k** in the set **Candidate**.

The second part (inside the nested loops):

- **if (SupplyCapacity [j] >= CandidateCapacity [k])**: It checks if the value at index **j** in array **SupplyCapacity** is greater than or equal to the value at index **k** in array **CandidateCapacity**.
- **A[j][k] = 1;**: If the condition is true, it sets the value at position **[j][k]** in array **A** to 1.

After setting the values, let's print each element of the array **A** using **write(A[j][k]);** and add a newline with **writeln(" ");** at the end of each inner loop. This is added to visualize the values of the array **A** in the console.

The purpose is to block initializes the 2D array **A** based on the conditions involving **SupplyCapacity** and **CandidateCapacity** and print the resulting values to the console. It might be useful for debugging or understanding the initial state of the array before the optimization process begins.

Linear Programming Model

IBM ILOG CPLEX Optimization Studio (v.22.1.1.0) software installed in Intel(R) Core(TM) i5 1.4 GHz Quad-Core processor with a 8 GB memory and macOS Ventura 13.6.1 operation system is employed for optimization analyses.

The code for the data file is given below:

```
/*********************************************
NDistributor = 12;
NFacilities = 3;
NCandidate = 6;

DistributorLatitude = [41.67 39.76 37.78 36.89 37.87 41.37 37.06 39.75 41.02 37.92 39.90 38.50];
DistributorLongitude = [26.55 30.52 29.09 30.71 32.49 33.77 37.37 37.01 40.51 40.21 41.26 43.37];

CandidateLatitude = [41.03 39.93 40.15 38.73 38.09 41.02];
CandidateLongitude = [28.78 33.28 29.53 35.37 27.33 30.28];

SupplyCapacity = [1000 1400 1800];
CandidateCapacity = [1710 1150 1100 570 1420 990];
*********************************************/
```

The code for the model file is given below:

```
*********************************************/
int NDistributor =...;
int NFacilities =...;
int NCandidate =...;

range Distributor = 1..NDistributor;
range Facilities = 1..NFacilities;
range Candidate = 1..NCandidate;
float DistributorLatitude[Distributor] =...;
float DistributorLongitude[Distributor] =...;
float CandidateLatitude[Candidate] =...;
float CandidateLongitude[Candidate] =...;

int SupplyCapacity[Facilities] =...;
int CandidateCapacity[Candidate] =...;
int A[Facilities][Candidate];
```

```
execute {
for (var j in Facilities) {
for (var k in Candidate) {
A[j][k] = (SupplyCapacity[j] >= CandidateCapacity[k]) ? 1 : 0;
write(A[j][k]); }writeln(" ");  } }
dvar boolean y[Facilities][Candidate]; //1: if facility j is located at candidate
location k, 0: otherwise, j= 1,2,3 k=1,2,3,4,5
dvar boolean x[Distributor][Facilities]; // 1: if distributor i is assigned to
facility j, 0: otherwise, i= 1,...,8 j= 1,2,3
dvar boolean z[Distributor][Facilities][Candidate]; // 1: if distributor i is
assigned to facility j located at candidate location k
minimize sum(i in Distributor, j in Facilities, k in Candidate)
sqrt(pow(DistributorLatitude[i] -CandidateLatitude[k],2)
+pow(DistributorLongitude[i]-CandidateLongitude[k],2))*z[i][j][k];
subject to{
 forall(i in Distributor) sum(j in Facilities) x[i][j] == 1;
 forall(j in Facilities) sum(k in Candidate) y[j][k] == 1;
 forall(k in Candidate) sum(j in Facilities) y[j][k] <= 1;
forall(i in Distributor, j in Facilities, k in Candidate) z[i][j][k] >= x[i][j] +
y[j][k] - 1;
 forall(i in Distributor, j in Facilities, k in Candidate) z[i][j][k] <= x[i][j];
 forall(i in Distributor, j in Facilities, k in Candidate) z[i][j][k] <= y[j][k];
 forall(j in Facilities, k in Candidate) y[j][k] <= A[j][k]; }
```

Results

To find the minimum distance between 3 facilities and 12 distributors, an OPL minimization model was run. The optimal solution with objective 43.09 was found after 102 iterations. Please note that there were 687 constraints, 270 binary variables, and 1602 non-zero coefficients. The optimal solution for the facility location problem is given below. The results indicate that **Bursa** (İnegöl Mobilya ve Ağaç İşleri İhtisas Organize Sanayi Bölgesi), **Ankara** (Elmadağ Mobilyacılar İhtisas Organize Sanayi Bölgesi), and **Kayseri** (Kayseri Organize Sanayi Bölgesi) should be chosen as the location for the facilities. If the company builds its 3 facilities in these cities, they will be closest to its 12 distributors. Figure 2 shows a map on which the facilities and distributors are marked. Note that the arrows show which facility leads to which distributor.

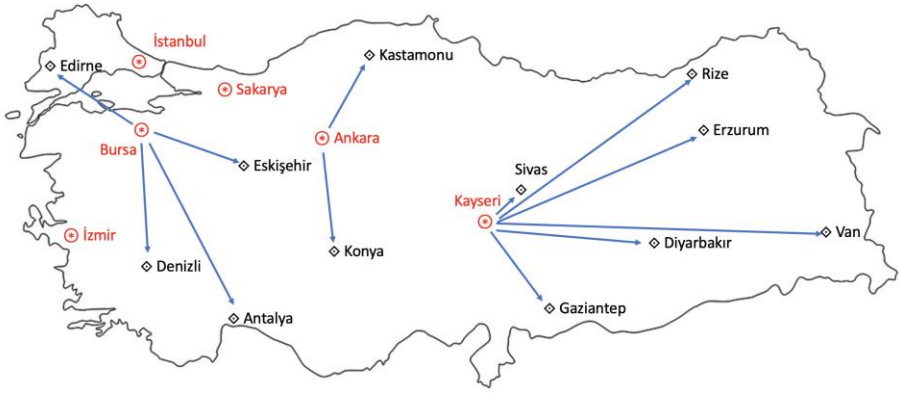


Figure 2: Optimal Solution for Minimal Distance between 3 Facility Locations and 12 Distributors

// solution (optimal) with objective 43.0937917475185

```
z = [[[0 0 0 0 0 0]
      [0 0 1 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 0 0 0]
      [0 0 1 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 0 0 0]
      [0 0 1 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 0 0 0]
      [0 0 1 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 0 0 0]
      [0 0 0 0 0 0]
      [0 1 0 0 0 0]]
     [[0 0 0 0 0 0]
      [0 0 0 0 0 0]
      [0 1 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]
     [[0 0 0 1 0 0]
      [0 0 0 0 0 0]
      [0 0 0 0 0 0]]];

x = [[0 1 0]
     [0 1 0]
     [0 1 0]
     [0 1 0]
     [0 0 1]
     [0 0 1]
     [1 0 0]
     [1 0 0]
     [1 0 0]
     [1 0 0]
     [1 0 0]
     [1 0 0]];

y = [[0 0 0 1 0 0]
     [0 0 1 0 0 0]
     [0 1 0 0 0 0]];
```

Conclusion

In this study, a facility location problem was modeled with 6 alternative locations for 3 facilities and 12 distributors. The minimum total distance was calculated to be 43.09. Please note that this is the total Euclidean distance in terms of latitude and longitude. The distance between two lines of latitude or longitude is 111 km, which makes roughly 4,800 km total distance for 3 facilities and 12 distributors.

It is assumed that the locations of facilities and distributors have only two dimensions. This assumption was made for the sake of simplicity. However, it is known that the actual roads are not straight. On the other hand, this limitation can be overcome by weighting the arc between the facility and the distributor according to the difficulty of the road, or the actual distances can be used as problem inputs.

According to the optimal solution, the first facility should be located in Kayseri to serve six distributors in Rize, Sivas, Erzurum, Van, Diyarbakır, and Gaziantep. The second facility should be located in Bursa to serve four distributors in Edirne, Eskişehir, Denizli, and Antalya. The third facility should be located in Ankara and two distributors in Kastamonu and Konya should be assigned to this facility.

References

Gültekin, H. (2021). *CPLEX OPL Tutorial 10 Data Modification and Script Language*. Retrieved from https://www.youtube.com/watch?v=InvmULmBrR0&list=PLyY17uOd5sPNgeqy2CguqyW0IENeEW4kS&index=12&ab_channel=HakanGultekin on October 26, 2023.

Güngör, C. (2022). Ulaştırma Problemleri: Mobilya Endüstrisi Örneği. Editor N. Ersoy, *Ziraat, Orman ve Su Ürünleri Alanında Yeni Trendler (pp. 173-182). İzmir: Duvar Yayınları.*

Kobu, B. (2006). *Üretim Yönetimi*. İstanbul: Beta Basım Yayım.

Sanayi Genel Müdürlüğü, 2022, *Mobilya Sektör Raporu*. T.C. Sanayi ve Teknoloji Bakanlığı. Retrieved from https://www.sanayi.gov.tr/plan-program-raporlar-ve-yayinlar/sektor-raporlari on December 10, 2023.

Taha, H. A. (2003). Operations research: An introduction. London: Pearson Education.

Ticaret Bakanlığı. (2021). *Mobilya Sektör Raporu*. İhracat Genel Müdürlüğü, Maden, Metal ve Orman Ürünleri Dairesi. Retrieved from https://ticaret.gov.tr/data/5b87000813b8761450e18d7b/Mobilya%20Sekt%C3%B6r%20Raporu%202021.pdf on December 10, 2023.

TÜİK. (2021). Dış Ticaret İstatistikleri. Retrieved from https://data.tuik.gov.tr/Kategori/GetKategori?p=dis-ticaret-104&dil=1 on December 10, 2023.

Üçüncü, K. (2003). *Tesis Planlama*. Trabzon: KTÜ Orman Fakültesi Orman Endüstri Mühendisliği Bölümü Yayın No. 68.

Winston, W. L. (2022). Operations research: Applications and algorithms. Boston: Cengage Learning.

Chapter 10

Viral Hemorrhagic Septicemia (Vhs) Virus Threat In Fish

***Sinan ÖZCAN*[11]**
***Ebru İfakat ÖZCAN*[2]**

ABSTRACT

Viral hemorrhagic septicemia disease (VHS) is one of the leading viral factors that cause diseases and significant economic losses in fish, especially trout, all over the world. Adult fish are more resistant to VHS virus than young fish. The most sensitive species are rainbow trout. The agent is isolated especially from kidney, spleen and heart tissues. Since it causes symptoms similar to other viral, bacterial and fungal diseases, it is very difficult to make a definitive diagnosis based on clinical symptoms and autopsy findings. In our country, the necessary analyzes against this virus must be carried out under laboratory conditions in aquaculture facilities. The fact that the VHS virus passes very quickly from fish to fish and spreads it to water through defecation creates a high risk group for other fish. For this reason, the necessary legal legislation should prepared and the cycle of fish transfer between cages and farms should eliminated, uncontrolled transfers of fry, eggs and fish between farms should prevented, farms should given egg and equipment disinfection training, the spread of viral factors in natural fish in rivers and seas should determined and the obtained strains should used in cultured fish. Some precautions can taken, such as investigating the pathogenicity of the disease and conducting vaccine development studies in the medium and long term.

Keywords: Fish, viral hemorrhagic septicemia virus, pathogen, aquaculture

Introduction

The most important factor that negatively affects aquaculture is fish diseases and causes great economic losses. In order to prevent these negative consequences, the European Union (EU) has put into effect the necessary legal regulations for fish health control with the name "EU Fish Health Regime" and

[1] [1] Arş. Gör.; Atatürk Üniversitesi Su Ürünleri Fakültesi Yetiştiricilik Bölümü. sinanozcan@atauni.edu.tr ORCID No: 0000-0003-2975-698X

[2] Doç. Dr.; Munzur Üniversitesi Su Ürünleri Fakültesi Temel Bilimler Bölümü. ebruozer@munzur.edu.tr ORCID No: 0000-0003-2017-6647

the directive numbered "91/67/EEC". Within the scope of this directive, fish farms are required to be inspected periodically for diseases, thus aiming to create fish disease-free zones. VHSV is also included in the list of "diseases that can be seen in enterprises in EU countries, cause serious economic losses, for which there is no treatment or vaccine, and the farms where they are found must be identified" (Anonym, 1991).

Viral hemorrhagic septicemia virus (VHSV) is one of the leading viral factors that cause diseases and significant economic losses in fish, especially trout. Mortality of VHS, which varies depending on size and genetic factors, can increase to 80-100% in juvenile and finger-sized fish. Although the disease progresses slowly in fish of two kg and above, it has been reported that mortality can reach 50% (Olesen, 1998). According to a study conducted in 1991, the annual damage caused by viral hemorrhagic septicemia disease (VHSH) to European aquaculture was estimated to approximately 40 million Pounds. In the VHS epidemic that occurred in Denmark in 2000, it was reported that mortality reached 50% and the financial loss was approximately 211 thousand Euros in two rainbow trout (*Oncorhynchus mykiss*) farms with an annual production of approximately 165 tons (Skall et al., 2005).

Viral hemorrhagic septicemia is listed among the most dangerous viral fish diseases that must be notified and monitored by the World Organization for Animal Health (OIE) (OIE, 2010).

Effects Of Vhs Vırus On Fısh

The survival of the VHS virus outside the host depends on the physiochemical conditions and temperature of the liquid environment (Ahne, 1981). The agent survives longer at 4°C compared to 20°C. The virus can survive for up to 28-35 days in freshwater at 4°C, and has been shown to maintain its infectivity for 1 year in filtered freshwater at 4°C (Hawley and Garver, 2008; Parry and Dixon, 1997). The virus survives longer as organic material, such as blood and ovarian fluid, is added to the environment. While the agent is inactivated in 13 days at 15°C in fresh water, this period is 4 days in sea water (Hawley and Garver, 2008). Freezing and thawing fish infected with VHS does not completely eliminate the virus, but it has been reported that it inactivates it by 90% (Arkush et al., 2006).

Adult fish are more resistant to VHS virus than young fish. The most sensitive species are rainbow trout. Depending on environmental conditions, fish mortality may range from 20% to 80%, and even 100% mortality may occur in trout larvae (CFSPH, 2003). Fish that contract the disease and survive constitute VHSV reservoirs (OIE, 2010). Surviving fish become lifelong

carriers and shed the virus into the environment through reproductive fluid and urine. The virus infects fish through the second gill lamellae and wounds on the body. Although the virus was isolated from eggs 3–4 hours after ovulation, vertical transmission of this virus through eggs has not yet been proven (De Kinkelin and Castric, 1982; Jørgensen PEV, 1980).

Although clinical symptoms in acute VHS cases are not specific, they are seen as petechial hemorrhages and exophthalmos in the skin, fin bases, muscles and internal organs. Ascites is seen at necropsy. In the acute form, mortality is very high; It can reach 100% in juvenile fish and 30-90% in adults. In the chronic form, infected fish do not show any clinical signs or pathology (Batts and Winton, 2002; Skall et al., 2005). In some hosts, chronic infection is characterized by neurological symptoms such as unsteady and erratic swimming and pale gills (Kim and Faisal, 2010; Wolf, 1988).

Acutely infected fish show behavioral changes by congregating at the outlet or bottom of ponds or tanks. Fish are often anorexic and subsequently lethargic (OIE, 2010). Mortality begins a few days after clinical symptoms appear. Mortality rate varies depending on the fish species, age, environmental conditions and virus titer. The mortality rate in juvenile fish can reach up to 100% in susceptible species and virulent strains (CFSPH, 2003).

Experimental studies have shown that the age of fish affects susceptibility to infection. For example, the VHSV IVb genotype that kills juvenile Pacific herring causes very little infection in adults of the same fish (Hershberger et al., 1999). Researchers have stated that immunity to the virus increases with age. In an experimental infection with genotype 1a in rainbow trout, it was reported that the mortality rate reached 100% in those weighing up to 3 grams, and the mortality rate was between 10-15% in those larger than 3 grams (Smail and Snow, 2011).

Dıagnosıs Of Vhs Vırus In Fısh

Although sudden deaths, lethargy, darkening of the skin color, exophthalmos, anemia, hemorrhage at the bases of the fins, gills, skin and eyes, abnormal swimming, ascites and edema in the abdominal cavity may suggest the disease, clinical symptoms alone are not sufficient for diagnosis, as similar findings are seen in other diseases (OIE, 2010). The pathological appearance includes petechial hemorrhages in the skin, muscles and internal organs. Petechial hemorrhages in the dorsal muscles are common symptoms in VHS cases. The kidney is dark red and the spleen is swollen. The liver and gastrointestinal tract are pale and the intestines are full of nutrients (OIE, 2010).

Protectıon And Control From Vhs Vırus In Fısh

Taking strict biosecurity measures, such as avoiding surface water, is important in protecting against disease. Inactivating the water entering the facility with an ultraviolet system may be effective, but it is an expensive and limited application area (Huber et al., 2010; Overturf et al., 2001).

Selecting disease-resistant species for cultivation is a feasible method, although controversial. A program to breed rainbow trout resistant to VHSV was initiated in the mid-1980s (Chevassus and Dorson, 1990). This program is based on the selection of adult female and male individuals that have been made resistant to the disease through experimental methods. Resistance to VHSV increased significantly when the first generation and the third generation of offspring obtained from disease-resistant individuals were compared (Dorson et al., 1995).

Sanitation programs began to be implemented in Denmark in the 1960s to control the spread of VHSV. The implemented program consisted of three main stages; dry keeping, disinfection and restocking (Gregory, 2008; Skall et al., 2005). When the water temperature rose, the fish in the ponds were first destroyed, followed by dry storage and disinfection. Cage systems are disinfected by being taken out of the river or lake where they are located. The dried ponds were cleaned with quicklime, and all tools and equipment on the farm were cleaned using formalin or iodine. New fish replaced the destroyed fish and were selected from virus-free certified populations. Thanks to this method applied, the number of enterprises infected with VHSV in Denmark decreased from 500 to 26 in 27 years (Gregory, 2008; Skall et al., 2005). To date, four types of vaccines have been developed and tested for VHSV: live, killed, recombinant vaccine and DNA vaccine (Byon et al., 2006; De Kinkelin et al., 1995; Lecocq-Xhonneux et al., 1994). Although extensive research has been conducted and the effectiveness of experimental vaccine studies has been demonstrated, there is no commercial vaccine available for VHSV yet (Lorenzen et al., 2002). A live-attenuated vaccine has been developed with varying degrees of protective effect on rainbow trout, but live vaccines are not approved (De Kinkelin et al., 1980; De Kinkelin, 1988; Jørgensen PEV, 1982; Smail and Snow, 2011).

Vhs Vırus Threat To The Fıshıng Industry

Chairman of the Board of Directors of the Aquaculture Producers' Central Association said that the VHS virus started to appear in Turkey and caused fish deaths, especially in the Black Sea. In a statement, he said: "A disease we call VHS has begun to plague our country. Since this disease is in the waters of our

country, it spreads quickly; this is a very dangerous disease. Since it kills fish and is a notifiable disease, our Ministry of Agriculture and Forestry, General Directorate of Food Control. "He needs to find a solution." Stating that fish deaths and fry deaths have increased recently, he said, "It is said that the reason for this is VHS. Of course, VHS is actually in our country, the General Directorate of Fisheries or other relevant general directorates do not want to spread it too much. We do not want it to spread either; but recently, the relevant general directorate has Directorate, General Directorate of Food and Control have written to the provinces; as far as I know, they have taken a sample from 8 businesses and asked for it to be sent to Bornova. It is present in sea waters, inland waters and lakes, it has started to spread everywhere, there is no solution for this. Food and Control Our General Directorate needs to take urgent measures. We have 2,300 enterprises, this is not a small number. This means 571 thousand tons of production will be wasted, or they say it has spread because it will spread to other seas, He said that I hope it will not spread; but we want the necessary measures to be taken so that we do not experience such problems. (URL-1, 2023).

Figure 1. Appearance of VHS virus in fish (URL-1, 2023).

It has also been stated that the disease in question is most commonly seen in puppies coming from France, and that French puppies may have spread this disease in Turkey. It has been stated that the virus in question manifests itself mostly in the form of darkening of color and swelling in the eyes in fish, but unfortunately it does not have many symptoms in the early stages and therefore effects may occur in the future. It has also been stated that for this disease, which manifests itself with bleeding on the skin on the underside of the fins, unfortunately, no clear treatment method has yet been developed in the world (URL-1, 2023).

Figure 2. Appearance of VHS virus in fish eyes (URL-1, 2023).

In conclusion; In our country, the necessary analyzes against this virus must be carried out under laboratory conditions in aquaculture facilities. The fact that the VHS virus passes very quickly from fish to fish and spreads it to the water through defecation creates a high risk group for other fish. Therefore, this virus; To reduce its spread by its presence in the region; Eliminating the fish transfer cycle between cages in dams and farms by preparing the necessary legal legislation, preventing uncontrolled transfers of fry, eggs and fish between enterprises, establishing disease-free enterprises and supplying live material from these enterprises, restocking infected farms, providing egg and equipment disinfection training to enterprises. Periodic screening activities should be carried out and vaccine development studies should be carried out in the medium and long term. Since there is no evidence that it shows symptoms of disease in humans, this virus must be removed from facilities in a controlled manner (URL-1, 2023).

References

Ahne, W. (1981). Serological Techniques Currently Used in Fish Virology, Dev. Biol. Stand., 49, 327.

Anonym, (1991). Concerning the animal health conditions governing the placing on market of aquaculture animals and products. Official Journal L 046, 19/02/1991, p. 0001-0018.

Arkush, K.D., Mendonca, H.L., Mcbride, A.M., Yun, S., Mcdowell, T.S., & Hedrick, R.P. (2006). Effects of temperature on infectivity and of commercial freezing on survival of the North American strain of viral hemorrhagic septicemia virus (VHSV). Dis. Aquat. Org. 69, 145–151.

Batts, B., & Winton, J. (2002). Expanded host and geographic ranges for North American VHSV: genetic analysis of new isolates. Fifth International Symposium for Viruses of Lower Vertebrates, Seattle, Washington, Abstract Book, P-43, 27–30 August, 2002.

Byon, J.Y., Ohira, T., Hirono, I., & Aoki, T. (2006). Comparative immune responses in Japanese flounder, Paralichthys olivaceus after vaccination with viral hemorrhagic septicemia virus (VHSV) recombinant glycoprotein and DNA vaccine using a microarray analysis. Vaccine 24, 921–930

Chevassus, B., & Dorson, M. (1990). Genetics of resistance to disease in fishes. Aquaculture, 85, 83–107.

CFSPH (Center for Food Securty and Public Health) (2003). Viral Hemorrhagic Septicemia, Institute for International Cooperation in Animal Biologocs and Collage of Veterinary Medicine, Iowa State University, Ames, Iowa, 3.

De Kinkelin, P. (1988). Vaccination against viral haemorrhagic septicaemia. In: Ellis, A.E. (Ed.), Fish Vaccination. Academic Press, London, pp. 172–192.

De Kinkelin, P., Bearzotti-Le, B.M., & Bernard, J. (1980). Viral Hemorrhagic Septisemia of Rainbow Trout Selection of A Thermoresistant Virus Variant and Comparison of Polypeptide Synthesis with The Wild-Type Virus Strain. Journal of Virology, 36,652-658.

De Kinkelin, P., & Castric, J. (1982). An Experimental Study of The Susceptibility ofAtlantic Salmon Fry (*Salmo salar*) to Viral Hemorhhagic Septicemia. Journal of Fish Diseases, 5, 57–65.

De Kinkelin, P., Bearzotti, M., Castric, J., Nougayrede, P., Lecocq-Xhonneux, F., & Thiry, M. (1995). Eighteen years of vaccination against viral haemorrhagic septicaemia in France. Vet. Res. 26, 379–387.

Dorson, M., Quillet, E., Hollebecq, M.G., Torhy, C., & Chevassus, B. (1995). Selection of rainbow trout resistant to viral haemorrhagic septicaemia virus and transmission of resistance by gynogenesis. Vet. Res. 26, 361–368.

Gregory, A. (2008). A qualitative assessment of the risk of introduction of viral haemorrhagic septicaemia virus into the rainbow trout industry Scotland, Fisheries Research Services Internal Report.

Jørgensen, PEV. (1980). Egtved Virus: The Susceptibilty of Brown Trout and Rainbow Trout to Eight Virus Isolates and The Significance of The Findings for The VHS Control, Pages 37 in W. Ahne, ed. Fish Diseases. Third COPRAQSession. SpringerVerlag, Berlin, Heidelberg, New York

Jørgensen, PEV. (1982). Egtved virus: temperature-dependent immune response of trout to infection with low-virulence virus. J. Fish Dis. 5, 47–55.

Kim, R., & Faisal, M. (2010). Comparative susceptibility of representative Great Lakes fish species to the North American viral hemorrhagic septicemia virus sublineage IVb. Dis. Aquat. Organ. 91, 23–34.

Lecocq-Xhonneux, F., Thiry, M., Dheur, I., Rossius, M., Vanderheijden, N., & Martial, J., et al. (1994). A recombinant viral haemorrhagic septicaemia virus glycoprotein expressed in insect cells induces protective immunity in rainbow trout. J. Gen. Virol. 75 (Pt 7), 1579–1587.

Lorenzen, N., Lorenzen, E., Einer-Jensen, K., & LaPatra, S.E. (2002). Immunity induced shortly after DNA vaccination of rainbow trout against rhabdoviruses protects against heterologous virus but not against bacterial pathogens. Developmental and Comparative Immunology 26, 173–179.

Hawley, L.M., & Garver, K.A. (2008). Stability of viral hemorrhagic septicemia virus (VHSV) in freshwater andseawater at various temperatures. Dis. Aquat. Org. 82, 171–178.

Hershberger, P.K., Kocan, R.M., Elder, N.E., Meyers, T.R., & Winton, J.R. (1999). Epizootiology of Viral Hemorrhagic Septisemia Virus in Pacific Herring from TheSpawn-On-Kelp Fishery in Prince William Sound, Alaska, USA. Diseases of Aquatic Organisms, 37, 23–31.

Huber, P., Petri, B., Allen, S., & Lumsden, J. (2010). Viral hemorrhagic septicaemia virus IVb inactivation by ultraviolet light, and storage viability at 4 and − 20°C. J. Fish Dis. 33, 377–380.

Olesen, N. (1998). Sanitation of viral haemorrhagic septicaemia (VHS). J. Appl. Ichthyol. 14, 173-177.

OIE. (2010). Manual and Diagnostic Tests for Aquatic Animals, Chapter 2.3.9. Viral Hemorrhagic Septicemia World Organisation for Animal Health.

Overturf, K., LaPatra, S., & Powell, M. (2001). Real-time PCR for the detection and quantitative analysis of IHNV in salmonids. Journal of Fish Disease 24, 325–333.

Parry, L., & Dixon, P.F. (1997). Stability of nine viral haemorrhagic septicaemia virus (VHSV) isolates in seawater. Bull. Eur. Assoc. Fish Pathol. 17, 31–36.

Skall, H.F., Olesen, N.J., & Mellergaard, S. (2005). Viral haemorrhagic septicaemia virus in marine fish and its implications for fish farming – a review. J. Fish Diseases, 28, 509–529.

Smail, D.A., Snow, M. (2011). Viral hemorrhagic septicemia. In: Woo, P.T.K., Bruno, D.W. (Eds.), Fish Diseases and Disorders, vol. 3. CAB International, Wallingford, pp. 123–146.

URL-1. (2023). https://www.cumhuriyet.com.tr/turkiye/balikta-vhs-virusu-tehdidi-2135933. Erişim Tarihi: 03.11.2023

Wolf, K. (1988). Viral Hemorrhagic Septicemia. In: Wolf, K. (ed.) Fish Viruses and Fish Viral Diseases. Cornell University Press, Ithaca, New York, pp. 217–249.

Chapter 11

Various Afforestation Techniques In Dry Areas

Endam ÖZKAYA[1]

INTRODUCTION

Soil is an important and indispensable natural asset as it provides living space for many living things. It has many functions such as regulating the climate, ensuring the carbon and nitrogen cycle, filtering water, regulating flood and flood risks, contributing to the supply of raw materials for many sectors, and is a resource with a large share and important contributions to the life of living things. Therefore, protecting it and ensuring its sustainability in the long term is vital for the development of societies (URL-1).

Soil is a non-renewable natural resource. Therefore, leaving soils to future generations in a healthy way and ensuring their continuity can only be achieved through the adoption and implementation of protective and sustainable soil management plans (1;2). Sustainable management of soils can be achieved by taking into account the structure, texture, content and climatic conditions to which the soil is exposed and organizing the biological and cultural services to be obtained from the soil according to these characteristics (URL-2). Today, soils are gradually losing their fertility and their sustainability is jeopardized by both human activities and natural factors. Soil health and sustainability are under great threat, especially in arid and semi-arid areas where a large part of our country is located (3). Drought, desertification, loss of productivity of soils as a result of erosion, degradation of their physical, chemical and biological properties, and thus decrease in productivity are natural events that can be effective in arid and semi-arid areas and threaten soil health and sustainability. These problems, which threaten a large area in our country as in many countries around the world, can be named as land degradation caused by various factors including climate changes and human activities (4).

In order to reduce the negative effects of all these human activities and natural events on the soil and to ensure the sustainability of soils; it is necessary to take precautions on issues that cause climate change, to predict the risk of drought in advance and to take precautions, to prevent the destruction of vegetation in the fight against desertification and erosion and to give importance

[1] Kilis 7 Aralik University, Graduate School of Natural and Applied Sciences,
Department of Horticulture, Kilis/TURKEY
*corresponding author: endamozkaya44@gmail.com, Orcid no:0009 0000 2616 0633

to afforestation works. In this study, afforestation studies and special afforestation techniques applied to prevent soil degradation caused by various reasons in arid areas are mentioned.

1. AFFORESTATION ACTIVITIES IN ARID AREAS

1.1.Definition, Purpose and Importance of Afforestation

Today, there is an increase in urbanization and population growth rates due to the impact of technology and industrialization, bringing many problems with it. These problems can be listed as climate change, decrease in biodiversity, deforestation, desertification, erosion and drought risk. Drought is the irregularization of the precipitation regime with the effect of climate change and its course at rates below normal throughout the year. Arid areas are areas where natural resources and ecosystems are affected as a result of this irregular rainfall, environmental services are restricted and access to water is difficult (5). These areas defined as drylands constitute 41% of the world (approximately 6 billion ha) and approximately two billion people live in these areas today (1). In arid areas, precipitation is low and evapotranspiration rate is high. Soils in these areas are poor in organic matter (24). No matter how deep they are, they also lack the beneficial water necessary for plant life. Therefore, arid areas usually have flora and fauna systems that live in harmony with these conditions. Generally, steppe ecosystem covers quite large areas (3; 6).

Arid and semi-arid areas are ecosystems where many extreme natural phenomena are observed together. However, years of wrong agricultural practices, deforestation and destruction of existing vegetation cause these areas to face the risk of desertification and erosion (3). These ecologically sensitive areas can be transformed into ecologically, economically and socially productive areas where soil structure, fertility and sustainability are ensured when rehabilitated with properly planned afforestation works (7).

Afforestation is the transformation and development of forested areas, which are generally destroyed or damaged by deforestation, by using appropriate plant species (8). It is an effort to reduce and correct the negative effects of deforestation, to filter the air and purify it from dirt and dust, to sequester CO2 and to increase human welfare by helping to reduce climate change (9;10). The purpose of afforestation activities in arid areas is soil improvement and conservation. However, they are important studies that serve many ecological, economic and social purposes. The objectives of afforestation activities can be listed as follows.

- Improving soil fertility,
- Ensuring access to healthy food,

- Establishment of urban green spaces and urban forests,
- Reducing air and noise pollution,
- Prevention of dust transport and erosion,
- Prevention of floods and flood disasters,
- Protection of water resources,
- Extending the life of dams,
- Meeting the need for wood raw materials,
- Conservation of biodiversity and habitat areas
- Providing aesthetic and activity areas in the city where people can socialize (3).

The fact that trees have a high rate of carbon sequestration is another proof of how important a role they play in reducing the negative effects of both climate change and global warming. In the 21st century, with the increasing pressure of climate change on agriculture and healthy environment, it has been understood by the world that afforestation is the best method to eliminate this pressure. Therefore, within the scope of the 'UN Sustainable Development Goals', to which many countries in the world, such as our country, are parties in 2015, stopping deforestation, ensuring sustainable management of forests and including effectively planned afforestation activities have become among the goals on the agenda of the world (3; URL-5).

Wood and its products have an important place in the economy all of countries. However, not all countries have sufficient forest areas to provide the wood they need. The distribution of forest areas in the world may vary according to countries and regions. This situation is also valid for our country. Our country has a geography consisting of 4 different climate types and 7 different regions. Therefore, the distribution of forest areas varies according to climate type, soil structure and intended use (11). For afforestation activities, large, uninterrupted, well-defined slopes with clear boundaries and slope rates above 20%, rocky areas, and lands unsuitable for agriculture are the most suitable areas. In arid and semi-arid areas, including our country, roadsides, streets, gardens and park areas, windbreak applications that differ according to the purpose of use, protective forest strips can be considered as suitable areas for afforestation (11). Afforestation activities can only be successful if a correct and well-managed planning is realized. For this purpose, selecting the appropriate plant species, preparing the afforestation area, carrying out the planting in a controlled manner, ensuring the maintenance and management in the best way is of great importance for the success of the work and the long-term sustainability of the are (11).

1.2. Determination of Species to be Used in Afforestation

The most important phase of afforestation works is the selection of tree species to be planted or planted. Because the selected species will occupy the land for 50-100 years. Therefore, the selected species should be easily adaptable to the soil and existing ecological conditions. If the following three stages are carried out while selecting species in afforestation areas, the success of the work and the efficiency obtained will increase.

- The purpose of afforestation should be determined.
- The ecological conditions of the area to be afforested should be determined.
- The growing requirements of the plant used in afforestation and the ecological conditions of the area should be evaluated together (12).

Before starting afforestation activities in arid regions, the soil should be identified and improved with locally suitable species. After that, afforestation works can be started with suitable species that adapt. The most important feature sought in the species to be selected first is drought resistance. Selecting species with thick, narrow and small leaves and deep root systems facilitates the adaptation process of the plant to the site and increases the success of the work. Plants with a deep root system can penetrate deeper into the soil, allowing the plant to benefit more from the moisture in the soil, either from the ground water or from a little rainfall. In areas where the ground water is closer to the surface, plants with a fringe root system can be used. Another important issue is whether the species used serve the purpose of the afforestation work as well as their suitability for growing conditions. For example, in order to obtain quality products in an afforestation area established for industrial wood production, the most suitable species (e.g. pine, eucalyptus, acacia, etc.) are determined and planted.

In afforestation in arid areas, soil adaptation and adaptation of the plant to climatic conditions are important. In particular, the plant must be resistant to the increased salinity in the soil with drought. Some soils may contain mycorrhizal fungi that attach to plant roots in terms of their structure or thanks to the plant species previously cultivated in the area. These fungi ensure that soil organic matter binds to each other and to plant roots. Thus, the yield obtained from the plant increases. However, if these fungi are not present in the soil, it is recommended to inoculate the soil before planting (11;12).

1.3. Preparation of Afforestation Area

Soil preparation must be completed in advance so that the plant can be introduced to the soil in the most appropriate way without damage. In order to

prepare the area to be afforested, the area is first identified and then the existing wild bushes and weeds are cleaned. The cleaning method may vary according to the plant type. If there are live trees that need to be preserved in the area, the weeds in their roots are first cut and weeded. These weeds are gathered together and disposed of by controlled burning before planting. However, if the area is covered with shrub species that are taller than weeds, it is easier to burn them first and then uproot them. This is because the shrubs need to be uprooted to prevent them from growing again. This will also prevent these shrubs from wasting soil moisture. If the area is very steep, the grass on the surface is not burned but only plowed. Another important factor that will ensure the success of the afforestation work is the preservation and transportation of the plants from the nursery where they are grown until they are taken to the afforestation site without stress and without damaging their root systems. If the saplings are to be transported in the form of roots without soil, they should be transported by ensuring that they do not dry out, and if they are to be transported in the form of roots with soil, they should be transported by ensuring that the soil remains moist. These saplings brought to the afforestation site should be planted as quickly as possible, weather conditions permitting. After the cleaning process on the soil surface is done, the process of digging pits for the brought saplings can now be started (11;3).

1.3.1.Digging the pits:

The width of the pits may vary according to the size of the seedlings. However, pits of 30*30*30 dimensions are usually sufficient. Stones should be removed from the pits dug in stony areas. In arid areas, these stones can be placed in the root zones to prevent the soil from moving with the wind. The soil removed from the pits should be taken out right next to the pit in rainy areas. In arid regions, the soil can be loosened after the pit is opened and filled back into the pit until planting is carried out. Opening the pits in a row at equal intervals and distances will also facilitate subsequent maintenance (11),(Figure 2).

Figure 2. Digging Pits in Afforestation Areas

1.3.2. Terraces:

Terraces are stepping systems created by excavating the slopes along the escarpment curves and piling the soil between two layers on lands with high slope rates. Thus, the land is cascaded and the steps are flat areas. Planting can be realized by opening pits in these flat areas. Increasing slope and soil structure affect the step width. As the slope increases, the step width narrows and the number of steps increases. The purpose of terracing is to allow rainwater to flow through the slopes formed between the terraces and to be collected in the flat areas and delivered to the plant (11;13),(Figure 3).

Figure 3. Terracing Process in Afforestation Areas

1.3.3.Leveling Strips:

In areas with little slope and no risk of erosion, terracing can still be used by following the slope curves. In these strips, the soil on the soil is cleaned and the soil is cultivated at a depth of 15-20 cm. Between the cultivated strips there are 5m strips that are left uncleared. They are generally 2- 2.5 m wide strips and trees are planted on them at equal intervals (11).

1.3.4.Hand Tools:

Suitable hand tools are used for the work to be done with manpower in the area to be afforested. The most commonly used tools are picks and hoes with plates of different widths (11).

1.3.5. Mechanical Tools Used in Afforestation Works:

Today, with the development of technology, mechanical tools are generally used in large and suitable lands. Crawler tractors (dozers), rubber wheeled tractors, graders, excavators are mechanical tools used in afforestation works when necessary. They help to speed up the work by saving time in many situations such as soil cultivation, creation of terraces, opening planting pits, transportation of soils (URL-3).

1.3.6. Construction of Roads and Trails:

Roads and paths should be constructed in order to ensure that maintenance, management and supervision in afforestation areas are maintained in a healthy manner and not interrupted. Before planting, the areas to be afforested should be divided in accordance with the topography of the land. Between these sections, a main axis should be created to provide access for construction machinery, and pathways should be determined to provide access for workers through this axis. The main road axis should be paved with a material that will not be affected by slipperiness in winter and excessive sand in summer. The slope of the road should be suitable for transportation and should not exceed 10%. In hilly and mountainous areas, the road width should generally be 2-2.5 m. Road edges should be defined with stones or retaining walls. Trails are sloping roads with a maximum width of 1.5 m, which can increase up to 15% from time to time. They should be marked with stones and have good drainage systems. Thus, both the deterioration caused by landslides in sloping areas and the deterioration caused by the intensity of rainfall are saved (11),(Figure 4).

Figure 4. Roads and Trails in Afforestation Areas

1.4. Afforestation through sowing and planting

Determining the planting spacing between plants, planting time and the suitability of weather conditions are important issues to be considered during the planting phase. After the site is prepared and the saplings are transported to the site in a controlled manner, planting operations are started at the beginning of winter after the soil is saturated with the first rains. Planting work should start in the fall and end in the spring. The season following the soil cultivation period is the most suitable season for planting. In areas with arid and semi-arid climates, tubed-coated saplings should be preferred, and the intervals between plants should be determined by taking into account rainfall and evaporation conditions. In these areas, despite the danger of drying out the plants, planting should be done in overcast and cloudy weather, or even in periods of light

rainfall, which eliminates the danger of drying out and ensures successful results. Planting can be done in spring against the danger of frost that may occur in winter. If the afforestation area is located in high areas, it should be protected by placing stones around the sapling (11;3).

Planting spacing should be left wide in arid areas. Normally, a planting distance of 1.5 meters is sufficient for afforestation works. However, in arid areas, a distance of 2.5-3.5 meters may be more suitable for this distance. The reason for this is that competition between plants starts much earlier in dense plantings and causes an increase in thinning operations. Thus, additional cost is added to the budget of the study (11;3).

In planting studies, different methods such as edge planting in the pit, ordinary pit planting, deep planting in the pit, hill planting in the pit, hill planting with pit in the pit can be used. Generally, the most preferred planting methods are edge planting in the pit and ordinary pit planting methods. The most suitable depth for planting is 30-40 cm of annealed and moist soil. Saplings brought in baled and packaged form should be placed in planting crates wrapped with damp moss and telis while planting, so that they are protected from the wind, distributed proportionally to the number of workers and planted on the same day. In case of moisture loss, the covered seedlings should be watered first and then transported to the planting place together with their containers and planted. Planting pits should be dug at least 5 cm deeper than the root length. The sapling removed from the crate should be placed in the pit in such a way that the roots are not damaged and the root should be covered with moist topsoil. Following the planting, the worker should compress the soil by applying pressure with the foot towards the root area. Thus, the planting phase is completed (11;3), (Figure 5).

Figure 5. Planting application (3)

Afforestation by planting is a method used on lands where afforestation by planting is not suitable. In this method, where afforestation costs are greatly

reduced, some species are brought directly to the land by sowing from seed. Thus, nursery costs are eliminated and the transportation of seeds to the field requires much less cost than the transportation of seedlings. In afforestation by sowing, site preparation is almost the same as the planting method. In this method, planting holes do not need to be deep. The soil is cultivated in strips and the seeds are sown on these strips. However, in order to use afforestation by planting method, it is necessary to know the application conditions very well, to make applications in suitable areas with suitable species, and not to insist on unsuitable places and situations. However, arid and semi-arid areas, places and aspects dominated by high temperatures and drying winds, bare slopes with excessive slopes, areas with insufficient physiological depth, horizontal stratified and uncracked bedrock, wild, wet and tightly stacked soils and areas with dense sap cover are not suitable for afforestation by planting (3).

1.5. Maintenance Works in Afforestation Areas

Maintenance operations in afforestation areas are the processes of weeding, hoeing, completion, irrigation, shoot control and terrace repair carried out to combat herbaceous and woody plants that adversely affect the growth and development of the plant in areas where land preparation has been completed with labor or mechanical tools. Maintenance works are important in order to protect the sapling from all adverse conditions, all kinds of pests that prevent its development and to increase its resistance during the process of the sapling's complete attachment to the soil after planting (3).

1.5.1.Completion:

The fact that the planted saplings are exposed to unfavorable conditions during or after the planting phase may cause regional mass drying or occasional drying in excess of 20% in the field. In these cases, the completion process involves the removal of damaged plants, re-tillage of these areas, and the planting of new recommended plant species. Large-scale completion operations are always costly. For this reason, the afforested area should be visited for control purposes 3-4 weeks after all operations are completed and new plants should be planted immediately next to the dried plants (11;3).

1.5.2. Weeding and Grubbing:

It is the process of separating the herbaceous or woody plants that put pressure on the development of the saplings in the root areas of the saplings with the help of a hoe, starting from the priority areas in the field before the seeds are poured after the spring rains in the vegetation period after the planting

of the afforestation area, and loosening the soil in the root area and providing aeration (11;3).

1.5.3.Irrigation:

Irrigation is not practiced in arid and semi-arid areas because the rainfall regime is irregular and less than normal and high summer temperatures increase irrigation costs. Generally, winter and spring rainfall is collected and this harvested water is utilized (14;15). However, the need for irrigation should be minimized by choosing appropriate species and applying techniques that increase the water holding capacity of the soil. In afforestation activities carried out in arid and semi-arid areas, irrigation can be carried out in the first two years in June-September in accordance with plant needs, and then the amount can be gradually reduced (11).

1.5.4.Shoot Control:

It is the process of cleaning and controlling these shoots in order to prevent damage to the mother plant with the re-development of root particles that are not cleaned from the soil after tillage and planting (3).

1.5.5. Protection against Grazing and Fire:

It is very important to take measures against free livestock grazing in the areas planned to be afforested, especially in the first 6 years. The reason is to prevent damage to plants that are still in the development and adaptation stage by animals. If animals are grazing close to the afforestation area or if afforestation is to be carried out in areas where free grazing is legally permitted, a very costly work should not be undertaken. Fires are the biggest danger that can be seen in afforestation areas. Unless fires are brought under control with measures, it is inevitable that all afforestation areas will be lost.

The first measure against the danger of fire for any reason is to raise public awareness. Involving the people living around or near the forests in all processes of the forests enables the creation of conservation awareness. The most important measure to be taken during the planning phase of afforestation areas is the establishment of fire safety strips. These strips can be at least 8-10 m wide, cleared of all grass and bushes so that the fire cannot pass through. In arid areas, these strips should be kept clean until the rains begin, especially in the summer months, against the fire hazard that can be triggered by high temperatures. In large and continuous afforestation areas, dividing the area into zones in certain hectares and drawing fire safety strips between them prevents fires from spreading to large areas (11;16), (Figure 6).

Figure 6. Fire Safety Strips

1.5.6. Cost of Afforestation Works

The cost of afforestation works varies depending on the size of the afforestation area, the type of soil preparation, the number of plants planted per hectare, the completion, maintenance and protection methods. Maintenance with labor is always more costly than maintenance with mechanical tools. In this regard, afforestation studies carried out under the consultancy of trained people by encouraging volunteerism with the support of many institutions and organizations can contribute to the reduction of labor costs and can be effective in developing forest protection awareness in the society (11).

2.AFFORESTATION TECHNIQUES APPLIED IN ARID AREAS

2.1. Afforestation for the Prevention of Erosion

Erosion is a natural disaster in our country and in the world, where the soil is eroded by the force of water and wind and moved from one place to another, damaging the vegetation and soil health, significantly increasing the risks of soil degradation and desertification. Arid and semi-arid climate conditions, which are effective in a large part of our country, cause us to have large areas sensitive to erosion. In arid and semi-arid areas, erosion caused by the effect of water and wind on slopes devoid of vegetation negatively affects agricultural and environmental activities. Erosion can occur as a result of human activities as well as the effects of natural factors. While excessive and free grazing, destruction of vegetation cover and deforestation, establishment of agricultural areas towards the slopes, unplanned construction and misuse of land are human activities that trigger erosion risk, excessive and irregular rainfall, strong winds, light and loose structured soils are natural factors that trigger erosion (URL-4). In combating erosion; while it is possible to prevent damage to the soil by intervening in human activities, it is not possible to fully intervene in natural factors. However, soil resistance can be increased through rehabilitation works. One of the most important works on land rehabilitation in the fight against erosion is undoubtedly afforestation. Afforestation works can restrict soil

mobility that causes erosion. Soil masses carried by rainfall or strong winds from slopes to fertile lands can be prevented by the plants used in afforestation works. In arid areas, rainfall can sometimes be heavy, even for short periods. Afforestation is essential to control water in these areas. The first measures to be taken in these areas are to graze the area with appropriate species, to regulate grazing, to take appropriate measures against fire, and to establish short terraces for afforestation. These measures must be taken in order to keep the water on the land and slow down the flow rate. In erosion caused by wind force, terracing, grazing with appropriate drought-resistant species and windbreaks are practices that help prevent erosion (6),(Figure 7).

Figure 7. Afforestations for the Prevention of Erosion

2.2. Afforestation of Swampy Areas

Swamps are areas with poor soil drainage, high ground water levels, flat lands with inadequate slope, lakes and rivers. These areas should not be used for afforestation activities unless it is mandatory. If they are to be used, they should be rehabilitated. The first step in afforestation activities in swampy areas is soil analysis. For example, if there is excessive salinization in the soil, the selection of species suitable for this situation or soil rehabilitation ensures success in afforestation. Site preparation for afforestation in swamps begins with the creation of embankments or slightly sloping ditches. In these areas, planting is done on the embankments and water is carried to wider channels with the help of ditches and drainage of the site is provided. The number of plant species that can be grown in swampy areas is limited. In plant species selection, species such as willow, alder, sweetgum, eucalyptus, ash, swamp cypress, swamp oak can be preferred (11;17), (Figure 8).

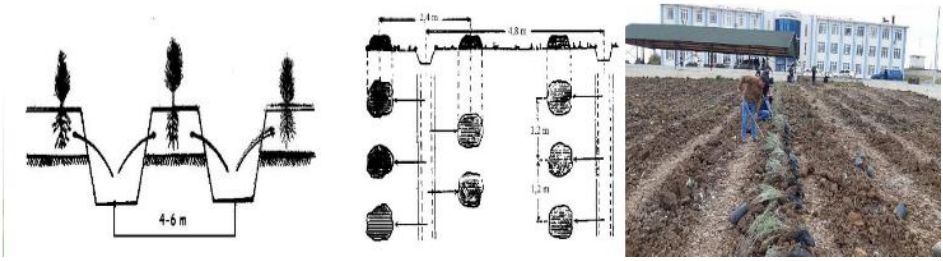


Figure 8. Embankment planting in marshes (1st image), Trench planting (2nd image) (18;19)

2.3. Afforestation of Dune Areas

Dune areas are areas formed as a result of wind erosion caused by strong winds. If a general definition is to be made, dune areas are areas formed as a result of the transportation and accumulation of light, loose and volatile soils that do not contain binding substances such as humus and clay under the influence of wind. Afforestation works are of great importance in order to make these areas, which are subjected to soil degradation as a result of erosion, productive again (20). Sand dunes reduce the productivity of agricultural areas and forests by affecting them; they restrict their use by affecting transportation networks, water resources, settlements and river beds. Since they cause these negative conditions, dune areas should be reclaimed and dust transportation should be stopped in these areas. Rehabilitation of dune areas is carried out in two stages: temporary and permanent stabilization. Temporary stabilization is the creation of pre-dune areas that allow the dune source to be taken under control. Sand is prevented from moving inland by sand dunes piled in front of the source. Permanent stabilization is the afforestation works carried out in these areas. These dune areas, which are formed as a result of wind erosion, especially in arid areas, are first screened with wooden, plastic material fences, and then the dune movement is stopped by grazing and afforestation with appropriate species between these fences, and the land is covered with fertile vegetation again. Our country has experienced and achieved successful results in afforestation in dune areas with the wind erosion in Konya Karapınar district in 1960 and the reforestation activities carried out in this area (21;17), (Figure 9).

Figure 9. Afforestation Works in Sandy Areas

2.4.Afforestation with Windbreaks and Protective Forest Strips

Windbreaks, protective forest strips and afforestation activities are of great importance for agriculture and forestry in areas with arid and semi-arid climatic conditions. Windbreaks are afforestation methods applied to protect soil fertility in agricultural areas located in arid and semi-arid plain areas exposed to strong winds. These curtains, which are established by using live plants in strips at certain intervals, prevent dust transportation and snow blizzards by acting as a shield in areas 10 times wider than their height. Thus, it provides significant protection of crop and soil fertility. Windbreaks using plant species that are resistant to drought and strong winds, can root quickly and grow fast, and can reach a certain crown diameter are an effective and sustainable afforestation technique for combating wind erosion (11), (Figure 10).

Figure 10. Afforestation with Windbreaks

In order to achieve the benefits of protective forest strips, some special conditions must be met in order to achieve the benefits appropriate to the purpose for which they are established. The purpose of establishing protective forest strips is important. Forest strips established to prevent water erosion should be placed to follow the leveling curves, while forest strips established to prevent wind erosion should be placed perpendicular to the prevailing wind

direction. The first and most important issue in the establishment of protective forest strips is to determine the wind direction (22). After the length of the protective forest strips established to follow the leveling curves exceeds 1 km, diagonal secondary strips should be established. However, these strips should be in an order that will not affect activities in agricultural areas. Protective forest strips can be established to protect agricultural areas from the effects of water and wind, as well as to protect farm areas and to protect grazing animals in meadows and pastures. To protect the fertile surface of the soil from the erosive effects of wind, windbreaks and protective forest strips can be established, especially around agricultural areas. This protects the soil, provides shade for livestock, and creates enjoyable and productive areas for people. In addition, if agriculture is already being practiced in this area, the risk of wind erosion will be eliminated and the yield to be obtained from the unit area will be increased (16).

2.5.Urban Road Afforestation

Afforestation activities in arid and semi-arid areas are important efforts to prevent many disasters caused by human activities and natural factors. However, in addition to the prevention of these risky situations, there are also studies in which the aesthetic and functional features of the plants used in afforestation are prioritized. Afforestation works carried out in the city and on roadsides can be given as an example. The functions of such afforestation works can be listed as regulating climate changes, preventing air and noise pollution, reducing the urban heat island effect, relieving intercity traffic, and providing aesthetic and social environments for people living in cities (23). Roadside plantations contribute to increasing comfort in transportation and protect the road directions against possible dust storms that may occur especially in arid areas. They can also act as wind screens for the fields around them, if any. Road plantations planted with appropriate species can produce fruit and tannins, while at the same time contributing to the increase and improvement of biodiversity and the development of beekeeping. These plantations, planted along the road direction, also provide a great benefit in terms of wood production. It is effective to select the plants used in road afforestation from species suitable for local climate and soil conditions, to prefer species with columnar and symmetrical forms with well-developing top shoots, and to select plant species from species suitable for the purpose of afforestation. In addition, planning by taking into consideration features such as the preference of species that can quickly adapt to difficult conditions and are resistant to all kinds of diseases and pests ensures effective and successful results in the long term (11;23), (Figure 11).

Figure 11. Urban Road Afforestation

CONCLUSIONS AND RECOMMENDATIONS

Drought, which affects a large part of our country, brings along soil degradation and many natural disasters. In these areas, there are many problems that trigger soil and land degradation caused by human activities such as deforestation, allowing overgrazing, off-purpose land uses, use of intensive processing techniques in agricultural areas, unconscious irrigation, industrial wastes.

The areas affected by disasters caused by various reasons in arid areas are basically lands devoid of vegetation cover. Therefore, even if the stages of combating these disasters are different, they are generally completed with afforestation activities. Arid areas are sensitive areas for afforestation activities. Afforestation activities in these areas require careful planning in accordance with their purpose. Preferring methods suitable for the ecological and economic conditions of the area to be afforested, and afforestation with appropriate plant species and varieties allow to increase the yield lost in arid areas. Various afforestation techniques used in arid areas include combating erosion, rehabilitating swamp and dune areas, establishing windbreaks and forest strips that act as shelters to protect soil fertility, and road afforestation in urban areas to combat climate change and environmental pollution.

Afforestation works carried out in arid areas, together with the use of afforestation techniques appropriate to the needs of the region and correct implementation stages, contribute to the fertility of soils, to obtain sustainable areas in the long term, to provide economic gains in the region, to the development of agriculture and forestry activities, to the continuity of wood raw material production, to the increase of yields obtained from agricultural areas, to the formation and development of habitat areas and to the increase of biodiversity, to the creation of aesthetically and socially appropriate urban areas.

REFERENCES

(1) Özkaya, E., Kuzucu, M. and Gökçen, İ.S. (2023). "Sustainable Soil Management in Arid Areas" / Book of Agriculture, Forestry and Fisheries in a Globalizing World, ISBN: 978-625-6945-39-5 Editor: Dr. Alaeddin BOBAT/ Chapter:2, pp.29-50.

(2) Kuzucu, M. (2021). The Importance of Mulching for Soil Moisture Storage in Dry Agricultural Areas. International Journal of Environmental Trends (IJENT), 5(1), 16-27.

(3) Ministry of Forestry and Water Affairs (2013). General Directorate for Combating Erosion - Guidelines for Afforestation and Rehabilitation in Arid and Semi-Arid Areas/190 p.

(4) UNCCD, (1995). United Nations Convention to Combat Desertification in Countries Experiencing Severe Drought and/or Desertification, Especially in Africa, Text with Annexes, UNEP, Geneva.

(5) FAO (2016). FAO (2016). Global forest resources assessment 2015. How are the world's forests changing? Second Edition, Food and Agriculture Organization of the United Nations, Rome, Italy, p 56.

(6) Kuzucu, M. and Dökmen, F. (2015). Effects of Tillage on Soil Water Content in Dry Areas. Agriculture and Agricultural Science Procedia, 4, 126-132.

(7) Aytuğ, B., Görecelioğlu E. (1993). Anadolu Bitki Örtüsünün Geç Kuaterner'deki Gelişimi. İ.Ü. Orman Fakültesi Dergisi, Seri B, Cilt 3, Sayı 4, s. 27-46. Bernhard-Reversat, F., (ed.) 2001. Kongo savanasında egzotik ağaç plantasyonlarının bitki çeşitliliği ve biyolojik toprak verimliliği üzerindeki etkisi: okaliptüslere özel referansla

(8) Gillis, Justin (16 Mayıs 2016). "Latin Amerika'da Ormanlar Karbondioksitle Mücadele Edebilir". NYT. 20 Mayıs 2016 tarihindeki kaynağından arşivlenmiştir. Erişim tarihi: 25 Haziran 2023. https://en.wikipedia.org/wiki/Reforestation

(9) Rosane, O. (2019). "Milyarlarca Ağaç Dikmek 'Bugün Mevcut Olan En İyi İklim Değişikliği Çözümü', Çalışma Bulguları". Rosane, Olivia (5 Temmuz 2019). Ecowatch. Erişim tarihi: 25 Kasım 2019. https://en.wikipedia.org/wiki/Reforestation

(10) Deutsche Welle. AP ve Reuters, AFP. (2019). "Planting 1 trillion trees could stop climate change, argues study". "Planting 1 trillion trees could stop climate change, argues study". Deutsche Welle. AP, Reuters, AFP. 4 Temmuz 2019. Erişim tarihi: 25 Kasım 2019. https://en.wikipedia.org/wiki/Reforestation

(11) FAO (1956). "Technique of Afforestation in Arid Regions"/Trans: Turgut E. Beşkök/147 p.
(12) Ürgenç, S.İ. and Çepel, N. (2001). "Species Selection for Afforestation", Practical Principles of Seed Sowing and Sapling Planting/ TEMA Foundation publications No:33/268 pp.
(13) Kuzucu, M. (2019). Effects of Soil Tillage Methods and Organic Fertilization on Yield and Soil Organic Matter in Sloping Olive Orchards of Kilis. Fresenius Environmental Bulletin, 28(1), 446-451.
(14) Yazar, A., Kuzucu, M., Celik, I., Sezen, S. M. and Jacobsen, S. E. (2014). Water harvesting for improved water productivity in dry environments of the Mediterranean region case study: Pistachio in Turkey. Journal of Agronomy and Crop Science, 200(5), 361-370.
(15) Kuzucu, M., Dökmen, F. and Güneş, A. (2016). Effects of climate change on agriculture production under rain-fed condition. International Journal of Electronics Mechanical and Mechatronics Engineering, 6(1), 1057-1065.
(16) OGM (2020). Protective Forest Strips and Trials of Establishment of Protective Forest Strips in Bala/142 pp.
(17) Turna, İ., Genç, M. and Güney, D. (2021). Nature Conservation Oriented Afforestation/Forests and Forestry in Turkey on the Ecology and Economy Axis/119-160 pp.
(18) Ürgenç, S.İ. and Çepel, N. (2001). Practical Principles of Species Selection, Seed Sowing and Sapling Planting for Afforestations/ TEMA Foundation Publications No:33/268 pp.
(19) Yahyaoğlu, Z. (1997). Afforestation Technique Lecture Note, KTU Faculty of Forestry, Lecture Series: 44, 100s., Trabzon.
(20) Atay, İ., Aytuğ, B., Selik, M., Ürgenç, S. and Yaltırık, F. 1990: Technically Appropriate Maintenance and Pruning of Urban Trees, Forestry Education and Culture Foundation, Publication No: 2, Istanbul.
(21) Güney, D. (2020). Karadeniz Technical University 2019-2020 Afforestation Technique (9) Lecture Notes
(22) Suss, N. I. (1944). Measures for rural amelioration with the aid of fore:=try, and science during the war and post- war periods; Byull. Inst. zem. Khoz. Yu.-v. SSSR 3:3-13. For. Abstr. 7 (4) : 24.4.
(23) Uzun, A. (2007). Critique of Istanbul Urban and Road Afforestations/ Urban Afforestations/ 21 pp.
(24) Gokcen, I. S., and Kuzucu, M. (2023). Soil quality and fertility in vineyards of Kilis province of Turkey, the northwest of “fertile crescent”.

Emirates Journal of Food and Agriculture. 2023. 35(7), p: 657-665 doi: 10.9755/ejfa.2023.v35.i7.3116
URL-1: https://topraktema.org/topragin-islevleri. Access Date: 22.04.2023.
URL-2:https://topraktema.org/kategoriler/toprağın-geleceği/suerdueruelebilir-toprak-yonetimi/ Access Date: 07.05.2023
URL-3:https://www.leonardit.com.tr/image/catalog/pdf/agaclandirma-teknikleri.pdf.
Access Date:10.06.2023.
URL-4: https://topraktema.org/media/1340/erozyon.pdf. Access Date:17.05.2023.
URL-5: http://www.surdurulebilirkalkinma.gov.tr/ Access Date:26.05.2023.
URL-6:https://docplayer.biz.tr/5043064-Agaclandirma-teknigi-orman-kurma-ve-agaclandirma-yontemleri-dosya-3.html Access Date:14.07.2023.
URL-7: https://www.ktu.edu.tr/dosyalar/silvikultur_1053f.pdf Access Date:18.07.2023.

Chapter 12

Rotifer Preparation Techniques For Scanning Electron Microscopy (SEM)

Hilal BULUT[1]

Introduction

General Characteristics of Rotifera

In freshwater communities, rotifer species provide food for many predatory invertebrates. They are also used as indicators to determine water quality in freshwater ecosystems (Ganon and Stember 1978). The Rotifera phylum is a group of living things that typically vary in length between 50–2,000 μm, are found mostly in freshwater, and include approximately 2,000 different species and characterized by the presence of a ciliated “corona” and a muscular pharynx called “mastax” (Fontaneto, 2015).

Although most rotifers live in fresh water, there are also members of some genera that can live in brackish and salt water. Some species of rotifers, which are very important for the food chain, are indicative of quality and eutrophication states of the water that they live in (Saler, 2009). Members of the Rotifera group have two notable features. The first of these is a special ciliated area called the corona, located in the front parts. The corona region is a structure consisting of two concentric eyelash rings, usually called the trocus and cingulum. The corona of many Rotifera species resembles a rotating wheel. For this reason, the Rotifera phylum is also known as 'animals with wheels'. While all Rotifera members use the corona as a food gathering organ, in free-swimming Rotifera species the corona is also used as a locomotion organ. A second distinctive feature that all Rotifera species have is It is a muscular pharynx structure called the trophies and includes a complex set of jaws (Wallace and Snell, 2010). Rotifers are represented by approximately 2000 species and most of them are freshwater animals. A few of them live in the seas and a few live in algae. A few species are parasitic, some are sessile, a few species are colonies, and the remaining species are free-living. They feed on phytoplankton or are predators. Their distribution areas are quite wide. They are represented in fresh waters in large quantities and with many species in the same region. As

1- [1] Doç.Dr.; Firat University Fisheries Faculty, Elazig Department of Basic Sciences hilalhaykir@gmail.com ORCID No: 0000-0002-0332-8613

long as there is enough food, they reach 5000 individuals per liter, and in sewage water they reach 12,000 individuals per liter. Some species occur in salty and brackish waters; Approximately 50 species of Rotifera are marine. Some of the species belonging to the bedelloid group produce biofilm, lichen and liver cells. Rotifera live on algae. Rotifers mainly feed on smaller animals, algae, and organic particulates, although some species are parasitic. Depending on the species, they filter feed or actively hunt and capture prey (Brusca and Brusca, 2003; Ruppert, et al., 2004; Segers, 2007; Wallace, 2002; Zhang, 2011). These are generally concentrated in the soil (32,000-2 million/m^3). This ratio varies depending on the moisture density of the soil; They play a very important role in the nutrient cycle in the soil. Rotifers are among the smallest multicellular animals. Their size is approximately 40-1000 μ (males), 3 mm in some species (females). Rotifera body consists of three parts: head, body and feet. The corona in the head carries the mouth opening, tactile and optical senses. The corona (garland organ) serves to provide locomotion and nutrition. There are cilia on the front surface of the corona and the mouth is located in the center of these cilia. This part surrounding the mouth is called the buccal area. Rotifera sac has a cylindrical-shaped body. The body surface is covered with the cuticle, which is formed by the outward secretion of a thin hypodermis layer. The cuticle has a thin and flexible structure. The cuticle layer thickens in some groups and It surrounds you like armor and is called Lorika. In the body located in the middle part of the body and filled with body fluid; consisting of excretory organ with flame cells, digestive system, ovary and vitellarium. It includes the genital organ (germovitellarium), brain, circular and longitudinal muscles. The foot is located at the rear end of the body. It consists of flat or interlocking sections and has two small extensions called fingers at its tip. This area contains foot muscles and a pair of glands. There are glands in the foot that secrete secretions. With the secretions of these glands, Rotifera anchor themselves to a place temporarily or permanently. Some Rotifera do not have feet. The body is generally elongated or round bag-shaped and is divided into 3 parts: head, neck and trunk. In some species, a short neck is noticeable. The foot emerges from the posterior end of the body; It is a narrow section that is flat or composed of many interlocking compartments; The cuticle has gained flexibility due to its jointed structure and thin structure. Body surfaces are generally covered with a cuticle secreted by the hypodermis (Figure 1).

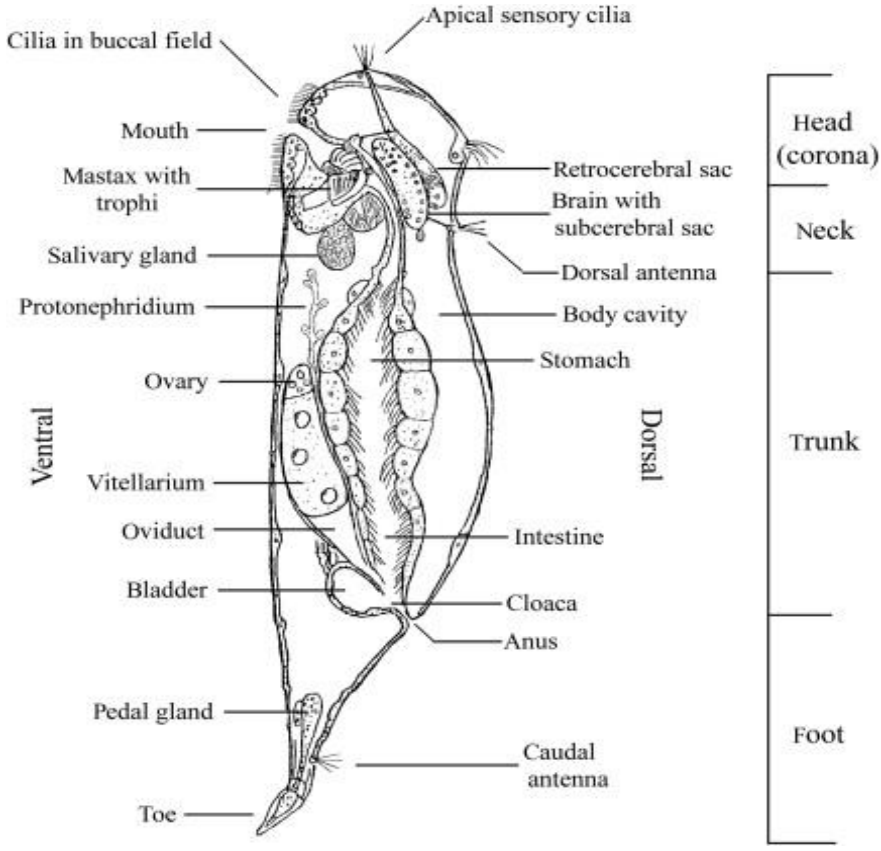


Figure 1. General body structure of the Rotifera group (Wallace and Snell,2010)

Reproduction

Rotifera individuals show sexual and asexual reproduction. Females generally reproduce by parthenogenesis during the summer months. For this reason, males are mostly formed at certain times of the year. Females (diploid) emerge from thin-shelled eggs. Offspring hatch from the eggs formed by parthenogenesis in 2-5 days. Females can produce offspring 20 to 40 times a year in this way. These are called amictic females, and the eggs they produce are called amictic eggs. There are two types of these eggs, one small and the other larger. Females develop from the larger parthenogenetic eggs, and males form from the smaller eggs. In winter, females make thick-shelled winter eggs. These are eggs that need to be fertilized. Fertilized winter eggs develop in spring and become amictic. It produces female individuals called. The reproductive organs of females are divided into three

parts: ovary, vitellarium and follicular layer. The ovary is united with the vitellarium, which produces vitellus, and this structure is called germovitellarium. Vitellarium has a fixed number of large nuclei and some species. It is an important characteristic feature in classification.

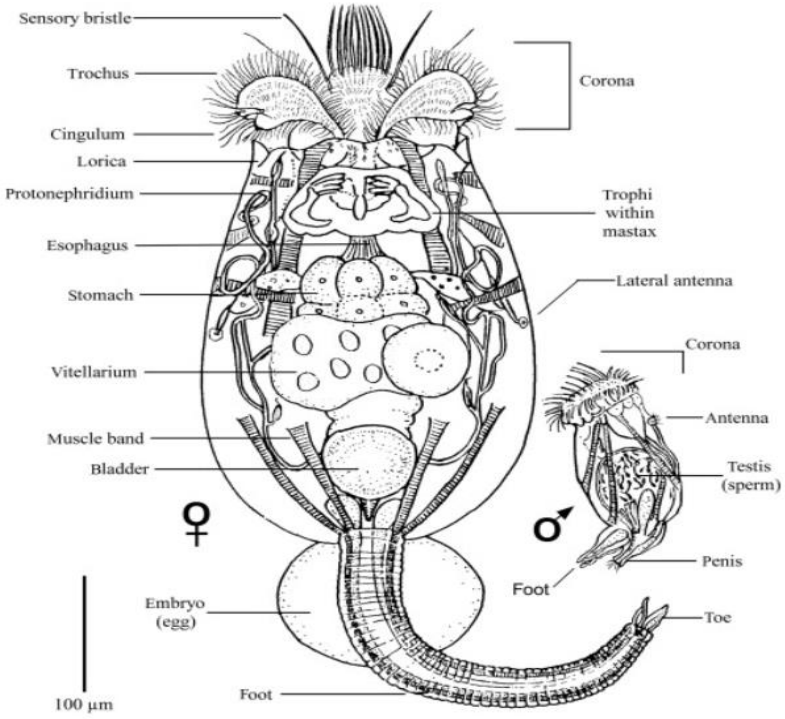


Figure 2. Monogononta rotifer (Wallace and Snell,2010)

The male reproductive system contains pear-shaped, rounded testicles and a ciliated sperm duct. A ciliated vasdeferens extends from the testicle to the penis, which has 1 or rarely 2 auxiliary (prostate) glands that excrete into it. Classically, there are three classes within the Rotifera phylum: Seisonidea, Bdelloidea and Monogononta. Seisonidea consists of marine forms, in which the corona is remnant, the sexes are the same size; Females do not have a double-ovary vitellarium. Monogononta is represented by 1,570 species. Organisms in this group are found in all types of aquatic ecosystems; These organisms, which have swimming and sessile forms, have a single germovitellarium and produce amictic, myctic and dormant eggs. Males are small in stature (Figure2). Bdelloidea is represented by 461 species, the corona usually bears a pair of trochal discs. They reproduce

parthenogenetically, females It has two germovitellaria (Segers, 2007; Fontaneto et al., 2008; Hickman Jr. et al., 2014).

In the Bdelloidea group, parthenogenetic reproduction produces diploid eggs that yield diploid female individuals. These females reach maturity within a few days. In the class Monogononta, females produce two types of eggs depending on environmental conditions. For most of the year, diploid females are slender. It produces shelled diploid amictic eggs. Amictic eggs develop parthenogenetically into diploid females. Environmental factors for example, extreme population density, nutrition, or photoperiod can initiate the formation of diploid myctic females that produce thin-shelled haploid eggs from amictic eggs. If these eggs are not fertilized, they develop into haploid males. If the eggs, called mictic eggs, are fertilized, they form eggs with thick, durable shells and remain in a resting state. These winter eggs develop into amictic females when environmental conditions become suitable again. In the class Seisonidea, females produce haploid eggs that must be fertilized and these can give rise to males or females. Most Rotifera species are oviparous, a few are ovoviviparous or viviparous (Hickman Jr. et al., 2014).

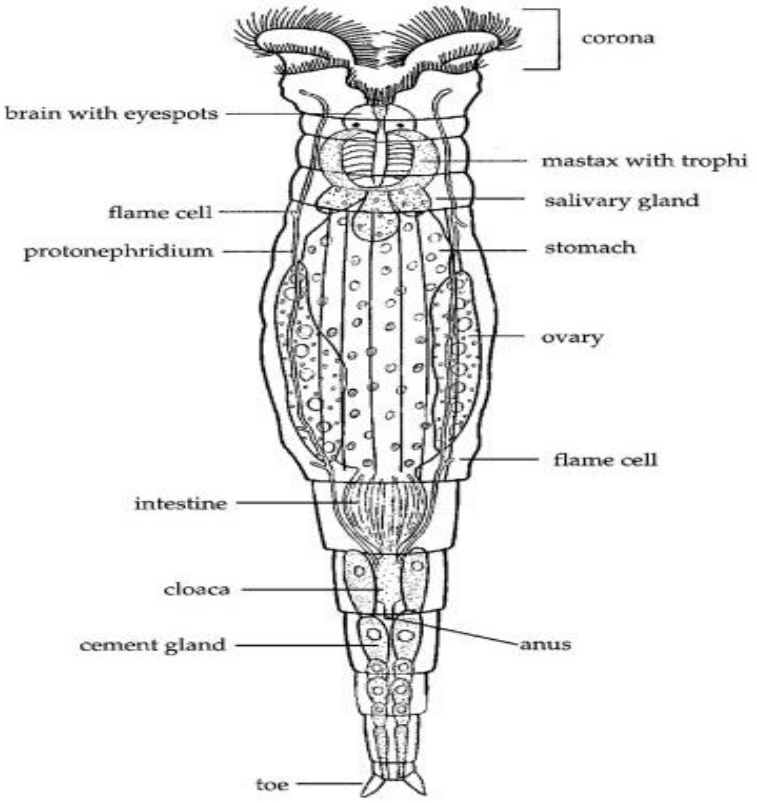


Figure 3. Bdelloid Rotifer (Wallace and Snell, 2001)

Communication and Perception

Rotifers have coronal and apical sensory bristles and often paired ciliary pits, presumably chemoreceptive**.** It is typical for these organisms to have at least one photosensitive ocelli on the dorsal or ventral aspect of the cerebral ganglion, with many species having one or two pairs of ocelli. Some may also have lateral or apical ocelli which are also photosensitive. Some rotifers have sensory hairs on their antennae, or their antennae may consist of sensory hairs. (Brusca and Brusca, 2003; Hyman, 1951; Wallace, 2002).

Predation

As planktonic animals, adult rotifers and their eggs serve as prey to many larger animals, including birds, insects and insect larvae, bugs, beetles, water fleas, copepods, nematodes, carnivorous plants, fungi, and other rotifers. ("Rotifera", 2012; Brusca and Brusca, 2003).

Rotifer trophi types

Malleate: Similar to the malleoramate type: fulcrum short, rami more or less triangular or lyriform, in a straight angle with the fulcrum. The unci plates have several teeth, but generally less than in the malleoramate type (4-12 teeth), and the connection between the teeth is more strongly developed. The manubria are provided with a shaft, which is typically fairly short (more elongate in the submalleate trophi of Lecanidae and some Proalidae).

Malleoramate: Fulcrum short, rami more or less triangular, flat; unci teeth numerous, occasionally resembling striations; manubria crescent-shaped, without shaft.

Uncinate: Similar to the malleoramate type, but all trophi elements except the unci strongly reduced. Unci teeth few (2-5 teeth per uncus), elongate and curved supporting rods for the mastax. In Atrochidae and Collothecidae

Virgate: Fulcrum elongate, rami bent towards dorsally, unci with few teeth or reduced, and manubria mostly with elongate shafts. The virgate trophi type is the most variable of all trophi types; occasionally it is asymmetrical (e.g., *Trichocerca*). Virgate trophi occasionally consist of thin, hence hardly discernable elements (e.g., many Synchaetidae).

Forcipate: Fulcrum mostly short, rami elongate, long pincers usually armed with anterior and median teeth. Unci strong, but with a single or few teeth only, dagger- or sword shaped. Manubria long, thin, often with intramallei. In Dicranophoridae and Ituridae.

Incudate: Fulcrum short, rami elongate, pincer-shaped. Manubria and unci stronglyreduced.InAsplanchnidae(Figure4).

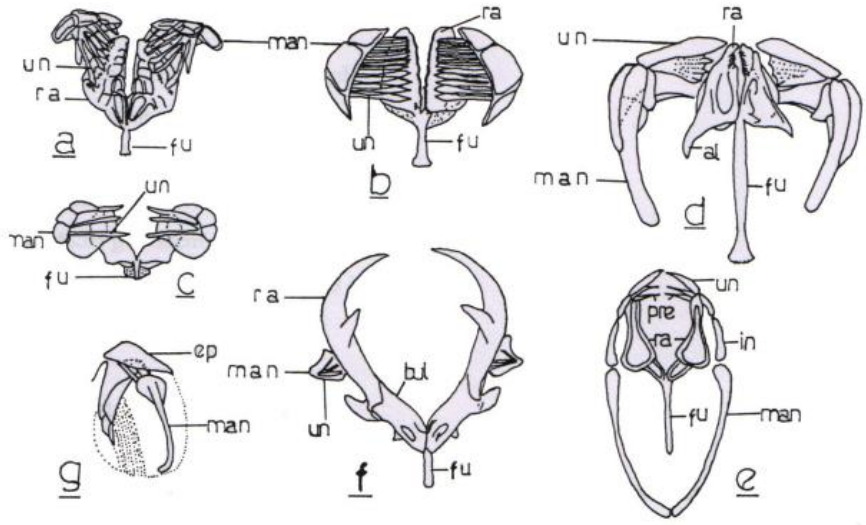


Figure 4. a. malleat type, b. malleoramate type, c. uncinate type, d. virgate type, e. forcipate type, f. incudate type, un. unkus, ra. ramus, fu. fulkrum, man. manibrium, al. alua, bul. bulla, in. intramallei, prepreunkal (Koste 1974).

Preparation of the trophi structure of loricate rotifers for Scanning Electron Microscopy (Sem):

- A single individual, identified from samples collected in the field and containing 4% formaldehyde, is placed on a microscope slide,
- First take a photograph of the general shape of an individual that has been taken on a microscope slide or make a note of some details,
- Wash the individual about 10 times with distilled water (distill 1 drop on the individual and remove the water),
- Dividing a lamella measuring 18 x 18 mm into 4 equal parts,
- Place the washed specimen on a piece of the cover slip that has been divided into 4 equal parts,
- The location of the individual should be marked and circled with a glass pencil, and the part outside the circle should be coloured with a glass pencil (the individual's SEM). The other parts are coloured to make them easier to find in a scanning electron microscope).

- Placement of the coverslip piece on the stap and gold plating (suitable pieces of carbon paper were cut and glued to the stap, then a suitable size lamella piece are placed on the prepared stap and placed in the gold plating device).
- After gold-plating, the individual was located in the SEM and images are taken at the desired angles and magnifications (after 30 seconds of gold-plating, samples are placed in the holder and placed in the electron microscope, images are taken after 15-20 minutes of vacuuming),
- The recorded images were burned onto a CD storage medium.

Preparation of the trophi structure of semi-loricate or illoricate rotifers for Scanning Electron Microscopy (Sem):

- A single individual, identified from samples collected in the field and containing 4% formaldehyde, is placed on a microscope slide,
- First take a photograph of the general shape of an individual that has been taken on a microscope slide or make a note of some details,
- Wash the individual about 10 times with distilled water (distill 1 drop on the individual and remove the water),
- Dividing a lamella measuring 18 x 18 mm into 4 equal parts,
- Cover one of the coverslips, divided into 4 equal parts, by dropping a drop of glycerine on a microscope slide (the glycerine allows the structure of the trophies on the coverslip to be seen more clearly).
- The washed specimen is placed on a coverslip which is covered with glycerol,
- Under the microscope, drop 1 drop of NaOCI (bleach) onto the washed individual and wait for all parts of the individual to melt, except for the trophi,
- Repeatedly wash the trophy structure with distilled water to remove crystallisation from the individual whose other parts have melted, leaving only the trophy structure.
- After washing is completed, use the capillary dissecting needle to position the trophic structure as desired,
- The location of the trophy structure should be marked and circled with a glass pencil. The area outside the circle should be coloured with a glass pencil,
- Placing the cover slip on the stap and gold plating
- After gold-plating, the individual was located in the SEM and images are taken at the desired angles and magnifications (after 30 seconds of

gold-plating, samples are placed in the holder and placed in the electron microscope, images are taken after 15-20 minutes of vacuuming),

- The recorded images were burned onto a CD storage medium (Bulut, 2014).

References

Brusca, R., & Brusca, G. (2003). *Invertebrates (2nd Edition)*. Sunderland, MA: Sinauer Associates.

Bulut, H. (2014). Malatya İlindeki Maryap, Kaldırım ve Halikan Göletleri Zooplanktonu, Fırat Üniversitesi Fen Bilimleri Enstitüsü, Doktora Tezi,184s.

Fontaneto, D., De Smet, W.H., & Melone, G. (2008). Identification Key to the Genera of Marine Rotifers Worldwide, Meiofauna Marina, 16 (2008) 75-99.

Fontaneto, D., & De Smet, W.H. (2015). Chapter 4 -Rotifera In book: Handbook of Zoology, Gastrotricha, Cycloneuralia and Gnathifera, Volume 3, Publisher: de Gruyter Editors: Andreas Schmidt-Rhaesa 217- 300s.

Gannon J.E. & Stemberger R.S. (1978). Zooplankton (especially crustaceans and rotifers) as indicators of water quality. Trans. Am. Microsc. Soc. 97 (1): 16–35.

Hickman, Jr., Roberts, L.S., Keen, S.L., Eisenhour, D.J., Larson, A., & I'Anson, H. (2014). Zooloji Entegre Prensipler, 16. Baskıdan Çeviri, Çeviri Ed. Ertunç GÜNDÜZ, Palme Yayıncılık, Ankara, 2014.

Hyman, L. (1951). The Invertebrates, volüme III; Acanthocephala, Aschelminthes and Entoprocota. Ew York, McGraw Hill.

Koste, W. (1974) Rotatorien aus einem Ufersee des unteren Rio Tapajos dem Lago Paroni (Amazonien). Gewass. Abw£iss. 53, 43-68.

"Rotifera" 2012. (On-line). Encyclopedia of Life. Accessed March 14, 2013 at http://eol.org/pages/6851/overview.

Ruppert, E.R., & Fox, R.B. (2004). *Invertebrate zoology: A functional evolutionary approach (7th Edition)*. Belmont, CA: Thomson-Brooks/Cole.

Saler, S., 2009. Rotıfers of Kepektas Dam Lake (Elazıg-Turkey). Iranian Journal of Science & Technology, Transaction A, Vol. 33, No. A1

Segers, H. (2007). Annotated checklist of the rotifers (Phylum Rotifera), with notes on nomenclature, taxonomy and distribution. *Zootaxa*, 1564, 1-104. Accessed March 14, 2013 at http://www.mapress.com/zootaxa/2007f/zt01564p104.pdf.

Wallace, R. (2002). Rotifers: exquisite metazoans. *Integrative and Comparative Biology*, 42/3, 660-667.

Wallace, R.L. & Snell. T.W. (2001). Rotifera. Chapter 8. In Ecology and classifications of North American freshwater invertebrates, 2nd

edition. pp 173–235. (J. Thorp and A. Covich, eds.). Elsevier Inc., Amsterdam. T

Wallace, R.L. & Snell, T.W. (2010). Rotifera. Chapter 8. In: Ecology and Classifications of North American Freshwater Invertebrates, 3rd edition. pp 173–235. (Jim Thorp and Alan Covich, eds.) Elsevier. Oxford. D

Zhang, Z. (2011). Animal biodiversity: an introduction to higher-level classification and taxonomic richness. *Zootaxa*, 3148, 7-12.

Chapter 13

A Review For Ecotoxicological Assessment Of Microplastics İn Aquatic Ecosystems

Selin ERTÜRK GÜRKAN[1]

Abstract

Microplastics (MPs) can be found in nature in a wide range of shapes and forms, leading to diverse distribution patterns. Their presence in both biotic and abiotic sources is well-known, and the analysis of microplastics in these environments is crucial for conducting risk assessments of this emerging environmental pollutant. In this context, since the identification of MPs, their abundance in nature, pathways of ingestion by living organisms, and potential effects on organisms have been extensively researched and are still under investigation. This study compiles some research evaluating the presence of MPs in aquatic ecosystems (sea and freshwater) and aquatic organisms, as well as the mechanisms of impact on living organisms. The hope is that this review will contribute to more comprehensive and solution-oriented studies, allowing us to monitor the ecological outcomes of microplastics more effectively.

Keywords: Microplastics, sea, freshwater, aquatic organisms

Introduction

It is a well-known fact that environmental pollution can lead to potential adverse effects on the health of organisms through the imbalances it causes in the ecosystem. Plastics have gained significant importance among pollutants with their exponential increase in the production chain to meet the continuously growing demands (Kunwar et al., 2016; Lombardo et al., 2022). Plastic is typically composed of synthetic, high-molecular-weight organic polymers resulting from the polymerization of derivatives of petroleum, gas, or coal. Following the initial production of plastic materials, a range of plastic types emerged that are lightweight, durable, malleable, and resistant to heat. Over time, these plastic varieties have become fundamental factors in various industrial sectors and the production chain (Ivleva et al., 2017). Research addressing the entry of plastic residues, especially into aquatic ecosystems, and discussing the scale and scope of production efforts to increase the dimension of plastic usage

[1] Faculty of Science, Biology Department, Çanakkale Onsekiz Mart University
serturk@comu.edu.tr

has been available since the 1970s (Carpenter and Smith, 1972). Today, plastics have become an integral part of modern life and a prominently consumed material. To the extent that the global production quantity now exceeds 300 million tons annually (PlasticsEurope, 2015). The tragic part of the matter is that approximately 50% of plastic products are used only once. After use, leaving them as waste in the ecosystem results in a significant and inescapable burden of waste (Waters et al., 2016; Galloway et al., 2017).

While the rate of plastic production in Europe has been restrained in the last 20 years, it has globally increased, reaching 311 million metric tons in 2014. This figure includes only thermoplastics, thermosets, adhesives, coatings, and seals. Unfortunately, 2014 data also indicates that only 69.2% of plastics are recycled (29.7%) or energy recovered (39.5%) (PlasticsEurope, 2015). The remaining plastic waste is transported to landfill sites, where some of it disperses through physical factors such as wind and rain. Due to the long-lasting nature of plastic degradation (Barnes et al., 2009), its accumulation in marine (Cole et al., 2011; Costa et al., 2010; do Sul et al., 2014), freshwater (Dris et al., 2015; Eerkes-Medrano et al., 2015), and terrestrial (Huerta Lwanga et al., 2016) ecosystems is a scientific and public concern (Ivleva et al., 2017).

At the international level, there is still no consensus on the definition and classification of microplastics, often leading to the comparison of data in an uncertain manner (Hartmann et al., 2019). Until now, the general consensus is that the size of microplastics (MPs) is limited to a minimum of 1 micrometer (Frias et al., 2018); however, there is still a debate about the maximum size that can be considered for microplastics (Pittura et al., 2022). Although all sizes smaller than 10 mm are generally considered as microplastics (MP) within plastic waste (Graham and Thompson, 2009; Ryan et al., 2009; Browne et al., 2011), Andrady (2011) defined microplastics (MPs) as plastics with a diameter of less than 5 mm and the most commonly used definition of MP with a diameter of 1-5 mm, setting the upper limit at 5 mm (Barnes et al., 2009; Hidalgo-Ruz et al., 2012; Cole et al., 2014; do Sul et al., 2014). To understand the pathways of interaction of microplastics, it is crucial to comprehend the dynamism inherent in their structure. As microplastics undergo continuous changes in size, shape, and other characteristics over time, their biological status and accessibility will likewise undergo corresponding variations. The prevailing consensus suggests that microplastics primarily result from the abrasion of larger plastic waste over time (Bergmann et al., 2015; Galloway et al., 2017). Microplastics are categorized into primary and secondary microplastics. Primary microplastics include those that are already produced in micro size in various forms, while secondary microplastics encompass all microplastic particles formed in the

environment as a result of the gradual breakdown of macro-sized plastics. This process can occur in a variety of environments, ranging from marine and freshwater ecosystems to terrestrial ecosystems (Andrady, 2011; Cole et al., 2011; do Sul and Costa, 2014; Zhang et al., 2019), through various external factors such as UV radiation, bacteria, or friction (Pittura et al., 2022).

According to Van Sebille et al., (2016), the primary sources of microplastics are illegal waste discharge (plastic waste disposed of or inadequately managed in the environment) and insufficient waste management. Jambeck and colleagues (2015) claimed that 20 out of 192 countries with coastlines are responsible for 80% of the plastics dumped into the world's oceans. Sixteen of these 20 countries, such as China, Indonesia, and the Philippines, are low to upper-middle-income countries experiencing rapid economic growth but struggling with poorly organized waste management (Prokić et al., 2019).

While the full extent of the impact of microplastics (MP) on public health is not yet fully understood, there is a substantial body of research and an increasing number of reports documenting the negative effects of MPs on marine and freshwater biota. This study compiles research that evaluates the potential adverse effects of the presence of microplastics on organisms in aquatic ecosystems to date.

Abundance of Microplastics in Aquatic Environment

Microplastics can float or settle to the bottom depending on the type of polymer they contain. This explains their presence in both the water surface, water column, and sediment (Anderson et al., 2016; Smith et al., 2018; Choi et al., 2020). Additionally, they possess surface characteristics that facilitate easy binding of chemical pollutants; especially due to the high content of hydrophobic materials in their structure, they can act as carriers, particularly for hydrophobic pollutants (Cole et al., 2011; Prokić et al., 2019). In this way, they can enhance the adverse effects of different chemicals in the environment. Among the factors that significantly determine the absorption capacity of microplastics for chemical substances are physicochemical properties such as chemical content, color, surface shape, and size (Prokić et al., 2019). Therefore, in an aquatic ecosystem, microplastics can exist on their own, but they can also act like a toxic cocktail by carrying organic matter and chemical pollutants or accumulating bacteria (Zhang et al., 2017; Tang et al., 2018).

The primary sources of microplastic entry into aquatic ecosystems are industrial or domestic discharges, but they can also enter the ecosystem in significant amounts through cosmetics, cleaning products, and other components (Oliveira et al., 2013; da Costa et al., 2016; Auta et al., 2017; Frias and Nash,

2019; Hamed et al., 2022). For instance, much of the equipment used in aquaculture facilities is still made of plastic polymers (Huntington, 2019). Moreover, significant amounts of plastic and non-plastic materials can naturally enter aquatic ecosystems during aquaculture activities through accidental abandonment, loss, or indiscriminate disposal (Lusher et al., 2017; Sandra et al., 2019). Considering that plastic waste resulting from aquaculture activities in Europe could range from 5,933 to 19,622 tons per year (Viool et al., 2018), the severity of the situation becomes evident. In addition to the presence of plastics in sediments resulting from aquaculture activities (Krüger et al., 2020), it has been observed that fish in aquaculture areas have higher rates of plastic ingestion compared to offshore (Ory et al., 2018; Savoca et al., 2021).

The first investigations into the presence of microplastics and the pollution they cause date back to the 1970s (Carpenter and Smith, 1972; Carpenter et al., 1972). Only a few study reports on plastic pollution at this small particle size were published initially, and subsequently, very few similar studies were conducted (Gregory, 1977, 1978; Shiber, 1979; Ryan, 1988; Khordagui and Abu-Hilal, 1994; Shaw and Day, 1994). As we entered the 2000s, findings of resurging plastic pollution made it a significant research topic up to the present day (Moore et al., 2001a, b, 2002). Indeed, during this period, a 22-year monitoring study was conducted in the North Atlantic (Law et al., 2010). Research on the detection of microplastic pollution and its presence in aquatic systems has predominantly focused on marine ecosystems (Table 1). In these studies, it has been revealed that microplastics are commonly found in water, sediment, and biota. Considering the potential threat of microplastics to the continuity and health of marine ecosystems, every piece of information gained regarding the abundance and quantity of microplastics in marine systems is crucial (Zhang et al., 2019).

Table 1. Studies on the presence of microplastics in aquatic ecosystems

Reference	Region	Sampling type	MPs type
Marine environment			
Galil et al., 1995	Mediterranean Sea	Sediment	Plastic litter
Galgani et al., 1995	Mediterranean Sea	Sediment	Plastic debris
Stefatos et al., 1999	Greek Gulfs	Sediment	Plastic debris
Galgani et al., 2000	European Seas	Sediment	Plastic litter
Aliani & Molcard, 2003	Ligurian Sea	Biota	Plastic bags, plastic debris
Katsanevakis & Katsarou, 2004	Mediterranean Sea	Sediment	Plastic debris
Tonay et al., 2007	Black Sea	Biota	Plastic debris
Akoumianaki et al., 2008	Saronikos Gulf	Biota	Plastic litter

Koutsodendris et al., 2008	Greek Gulfs	Sediment	Plastic litter
Graham & Thompson, 2009	Florida	Biota	Plastic fragments
Galimany et al., 2009	Mediterranean Sea	Biota	Fiberglass
Boerger et al., 2010	Pacific	Biota	Plastic fragments
Topçu & Öztürk, 2010	Black Sea	Sediment	Plastic litter
Murray & Cowie, 2011	Clyde Sea	Biota	Plastic strands
Ramos et al., 2012	Brasil	Biota	Nylon fragment
Ramirez-Llodra et al., 2013	Mediterranean Sea	Sediment	Plastic litter
Anastasopoulou et al., 2013	Ionian Sea	Biota	Plastic fragments, Textile fibers
Sánchez et al., 2013	Mediterranean Sea	Sediment	Plastic litter
Collignon et al., 2014	Corsica	Biota	Filament, PS, film
Pham et al., 2014	European Seas	Sediment	Plastic litter
Van Cauwenberghe & Janssen, 2014	North Sea	Biota	Fibre- and particle-shaped
Eryaşar et al., 2014	Mersin-Turkey	Sea water-Sediment	Plastic debris
Bellas et al., 2016	Mediterranean Sea	Biota	Different types of MPs
Remy et al., 2015	Corsica	Biota	Cellulose fibers
Collard et al., 2015	Atlantic	Biota	PP
Romeo et al., 2015, 2016	Mediterranean Sea	Biota	Plastic debris
Battaglia et al., 2016	Mediterranean Sea	Biota	Plastic debris
Suaria et al., 2016	Tyrrhenian Sea	Sea water	Synthetic polymers
Fastelli et al., 2016	Tyrrhenian Sea	Sediment	Plastic litter
Nadal et al., 2016	Balearic Basin	Biota	Filament
Rummel et al., 2016	North & Baltic Sea	Biota	PE
Cartes et al., 2016	Balearic Basin	Biota	Trawl nets fragment
Gusmão et al., 2016	Atlantic	Biota	Microfiber
Gündoğdu, 2017	İskenderun Bay	Sediment	Fragment
Guerranti et al., 2017	Tyrrhenian Sea	Sediment	Plastic litter
Cannas et al., 2017	Tyrrhenian Sea	Sediment	Plastic litter
Güven et al., 2017	Mediterranean Sea	Biota	Fibers, hard plastic nylon, rubber
Karlsson et al., 2017	North Sea	Sediment-Biota	PE, PP, PS
Avio et al., 2017	Tyrrhenian Sea	Biota	PP lines, PS
Morgana et al., 2018	Arctic Ocean	Sea water-biota	PE, PP, PVC, PS
Xu et al., 2018	East China Sea	Sea water	PVC
Baini et al., 2018	Tyrrhenian Sea	Sea water	PE, PP
Hipfner et al., 2018	Pacific Ocean	Biota	Microfibres

Digka et al., 2018	Mediterranean Sea	Biota	PE, PP, PVC, PS, PET
Cincinelli et al., 2019	Mediterranean Sea	Sea water	Plastic debris
Caldwell et al., 2019	Tyrrhenian Sea	Sea water	fragment, film, lines
Mohsen et al., 2019	Yellow Sea	Sediment-Biota	Polyester, PE, PP, PVA
Renzi et al., 2019	Salina Island	Sediment-Biota	Plastic litter
Valente et al., 2019	Tyrrhenian Sea	Biota	Marine litter
Bottari et al., 2019	Tyrrhenian Sea	Biota	Fibers
Doğruyol et al., 2019	Golden Horn Estuary	Sediment	Plastic debris
Giani et al., 2019	Tyrrhenian Sea	Biota	Fibers
Mancuso et al., 2019	Tyrrhenian Sea	Biota	Black Fibers
Cau et al., 2019	Tyrrhenian Sea	Biota	fragment, films, pellet
Yabanlı et al., 2019	Aegean-Mediterranean	Sediment	Fragment
Zhang et al., 2019	China Sea	Biota	Fibers, Polyester
Erni-Cassola et al., 2019	Meta-analysis	Sea water	-
Savoca et al., 2019, 2020	Tyrrhenian Sea	Sea water- Biota	Nylon 66
Mistri et al., 2020	Tyrrhenian Sea	Sediment	Filaments
Gedik & Eryaşar, 2020	Mediterranean Sea	Biota	PET, PE, PP
Piazzolla et al., 2020	Tyrrhenian Sea	Sediment	Microlitter
Missawi et al., 2020	Tyrrhenian Sea	Sediment-Biota	PE
Capillo et al., 2020	Tyrrhenian Sea	Biota	Synthetic microfibers
Gündoğdu et al., 2020	Turkish coasts	Biota	PP, PE, PET, polyester
Sbrana et al., 2020	Tyrrhenian Sea	Biota	PE, PP, PS
Coyle et al., 2020	Review	Biota	-
Hidalgo-Ruz et al., 2020	Marmara Sea	Sediment	PS
Yozukmaz et al., 2021	Aegean Sea	Sea water-Biota	Fiber, fragment, film
Vecchi et al., 2021	Tyrrhenian Sea	Biota	Fiber, fragment, film
Erkan et al., 2021	Marmara Sea	Sediment	PE, PP, PET, PVC, PA, PS
Çullu et al., 2021	Marmara Sea	Sea water	PE
Wang et al., 2021	Review	Sea water	-
Ben Ismail et al., 2022	Tyrrhenian Sea	Biota	PE, PP, PS, PVA
Capparelli et al., 2022	Gulf of Mexico	Sediment-Biota	Fiber, fragment
Acar et al., 2022	Çanakkale Strait	Biota	Filament
Lombardo et al., 2022	Eivissa	Biota	Fiber, fragments

Kılıç et al., 2022	İskenderun Bay	Biota	PE, PA, Polyester
Şener & Yabanlı, 2023	Aegean Sea	Sediment	PP, PE, PVC, PS, polyester
Ergün et al., 2023	Aegean Sea-Persian Gulf	Biota	Microlitter
	Freshwater environment		
Zbyszewski & Corcoran, 2011	Great Lakes, Canada	Freshwater	Pellets, fragment, PS
Moore at al., 2011	California rivers	Freshwater	Plastic debris
Alencastro, 2012	Lake Geneva	Freshwater	Pellets, PS, fiber
Eriksen et al., 2013	Great Lakes, USA	Sediment	Plastic debris
Lechner et al., 2014	Danube	Freshwater	Plastic litter
Yonkos et al., 2014	Chesapeake Bay, USA	Freshwater	Plastic debris
Free et al., 2014	Lake Hovsgol	Sediment	Plastic debris
Castañeda et al., 2014	St. Lawrence River	Sediment	Microbeads
Rech et al., 2014	Chilean Rivers	Sediment	Plastic litter, PS
Klein et al., 2015	Rhine-Main	Sediment	PE, PP, PS, PA
Faure et al., 2015	Swiss lakes	Sediment	PE, PP, PS
Mani et al., 2015	Rhine River	Freshwater	Plastic debris
Imhof et al., 2016	Lake Garda	Sediment	PE, PP, PS, PVC, PA
Peng et al., 2017	Changjiang Estuary	Sediment	Fiber
Schmid et al., 2018	Amazon River	Biota	Pellet
Acar &Ateş, 2018	Çanakkale Strait	Biota	Fiber
Çomaklı et al., 2020	Erzurum Crater Lake	Freshwater	PP, PE
Turhan, 2021	Sürgü Dam Reservoir	Water-Sediment-Biota	PET, PP
Atici et al., 2021	Lake Van	Biota	PE, PP
Almas et al., 2022	Susurluk Basin	Sediment	Fiber
Gedik & Atasaral, 2022	Turkish Lakes	Sediment-Biota	PET
Yücel & Kılıç, 2022	Seyhan River	Biota	Fiber
Gündoğdu et al., 2023	Munzur-Pülümür River	Sediment	PE, PS, PP

PE: Polyethylene, PP: Polypropylene, PS: Polystyrene, PVC: Polyvinyl chloride, PV: Polyvinyl, PA: Polyamide, PVA: Polyvinyl acetate, PET: Polyethylene terephthalate

The Effects of Microplastics on Aquatic Organisms

The environmental burden of microplastics is influenced not only by anthropogenic sources but also by environmental factors (Eerkes-Medrano et al., 2015; Aliko et al., 2022; Multisanti et al., 2022). However, the primary pathways for the entry of microplastics into aquatic ecosystems, especially freshwater systems, are poorly filtered surface waters and poorly managed wastewater (Free

et al., 2014). The most crucial factors determining the fate of microplastics entering aquatic environments are their density; depending on microplastic density, they will either remain suspended in the water column or sink to the bottom. In either case, they will be ingested by non-target organisms that perceive them as prey (Wang et al., 2021).

The size range of microplastics allows them to be consumed by almost every aquatic organism with different feeding habits and even at different trophic levels. Therefore, microplastics can enter the food chain and accumulate at higher trophic levels (Cole et al., 2013; Imhof et al., 2013; Wright et al., 2013b). The impact of microplastics on aquatic organisms can be expressed in three steps: (1) damage to the digestive system or hindrance of nutrient intake, (2) incorporation of these particles into tissues, and (3) transportation of other potential pollutants that may be present with microplastics (Cole et al., 2011). Modern plastics are typically structured as polymers, with a complex composition that can include chemical additives as well as bacteria and organic matter. The transfer of these substances to animal tissues allows various potentially harmful plastic additives and chemicals transported by persistent water to penetrate tissues. These substances can intervene in metabolic processes by facilitating signal transmission activation in tissues (Galloway, 2015; Koelmans et al., 2016; Galloway et al., 2017). Of course, at this point, the damage that microplastic pollution can cause in aquatic organisms will vary depending on the plastic uptake mechanism, excretion rate, and individual digestive physiology (Hakanson, 1984; Hamed et al., 2022). The uptake of microplastics (MPs) by organisms in aquatic ecosystems can occur either directly or indirectly (Nelms et al., 2018). Direct ingestion may occur randomly, as seen in filter-feeding organisms, or it can happen when plastics are mistakenly consumed as food. Indirect plastic intake can progress through the transfer of MPs along food webs. Some studies have shown that the intestines of juvenile fish contain a higher concentration of plastics compared to adults, which could be associated with a greater risk (Kühn and van Franeker, 2012; Prokić et al., 2019).

In the early studies assessing the effects of microplastics on aquatic organisms, it was reported that more than 690 marine species were affected by marine litter (Gall and Thompson, 2015), with substantial amounts of microplastics found in some of these species (Murray and Cowie, 2011; Lusher et al., 2013). However, researchers later shifted their focus from identifying the presence of microplastics in animals to determining the physiological and health impacts of microplastic digestion (Rochman et al., 2013; Wright et al., 2013a; Cole et al., 2013, 2014; Pedà et al., 2016; Alomar et al., 2017, 2021; Wieczorek et al., 2018; Berglund et al., 2019; detailed in Haegerbaeumer et al., 2019; Hara et al., 2020; Solomando

et al., 2020; Rios-Fuster et al., 2021). When de Sa et al. (2018) examined field and laboratory studies on the impact of microplastics (MPs), they noted that fish were the most extensively studied group, accounting for 44%, followed by crustaceans (21%), mollusks (14%), and annelids (6%). Some studies about effects of MPs on aquatic invertebrates and vertebrates were presented in Table 2 and 3.

The effects of microplastics (MPs) on organisms, like other environmental pollutants, will certainly yield speculative results when directly assessed at the ecosystem level (Galloway et al., 2017). However, this impact is a concern that cannot be ignored. Behavioral changes, physiological alterations, and ecological processes are significant links in individuals' responses to any situation, serving as indicators of the same system. Understanding the ecological impact of MPs involves observing how individuals' behaviors, such as predator-prey relationships, feeding strategies/habits, digging, and guidance, are altered (Weis, 2014).

Table 2. *in vitro* Studies about MPs effect on aquatic invertebrates

Reference	**Organisms**	**MPs type**	**The effects**
Browne et al., 2008	*Mytilus edulis*	florescence-labeled PS	Translocation in hemolymph
Von Moos et al., 2012	*M. edulis*	PE	Cellular damage
Cole et al., 2013	Zooplankton	PS spheres	Uptake of MPs
Wright et al., 2013a	*Arenicola morina*	PVC	Energy reserves
Lee et al., 2013	*Tigriopus japonicus*	PS	Toxicity
Farrell and Nelson, 2013	*M. edulis* *Carcinus maenas*	Florescent PS	Trophic transfer of MPs
Kaposi et al., 2013	*Tripneustes gratilla*	PE	Growth
Hämer et al., 2014	*Idotea emarginata*	Microbeads	Digestive system
Cole et al., 2015	*Calanus helgolandicus*	PS	Feeding, function, fecundity
Watts et al., 2015	*C. maenas*	PP	Food consumption, Energy balance
Cole and Galloway, 2015	*Crassostrea gigas*	PS	Larval feeding-growth
Jeong et al., 2016	*Brachionus koreanus*	PS microbeads	Toxicity, oxidative stress
Paul-Pont et al., 2016	*Mytilus spp*.	PS	Toxicity
Rist et al., 2016	*Perna viridis*	PVC	Survival
Ogonowski et al., 2016	*Daphnia magna*	Fluorescent microbeads	Survival
Welden & Cowie, 2016	*Nephrops norvegicus*	PP	Gut morphology

Green, 2016	*Ostrea edulis*	PP	Respiration-Filtration rates
Sussarellu et al., 2016	Pacific oyster	PS	Oocyte morphology
Blarer and Burkhardt-Holm, 2016	*Gammarus fossarum*	PA	Digestive system
Setälä et al., 2016	*Mytilus trossulus* *Gammarus* spp. Mysid shrimps	Ps beads	MPs uptake
Ribeiro et al., 2017	*Scrobicularia plana*	PS	Oxidative stres, Genotoxicity
Santana et al., 2017	*Perna perna*	PVC	Digestive system
Magara et al., 2018	*M. edulis*	PE	Oxidative stress response
Tang et al., 2018	*Pocillopora damicornis*	PS	Toxicity, Oxidative stress, Molecular responses
Revel et al., 2019	*Mytilus spp.*	PE, PP	Tissue damage
Choi et al., 2020	*Tigriopus japonicus*	PS	Toxicity, Oxidative stress
Katsumiti et al., 2021	*Mytilus galloprovincialis*	PS	Cell viability, Toxicity
Liu et al., 2022	*Apostichopus japonicus*	PS	Growth performance, immune response
Alomar et al., 2022	*Sparus aurata* *M.galloprovincialis*	PE, PP	Growth performance, Food consumption
González-Soto et al., 2022	*M.galloprovincialis*	PS beads	Enzyme activity DNA damage
Porter et al., 2022	*Hediste diversicolor*	PA	MPs uptake

PE: Polyethylene, PP: Polypropylene, PS: Polystyrene, PVC: Polyvinyl chloride, PV: Polyvinyl, PA: Polyamide, PVA: Polyvinyl acetate, PET: Polyethylene terephthalate

Table 3. *in vitro* Studies about MPs effect on aquatic vertebrates

Reference	**Organisms**	**MPs type**	**The effects**
Katsanevakis et al., 2007	*Serranus hepatus* *Gobius geniporus*	Nylon line	MPs uptake
Cedervall et al., 2012	*Salmo salar* *Carassius carassius*	PS	Behaviour metabolism
Oliveira et al., 2013	*Pomatoschistus microps*	Pyrene	Oxidative stress
Avio et al., 2015	*Mugil cephalus*	PE, PS	MPs ingestion
Mazurais et al., 2015	*Dicentrarchus labrax*	PE	Mortality rates, Growth
Mattsson et al., 2015	*Daphnia magna* *C. carassius*	PS	Behaviour metabolism
Greven et al., 2016	*Pimephales promelas*	PS, PC	Immune system

Peda et al., 2016	*D. labrax*	PVC	Digestive system
Khan et al., 2017	*Oncorhynchus mykiss*	PE	Digestive system
Espinosa et al., 2018	*D. labrax* *Sparus aurata*	PVC, PE	Immune system
Ding et al., 2018	*Oreochromis niloticus*	PS	Toxicity
Espinosa et al., 2019	*D. labrax*	PE	Oxidative stress
Pannetier et al., 2019	Fish cell line	PE, PP	Toxicity
Roch et al., 2020	*O. mykiss* *Thymallus thymallus* *C. carassius* *Cyprinus carpio*	PE, PP, PET, PS, PVC	MPs uptake
Ahrendt et al., 2020	*Girella laevifrons*	PS	Immune system
Huang et al., 2020	*Poecilia reticulata*	PS	Growth, Immune system
Batel et al., 2020	*Danio rerio*	PE	Toxicity, Oxidative stress
Zwollo et al., 2021	*O. mykiss*	PS	B cell development
Norland et al., 2021	*Clupea harengus*	PS, PE	Digestive system
Rios-Fuster et al., 2021	*S. aurata*	PE	Physiology, Behaviour
Kaloyianni et al., 2021	*D. rerio* *Perca fluviatilis*	PS	Toxicity
Bunge et al., 2021	*Gasterosteus acuelatus*	Fibers	Growth
Salimi et al., 2022	not reached	PVC	Toxicity
Hasegawa et al., 2022	*Myoxocephalus brandti*	PE	Trophic transfer
Solomando et al., 2022	*Seriola dumerili*	Fibers Fragment	Oxidative stress
Ito et al., 2022	*Pagrus major* *Fundulus heteroclitus*	PE	Digestive system
Seeley et al., 2023	*Spartina alterniflora*	PS	Mortality rate
Boháčková et al., 2023	*O. mykiss*	PET, PVC	Cell lines
Hollerova et al., 2023	*O. mykiss*	PS	Oxidative stress
Chen et al., 2023	*D. rerio*	Fibers	Digestive system
McCormick et al., 2023	*Acanthochromis polyacanthus*	DEHP, DEHT	Toxicity
Mtega et al., 2023	*O. niloticus*	PE, PP, PVC, PET	Toxicity
Zhang et al., 2023	*D. rerio*	PA, PS	Growth, Immune System
Kim et al., 2023	*Carassius auratus*	Microfiber	Antioxidant responses

PE: Polyethylene, PP: Polypropylene, PS: Polystyrene, PVC: Polyvinyl chloride, PV: Polyvinyl, PA: Polyamide, PVA: Polyvinyl acetate, PET: Polyethylene terephthalate, PC: Polycarbonate, DEHP: di-2-ethylhexyl phytalate, DEHT: di-2-ethylhexyl terephytalate

Predictions on the Fate of Microplastics

The presence of microplastics has led to a series of studies, especially focusing on the status, distribution, and quantity of these particles in aquatic ecosystems. Currently, ongoing research is gaining significant momentum in assessing how and to what extent microplastics enter aquatic organisms, and even in evaluating the adverse effects of these particles on living organisms. Particularly, data obtained from living organisms can provide fundamental information to assess the spatial and temporal presence of microplastics in the environment and even their potential impacts on marine ecosystems. However, at this point, it is crucial to monitor and evaluate microplastic pollution with a more comprehensive perspective that includes not only possible physiological, toxicological, or genetic effects on bioindicator species but also abiotic factors.

One of the fundamental issues that may create a contradiction is whether microplastics can be evaluated just like other environmental pollutants. Measures taken for other environmental pollutants generally involve restricting their use, and most of the time, these measures are sufficient. However, achieving control over microplastics, independent of their different surface area compared to other pollutants, organic matter, and even bacteria, does not seem feasible (Diamond et al., 2015; Galloway et al., 2017). With all these features, microplastics continue to enter ecosystems as a continuous anthropogenic agent on a global scale.

Efforts to prevent global microplastic pollution should be based on various strategies, including international cooperation, policy regulations, industry standards, and increasing awareness among consumers. For example, global agreements and protocols can be developed, participation in these agreements can be encouraged, and international standards can be established. Stricter standards and regulations should be set for plastic manufacturers and other industries. These standards should focus on reducing microplastic production and making plastic products more environmentally friendly. It is essential to encourage the use of environmentally friendly materials instead of plastic. The development and use of biodegradable materials and plastic alternatives should be supported. Efforts should be made to target the reduction of plastic waste by creating more effective recycling systems. Strategies based on circular economy principles should be developed to promote the use and recycling of products throughout their lifecycle. Measures should be taken to improve water treatment facilities and wastewater discharge standards to prevent microplastic pollution in seas and water sources. Detection and cleaning technologies for plastics should be developed to increase the capacity to monitor and remove microplastics in water systems and oceans. Raising awareness among communities about microplastic pollution is crucial. Through educational campaigns and awareness activities, individuals,

consumers, and businesses can become more conscious of microplastic pollution. Financial support and incentive mechanisms should be established to encourage the transition to environmentally friendly technologies and business models. This can facilitate the transition to eco-friendly practices and promote sustainable solutions.

These recommendations aim to adopt a global approach to combating microplastic pollution. Without coordination and collaboration on a global level, finding effective solutions to microplastic pollution can be challenging.

References

Acar S., Ateş A. 2018. Presence of microplastics in the stomachs of *Carcinus aestuarii* Nardo, 1857 in Cardak Lagoon, Canakkale Strait, Turkey. Cah Biol Mar 59(5).

Acar S., Gürkan S.E., Ateş A.S., Özdilek Ş.Y. 2022. Presence of microplastics in stomach contents of blue crab *Callinectes sapidus* (Rathbun, 1896) in Canakkale Strait. Agribalkan, 368.

Ahrendt C., Perez-Venegas D.J., Urbina M., Gonzalez C., Echeveste P., Aldana M., ... Galbán-Malagón C. 2020. Microplastic ingestion cause intestinal lesions in the intertidal fish *Girella laevifrons*. Mar Pollut Bull 151: 110795.

Akoumianaki I., Kontolefas P., Katsanevakis S., Nicolaidou A., Verriopoulos G. 2008. Subtidal littering: Indirect effects on soft substratum macrofauna? Mediterr Mar Sci 9(2): 35-52.

Alencastro D. 2012. Pollution due to plastics and microplastics in Lake Geneva and in the Mediterranean Sea. Arch Sci 65: 157-164.

Aliani S., Molcard A. 2003. Hitch-hiking on floating marine debris: macrobenthic species in the Western Mediterranean Sea. In *Migrations and Dispersal of Marine Organisms: Proceedings of the 37 th European Marine Biology Symposium held in Reykjavík, Iceland, 5–9 August 2002* (pp. 59-67). Springer Netherlands.

Aliko V., Multisanti C.R., Turani B., Faggio C. 2022. Get rid of marine pollution: Bioremediation an innovative, attractive, and successful cleaning strategy. Sustainability 14(18): 11784.

Almas F.F., Bezirci G., Çağan A.S., Gökdağ K., Çırak T., Kankılıç G.B., ... Tavşanoğlu Ü.N. 2022. Tracking the microplastic accumulation from past to present in the freshwater ecosystems: A case study in Susurluk Basin, Turkey. Chemosphere 303, 135007.

Alomar C., Sureda A., Capó X., Guijarro B., Tejada S., Deudero S. 2017. Microplastic ingestion by *Mullus surmuletus* Linnaeus, 1758 fish and its potential for causing oxidative stress. Environ Res 159: 135-142.

Alomar C., Sanz-Martín M., Compa M., Rios-Fuster B., Alvarez ´ E., Ripolles V., Deudero S., 2021. Microplastic ingestion in reared aquaculture fish: biological responses to low-density polyethylene controlled diets in *Sparus aurata*. Environ Pollut 116960.

Alomar C., Compa M., Sanz-Martín M., Fagiano V., Álvarez E., Valencia J.M., Deudero S. 2022. A holistic approach to plastic pollution in integrated multi-trophic aquaculture facilities: Plastic ingestion in *Sparus aurata* and *Mytilus galloprovincialis*. Aquac 561, 738666.

Anastasopoulou A., Mytilineou C., Smith C.J., Papadopoulou K.N. 2013. Plastic debris ingested by deep-water fish of the Ionian Sea (Eastern Mediterranean). Deep Sea Res Part I Oceanogr 74: 11-13.

Anderson J.C., Park B.J., Palace V.P. 2016. Microplastics in aquatic environments: implications for Canadian ecosystems. Environ Pollut 218: 269-280.

Andrady A.L. 2011. Microplastics in the marine environment. Mar Pollut Bull 62 (8): 1596-1605.

Atici A.A., Sepil A., Sen F. 2021. High levels of microplastic ingestion by commercial, planktivorous *Alburnus tarichi* in Lake Van, Turkey. Food Addit Contam 38(10): 1767-1777.

Auta H.S., Emenike C.U., Fauziah S.H. 2017. Distribution and importance of microplastics in the marine environment: a review of the sources, fate, effects, and potential solutions. Environ Int 102: 165-176.

Avio C.G., Gorbi S., Regoli F. 2015. Experimental development of a new protocol for extraction and characterization of microplastics in fish tissues: first observations in commercial species from Adriatic Sea. Mar Environ Res 111: 18-26.

Avio C.G., Cardelli L.R., Gorbi S., Pellegrini D., Regoli F. 2017. Microplastics pollution after the removal of the costa Concordia wreck: first evidence from a biomonitoring case study. Environ Pollut 227: 207-214.

Baini M., Fossi M.C., Galli M., Caliani I., Campani T., Finoia M.G., Panti C. 2018. Abundance and characterization of microplastics in the coastal waters of Tuscany (Italy): the application of the MSFD monitoring protocol in the Mediterranean Sea. Mar Pollut Bull 133: 543-552.

Barnes D.K., Galgani F., Thompson R.C., Barlaz M. 2009. Accumulation and fragmentation of plastic debris in global environments. Philos Trans R Soc Lond B Biol Sci 364(1526): 1985-1998.

Batel A., Baumann L., Carteny C.C., Cormier B., Keiter S.H., Braunbeck T. 2020. Histological, enzymatic and chemical analyses of the potential effects of differently sized microplastic particles upon long-term ingestion in zebrafish (*Danio rerio*). Mar Pollut Bull 153, 111022.

Battaglia P., Pedà C., Musolino S., Esposito V., Andaloro F., Romeo T. 2016. Diet and first documented data on plastic ingestion of *Trachinotus ovatus* L. 1758 (Pisces: Carangidae) from the Strait of Messina (central Mediterranean Sea). Ital J Zool 83(1): 121-129.

Bellas J., Martínez-Armental J., Martínez-Cámara A., Besada V., Martínez-Gómez C. 2016. Ingestion of microplastics by demersal fish from the Spanish Atlantic and Mediterranean coasts. Mar Pollut Bull 109: 55-60.

Ben Ismail S., Costa E., Jaziri H., Morgana S., Boukthir M., Ben Ismail M.A., Minetti R., Montarsolo A., Narizzano R., Sammari C., Faimali M., Garaventa F. 2022. Evolution of the distribution and dynamic of microplastic in water and biota: a study case from the Gulf of Gabes (Southern Mediterranean Sea). Front Mar Sci 9, 786026.

Berglund E., Fogelberg V., Nilsson P.A., Hollander J. 2019. Microplastics in a freshwater mussel (*Anodonta anatina*) in Northern Europe. Sci Total Environ 697, 134192.

Bergmann M., Gutow L., Klages M. 2015. *Marine anthropogenic litter* (p. 447). Springer Nature.

Blarer P., Burkhardt-Holm P. 2016. Microplastics affect assimilation efficiency in the freshwater amphipod *Gammarus fossarum*. Environ Sci Pollut Res 23: 23522-23532.

Boerger C.M., Lattin G.L., Moore S.L., Moore C.J. 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Mar Pollut Bull 60(12): 2275-2278.

Boháčková J., Havlíčková L., Semerád J., Titov I., Trhlíková O., Beneš H., Cajthaml T. 2023. In vitro toxicity assessment of polyethylene terephthalate and polyvinyl chloride microplastics using three cell lines from rainbow trout (*Oncorhynchus mykiss*). Chemosphere 312, 136996.

Bottari T., Savoca S., Mancuso M., Capillo G., Panarello G., Bonsignore M., Crupi R., Sanfilippo M., D'Urso L., Compagnini G., Neri F., Romeo T., Luna G.M., Spano ` N., Fazio E. 2019. Plastics occurrence in the gastrointestinal tract of Zeus faber and *Lepidopus caudatus* from the Tyrrhenian Sea. Mar Pollut Bull 146: 408-416.

Browne M.A., Dissanayake A., Galloway T.S., Lowe D.M., Thompson R.C. 2008. Ingested microscopic plastic translocates to the circulatory system of the mussel, *Mytilus edulis* (L.). Environ Sci Tech 42(13): 5026-5031.

Browne M.A., Crump P., Niven S.J., Teuten E., Tonkin A., Galloway T., Thompson R. 2011. Accumulation of microplastic on shorelines woldwide: sources and sinks. Environ Sci Tech 45(21): 9175-9179.

Bunge A., Kammann U., Scharsack J.P. 2021. Exposure to microplastic fibers does not change fish early life stage development of three-spined sticklebacks (*Gasterosteus aculeatus*). Microplast Nanoplast 1: 1-9.

Caldwell J., Petri-Fink A., Rothen-Rutishauser B., Lehner R. 2019. Assessing meso-and microplastic pollution in the ligurian and tyrrhenian seas. Mar Pollut Bull 149, 110572.

Cannas S., Fastelli P., Guerranti C., Renzi M. 2017. Plastic litter in sediments from the coasts of South Tuscany (Tyrrhenian Sea). Mar Pollut Bull 119 (1): 372-375.

Capillo G., Savoca S., Panarello G., Mancuso M., Branca C., Romano V., D'Angelo G., Bottari T., Spano N. 2020. Quali-quantitative analysis of plastics and synthetic microfibers found in demersal species from Southern Tyrrhenian Sea (Central Mediterranean). Mar Pollut Bull 150, 110596.

Capparelli M.V., Gómez-Ponce M.A., Borges-Ramírez M.M., Rendón-von Osten J., Celis-Hernández O., Briceño-Vera A.E., Moulatlet G.M. 2022. Ecological traits influence the bioaccumulation of microplastics in commercially important estuarine crabs from the southeastern Gulf of Mexico. Mar Pollut Bull 183, 114088.

Carpenter E.J., Smith Jr K.L. 1972. Plastics on the Sargasso Sea surface. Science, 175(4027): 1240-1241.

Carpenter E.J., Anderson S.J., Harvey G.R., Miklas H.P., Peck B.B. 1972. Polystyrene spherules in coastal waters. Science, 178(4062): 749-750.

Cartes J.E., Soler-Membrives A., Stefanescu C., Lombarte A., Carrasson M. 2016. Contributions of allochthonous inputs of food to the diets of benthopelagic fish over the northwest Mediterranean slope (to 2300m). Deep Sea Res Part Oceanogr Res Pap 109, 123e136

Castañeda R.A., Avlijas S., Simard M.A., Ricciardi A. 2014. Microplastic pollution in St. Lawrence river sediments. Can J Fish Aquat Sci 71(12): 1767-1771.

Cau A., Avio C.G., Dessì C., Follesa M.C., Moccia D., Regoli F. 2019. Microplastics in the crustaceans *Nephrops norvegicus* and *Aristeus antennatus*: flagship species for deep-sea environments? Environ Pollut 255, 113107.

Cedervall T., Hansson L.A., Lard M., Frohm B., Linse S. 2012. Food chain transport of nanoparticles affects behaviour and fat metabolism in fish. PloS one, 7(2), e32254.

Chen Q., Gao Z., Wang K., Magnuson J.T., Chen Y., Li M., Xu L. 2023. High accumulation of microplastic fibers in fish hindgut induces an enhancement of triphenyl phosphate hydroxylation. Environ Pollut 317, 120804.

Choi J.S., Hong S.H., Park J.W. 2020. Evaluation of microplastic toxicity in accordance with different sizes and exposure times in the marine copepod *Tigriopus japonicus*. Mar Environ Res 153, 104838.

Cincinelli A., Martellini T., Guerranti C., Scopetani C., Chelazzi D., Giarrizzo T. 2019. A potpourri of microplastics in the sea surface and water column of the Mediterranean Sea. Trac-Trend Anal Chem 110: 321-326.

Cole M., Lindeque P., Halsband C., Galloway T.S. 2011. Microplastics as contaminants in the marine environment: a review. Mar Pollut Bull 62(12): 2588-2597.

Cole M., Lindeque P., Fileman E., Halsband C., Goodhead R., Moger J., Galloway T.S. 2013. Microplastic ingestion by zooplankton. Environ Sci Tech 47(12): 6646-6655.

Cole M., Webb H., Lindeque P.K., Fileman E.S., Halsband C., Galloway T.S. 2014. Isolation of microplastics in biota-rich seawater samples and marine organisms. Sci Rep 4:4528.

Cole M. Galloway T. 2015. Ingestion of nanoplastics and microplastics by Pacific oyster larvae. Environ Sci Technol 49: 14625-14632.

Cole M., Lindeque P., Fileman E., Halsband C., Galloway T.S. 2015. The impact of polystyrene microplastics on feeding, function and fecundity in the marine copepod C*alanus helgolandicus*. Environ Sci Technol 49(2): 1130-1137.

Collard F., Gilbert B., Eppe G., Parmentier E., Das K. 2015. Detection of anthropogenic particles in fish stomachs: an isolation method adapted to identification by Raman spectroscopy. Arch Environ Contam Toxicol 69: 331-339.

Collignon A., Hecq J.H., Galgani F., Collard F., Goffart A. 2014. Annual variation in neustonic micro-and meso-plastic particles and zooplankton in the Bay of Calvi (Mediterranean–Corsica). Mar Pollut Bull 79(1-2): 293-298.

Costa M.F., Ivar do Sul J.A., Silva-Cavalcanti J.S., Araújo M.C.B., Spengler Â., Tourinho P.S. 2010. On the importance of size of plastic fragments and pellets on the strandline: a snapshot of a Brazilian beach. Environ Monit Assess 168: 299-304.

Coyle R., Hardiman G., O'Driscoll K., 2020. Microplastics in the marine environment: a review of their sources, distribution processes, uptake and exchange in ecosystems. CSCEE 2, 100010.

Çomaklı E., Bingöl M.S., Bilgili A. 2020. Assessment of microplastic pollution in a crater lake at high altitude: A case study in an urban crater Lake in Erzurum, Turkey. Water Air Soil Pollut 231: 1-6.

Çullu A.F., Sönmez V.Z., Sivri, N. 2021. Microplastic contamination in surface waters of the Küçükçekmece Lagoon, Marmara Sea (Turkey): Sources and areal distribution. Environ Pollut 268, 115801.

da Costa J.P., Santos P.S., Duarte A.C., Rocha-Santos T. 2016. (Nano) plastics in the environment-sources, fates and effects. Sci Total Environ 566: 15-26.

De Sá L.C., Oliveira M., Ribeiro F., Rocha T.L., Futter M.N. 2018. Studies of the effects of microplastics on aquatic organisms: what do we know and where should we focus our efforts in the future? Sci Total Environ 645: 1029-1039.

Diamond M.L., de Wit C.A., Molander S., Scheringer M., Backhaus T., Lohmann R., Zetzsch C. 2015. Exploring the planetary boundary for chemical pollution. Environ Int 78: 8-15.

Digka N., Tsangaris C., Torre M., Anastasopoulou A., Zeri C. 2018. Microplastics in mussels and fish from the northern Ionian Sea. Mar Pollut Bull 135: 30-40.

Ding J., Zhang S., Razanajatovo R.M., Zou H., Zhu W. 2018. Accumulation, tissue distribution, and biochemical effects of polystyrene microplastics in the freshwater fish red tilapia (*Oreochromis niloticus*). Environ Pollut 238: 1-9.

do Sul J.A.I., Costa M.F. 2014. The present and future of microplastic pollution in the marine environment. Environ Pollut 185: 352-364.

Doğruyol P., Şener M., Balkaya N. 2019. Determination of microplastics and large plastics in the sediments of the Golden Horn Estuary (Halic), Istanbul, Turkey. Desalination Water Treat 172, 344-350.

Dris R., Imhof H., Sanchez W., Gasperi J., Galgani F., Tassin B., Laforsch C. 2015. Beyond the ocean: contamination of freshwater ecosystems with (micro-) plastic particles. Environ Chem 12(5): 539-550.

Eerkes-Medrano D., Thompson R.C., Aldridge D.C. 2015. Microplastics in freshwater systems: a review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. Water Res 75: 63-82.

Ergün S., Vazirzadeh A., Yigit M., Yilmaz S., Erdem M., Erdem B., Buyukates Y. 2023. Evaluation of microplastic in caged fish from Turkish and Iranian waters with health risk assessment for human consumers. Med Sci Forum 19(1): 9.

Eriksen M., Mason S., Wilson S., Box C., Zellers A., Edwards W., Amato S. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. Mar Pollut Bull 77(1-2): 177-182.

Erkan H.S., Turan N.B., Albay M., Engin G.O. 2021. Microplastic pollution in seabed sediments at different sites on the shores of Istanbul-Turkey: Preliminary results. J Clean Prod 328, 129539.

Erni-Cassola G., Zadjelovic V., Gibson M.I., Christie-Olez J.A., 2019. Distribution of plastic polymer types in the marine environment; a metaanalysis. J Hazard Mater 369: 691-698.

Eryaşar A.R., Özbilgin H. Gücü A.C., Sakınan S. 2014. Marine debris in bottom trawl catches and their effects on the selectivity grids in the north eastern Mediterranean. Mar Pollut Bull 81(1): 80-84.

Espinosa C., Beltrán J.M.G., Esteban M.A., Cuesta A. 2018. In vitro effects of virgin microplastics on fish head-kidney leucocyte activities. Environ Pollut 235: 30-38.

Espinosa C., Esteban M.Á., Cuesta A. 2019. Dietary administration of PVC and PE microplastics produces histological damage, oxidative stress and immunoregulation in European sea bass (*Dicentrarchus labrax* L.). Fish Shellfish Immunol 95: 574-583.

Farrell P., Nelson K. 2013. Trophic level transfer of microplastic: *Mytilus edulis* (L.) to *Carcinus maenas* (L.). Environ Pollut 177: 1-3.

Fastelli P., Blašković A., Bernardi G., Romeo T., Čižmek H., Andaloro F., Renzi M. 2016. Plastic litter in sediments from a marine area likely to become protected (Aeolian Archipelago's islands, Tyrrhenian sea). Mar Pollut Bull 113(1-2): 526-529.

Faure F., Demars C., Wieser O., Kunz M., De Alencastro L.F. 2015. Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. Environ Chem 12(5): 582-591.

Free C.M., Jensen O.P., Mason S.A., Eriksen M., Williamson N.J., Boldgiv B. 2014. High-levels of microplastic pollution in a large, remote, mountain lake. Mar Pollut Bull 85(1): 156-163.

Frias J., Pagter E., Nash R., O'Connor I., Carretero O., Filgueiras A., Gerdts G. 2018. Standardised protocol for monitoring microplastics in sediments. Deliverable 4.2.

Frias J.P., Nash R. 2019. Microplastics: Finding a consensus on the definition. Mar Pollut Bull 138: 145-147.

Galgani F., Jaunet S., Campillo A., Guenegen X., His E. 1995. Distribution and abundance of debris on the continental shelf of the north-western Mediterranean Sea. Mar Pollut Bull 30(11): 713-717.

Galgani F., Leaute J.P., Moguedet P., Souplet A., Verin Y., Carpentier A., Nerisson P. 2000. Litter on the sea floor along European coasts. Mar Pollut Bull 40(6): 516-527.

Galil B.S., Golik A., Türkay M. 1995. Litter at the bottom of the sea: a sea bed survey in the Eastern Mediterranean. Mar Pollut Bull 30(1): 22-24.

Galimany E., Ramón M., Delgado M. 2009. First evidence of fiberglass ingestion by a marine invertebrate (*Mytilus galloprovincialis* L.) in a NW Mediterranean estuary. Mar Pollut Bull 58(9): 1334-1338.

Gall S.C., Thompson R.C. 2015. The impact of debris on marine life. Mar Pollut Bull 92: 170-179.

Galloway T.S. 2015. *in Marine Anthropogenic Litter* (eds Bergmann M., Gutow L., Klages M.) 343-366 (Springer, 2015).

Galloway T.S., Cole M., Lewis C. 2017. Interactions of microplastic debris throughout the marine ecosystem. Nat Ecol Evol 1(5), 0116.

Gedik K., Atasaral Ş. 2022. The microplastic pattern in Turkish lakes: sediment and bivalve samples from Çıldır Lake, Almus Dam Lake, and Kartalkaya Dam Lake. T J Zool 46(5): 397-408.

Gedik K., Eryaşar A.R. 2020. Microplastic pollution profile of Mediterranean mussels (*Mytilus galloprovincialis*) collected along the Turkish coasts. Chemosphere, 260, 127570.

Giani D., Baini M., Galli M., Casini S., Fossi M.C. 2019. Microplastics occurrence in edible fish species (*Mullus barbatus* and *Merluccius merluccius*) collected in three different geographical sub-areas of the Mediterranean Sea. Mar Pollut Bull 140: 129e137.

González-Soto N., Campos L., Navarro E., Bilbao E., Guilhermino L., Cajaraville M.P. 2022. Effects of microplastics alone or with sorbed oil compounds from the water accommodated fraction of a North Sea crude oil on marine mussels (*Mytilus galloprovincialis*). Sci Total Environ 851, 157999.

Graham E.R., Thompson J.T. 2009. Deposit-and suspension-feeding sea cucumbers (Echinodermata) ingest plastic fragments. J Exp Mar Biol Ecol 368(1): 22-29.

Green D.S. 2016. Effects of microplastics on European flat oysters, *Ostrea edulis* and their associated benthic communities. Environ Pollut 216: 95-103.

Gregory M.R. 1977. Plastic pellets on New Zealand beaches. Mar Pollut Bull 8(4): 82-84.

Gregory M.R. 1978. Accumulation and distribution of virgin plastic granules on New Zealand beaches. N Z J Mar Freshwater Res 12(4): 399-414.

Greven A.C., Merk T., Karagöz F., Mohr K., Klapper M., Jovanović B., Palić D. 2016. Polycarbonate and polystyrene nanoplastic particles act as stressors to the innate immune system of fathead minnow (*Pimephales promelas*). Environ Toxicol Chem 35(12): 3093-3100.

Guerranti C., Cannas S., Scopetani C., Fastelli P., Cincinelli A., Renzi M., 2017. Plastic litter in aquatic environments of maremma Regional Park (Tyrrhenian Sea, Italy): contribution by the ombrone river and levels in marine sediments. Mar Pollut Bull 117 (1-2): 366-370.

Gusmão F., Di Domenico M., Amaral A.C.Z., Martínez A., Gonzalez B.C., Worsaae K., da Cunha Lana P. 2016. In situ ingestion of microfibres by meiofauna from sandy beaches. Environ Pollut 216: 584-590.

Gündoğdu S. 2017. High level of micro-plastic pollution in the Iskenderun Bay NE Levantine coast of Turkey. EgeJFAS 34(4): 401-408.

Gündoğdu S., Cevik C., Ataş N.T. 2020. Occurrence of microplastics in the gastrointestinal tracts of some edible fish speciesalong the Turkish coast. Turk J Zool 44(4): 312-323.

Gündoğdu S., Kutlu B., Özcan T., Büyükdeveci F., Blettler M.C. 2023. Microplastic pollution in two remote rivers of Türkiye. Environ Monit Assess 195(6): 791.

Güven O., Gökdağ K., Jovanović B., Kıdeyş A.E. 2017. Microplastic litter composition of the Turkish territorial waters of the Mediterranean Sea, and its occurrence in the gastrointestinal tract of fish. Environ Pollut 223: 286-294.

Haegerbaeumer A., Mueller M.T., Fueser H., Traunspurger W. 2019. Impacts of micro-and nano-sized plastic particles on benthic invertebrates: a literature review and gap analysis. Front Environ Sci 7: 17.

Hakanson L. 1984. Metals in fish and sediments from the River Kolbacksan water system, Sweden. Arch Hydrobiol 101(3).

Hamed M., Martyniuk C.J., Naguib M., Lee J.S., Sayed A.E.D.H. 2022. Neurotoxic effects of different sizes of plastics (nano, micro, and macro) on juvenile common carp (*Cyprinus carpio*). Front Mol Neurosci 15, 1028364.

Hämer J., Gutow L., Köhler A., Saborowski R. 2014. Fate of microplastics in the marine isopod *Idotea emarginata*. Environ Sci Tech 48(22): 13451-13458.

Hara J., Frias J., Nash R. 2020. Quantification of microplastic ingestion by the decapod crustacean *Nephrops norvegicus* from Irish waters. Mar Pollut Bull 152: 110905.

Hartmann N.B., Huffer T., Thompson R.C., Hassellöv M., Verschoor A., Daugaard A.E., Rist S., Karlsson T., Brennholt N., Cole M., Herrling M.P., Hess M.C., Ivleva N.P., Lusher A.L., Wagner M. 2019 Are we speaking the same language? Recommendations for a definition and categorization framework for plastic debris. Environ Sci Technol 53:1039-1047.

Hasegawa T., Mizukawa K., Yeo B.G., Sekioka T., Takada H., Nakaoka M. 2022. The significance of trophic transfer of microplastics in the accumulation of plastic additives in fish: an experimental study using brominated flame retardants and UV stabilizers. Mar Pollut Bull 185, 114343.

Hidalgo-Ruz V., Gutow L., Thompson R.C., Thiel M. 2012. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ Sci Tech 46(6): 3060-3075.

Hidalgo-Ruz L. Gutow R.C. Baysal A., Saygin H., Ustabasi G.S. (2020). Microplastic occurrences in sediments collected from Marmara Sea-Istanbul, Turkey. Bull Environ Contam Toxicol 105: 522-529.

Hipfner J.M., Galbraith M., Tucker S., Studholme K.R., Domalik A.D., Pearson S.F., Hodum P. 2018. Two forage fishes as potential conduits for the vertical transfer of microfibres in Northeastern Pacific Ocean food webs. Environ Pollut 239: 215-222.

Hollerova A., Hodkovicova N., Blahova J., Faldyna M., Franc A., Pavlokova S., Svobodova Z. 2023. Polystyrene microparticles can affect the health status of freshwater fish–Threat of oral microplastics intake. Sci Total Environ 858, 159976.

Huang J.N., Wen B., Meng L.J., Li X.X., Wang M.H., Gao J.Z., Chen Z.Z. 2020. Integrated response of growth, antioxidant defense and isotopic composition to microplastics in juvenile guppy (*Poecilia reticulata*). J Hazard Mater 399, 123044.

Huerta Lwanga E., Gertsen H., Gooren H., Peters P., Salánki T., Van Der Ploeg M., Geissen V. 2016. Microplastics in the terrestrial ecosystem: implications for *Lumbricus terrestris* (Oligochaeta, Lumbricidae). Environ Sci Tech 50(5): 2685-2691.

Huntington T., 2019. Marine Litter and Aquaculture Gear e White Paper. Report Produced by Poseidon Aquatic Resources Management Ltd for the Aquaculture Stewardship Council, p. 20 (plus appendices).

Imhof H.K., Ivleva N.P., Schmid J., Niessner R., Laforsch C. 2013. Contamination of beach sediments of a subalpine lake with microplastic particles. Curr Biol 23(19): R867-R868.

Imhof H.K., Laforsch C., Wiesheu A.C., Schmid J., Anger P.M., Niessner R., Ivleva N.P. 2016. Pigments and plastic in limnetic ecosystems: A qualitative and quantitative study on microparticles of different size classes. Water Res 98: 64-74.

Ito M., Hano T., Kono K., Ohkubo N. 2022. Desorption of polycyclic aromatic hydrocarbons from polyethylene microplastics in two morphologically different digestive tracts of marine teleosts: Gastric red seabream (*Pagrus*

major) and agastric mummichog (*Fundulus heteroclitus*). Environ Pollut 308, 119589.

Ivleva N.P., Wiesheu A.C., Niessner R. 2017. Microplastic in aquatic ecosystems. Angew Chem Int Ed Engl 56(7): 1720-1739.

Jambeck J.R., Geyer R., Wilcox C., Siegler T.R., Perryman M., Andrady A., Law K.L. 2015. Plastic waste inputs from land into the ocean. Science, 347(6223): 768-771.

Jeong C.B., Won E.J., Kang H.M., Lee M.C., Hwang D.S., Hwang U.K., Lee J.S. 2016. Microplastic size-dependent toxicity, oxidative stress induction, and p-JNK and p-p38 activation in the monogonont rotifer (*Brachionus koreanus*). Environ Sci Tech 50(16): 8849-8857.

Kaloyianni M., Bobori D.C., Xanthopoulou D., Malioufa G., Sampsonidis I., Kalogiannis S., Bikiaris D.N. 2021. Toxicity and functional tissue responses of two freshwater fish after exposure to polystyrene microplastics. Toxics 9(11), 289.

Kaposi K.L., Mos B., Kelaher B. Dworjanyn S.A. 2013. Ingestion of microplastic has limited impact on a marine larva. Environ Sci Technol 48: 1638-1645.

Karlsson T.M., Vethaak A.D., Almroth B.C., Ariese F., van Velzen M., Hassellöv M., Leslie H.A. 2017. Screening for microplastics in sediment, water, marine invertebrates and fish: method development and microplastic accumulation. Mar Pollut Bull 122(1-2): 403-408.

Katsanevakis S., Katsarou A. 2004. Influences on the distribution of marine debris on the seafloor of shallow coastal areas in Greece (Eastern Mediterranean). Water Air Soil Pollut 159: 325-337.

Katsanevakis S., Verriopoulos G., Nicolaidou A., Thessalou-Legaki M. 2007. Effect of marine litter on the benthic megafauna of coastal soft bottoms: a manipulative field experiment. Mar Pollut Bull 54(6): 771-778.

Katsumiti A., Losada-Carrillo M.P., Barros M., Cajaraville M.P. 2021. Polystyrene nanoplastics and microplastics can act as Trojan horse carriers of benzo (a) pyrene to mussel hemocytes in vitro. Sci Rep 11(1), 22396.

Khan F.R., Boyle D., Chang E., Bury N.R. 2017. Do polyethylene microplastic beads alter the intestinal uptake of Ag in rainbow trout (*Oncorhynchus mykiss*)? Analysis of the MP vector effect using in vitro gut sacs. Environ Pollut 231: 200-206.

Khordagui H.K., Abu-Hilal A.H. 1994. Industrial plastic on the southern beaches of the Arabian Gulf and the western beaches of the Gulf of Oman. Environ Pollut 84(3): 325-327.

Kılıç E. 2022. Microplastic ingestion evidence by economically important farmed fish species from Turkey. Mar Pollut Bull 183, 114097.

Kim J.A., Kim M.J., Park Y.S., Kang C.K., Kim J.H., Choi C.Y. (2023). Effects of microfiber and bead microplastic exposure in the goldfish *Carassius auratus*: Bioaccumulation, antioxidant responses, and cell damage. Aquat Toxicol 263, 106684.

Klein S., Worch E., Knepper T.P. 2015. Occurrence and spatial distribution of microplastics in river shore sediments of the Rhine-Main area in Germany. Environ Sci Tech 49(10): 6070-6076.

Koelmans A.A., Bakir A., Burton G.A. Janssen C.R. 2016. Microplastic as a vector for chemicals in the aquatic environment: critical review and model-supported reinterpretation of empirical studies. Environ Sci Tech. 50: 3315-3326.

Koutsodendris A., Papatheodorou G., Kougiourouki O., Georgiadis M. 2008. Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. Estuar Coast Shelf Sci 77(3): 501-512.

Krüger L., Casado-Coy N., Valle C., Ramos M., Sanchez-Jerez P., Gago J., SanzLazaro C. 2020. Plastic debris accumulation in the seabed derived from coastal fish farming. Environ Pollut 257, 113336.

Kunwar B., Cheng H.N., Chandrashekaran S.R., Sharma B.K. 2016. Plastics to fuel: A review. Renew Sustain Energy Rev 54: 421-428.

Kühn S., van Franeker J.A. 2012. Plastic ingestion by the northern fulmar (*Fulmarus glacialis*) in Iceland. Mar Pollut Bull 64(6): 1252-1254.

Law K.L., Morét-Ferguson S., Maximenko N.A., Proskurowski G., Peacock E.E., Hafner J., Reddy C.M. 2010. Plastic accumulation in the North Atlantic subtropical gyre. Science, 329(5996): 1185-1188.

Lechner A., Keckeis H., Lumesberger-Loisl F., Zens B., Krusch R., Tritthart M., Schludermann E. 2014. The Danube so colourful: a potpourri of plastic litter outnumbers fish larvae in Europe's second largest river. Environ Pollut 188: 177-181.

Lee K.W., Shim W.J., Kwon O.Y., Kang J.H. 2013. Size-dependent effects of micro polystyrene particles in the marine copepod *Tigriopus japonicus*. Environ Sci Tech 47(19): 11278-11283.

Liu J., Xu D., Chen Y., Zhao C., Liu, L., Gu Y., Ren Y., Xia B. 2022. Adverse effects of dietary virgin (nano)microplastics on growth performance, immune response, and resistance to ammonia stress and pathogen challenge in juvenile sea cucumber *Apostichopus japonicus* (Selenka). J Hazard Mater 423, 127038.

Lombardo J., Solomando A., Cohen-Sánchez A., Pinya S., Tejada S., Ferriol P., Mateu-Vicens G., Box A., Faggio C., Sureda A. 2022. Effects of human

activity on markers of oxidative stress in the intestine of *Holothuria tubulosa*, with special reference to the presence of microplastics. Int J Mol Sci 23, 9018.

Lusher A.L., McHugh M., Thompson R.C. 2013. Occurrence of microplastics in the gastronintestinal tract of pelagic and demersal fish from the English channel. Mar Pollut Bull 67: 94-99.

Lusher A.L., Hollman P.C.H., Mendoza-Hill J.J. 2017. Microplastics in Fisheries and Aquaculture: Status of Knowledge on their Occurrence and Implications for Aquatic Organisms and Food Safety. FAO Fisheries and Aquaculture Technical Paper. No. 615. Rome, Italy

Magara G., Elia A.C., Syberg K., Khan F.R. 2018. Single contaminant and combined exposures of polyethylene microplastics and fluoranthene: accumulation and oxidative stress response in the blue mussel, *Mytilus edulis*. J Toxicol Environ Health, Part A 81(16): 761-773.

Mancuso M., Savoca S., Bottari T. 2019. First record of microplastics ingestion by European hake *Merluccius merluccius* from the Tyrrhenian Sicilian coast (Central Mediterranean Sea). J Fish Biol 94(3): 517-519.

Mani, T., Hauk A., Walter U., Burkhardt-Holm P. 2015. Microplastics profile along the Rhine River. Sci Rep 5: 17988.

Mattsson K., Ekvall M.T., Hansson L.A., Linse S., Malmendal A., Cedervall T. 2015. Altered behavior, physiology, and metabolism in fish exposed to polystyrene nanoparticles. Environ Sci Tech 49(1): 553-561.

Mazurais D., Ernande B., Quazuguel P., Severe A., Huelvan C., Madec L., Zambonino-Infante J. 2015. Evaluation of the impact of polyethylene microbeads ingestion in European sea bass (*Dicentrarchus labrax*) larvae. Mar Environ Res 112: 78-85.

McCormick M.I., Fakan E.P., Vamvounis G., Bosshard S., Moad C., Smyth E., Allan B.J.M. 2023. No effects of plasticized microplastics on the body condition and reproduction of a marine fish. ICES J Mar Sci fsad049.

Missawi O., Bousserrhine N., Belbekhouche S., Zitouni N., Alphonse V., Boughattas I., Banni M. 2020. Abundance and distribution of small microplastics ($\leq$ 3 μm) in sediments and seaworms from the southern Mediterranean coasts and characterisation of their potential harmful effects. Environ Pollut 263, 114634.

Mistri M., Scoponi M., Canata T., Moruzzi L., Massara F., Munari C. 2020. Types, occurrence and distribution of microplastics in sediments from the northern Tyrrhenian Sea. Mar Pollut Bull 153, 111016.

Mohsen M., Wang Q., Zhang L., Sun L., Lin C., Yang H. 2019. Microplastic ingestion by the farmed sea cucumber *Apostichopus japonicus* in China. Environ Pollut 245: 1071-1078.

Moore C.J., Moore S.L., Leecaster M.K., Weisberg S.B. 2001a. A comparison of plastic and plankton in the North Pacific central gyre. Mar Pollut Bull 42(12): 1297-1300.

Moore S.L., Gregorio D., Carreon M., Weisberg S.B., Leecaster M.K. 2001b. Composition and distribution of beach debris in Orange County, California. Mar Pollut Bull 42(3): 241-245.

Moore C.J., Moore S.L., Weisberg S.B., Lattin G.L., Zellers A.F. 2002. A comparison of neustonic plastic and zooplankton abundance in southern California's coastal waters. Mar Pollut Bull 44(10): 1035-1038.

Moore C.J., Lattin G.L., Zellers A.F. 2011. Quantity and type of plastic debris flowing from two urban rivers to coastal waters and beaches of Southern California. J Integr Coast Zone Manag 11(1): 65-73.

Morgana S., Ghigliotti L., Est´evez-Calvar N., Stifanese R., Wieckzorek A., Doyle T., Christiansen J.S., Faimali M., Garaventa F. 2018. Microplastics in the Arctic: a case study with sub-surface water and fish samples off northeast GCeenland. Environ Poll 242: 1078-1086.

Mtega M.P., Mihale M.J., Kilulya K.F. 2023. Evaluation of toxicological risks and effects of microplastics on Nile Tilapia (*Oreochromis niloticus*) under in vitro laboratory conditions. EAJBCS 4(2): 54-68.

Multisanti C.R., Marola C., Perugini M., Aliko V., Faggio C. 2022. Sentinel species selection for monitoring microplastic pollution: A review on one health approach. Eco Indic 145, 109587.

Murray F., Cowie P.R. 2011. Plastic contamination in the decapod crustacean *Nephrops norvegicus* (Linnaeus, 1758). Mar Pollut Bull 62: 1207-1217.

Nadal M.A., Alomar C., Deudero S. 2016. High levels of microplastic ingestion by the semipelagic fish bogue *Boops boops* (L.) around the Balearic Islands. Environ Pollut 214, 517e523.

Nelms S.E., Galloway T.S., Godley B.J., Jarvis D.S., Lindeque P.K. 2018. Investigating microplastic trophic transfer in marine top predators. Environ Pollut 238: 999-1007.

Norland S., Vorkamp K., Bogevik A.S., Koelmans A.A., Diepens N.J., Burgerhout E., Rønnestad I. 2021. Assessing microplastic as a vector for chemical entry into fish larvae using a novel tube-feeding approach. Chemosphere, 265, 129144.

Ogonowski M., Schür C., Jarsén Å., Gorokhova E. 2016. The effects of natural and anthropogenic microparticles on individual fitness in *Daphnia magna*. PloS one, 11(5), e0155063.

Oliveira M., Ribeiro A., Hylland K., Guilhermino L. 2013. Single and combined effects of 653 microplastics and pyrene on juveniles (0+ group) of the common goby 654 *Pomatoschistus microps* (Teleostei, Gobiidae). Ecol Indic 34: 641-647.

Ory N.C., Gallardo C., Lenz M., Thiel M. 2018. Capture, swallowing, and egestion of microplastics by a planktivorous juvenile fish. Environ Pollut 240: 566-573.

Pannetier P., Cachot J., Clérandeau C., Faure F., Van Arkel K., de Alencastro L.F., Morin B. 2019. Toxicity assessment of pollutants sorbed on environmental sample microplastics collected on beaches: Part I-adverse effects on fish cell line. Environ Pollut 248: 1088-1097.

Paul-Pont I., Lacroix C., Fernández C.G., Hégaret H., Lambert C., Le Goïc N., Soudant P. 2016. Exposure of marine mussels *Mytilus* spp. to polystyrene microplastics: toxicity and influence on fluoranthene bioaccumulation. Environ Pollut 216: 724-737.

Peda C., Caccamo L., Fossi M.C., Gai F., Andaloro F., Genovese L., Maricchiolo G. 2016. Intestinal alterations in European sea bass *Dicentrarchus labrax* (Linnaeus, 1758) exposed to microplastics: preliminary results. Environ Pollut 212: 251-256.

Peng G., Zhu B., Yang D., Su L., Shi H., Li D. 2017. Microplastics in sediments of the Changjiang Estuary, China. Environ Pollut 225, 283-290.

Pham C.K., Ramirez-Llodra E., Alt C.H., Amaro T., Bergmann M., Canals M., Tyler P.A. 2014. Marine litter distribution and density in European seas, from the shelves to deep basins. PloS one, 9(4), e95839.

Piazzolla D., Cafaro V., de Lucia G.A., Mancini E., Scanu S., Bonamano S., Piermattei V., Vianello A., Della Ventura G., Marcelli M. 2020. Microlitter pollution in coastal sediments of the northern Tyrrhenian Sea, Italy: microplastics and fly-ash occurrence and distribution. Estuar Coast Shelf Sci 106819.

Pittura L., Gorbi S., Mazzoli C., Nardi A., Benedetti M., Regoli F. 2022. Microplastics and Nanoplastics. In *Marine Analytical Chemistry* (pp. 349-388). Cham: Springer International Publishing.

PlasticsEurope, 2015. "Plastics—the Facts 2015", can be found under http://www.plasticseurope.org/Document/plastics-the-facts2015.aspx?FolID = 2.

Porter A., Barber D., Hobbs C., Love J., Power A.L., Bakir A., Lewis C. 2023. Uptake of microplastics by marine worms depends on feeding mode and particle shape but not exposure time. Sci Total Environ 857, 159287.

Prokić M.D., Radovanović T.B., Gavrić J.P., Faggio C. 2019. Ecotoxicological effects of microplastics: Examination of biomarkers, current state and future perspectives. TrAC 111: 37-46.

Ramirez-Llodra E., De Mol B., Company J.B., Coll M., Sardà F. 2013. Effects of natural and anthropogenic processes in the distribution of marine litter in the deep Mediterranean Sea. Prog Oceanogr 118: 273-287.

Ramos J.A., Barletta M. Costa M.F. 2012. Ingestion of nylon threads by Gerreidae while using a tropical estuary as foraging grounds. Aquat Biol 17(1): 29-34.

Rech S., Macaya-Caquilpán V., Pantoja J.F., Rivadeneira M.M., Madariaga D.J., Thiel M. 2014. Rivers as a source of marine litter–a study from the SE Pacific. Mar Pollut Bull 82(1-2): 66-75.

Remy F., Collard F., Gilbert B., Compère P., Eppe G., Lepoint G. 2015. When microplastic is not plastic: the ingestion of artificial cellulose fibers by macrofauna living in seagrass macrophytodetritus. Environ Sci Tech 49(18): 11158-11166.

Renzi M., Blaškovic A., Bernardi G., Russo G.F. 2018. Plastic litter transfer from sediments towards marine trophic webs: A case study on holothurians. Mar Pollut Bull 135: 376-385.

Revel M., Lagarde F., Perrein-Ettajani H., Bruneau M., Akcha F., Sussarellu R., Rouxel J., Costil K., Decottignies P., Cognie B., Châtel A., Mouneyrac C. 2019. Tissue-specific biomarker responses in the blue mussel *Mytilus* spp. exposed to a mixture of microplastics at environmentally relevant concentrations. Front Environ Sci 7: 0-14.

Ribeiro F., Garcia A.R., Pereira B.P., Fonseca M., Mestre N.C., Fonseca T.G., Bebianno M.J. 2017. Microplastics effects in *Scrobicularia plana*. Mar Pollut Bull 122(1-2): 379-391.

Rios-Fuster B., Arechavala-Lopez P., García-Marcos K., Alomar C., Compa M., Álvarez E., Deudero S. 2021. Experimental evidence of physiological and behavioral effects of microplastic ingestion in *Sparus aurata.* AquatiToxicol 231, 105737.

Rist S.E., Assidqi K., Zamani N.P., Appel D., Perschke M., Huhn M., Lenz M. 2016. Suspended micro-sized PVC particles impair the performance and decrease survival in the Asian green mussel *Perna viridis*. Mar Pollut Bull 111(1-2): 213-220.

Roch S., Friedrich C., Brinker A. 2020. Uptake routes of microplastics in fishes: practical and theoretical approaches to test existing theories. Sci Rep 10(1), 3896.

Rochman C.M., Hoh E., Kurobe T., Teh S.J. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci. Rep. 3: 3263.

Romeo T., Pietro B., Pedà C., Consoli P., Andaloro F., Fossi M.C. 2015. First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea. Mar Pollut Bull 95(1): 358-361.

Romeo T., Pedà C., Fossi M.C., Andaloro F., 2016. First record of plastic debris in the stomach of Mediterranean lanternfishes. Acta Adriat 1 (57): 115-124.

Rummel C.D., Löder M.G., Fricke N.F., Lang T., Griebeler E.M., Janke M., Gerdts G. 2016. Plastic ingestion by pelagic and demersal fish from the North Sea and Baltic Sea. Mar Pollut Bull 102(1):134-141.

Ryan P.G. 1988. The characteristics and distribution of plastic particles at the sea-surface off the southwestern Cape Province, South Africa. Mar Environ Res 25(4): 249-273.

Ryan P.G., Moore C.J., Van Franeker J.A., Moloney C.L. 2009. Monitoring the abundance of plastic debris in the marine environment. Philos Trans R Soc Lond B Biol Sci 364(1526): 1999-2012.

Salimi A., Alavehzadeh A., Ramezani M., Pourahmad J. 2022. Differences in sensitivity of human lymphocytes and fish lymphocytes to polyvinyl chloride microplastic toxicity. Toxicol Ind Health 38(2): 100-111.

Sánchez P., Masó M., Sáez R., De Juan S., Muntadas A., Demestre M. 2013. Baseline study of the distribution of marine debris on soft-bottom habitats associated with trawling grounds in the northern Mediterranean. Sci Mar 77(2): 247-255.

Sandra M., Devriese L., De Raedemaecker F., Lonneville B., Lukic I., Altvater S., Mata Lara M. 2019. Knowledge Wave on Marine Litter from Aquaculture Sources. D2.2 Aqua-Lit project. Oostende, Belgium, p. 85.

Santana M.F.M., Moreira F.T., Turra A., 2017. Trophic transference of microplastics under a low exposure scenario: insights on the likelihood of particle cascading along marine food-webs. Mar Pollut Bull 121 (1-2): 154-159.

Savoca S., Capillo G., Mancuso M., Bottari T., Crupi R., Branca C., Romano V., Faggio C., D'Angelo G., Spano ` N. 2019. Microplastics occurrence in the tyrrhenian waters and in the gastrointestinal tract of two congener species of seabreams. Environ Toxicol Pharmacol 67: 35-41.

Savoca S., Bottari T., Fazio E., Bonsignore M., Mancuso M., Luna G.M., Romeo T., D'Urso L., Capillo G., Panarello G., Greco S., Compagnini G., Lanteri G., Crupi R., Neri F., Spano ` N. 2020. Plastics occurrence in juveniles of *Engraulis encrasicolus* and *Sardina pilchardus* in the southern Tyrrhenian Sea. Sci Total Environ 718, 137457

Savoca S., Matanovi´c K., D'Angelo G., Vetri V., Anselmo S., Bottari T., Gjurˇcevi´c E. 2021. Ingestion of plastic and non-plastic microfibers by farmed gilthead sea bream (*Sparus aurata*) and common carp (*Cyprinus carpio*) at different life stages. Sci Total Environ 782, 146851.

Sbrana A., Valente T., Scacco U., Bianchi J., Silvestri C., Palazzo L. 2020. Spatial variability and influence of biological parameters on microplastic ingestion by *Boops boops* (L.) along the Italian coasts (Western Mediterranean Sea). Environ Pollut 114429.

Schmid K., Winemiller K.O., Chelazzi D., Cincinelli A., Dei L., Giarrizzo T. 2018. First evidence of microplastic ingestion by fishes from the Amazon River estuary. Mar Pollut Bull 133: 814-821.

Seeley M.E., Hale R.C., Zwollo P., Vogelbein W., Verry G., Wargo A.R. 2023. Microplastics exacerbate virus-mediated mortality in fish. Sci Total Environ 866, 161191.

Setälä O., Norkko J., Lehtiniemi M. 2016. Feeding type affects microplastic ingestion in a coastal invertebrate community. Mar Pollut Bull 102(1): 95-101.

Shaw D.G., Day R.H. 1994. Colour-and form-dependent loss of plastic micro-debris from the North Pacific Ocean. Mar Pollut Bull 28(1): 39-43.

Shiber J.G. 1979. Plastic pellets on the coast of Lebanon. Mar Pollut Bull 10(1): 28-30.

Smith M., Love D.C., Rochman C.M., Neff R.A. 2018. Microplastics in seafood and the implications for human health. Curr Environ Health Rep 5: 375-386.

Solomando A., Capo ´ X., Alomar C., Alvarez ´ E., Compa M., Valencia J.M., Sureda A. 2020. Long-term exposure to microplastics induces oxidative stress and a proinflammatory response in the gut of *Sparus aurata* Linnaeus, 1758. Environ Pollut 115295.

Solomando A., Cohen-Sánchez A., Box A., Montero I., Pinya S., Sureda A. 2022. Microplastic presence in the pelagic fish, *Seriola dumerili*, from Balearic Islands (Western Mediterranean), and assessment of oxidative stress and detoxification biomarkers in liver. Environ Res 212, 113369.

Stefatos A., Charalampakis M., Papatheodorou G., Ferentinos G. 1999. Marine debris on the seafloor of the Mediterranean Sea: examples from two enclosed gulfs in Western Greece. Mar Pollut Bull 38(5): 389-393.

Suaria G., Avio C.G., Mineo A., Lattin G.L., Magaldi M.G., Belmonte G., Moore C.J., Regoli F., Aliani S. 2016. The Mediterranean plastic soup: synthetic polymers in Mediterranean surface waters. Sci Rep 6, 37551.

Sussarellu R., Suquet M., Thomas Y., Lambert C., Fabioux C., Pernet M.E.J., Huvet A. 2016. Oyster reproduction is affected by exposure to polystyrene microplastics. PNAS 113(9): 2430-2435.

Şener İ., Yabanlı M. 2023. Macro-and microplastic abundance from recreational beaches along the South Aegean Sea (Türkiye). Mar Pollut Bull 194, 115329.

Tang J., Ni X., Zhou Z., Wang L., Lin S. 2018. Acute microplastic exposure raises stress response and suppresses detoxification and immune capacities in the scleractinian coral *Pocillopora damicornis*. Environ Pollut 243: 66-74.

Tonay A.M., Dede A., Ozturk A.A., Ozturk B. 2007. Stomach contents of harbour porpoises (*Phocoena phocoena*) from the Turkish Western Black Sea in spring and early summer. In *CIESM Congress Proceedings* (No. 38). CIESM, Monaco.

Topçu E.N., Öztürk B. 2010. Abundance and composition of solid waste materials on the western part of the Turkish Black Sea seabed. Aquat Ecosyst Health Manag 13(3): 301-306.

Turhan D.Ö. 2021. Evaluation of microplastics in the surface water, sediment and fish of Sürgü Dam Reservoir (Malatya) in Turkey. Turk J Fish Aquat Sci 22(7).

Valente T., Sbrana A., Scacco U., Jacomini C., Bianchi J., Palazzo L., de Lucia G.A., Silvestri C., Matiddi M. 2019. Exploring microplastic ingestion by three deep-water elasmobranch species: a case study from the Tyrrhenian Sea. Environ Pollut 253: 342-350.

Van Cauwenberghe L., Janssen C.R. 2014. Microplastics in bivalves cultured for human consumption. Environ Pollut 193: 65-70.

Van Sebille E., Spathi C., Gilbert A. 2016. The ocean plastic pollution challenge: towards solutions in the UK. Grant. Brief. Pap 19: 1-16.

Vecchi S., Bianchi J., Scalici M., Fabroni F., Tomassetti P. 2021. Field evidence for microplastic interactions in marine benthic invertebrates. Sci Rep 11 (1): 1-12.

Viool V., Oudmaijer S., Walser B., Claessens R., van Hoof L., Strootman W.J. 2018. Study to support impact assessment for options to reduce the level of ALDFG. In: European Commission. Framework Contract EASME/EMFF/2016/029.

Von Moos N., Burkhardt-Holm P., Köhler A. 2012. Uptake and effects of microplastics on cells and tissue of the blue mussel *Mytilus edulis* L. after an experimental exposure. Environ Sci Tech 46(20): 11327-11335.

Wang C., Zhao J., Xing B. 2021. Environmental source, fate, and toxicity of microplastics. J Hazard Mater 407, 124357.

Waters C.N., Zalasiewicz J., Summerhayes C., Barnosky A.D., Poirier C., Gałuszka A., Wolfe A.P. 2016. The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science, 351(6269), aad2622.

Watts A.J., Urbina M.A., Corr S., Lewis C., Galloway T.S. 2015. Ingestion of plastic microfibers by the crab *Carcinus maenas* and its effect on food consumption and energy balance. Environ Sci Techn 49(24): 14597-14604.

Weis J.S. 2014. Physiological, developmental and behavioral effects of marine pollution.

Welden N.A., Cowie P.R. 2016. Environment and gut morphology influence microplastic retention in langoustine, *Nephrops norvegicus*. Environ Pollut 214: 859-865.

Wieczorek A.M., Morrison L., Croot P.L., Allcock A.L., MacLoughlin E., Savard O., Doyle T.K. 2018. Frequency of microplastics in mesopelagic fishes from the Northwest Atlantic. Front Mar Sci 5, 39.

Wright, S.L., Rowe D., Thompson R.C., Galloway, T.S. 2013a. Microplastic ingestion decreases energy reserves in marine worms. Curr Biol 23: 1031-1033.

Wright S.L., Thompson R.C., Galloway T.S. 2013b. The physical impacts of microplastics on marine organisms: a review. Environ Pollut 178: 483-492.

Xu P., Peng G., Su L., Gao Y., Gao L., Li D. 2018. Microplastic risk assessment in surface waters: A case study in the Changjiang Estuary, China. Mar Pollut Bull 133: 647-654.

Yabanlı M., Yozukmaz A., Şener İ., Ölmez Ö.T. 2019. Microplastic pollution at the intersection of the Aegean and Mediterranean Seas: A study of the Datça Peninsula (Turkey). Mar Pollut Bull 145: 47-55.

Yonkos L.T., Friedel E.A., Perez-Reyes A.C., Ghosal S., Arthur C.D. 2014. Microplastics in four estuarine rivers in the Chesapeake Bay, USA. Environ Sci Tech 48(24): 14195-14202.

Yozukmaz A. 2021. Investigation of microplastics in edible wild mussels from İzmir Bay (Aegean Sea, Western Turkey): A risk assessment for the consumers. Mar Pollut Bull 171, 112733.

Yücel N., Kılıç E. 2022. Microplastic contamination in the freshwater crayfish *Pontastacus leptodactylus* (Eschscholtz, 1823). Mar Pollut Bull 185, 114337.

Zbyszewski M., Corcoran P.L. 2011. Distribution and degradation of fresh water plastic particles along the beaches of Lake Huron, Canada. Water Air Soil Pollut 220: 365-372.

Zhang C., Chen X., Wang J., Tan L. 2017. Toxic effects of microplastic on marine microalgae *Skeletonema costatum*: interactions between microplastic and algae. Environ Pollut 220, 1282e1288.

Zhang F., Wang X., Xu J., Zhu L., Peng G., Xu P., Li D. 2019. Food-web transfer of microplastics between wild caught fish and crustaceans in East China Sea. Mar Pollut Bull 146, 173-182.

Zhang X., Shi J., Yuan P., Li T., Cao Z., Zou W. 2023. Differential developmental and proinflammatory responses of zebrafish embryo to repetitive exposure of biodigested polyamide and polystyrene microplastics. J Hazard Mat 460, 132472.

Zwollo P., Quddos F., Bagdassarian C., Seeley M.E., Hale R.C., Abderhalden L. 2021. Polystyrene microplastics reduce abundance of developing B cells in rainbow trout (*Oncorhynchus mykiss*) primary cultures. Fish Shellfish Immunol 114: 102-111.

Chapter 14

A Research On The Physical Conditions And Problems Of Bursa-Yenişehir District Dairy Cattle Farms Regarding Business Buildings

Serhat AYAS1[11]

Summary

In this research, in the 1997, the status of Bursa-Yenişehir dairy cattle farms structures and their problems have been observed, the possibility of their improvement considering the characteristic of the region has been searched, the most suitable dairy cattle barns for this region has been investigated. According to the results obtained from the observation, determined some faults in the arrangement of the buildings in the farmyard. The majority of the barns were far from supplying the modern structural rules and the environmental requirements of the animals. It was concluded that the barns, which were planned as free loose barn were not appropriately used during the production period because of the deficiencies and the traditional habits made when they were planning. The types of the free-stall and free-loose barns, which were more suitable when compared to tied-stall barns, were suggest to the farmers for this region.

Keywords: Dairy cattle barns; Tied-stall barns; Free-stall barns; Free-loose barns; Barn types

Introduction

Turkey also made livestock production in the agribusinesses, and there are many problems related to business buildings and operating conditions. One of these problems is that agricultural businesses are small family agribusinesses. Apart from this problem, although animal products have a significant place in human nutrition, the amount of animal food per capita is lower than in developed countries. In addition, despite the high animal existence, the total agricultural production is low. Another significant problems are that the production per animal is below a certain standard. The business buildings are not of sufficient size and equipment and can not market the animal products. Apart from the above-mentioned structural problems in the agribusiness, there are problems such as the difficulty of accessing technical information by animal businesses, the inadequacy of modern tools and machines, unwillingness to cooperate, and inadequate animal improvement activities.

[1] [1]Yenisehir I.O. College, Uludag University, 16900 Yenisehir/Bursa, Turkey

Foodstuffs of animal origin in human life are crucial in balanced nutrition. Annual meat consumption is 39 kg per capita globally, and this value is around 20 kg in Turkey. These values are 123 kg and 91 kg in developed countries such as the USA and the EU. The protein value of red meat consumption should be considered, and this value should be 33 kg. The annual per capita red meat consumption in the world was 14.5 kg in 2019. While this value is 46 kg in the USA, 26 kg in the EU, it is at a low value such as 8.5 kg in Turkey (**TUİK, 2020**). The annual per capita consumption of red meat in Turkey was 8.6 kg in 2019, while this value dropped to 7 kg in 2010. When these values are compared with the values in the USA and EU countries, there is an animal protein deficit in Turkey. The amount of milk per capita in Turkey are low compared with the US and EU countries. The annual per capita consumption of 12.5 liters of milk, yoğurt consumption is 41.1 kg, cheese consumption is 14.2 kg in Turkey (**TUİK, 2020**). Animal barns were made several mistakes in planning in Turkey. As a result, animal health and productivity are negatively affected since the functions expected from barns are not fully achieved. One of the main mistakes made in planning is not considering the region's climate conditions. However, increasing animal productivity is achieved by establishing the most appropriate and economic balance for animals. In our country, the structuring of building elements and selecting materials are made in the same way and with the same type of barns, even in climatic regions that differ from each other. This situation unnecessarily increases the building cost (**Olgun and Öneş, 1989**). For the barns to fulfill their functions properly, they must prepare plans by the special conditions of various climatic and agricultural regions. It can be achieved by examining the barns in the different areas on-site, examining the detected problems under the light of the basic principles of barn planning technique, and developing suitable plan types for other conditions. In this study, the structural conditions and difficulties of the barns in the dairy cattle farming businesses of Yenişehir vicinity, which has an essential place in Bursa region's dairy cattle farming and which has the feature of an exemplary vicinity in this regard, were investigated and searched the possibilities of developing them. In addition, it was aimed to help the preparation of suitable barn types in a particular agribusiness courtyard layout by determining the general principles in the planning of the barns planned to be built in the future in this region.

Materials and Methods

This research was carried out in 1997 to determine the circumstance, competence, and improvement possibilities of the barns in the farmyard layout of dairy cattle farming businesses in the Bursa-Yenişehir district. For this purpose,

17 barns in 9 dairy cattle agribusinesses representing the agribusinesses in the district were selected as research materials. There are 2 barns in one of the established agribusinesses. In the research, 3 different barn types were examined, and it was determined that 13 of the barns with tied-stall barns, 3 of them were free-loose barns and 1 of them were free-stall barns. Yenişehir district, together with its villages, covers an area of 772 km^2. The Yenişehir plain is 240 m above sea level. Kocasu, which crosses the plain and mingles with Sakarya, is the lifeblood of the local agriculture. All the climatic characteristics of the Marmara region are seen in the Yenişehir vicinity. Summers are generally dry and hot. The rain mainly falls in spring and autumn, and winters are intermittent with snow. The distribution of precipitation to the seasons is 184.6 mm in the spring, 74.0 mm in the summer, 174.1 mm in the autumn and, 271 mm in the winter. The annual average temperature in Bursa is 14.4 °C. The highest average temperature was 30.9 °C in August, and the average minimum temperature was 1.7 °C in January (**Anonymous, 1997**). The climate data of Bursa province are given in **Table 1**. To research by its purpose, paying attention to selecting barns that could represent the district and the region by obtaining the information of "Yenişehir District Directorate of Agriculture" and the "Yenişehir Milk Businesses Association". In the selected agribusinesses, completed the data file of the agribusiness by adding the measurements, sketches, and photographs made within the agribusiness along with the previously prepared questionnaires. The building materials used in the barns were determined, the dimensions related to the interior layout of the barns were measured and cross-section-details were derived. In addition, information on ventilation and lighting in the barns was collected. Detailed information about the problems encountered in practice was obtained by interviewing the owners and workers in the business. The issues in the barns were tried to be determined by observations. The settlement and direction status of the barns and utilities in the agribusinesses were evaluated using the drawn sketch, plan, and examination information. Questionnaire studies, photographs, sketches, and plans drawn during the examination stage were used. In addition, the courtyard layout of the agribusinesses, the location of the barns and utilities, and the floor plans and details of these structures were drawn in scale. In the light of the measurement results and the plans drawn in the research, the barn systems, the arrangement of the stalls in closed barns, the manger way, the linkage arrangements, urine channels, service, and passageways, evaluated barn dimensions, building materials, and the dimensions of the various building elements, and determined problems. It has been investigated whether they are sufficient in various aspects in free loose and free-stall barns. According to the conditions of Bursa-Yenişehir district and the priciples in the literature,

appropriate barn plans were prepared for the region and the most suitable barn types were tried to be determined.

Results

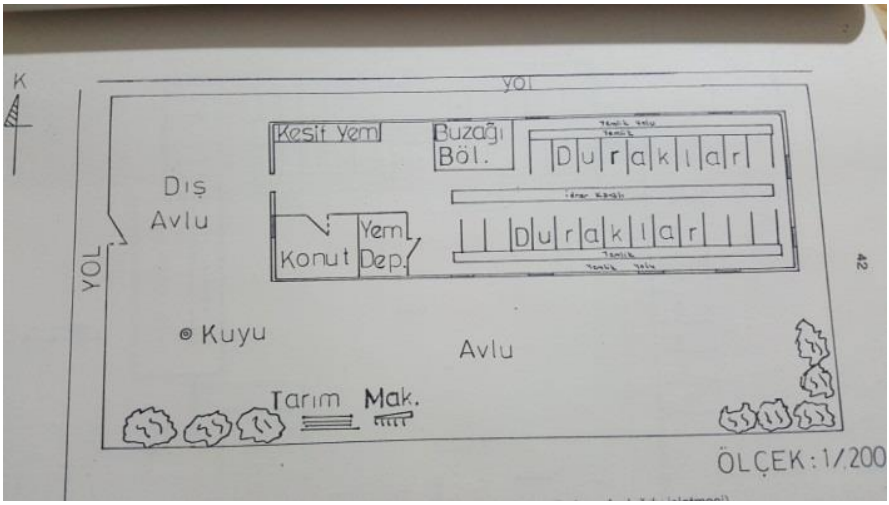
In the study, measurements, sketches, questionnaires, and observations were made in 17 barns in 9 agribusinesses as research material, and data on barns in the agribusiness were generated. The main occupation of all agribusinesses was dairy cattle farming.

Tablo 1. 1997 year Bursa province climate data

Meteorological Data	MOUNTS												
	1	2	3	4	5	6	7	8	9	10	11	12	Av.
Ave. Temp. (°C)	5.2	6.0	8.0	12.6	17.4	21.6	24.2	23.9	19.7	15.4	11.3	7.5	14.4
Ave. High Temp. (°C)	9.2	10.5	13.4	18.7	23.6	28.0	30.6	30.9	26.9	22.1	16.7	11.7	20.2
Ave. Low Temp. (°C)	1.7	2.1	3.4	7.0	11.2	14.4	16.7	16.7	13.3	10.0	7.0	3.9	9.0
Highest Temp. (°C)	23.8	26.1	32.5	36.2	37.0	40.5	41.3	42.6	40.1	35.4	31.0	26.5	42.6
Lowest Temp. (°C)	-20.5	-25.7	-8.7	-4.2	0.8	4.0	8.3	7.6	3.3	-1.0	-8.4	-17.9	-25.7
Ave. Rel. Hum (%)	76	74	72	70	70	63	59	60	66	72	76	75	69.0
Highest Rel. Humidity (%)	81	80	82	82	82	76	72	75	82	86	85	81	80.0
Ave. Precip. (mm)	96.5	83.9	73.0	59.0	52.6	30.2	26.8	17.0	41.7	57.1	75.3	99.7	713.1
Ave Wind Velocity (m/s)	3.4	3.3	2.9	2.4	2.0	2.3	2.9	2.8	2.4	2.0	2.3	3.2	2.7
Ave. Snowy Days	3.1	2.5	0.9	0.2	-	-	-	-	-	-	0.1	0.9	7.7

Depth of Snow Cover	0.8	0.5	0.19	0.1	-	-	-	-	-	-	0.33	0.35	0.8

Water supplied from the city network was used as a water resource in agribusinesses. The electricity needed in the agribusinesses was provided from the main transformers, and all agribusinesses benefit from electricity. The barns were built within the courtyard of the agribusinesses and separately from the homes, except for 3 agribusinesses within the agribusinesses examined. Most of the buildings that agribusinesses need were located in the courtyard. An example of courtyard arrangement was given in **Figure 1**. The sketch of an agribusiness where all the structures were collected in a courtyard was given in **Figure 2**. When examined the constructional dimensions, arrangement types, temperature, and relative humidity values in tied-stall barns, differences emerged compared to the standard values. This situation caused damage to the building elements of the barn, and the workers and animals in the barn to be negatively affected. The amount of heat lost from the building elements was high due to the insufficiency of the materials used for insulation in some barns. The floor plan and the cross-sectional area of a tied-stall barn were as given in **Figure 3**. Ventilation areas and ventilation windows in the barns were given in **Figure 4** and **5**. Natural ventilation system has been applied in all of the barns. Due to the insufficiency of the air inlet and outlet



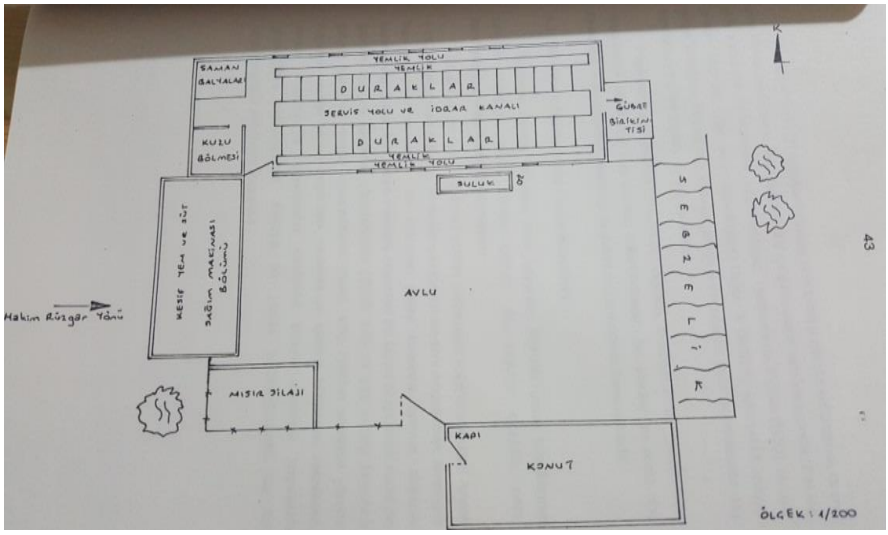


Figure 1. An example of the arrangement of a agribusiness courtyard

Figure 2. The sketch of an agribusiness where all the structures are collected in a courtyard.

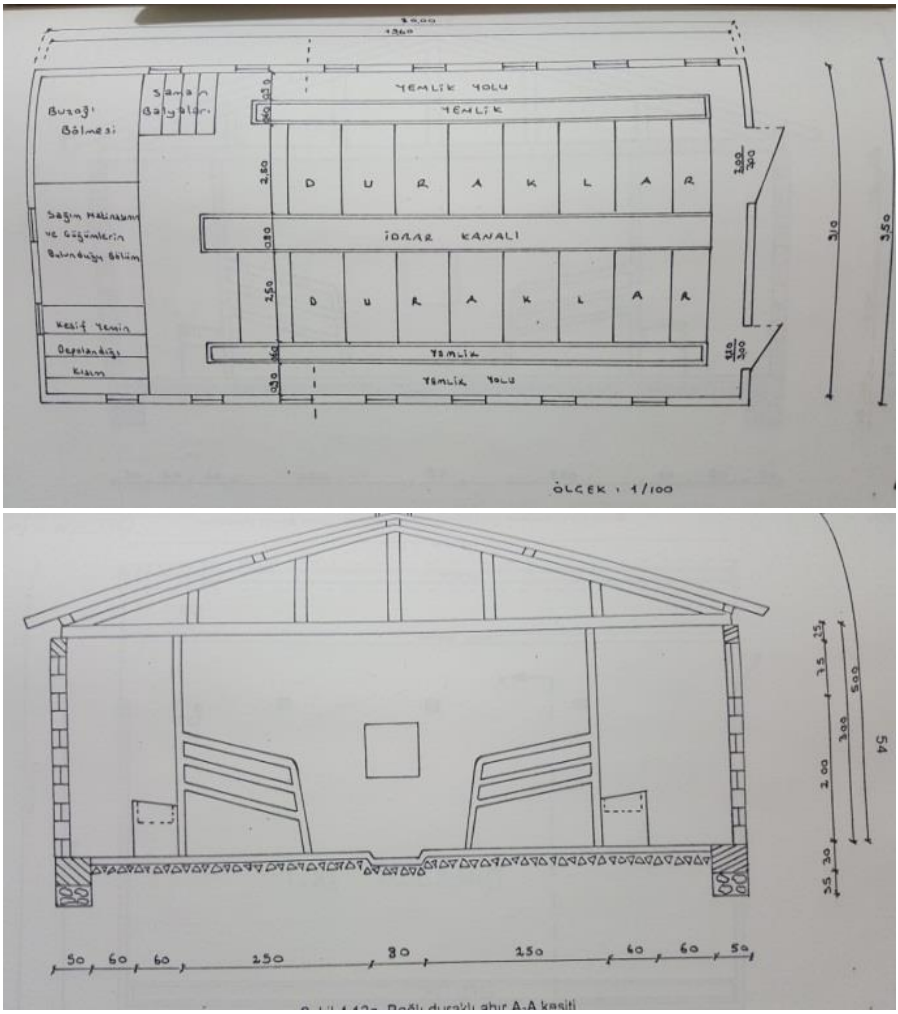


Figure 3. The floor plan and the cross sectional area of a stall barn

areas required for natural ventilation could not achieve the desired amount of air exchange the barn. The ventilation areas and windows in the barns examined were given in **Figures 4** and **5**. While only **4** of the barns had natural lighting systems, the others had natural and artificial lighting systems together. Natural lighting was made from windows, translucent plastic covers on the roof, and air outlet areas. The shortage of the total window area in the 11 barns examined led to the failure to provide the desired natural lighting. In the artificial lighting applied in the barns, the distribution of the desired light in the barn had been reduced due to the insufficiency of the lamps and the fact that they could not be appropriately placed. The natural lighting and insufficient lighting systems used in the barns examined were shown in **Figures 6 and 7.**

Figure 4. and Figure 5. Ventilation areas and ventilation windows in the barns

Figures 6 and 7. The natural lighting and insufficient lighting systems applied in the barns where the research was conducted are shown.

The research was carried out in 17 barns in 9 dairy cattle agribusinesses and it was determined that 13 (76.5%) of the barns had tied-stall barns, 1 (17.6%) free-loose barn and 3 (5.9%) free-stall barns. The number of milk cows in the barns mainly was between 1-10 heads. The grouping of the barns according to the number of milch cows was given in **Table 2.**

Table2. Grouping barns according to the number of milch cows

Groups by the number of dairy cows	Number of barns	%
1-10	10	58.8
11-20	6	35.3
21-30	1	5.9
Total	19	100.0

Findings of the physical conditions of the barns

Most of the barns in the study were in the east-west direction. The front of the 12 (70.6%) barns was towards the south. The barn widths varied between 7.0-24.0 meters, and the average was measured as 9.9 meters. The usable length of the barn floors varied between 12.0-31.0 m. The length of the barn mostly varied between 13.0-16.0 m. Values for barn floor area dimensions were given in **Table 3**.

Table 3. Values for barn floor area dimensions

Barn width (mm)	Number of barns	%	Barn length (m)	Number of barns	%
6-9	11	64.7	13-15	4	23.5
9-12	5	29.0	16-19	1	5.9
12-15	-	-	19-22	3	17.6
15-18	-	-	22-25	1	5.9
18-21	-	-	25-28	3	17.6
21 and upper	1	5.9	28 and upper	5	29.5
Total	17	100		17	100

In only 2 (15.4%) of the stall barns, there had been made stalls by the rules. Although the others do not had a stall platform, found stall partitions separating the cattles from each other. The widths of the barns have been measured between 1.10-1.85 m, and the lengths of the barns between 1.6-2.0 m. In the barns without stall partitions, animals of 0.80-1.85 m width were tied. The animals were chained to the stalls. The manger widths of the barns varied between 0.50-0.70 m and the average were measured 0.63 m. The height of the mangers from the stall varied between 0.20-0.85 m and their depth between 0.10-0.45 m. Droppings canal widths of barns were measured between 0.60-1.70 m, and were found to be high. Droppings canal slopes are generally inadequate and measured between 0-1.5%. It did not find the manger path in 2 barns. In addition, the manger road widths of 0.5-1.7 m were found in the barns in the partitions connected to the service road. The height of the barns from the bottom to the ridge piece had been measured between 2.5 and 3.0 m. The values of barn heights in stall barns were given in **Table 4**.

Table 4. Barn heights in stall barns

Barn heights	Number of barns	%
2.0-2.5	2	15.4
2.5-3.0	8	61.5
3.0-3.5	2	15.4
3.5-4.0	1	7.7

The air volume per cattle in the barns varied between 5.57-29.46 m^3, and an average of 20.89 m^3 was calculated. It has been calculated that the resting places of the free-loose barns varied between 128-300 m^2, and the areas per cattle varied between 8.4-30.0 m^2. It has been observed that the floors of the resting places of all barns were concrete. While the floor of the promenade of the barns was concrete in 2 barns, the others had soil. In the free-stall barn, which has 53 stalls along the length of the barn and out from the long side, stall lengths were measured as 2 m and stall widths as 1.0 m. The width of the service path was 2 m, and cleaned the service path and manger path during milking. In addition, partitions prepared for milking were allocated behind the stalls and between the service path and the mangers. The promenade area per cattle has been calculated as 16.7 m^2. Except for 7 (41.2%) of the barns examined in the research, there were no partitions reserved for calves and steers. The group partitions contained 2-7 cattles. The area of the partitions was calculated as 10.35 m^2 on average. In the free-stall barn, the style of the arrangement inside the barn was given in **Figure 8**. While some of the barns have partitions reserved for birth, no space is left for sick animals on any agribusiness. The birth and calf partition in a tied-stall barn was shown in **Figure 9**.

Figure 8. The style of the arrangement inside the barn in the free stall barn

Figure 9. Birth and calf compartment in a barn

The data on the manger, stall, and manure canal dimensions and service road widths in the barns were given in **Table 5**. In addition, the information on the number of milch cattles, width, length and height, and window and door dimensions of the barns were given in **Table 6.** Established ditches silos in the courtyard for 7 (41.2%) of the business for silage feed storage. Drinkers with a length of 2.5-20 m and a width of 04-0.8 m were planned in the barns to meet the water needs of the cattles. It was determined that threw of the manure collected in the barn out of the manure evacuation openings opened on the barn walls and accumulated during daily cleaning. A manure discharge opening in a barn was shown in **Figure 10**.

Figure 10. Manure discharge opening in a barn

While stone was used as the basic building material in 6 (35.3%) barns, concrete material was used in 11 (64.7%) barns. The barn floor consisted of compacted soil in 6 (35.3%) of the barns and concrete poured on stone blockage in 11 (64.7%) of the barns. It was determined that the walls of 4 (23.5%) of the barns were made of briquettes material, 7 (41.2%) of the walls of briquette and plaster material, and the walls of 6 (35.3%) of them were made of brick material. While 9 (64.3%) of the barns had wooden doors, 5 (35.7%) had doors made of iron or sheet metal. Door widths varied between 1.0-4.0 m, and heights varied between 2.30-3.10 m. It has been determined that window widths in barns varied between 0.8-3.0 m and heights varied between 0.45-0.90 m.

Discussion

Most of the barns surveyed had 1-10 head cattles. There should be cattles between 20-30 heads (**Kaygısız and Tümer, 2009**). Natural ventilation was used in all of the barns. Fresh air entered the barn through windows, doors, manure openings, or windows that opened for some reason. However, the insufficiency of the air intake holes and exit openings required for natural ventilation in most barns could not provide the barn's desired level of air exchange. **Arıcı et al. (2001)** reported that the insulation of the walls was an important precaution when roof insulation was not sufficient. It is also possible to reduce the barn volume by reducing door and window areas and building ceilings as other measures. Large openings for summer ventilation and small openings for winter ventilation are used as air entry windows (**Ekmekyapar, 2001**). **Yüksel et al. (2004)** determined that the dimensions of the sections to be used as air intake holes (0.05x0.75 m and 0.15x0.75 m) are the most appropriate. These results are consistent with the problems related to natural ventilation in barns found in previous studies (**Avcı, 2009; Alkan et al., 2011; Alkan, 2015**). While it was determined that sufficient lighting was done in only 4 barns, natural lighting couldn't be done at a sufficient

level due to the small window area in 9 barns. **Alkan (2015)** stated that the ratio of the window area to the barn floor area should be between 1/15-1/20 for the animals in the barn to benefit from natural light. **Yaslıoğlu and Arıcı (2005)** specified that should use 4-6 W/m^2 electric bulbs or 1.5-2.0 W/m^2 fluorescent lamps in the manger way to provide the required lighting intensity. These results were consistent with natural and artificial lighting problems in barns found in previous studies (**Özhan et al., 2009; Alkan et al., 2011; Alkan, 2015; Şirin and Kocaman, 2016; Bilgili and Aybek, 2019**). The long side of most of its barns is located in an east-west direction. The façade of 12 (70.6%) of the barns opens to the south. **Şimşek (1996)** and **Kayar (2011)** indicated the importance of placing in a north-south direction to benefit from natural lighting in double stall barns. In addition, in 3 free barns, the direction where the walls are open is the south direction. **Büyüktaş et al. (2016)** and **Uğurlu and Şahin (2010)** were suitable for the directions previously reported. While the average width of the mangers in the barns was 0.63 m, the heights of the mangers varied between 0.20-0.85 m. In the tied-stall barns, the manger path left in front of the wall was at most 1.0 m wide. **Arıcı et al. (2010)** previously stated 1.0 m manger path width was encountered in only 3 (23%) of the stall barns examined. The stall lengths in the barns varied between 1.5-2.5 m. **Yüksel and Şişman (2015)** reported that the mangers varied between 0.6-0.8 m depending on the structure. The width of the urinary canal in the barns was measured between 0.35-0.55 m and the average was calculated as 0.42 m. **Usta (2011)** and **Çayır et al. (2012)** stated that the width of the urinary canal varied between 0.30-0.40 m. However, it has been reported that these values were taken as 0.45-0.50 m in conditions where the cleaning was done mechanically. Service road widths in the barns varied between 0.60-2.00 m, and **Büyüktaş et al. (2016)** and **Olgun (2011)** are less than the recommended value of 1.5-2.0 m. Free loose stall barns are suitable for businesses with 60 or more cattle (**Anonymous 2016**). Service path widths in the barns varied between 0.60-2.00 m, and **Büyüktaş et al. (2016)** and **Olgun (2011)** were less than the recommended value of 1.5-2.0 m. Free stall barns are suitable for businesses with 60 or more cattle (**Anonymous 2016**). The average stall width of free stall barns was 1.00 m, and the average stall length was calculated as 2.0 m. **Olgun (2011)** specified that the optimum stall width was 1.15 m and stall length was 2.15 m. Previous studies were consistent with the results obtained in the research (**Öztürk et al., 2007; Arıcı et al., 2010; Yılmaz and Yardımcı, 2014**). Newborn calves were taken into individual calf partitions 2-3 days after birth in case of disease reinfection. Only 1 of the agribusiness had an calf partition. The area reserved as a calf partitions in this agribusiness was only wide enough for 4 calves to coexist. **Arıcı et al. (2010)** stated that usually 50% of dairy

cattles should have been kept in the barns. The milking house must separate a clean and well-drained part and provide adequate lighting, ventilation, and water. The window area in the milking place should be 1/10 of the floor area, and it is appropriate to plan one milking stall for every ten cattles (**Arıcı et al., 2010; Yüksel and Şişman, 2015)**.

Barn Building Elements

All of the barns had foundations, but the basic wall width was insufficient. İf the width of the foundation wall is taken 0.5-0.6 m, it is possible to carry the load on the foundation **(Alkan, 2015; Güğercin et al., 2017).** The height of 61.5% of the barns varied between 2.5-3.0 m. The distance between the service road and the ceiling complied with the values recommended in previous studies. It was essential to plan barn wall heights between 2.0-3.5 m in tied-stall barns and 2.5-3.0 m in free loose barns to constitute the desired air volume. **Kılıç et al. (2020)** reported that barn height ranges between 2.50-2.75 for warm regions. It has been observed that the widths of single winged doors in the barns examined are wider than the 1.00-1.25 m dimensions given in **Şirin and Kocaman (2016)**. The door width recommended for double-wing doors should be between 1.50-1.65 m (**Balaban and Şen, 1988**). Door heights are kept low in some barns. It can suggest that the door heights to be 2.0-2.4 m higher than the barn floor (**Göncü and Gökçe, 2017; Güler et al., 2017**). Barn window widths varied between 0.8-3.0 m, window heights 0.45-0.90 m, and the height of the windows from the ground varied between 1.00-1.25 m. The windows could not provide a homogeneous light distribution in the barn. **Özkütük et al. (2007)** and **Alkan (2015)** stated that window widths and heights should be planned 1.00-1.25 m in size, and the windows in a rectangular shape, adequate lighting and homogeneous distribution of light in the barn.

Choosing the Suitable Barn Type

The research results showed that the barns could not provide the environmental conditions desired by the animals due to various planning faults and lack of information. In terms of economic management, planning of dairy cattle barns of 30 heads and above will be appropriate considering factors such as the economic situation of the business manager, instability in milk prices, rapid increases in feed prices, high feed loan interest rates, and the obligation to employ workers. In determining the barn type, environmental conditions, regional habits, and opportunities to provide building materials are essential. When these factors are evaluated together, free-stall and free-loose barns are more suitable than tied-stall barns for the region. Tied-stall barns are not recommended than the other

two barn types due to both the construction cost and the difficulties in management, considering the region's environmental conditions. Although free-loose barns constitute the most suitable barn type for the region, they are preferred in tied-stall barns due to the habits of those engaged in animal husbandry in the region. The recommendations made in the study were consistent with previous studies (**Çaylı, 2006; Karabacak and Topak, 2007; Kocaman, 2008; Alkan 2015; Şirin ve Kocaman, 2016; Kurç ve Kocaman, 2016; Kılıç ve ark., 2020**).

Table 5. Measurements of manger, stall and urinary canal sizes and service road widths in barns

Business No	Barn Type	Feeder Dimension (m)				Stall Dimension (m)			Manure Channel Dimension (m)				Service Road (m)	Feeder Road (m)
		Width (m)	Feeder Height (m)	Feeder Height (m)	Feeder Thickness (m)	Width (m)	Length (m)	Base Materials	Width (m)	Depth to the Stall Side	Service Road (m)	Slope (%)		
1	Stall Barn	0.75	0.62	0.30	0.10	1.85	1.90	Concrete	0.95	0.05	0.95	0.5	0.95	0.95
2	Stall Barn	0.50	0.40	0.35	0.10	1.85	1.80	Concrete	0.50	0.10	-	0.0	-	1.00
3	Stall Barn	0.50	0.50	0.25	0.10	1.65	2.10	Concrete	-	-	0.80	1.0	0.80	-
4	Stall Barn	0.65	0.70	0.40	0.15	1.10	2.00	Concrete	0.60	0.05	0.60	0.5	0.60	1.00
5	Free Loose Barn	0.50	0.50	0.30	0.03	-	-	Concrete	0.60	0.05	0.60	0.5	0.60	0.60
6	Stall Barn	0.60	0.75	0.25	0.10	1.50	2.50	Concrete	1.00	0.15	3.00	0.5	2.00	1.70
7	Stall Barn	0.60	0.60	0.45	0.10	2.00	1.50	Concrete	1.00	0.05	1.00	1.5	1.00	0.95

8	Stall Barn	0.60	0.20	0.10	0.10	1.20	1.50	Concrete	0.35	0.05	1.35	0.5	1.35	0.95
9	Free Loose Barn	0.70	0.80	0.30	0.15	-	-	Soil	1.10	0.10	1.10	0.7	1.10	0.90
10	Stall Barn	0.60	0.65	0.35	0.10	1.70	1.80	Concrete	0.90	0.10	0.90	0.5	0.90	0.50
11	Free Loose Barn	0.50	0.90	0.60	0.15	-	-	Soil	0.80	0.15	0.80	1.5	0.80	-
12	Stall Barn	0.75	0.70	0.45	0.10	1.50	2.50	Concrete	0.55	0.05	0.60	0.5	0.60	0.90
13	Stall Barn	0.60	0.85	0.25	0.10	2.00	2.20	Concrete	0.40	0.08	-	0.0	-	-
14	Stall Barn	0.70	0.50	0.25	0.15	1.20	2.00	Concrete	0.80	0.10	0.80	1.0	0.80	0.90
15	Free Stall Barn	0.60	0.10	0.10	-	1.00	2.00	Concrete	1.70	0.05	1.70	0.6	1.70	0.90
16	Stall Barn	0.70	0.85	0.25	0.10	1.10	2.00	Concrete	0.36	0.10	2.00	1.5	2.00	1.00

17	Stall Barn	0.60	0.80	0.35	0.10	1.20	1.60	Concrete	-	-	-	0.0	-	-

Table 6. Measurements of the number of milking cows, width, length and height of the barns and the dimensions of windows and doors

Business No	Barn Type	Number of Milch Cows	Barn Width (m)	Barn Length (m)	Barn Height (m)	Window Dimension (mm)		The height of Windows form the Ground	Door Dimensions (mm)		Local
						Width (m)	Height (m)		Width (m)	Height (m)	
1	Stall Barn	11	8.0	13	3.5	0.8	0.40	1.45	1.20	1.85	Ayaz
2	Stall Barn	10	7.0	13	4.0	0.9	0.45	1.70	1.40	2.10	Osmaniye
3	Stall Barn	14	6.5	20	4.0	0.9	0.65	1.00	1.00	1.70	Karaköy
4	Stall Barn	13	8.5	24	5.0	1.6	0.60	2.00	2.00	2.00	Karaköy
5	Free Loose Barn	7	9.0	17	4.0	-	-	-	-	-	Karacaali
6	Stall Barn	10	9.5	20	5.0	0.9	0.75	2.00	2.00	3.00	Hayriye
7	Stall Barn	11	8.5	30	4.0	0.8	0.50	1.65	2.60	1.90	Avşar
8	Stall Barn	10	10.0	30	5.5	1.5	0.45	1.70	2.50	2.10	Karasıl

9	Free Loose Barn	20	10.0	30	5.5	-	-	-	-	-	Karasıl
10	Stall Barn	10	7.5	20	4.0	1.0	0.60	1.75	2.50	2.75	Karasıl
11	Free Loose Barn	9	8.0	16	4.0	-	-	-	-	-	Merkez
12	Stall Barn	9	8.5	25	4.5	0.9	0.90	2.50	1.50	2.00	Osmaniye
13	Stall Barn	14	9.5	32	4.5	3.0	0.50	2.00	1.60	2.00	Merkez
14	Stall Barn	8	7.7	15	3.5	1.1	0.80	1.20	1.10	2.00	Merkez
15	Free Stall Barn	26	24.0	26	6.0	-	-	-	4.00	3.00	Çardaköy
16	Stall Barn	10	8.0	26	4.3	1.0	0.50	0.50	3.30	2.00	Cihadiye
17	Stall Barn	9	8.5	15	4.5	0.9	0.50	0.50	1.50	2.00	Menteşe

Conclusions

This research, in 1997, investigated the structural condition and problems of dairy cattle farms in the Bursa-Yenişehir district. It was tried to determine the development possibilities and the selection of dairy cattle barns suitable for the region. According to the results, various faults have been identified in the arrangement of the buildings in the business courtyards. Most of the barns are far from providing suitable environmental conditions and modern barns required by the animals. It has been determined that the barns planned as free-loose barn types were not used during the whole production period due to traditional habits and various inadequacies. The barn capacity suitable for the region has been determined as 30 heads considering the physical conditions of the agribusinesses and environmental conditions. Free-loose barn and free-stall barn types are more suitable than tied-stall barns considering the regional requirements, and these barn types are recommended to be selected in planning.

References

Alkan, S., Karslı, T., Karabağ, K. (2011). Basic principles of planning dairy barns in organic agriculture. I. Ali Numan Kıraç Agriculture Congress and Fair with International Participation, 27-30 April, Eskişehir, Turkey.

Alkan, S. (2015). Major problems encountered in dairy cattle barns in Turkey. Academic Journal of Agriculture 4 (1): 43-48.

Anonymous, (1997). The Annual report of Meteorological Station, Bursa, Turkey. www.mgm.gov.tr/verideğerlendirme/il-ve-ilçeler-statistic.aspx?k

Anonymous, (2016). http://www.agriculture.gov.tr/agriculture/livestock/cattle

Arıcı, İ., Şimşek, E., Yaslıoğlu, E. (2001). Planning of dairy cattle barns. Sütaş Dairy Training Center Publications, Bursa, 26p.

Arıcı, İ., Şimşek, E., Yaslıoğlu, E. (2010). Planning of dairy Cattle barns. Sütaş Education Center Publications, Livestock Series. 4, Bursa.

Avcı, M.O. (2009). A research on climatic environmental conditions in barns of dairy farm in Aydın province. Adnan Menderes Üniversity Graduate of Natural and Applied Sciences Department of Farm Structure and Irrigation, MSc. Thesis, Aydın, Turkey.

Balaban, A and Şen, E. (1988). Agricultural structures, Publications of Ankara University Faculty of Agriculture, No: 721, Ankara, Turkey.

Bilgili, M.E. and Aybek, A. (2019). Evaluation in terms of requirements in application of carried out scientific studies for structural and mechanization properties of dairy cattle farms in Turkey. Çukurova 2. International Multidisciplinary Studies Congress. https://www.researchgate.net/ publication/333752

Büyüktaş, K., Atılgan, A., Tezcan, A. (2016). Agricultural production structures. Süleyman Demirel University Faculty of Agriculture Publication No: 101, Isparta.

Çayır, M., Atılgan, A., Öz, H. (2012). Manure and water in cattle shelters. Süleyman Demirel University Faculty of Agriculture Journal 7 (2): 1-9, ISSN 1304-9984.

Çaylı, A. (2006). A Research on environmental conditions control and solution proposals in dairy cattle shelters and a case of Kahramanmaras-Dereköy. KSU Institute of Science, Department of Agricultural Structures and Irrigation, Master Thesis, 59 p.

Ekmekyapar, T. (2001). Agricultural structures. Atatürk University Faculty of Agriculture Textbook. Publications No: 204, Erzurum.

Göncü, S., Gökçe, G. (2017). Technological applications for profitable and sustainable production in cattle breeding enterprises in Turkey. Çukurova J. Agric. Food Sci. 32: 29-34, 2017.

Güğercin, Ö., Koç, D.L., Büyüktaş, K., Baytorun, N., Polat, B., Polat, Ö.D. (2017). Determining of current situation of some animal barns in dairy cattle barns in Adana Province. Çukurova J. Agric. Food Sci. 32: 19-28.

Güler, O., Aydın, R., Diler, A., Yanar, M., Koçyiğit, R., Maraşlı, A. (2017). A Research on barn features of cattle farms; Example of Narman district of Erzurum province. Yüzüncü Yıl University Journal of Agricultural Sciences, 27 (3), 396-405.

Karabacak, A., and Topak, R. (2007). Structural conditions and problems of dairy cattle barns in Ereğli vicinity. Selçuk University Faculty of Agriculture Journal 21 (42): (2007) 55-58.

Kayar, Y. (2011). Evaluation of structural properties of housing in dairy cattle farm in Denizli region. Master Thesis, Depatment of Agricultural Structures and Irrigation, Denizli, Turkey.

Kaygısız, A. ve Tümer, R. (2009). The structural features of farms of dairy cattle in Kahramanmaraş Provınce: 2. Barns Traits. KSU J. Nat. 40 Sci., 12(1): 40-47.

Kılıç, İ., Yaylı, B., Alakberov, A. (2020). Structural status and evaluation of dairy cattle operations in Bakû. Journal of Agricultural Faculty of Bursa Uludag University, 34(2): 237-253.

Kocaman, İ. (2008). A Research on the development of different capacity tied stall dairy cattle barn projects for Kırklareli region. Tekirdağ Faculty of Agriculture Journal 5 (2), Tekirdağ.

Kurç, H. C., Kocaman, İ. (2016). A Structural examination of cattle breeding agribusinesses in Tekirdağ-Malkara region. Tekirdağ Agriculture Faculty Journal 2016: 13 (04).

Olgun, M. and Öneş, A. (1989). Problems and suggestions in animal agribusinesss in TİGEM agribusinesses. (Unpublished research), Ankara.

Olgun, M. (2011). Agricultural structures. Ankara University Faculty of Agriculture Textbook. Publication No. 529, Ankara.

Özhan, M., Tüzemen, N., Yanar, M. (2009). Cattle breeding. Atatürk University Faculty of Agriculture, Offset House, Erzurum.

Özkütük, K., Göncü Karakök, S., Gökçe, G. (2007). Cattle welfare in dairy cow barn design. HASAD Journal 2007, Year: 23, Issue: 32; 32-37s.

Şimşek, E. (1996). Great breeding dairy cattle agribusiness optimum design. Uludağ University Institute of Science (Ph.D Thesis). Bursa.

Şirin, Ü. and Kocaman, B. (2016). Optimum design of dairy cattle barns in Erzurum province. Journal of Agricultural Faculty of Gaziosmanpasa University, 33 (3): 28-38.

TUİK, (2020). http://www.tuik.gov.tr//PruTablo.do?alt_id=1001

Uğurlu, N., and Şahin, S. (2010). The structural properties of dairy cattle barns in Kayseri. Selçuk University Journal of Selçuk Agriculture and Food Sciences, 24 (2): (2010) 23-26.

Usta, S. (2011). Principles of creating architectural layouts in free-stall dairy cattle farms and development of type layout plans as suggestions for producers. Süleyman Demirel University Journal of Technical Sciences Vol: 1, Issue: 2, Page: 29-42, Isparta.

Yaslıoğlu, E., Arıcı, İ. (2005). A Research on the development of suitable cold barn types for dairy cattle in Bursa Region. Journal of Tekirdag Agricultural Faculty, 2/2: 1-13.

Yılmaz, H. İ., Yardımcı, N. (2014). Evaluation of agribusinesses in dairy cattle farms in terms of animal welfare in Isparta region. Harran Journal of Agricultural and Food Sciences, 18 (4), 27-34.

Yüksel, A.N., Soysal, M.İ., Kocaman, İ. and Soysal, S.İ. (2004). Dairy cattle basic book (Planning Dairy Cattle agribusiness/Dairy Cattle Breeding). Hasad Publishing, Istanbul.

Yüksel, A.N. and Şişman, C. B. (2015). Planning animal agribusiness. Hasad Publishing, Istanbul, Turkey.

Chapter 15

Nutritional Value Of Fish

Sinan ÖZCAN[1]

Abstract

Fish is a food composed of water, protein, fat, vitamins and minerals. It is rich in vitamins and minerals such as Iodine, Vitamin D, Calcium, Phosphorus, Potassium, Selenium and Folic acid and Omega Fatty acids, which are essential for the body. All nutrients it contains, including protein, have high bioavailability. With this content, fish is a functional food. The omega-3 fatty acids Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) found in fish are very useful in the prevention and treatment of diseases that affect human health, such as heart disease, cancer, diabetes and high blood pressure. In addition, when compared to farm animal meat in terms of nutritional value, fish meat is more advantageous than farm animal meat as it is high in protein and minerals and low in fat. Thus, it is beneficial to consume fish, which is an excellent food source that should used both for the nutrients it contains and its therapeutic role in the major diseases of our age, 2-3 times a week.

Keywords: Omega-3 fatty acids, protein, fat, vitamin, mineral

Introduction

Aquatic products are one of the oldest food sources of humans. It is known that in the periods before plants were cultivated and animals were domesticated for use as food, the most easily obtained and therefore most consumed foods were fish and other seafood. In parallel with the development of science and technology, some living species consumed in the early periods of history were not consumed as food over time, while fish and other seafood have been included in people's diets from the early periods of history to the present day. Although their composition is generally similar to red meat such as beef, sheep, pork and poultry meat; they also differ in terms of fat, some mineral and vitamin contents (Baysal, 2002).

Aquatic products are among the foods of animal origin and are important for human nutrition. When we examine the fish among aquatic products; It seems that fish is rich in full quality protein, long-chain polyunsaturated fatty acids

[1] Arş. Gör.; Atatürk Üniversitesi Su Ürünleri Fakültesi Yetiştiricilik Bölümü. sinanozcan@atauni.edu.tr ORCID No: 0000-0003-2975-698X

(omega-3-fatty acids), some vitamins and minerals. Fish generally contains 15-20% protein and this protein is highly digestible. This protein contains all essential amino acids, which cannot synthesized in the human body and must obtained from outside through food, in appropriate proportions. When the amount of protein contained in some fish is evaluated, it is seen that there is 15.27 grams of protein in 100 grams of haddock, 16.95 grams of protein in 100 grams of anchovy, and 19.48 grams of protein in 100 grams of sea bass. There are 18 grams of protein in 100 grams of shrimp, which is a seafood product, and 15 grams of protein in 100 grams of squid (URL-1, 2023).

The amount of fat in fish varies depending on many factors. The type of fish, its age, size, living environment, feeding conditions and seasonal factors affect the oil content of the fish. Fish oil contains healthy fats called omega-3 fatty acids that are not found in other foods. One of the omega-3 fatty acids in fish oil is EPA (eicosapentaenoic acid) and the other is DHA (decosahexaenoic acid). These fatty acids; It has positive effects on health such as a protective effect against cardiovascular diseases, a decrease in blood pressure and a decrease in the tendency for blood clotting. For example, 100 grams of whiting contains 0.20 grams of omega-3 fatty acids, and 100 grams of anchovy, which has a higher fat amount than whiting, contains 4.06 grams of omega-3 fatty acids (URL-1, 2023).

Fish is also an important source of vitamins and minerals. Oily fish are rich in vitamin A and vitamin D. Vitamin A; It is necessary for the mucosa covering the inner surface of the mouth, esophagus, stomach, small intestine and large intestine, and for skin and bone health. Vision is especially effective in seeing at dusk. It protects the body against infections. Its deficiency causes visual impairment, blindness, inability to see at dusk, and susceptibility to infections. Vitamin D is a vitamin required for the absorption of calcium and phosphorus. Calcium and phosphorus are minerals required for the formation and health of bone mass. Even if sufficient calcium and phosphorus are taken with food, what is important is the absorption of these minerals. If there is not enough vitamin D, the calcium and phosphorus cannot absorbed and cannot function. This condition results in the disease (rickets), also known as "that leg" in children, due to loss of bone mass and the neck not growing sufficiently. Vitamin D is not found in foods, but fish is a good source of vitamin D. Especially sardines, mackerel and salmon are the best sources of vitamin D. 100 grams of sardines contain 139 IU (international units) of vitamin D, meaning that when 100 grams of sardines are eaten, 69.5% of the daily vitamin D requirement is met (URL-1, 2023).

Seafood and fish are rich in minerals such as iodine, zinc and selenium. Iodine is necessary for the secretion of thyroid hormone, and its deficiency prevents the functions of thyroid hormone from being fulfilled. Chief among these functions are energy production and growth. Iodine deficiency causes the disease known as goiter in children and adults. It also causes mental retardation, hair loss and growth/developmental retardation. When we look at the amount of iodine contained in some fish, it is seen that whiting contains 19.50 micrograms of iodine in 100 grams of edible fish, sea bass contains 9.94 micrograms of iodine in 100 grams of edible fish, anchovy contains 10.68 micrograms of iodine in 100 grams of edible fish, and 100 grams of seafood shrimp contains 58 micrograms of iodine. The daily amount of iodine required is 150 micrograms and 100 grams of shrimp meets approximately 1/3 of the daily iodine intake. Zinc mineral is included in the structure of many enzymes that function in the copying of proteins. It is also a component of insulin and many other enzymes. Its deficiency causes growth retardation, sexual development retardation, delayed wound healing, skin changes, impaired sense of taste and smell, decreased intestinal functions and decreased resistance to diseases. To fulfill these tasks, 10 mg of zinc must taken per day. Approximately 20% of the daily zinc requirement is met by eating 100 grams of anchovies, 22% by eating 100 grams of sardines, and approximately 12% by eating 100 grams of shrimp. Selenium is a mineral that we need in very small amounts in our daily diet, but has very important functions. It is located in the structure of proteins called "selenoproteins", which play an important role in human health. Selenium functions in the antioxidant defense mechanism and thyroid hormone function. Selenium and iodine minerals work together to strengthen the function of thyroid hormone. 100 grams of haddock contains 23.4 micrograms of selenium, 100 grams of anchovy contains 26.4 micrograms of selenium, and 100 grams of shrimp contains 27 micrograms of selenium. As can seen here, whiting, anchovy and shrimp are important sources of selenium. There is almost no selenium in squid. A person needs to take 55 micrograms of selenium per day. Accordingly, consuming 100 grams of haddock, anchovy or squid will meet more than half of the daily selenium requirement (URL-1, 2023).

Fish Consumption And Its Importance In Nutrition

In recent years, with the rapid depletion of world resources, the gradual decrease in agricultural land, the pollution of water resources, and the increase in the world population, danger signals have begun to sound in the food industry. However, the rapid increase in diseases that are closely related to eating habits all over the world has brought the concept of healthy and proper

nutrition to the agenda (Anonymous, 1991). Fish, which is in the protein group of our basic nutrients, plays a key role in a healthy and balanced diet. With its nutritional value rich in phosphorus, calcium and iodine and the vitamins A, B1, B2 and D it contains, fish plays an important role in preventing many diseases, from heart diseases to depression. Research has shown that the average life expectancy is longer and people's physical resistance is stronger in societies that eat mainly fish, compared to those who eat mostly meat and vegetables. While the risk of heart disease decreases by 11% in individuals who consume fish 1 to 3 times a month, this figure decreases by 38% in individuals who consume fish 5 or more times a week. Additionally, fish consumption during pregnancy prevents premature birth and protects against low birth weight. Although fish is one of the keys to a healthy life, unfortunately it is among the least popular food groups in our country, region and province. Although our country is in an extremely suitable location for the fishing industry due to its geographical structure and the climate zone it is in, the average per capita seafood consumption in Turkey is 8.9 kilograms. This figure goes up to 24.6 kg in Italy, 31.2 kg in France, 44.7 kg in Spain and 60-70 kg in Japan (Baysal, 2002).

Energy And Carbohydrate Content Of Fish

Fish do not contain carbohydrates like other meats; therefore, the energy of fish meat comes from its fat and protein content. While the amount of protein does not vary greatly between fish species, there are large differences in the amount of fat. For this reason, the energy value of fish varies according to the amount of fat in their composition; the energy values of fatty fish are higher than lean fish. In general, when compared to other meats, it can said that fish contain less energy than the same amount of beef, pork, sheep or poultry. For example, 90 grams of cooked fish, other than oily fish such as sardines, contain less than 160 calories (Valverde et al., 2000).

Protein Content Of Fish

Fish, like other meats, are protein-rich foods, containing 18-20% protein. The main proteins found in fish are actin and myosin. These proteins combine in muscle tissue to form actomyosin. Apart from these, albumin is also among the basic proteins found in fish. Fish proteins contain all essential amino acids. Although essential amino acids (leucine, isolosine, lysine, valine, methionine, phenylalanine, threonine, tryptophan) have many important functions in the human body, they are molecules that cannot synthesized in the body, so food sources containing these amino acids increase the required protein quality of the diet. Since fish is rich in essential amino acids, it is among the foods with high

biological quality, such as eggs, meat and milk (Valverde et al., 2000). While fish meat is similar to other meats in terms of the amount of protein it contains and its protein quality; It differs greatly from these meats in terms of the amount of connective tissue it contains. Compared to red meat and poultry, fish contains much less collagen. While connective tissue constitutes approximately 15% of the bodies of land animals, this rate is only 3% for fish. Like the amount of connective tissue in fish, its composition is different from other meats; Some amino acids, such as hydroxyproline, are found in smaller amounts in fish connective tissue. All these differences ensure that fish meat is softer than other meats and that its connective tissue breaks down easily during cooking. Thus, fish proteins can easily hydrolyzed by digestive enzymes. This increases the body's utilization rate of these proteins. For this reason, fish can used instead of red meat in sick individuals who have difficulty consuming red meat, in the elderly and in children (Valverde et al., 2000).

Fat Content Of Fish

The fat content of fish varies widely; Not only depending on the type of fish, but also within the same type of fish, seasonal conditions, nutritional characteristics, salt content of the water and various other factors can greatly change the amount of fat contained in fish meat. For this reason, it is difficult to give a general amount regarding the fat content of fish; It can vary within a wide range of 1–14%. However, fish generally contain lower amounts of fat compared to the same amount of beef, pork, sheep or poultry and are therefore generally considered low-fat foods (Valverde et al., 2000). The fat content of fish consists mainly of triglycerides and long-chain polyunsaturated fatty acids (PUFA). The most important component that distinguishes fish from other foods in the meat group is undoubtedly very long chain polyunsaturated fatty acids. Because linolenic acid (alpha linolenic acid), one of the polyunsaturated fatty acids that plays a very important and essential role in human nutrition, is not synthesized in the human body, unlike the other two types of fatty acids taken with the diet, saturated fatty acids and monounsaturated fatty acids (n-9). Therefore, they are considered essential fatty acids (Lee, 2003). Polyunsaturated fatty acids are grouped as n-3 or n-6 fatty acids according to the first carbon with a double bond, starting from the methyl (CH3) radical; In n-3 fatty acids, the first double bond is located on the third (3-4) carbon, while in n-6 fatty acids, the first double bond is located on the sixth carbon (6-7). The predominant component of n–6 PUFA in humans is linolenic acid. This fatty acid can converted to arachidonic acid in the body. The essential fatty acid of n-3 PUFA is alpha linolenic acid, which can converted into eicosapentoenoic acid

(EPA) and docosahexaenoic acid (DHA) in the body. The reason why the metabolism of n-3 and n-6 fatty acids is so important is the formation of metabolites with hormonal activity such as eicosanoids, thromboxanes and leukotrienes, which are formed in these processes. These metabolites play key roles at many points in the body. Long-chain polyunsaturated fatty acids (PUFA) are the major structural component of phospholipid membranes of all tissues in the body and also affect membrane fluidity and ion transfer 5. Among these fatty acids, long-chain n-3 PUFA are especially abundant in the myocardium, retina, brain and spermatozoa, and are essential for the development of these tissues, their correct and complete functioning, and the functioning of many physiological processes they regulate. In general, n-3 fatty acids (alpha linolenic acid, EPA, DHA), depending on these functions, are used in the prevention and treatment of many diseases such as cardiovascular diseases, rheumatoid arthritis, cancer, asthma and Alzheimer's; It also plays an active role in retina and brain development in babies. In fact, considering that n-3 PUFAs are so widely distributed in all tissues of the body and play an essential role, it is not surprising that these fatty acids are effective in most of the diseases seen in humans (Hu et al., 2003). The intake of linoleic acid (n-3), whose sources are vegetable oils and various plants, alpha linolenic acid (n-6), whose sources are green leafy vegetables, and EPA and DHA, whose sources are fish and other aquatic products, in a certain ratio in the diet, is in the prevention of chronic diseases. It is important. In countries such as Japan and China, which consume large amounts of fish and other seafood in their diets, the linoleic acid / alpha linolenic acid ratio of the diet is 1/5; In western societies, this ratio has been found to 1/100. Studies indicate that the linoleic acid / alpha linolenic acid ratio of the diet should 1/5 – 1/10 for a healthy life. In order to maintain this ratio, it is necessary to increase the consumption of alpha linolenic acid, EPA and DHA sources, namely 2-3 portions (450 grams) of fish and other seafood, in line with the recommendation of the American Heart Association (AHA) in 2002 (Burr et al., 1989).

Vitamin Contents Of Fish

Fish are considered good sources of the B group vitamins thiamine (B1), riboflavin (B2), niacin (B3), vitamin B6 (pyridoxine), and vitamin B12, and the fat-soluble vitamins A and D (Burr et al., 1989). Vitamin A is found in the form of retinol in oily fish such as tuna, mackerel and herring. 100 grams of edible amounts of fish provide 10-15% of the recommended daily intake (RDA) for retinol in adults. Since it is a fat-soluble vitamin like vitamin A, the richest sources of vitamin D3 (calciferol) are oily deep sea fish. If the vitamin D

requirement for adults is accepted as 10 mcg, 100 g of fatty fish can meet 50-200% of this requirement, depending on the type. Fish are far superior to other animal-based foods in terms of their vitamin D content. Because while the vitamin D content of 100 grams of fish is 300–1000 IU, 100 grams of liver, which is among the richest sources, contains 100–400 IU, 1 liter of milk contains 3–10 IU, and an egg yolk contains 20–100 IU of vitamin D. Vitamin E, another fat-soluble vitamin, is found in significant amounts in most seafood, especially fish. 100 grams of fish can meet 10-20% of the daily vitamin E requirement of 5-10 mg. Cod liver oil has been used as a dietary supplement for more than 200 years because it is the richest source of fat-soluble vitamins. However, it should not forgotten that fish liver oil consumed in capsule form may more concentrated than fat-soluble vitamins, and its vitamin A or D contents may reach levels that will cause toxic effects. For this reason, it is accepted that consuming fish as food is healthier than taking it as a supplement (Norday, 2001). Fish meat is considered a good source of water-soluble B group vitamins such as thiamine (B1), riboflavin (B2), niacin (B3), vitamin B6, pyridoxine, and vitamin B12. 100 grams of fish provides approximately 10% of the daily requirements for thiamine, riboflavin and vitamin B6; It can meet 100% of the vitamin B12 requirement. The vitamin found in the least amount in fish is vitamin C (Yahia et al., 2003).

Mineral Contents Of Fish

Fish and other seafood have a special importance in a healthy nutrition model due to their rich mineral content. Because minerals such as iodine and selenium, which are abundant in fish and other seafood, are found in very small amounts in most foods other than these foods. Fish and other seafood are the richest sources of iodine. Especially fish living in salt waters contain a lot of iodine, and the processes applied during the processing of fish can also increase the iodine content. 100–200 mcg of iodine can obtained daily by consuming 2 portions of fish or other seafood per week. This can meet the daily iodine requirement of 150 mcg. The same applies to selenium. 100 grams of fish contains 12–60 mcg of selenium. Considering that 10-12 mcg of selenium is found in 100 grams of other meats or grains, the importance of fish and other seafood in meeting our daily requirement of 75 mcg of selenium can better understood. Phosphorus, magnesium and zinc are among the minerals that fish contain in abundance, and fish consumption is important in meeting the daily requirements of these minerals. The sodium potassium ratio in fish meat varies between 1:2 – 1:10. This range is quite suitable for healthy nutrition. The calcium content of fish is not very high. However, fish prepared with bones,

such as sardines and catfish, can considered good sources of calcium. Because the calcium content of fish consumed in this way increases up to 300 mg per 100 grams, which meets 30-740% of the daily calcium requirement for adults. On the other hand, the balance between calcium and phosphorus, which is very important for its functions in the body, was found to 2.15/1 on average in fish (varies depending on the fish type), and this ratio is close to ideal. Among the meat group foods, fish is one of the foods with the lowest iron content. However, the absorption of iron in the structure of fish, especially white fish, occurs at a high rate. For this reason, iron intake, even in small amounts, is more usable by the body (Valverde et al., 2000).

Conclusion

The importance of nutrition for the healthy development and functioning of the human body and protection from diseases has become an increasingly emphasized issue in recent years. Aquatic products, which are among the most valuable nutrients in terms of nutrients such as protein, fat, vitamins and minerals, have not only provided people with a healthy life through nutrition for centuries, but also directly or some of the products obtained from them have been used in the treatment of some diseases seen in humans. Many aquatic products are excellent sources of protein, fat, vitamins and minerals for human nutrition. Seafood, which has a high degree of digestibility among protein sources, is very low in fat compared to other high-protein foods. Additionally, seafood is the only source of n-3 series polyunsaturated long-chain fatty acids that have proven health benefits. While fish meat contributes 1% to world food production, it constitutes 5% of total protein production and 14% of total animal protein source. Aquatic products and fish will used more in human nutrition due to the hunger problem the world is facing and their positive contributions to human health. In addition, when compared to farm animal meat in terms of nutritional value, fish meat is more advantageous than farm animal meat as it is high in protein and minerals and low in fat. Finally, to summarize; Fish is a food composed of water, protein, fat, vitamins and minerals. It is rich in vitamins and minerals such as Iodine, Vitamin D, Calcium, Phosphorus, Potassium, Selenium and Folic acid, and Omega Fatty acids, which are essential for the body. All nutrients it contains, including protein, have high bioavailability. With this content, fish is a functional food.

References

Anonim, (1991). Besinlerin Bileşimleri, Türkiye Diyetisyenler Derneği Yayını, 3.Baskı, Ankara.

Baysal, A. (2002). Beslenme.Hatipoğlu Yayınevi, Ankara.

Burr, M.L., Fehily, A.M. & Gilbert, J.F. (1989). Effects of Changes in Fat, Fish, and Fibre Intakes On Death and Myocardial Reinfarction: Diet and Reinfarction Trial (DART). Lancet 2:757–61.

Hu, F.B., Cho, E. & Rexrode K.M. (2003). Fish and Long –Chain n-3 Fatty Acid Intake and Risk of Coronary Heart Disease and Total Mortality in Diabetic Women. Circulation 107:1852-1857.

Lee, K.W. (2003). The Role of Omega-3 Fatty Acids in the Secondary Prevention of Cardiovascular Disease .Q J Med 96:465-480.

Norday, A. (2001). Fish Consumption and Cardiovascular Disease. Eur Heart J Supplements 3 (Suppl D):4-7.

URL-1. (2023). Su Ürünlerinin Besleyici Değeri - Pınar Lezzet Fikirleri

Valverde, I.M., Periago, M.J. & Santaella, M. (2000). The Content and Nutritional Significance of Minerals on Fish Flesh in The presence And Absence of Bone. Food Chemistry 71:503-509.

Yahia, D.A., Madani, S. & Savelli, J.L. (2003). Dietary Fish Protein Lowers Blood Pressure and Alters Tissue Polyunsaturated Fatty Acid Composition in Spontane ously Hypertensive Rats. Nutrition 19:342-346.

Chapter 16

Forestry And Forestry Industry: Classification, Sales And Customer Preferences In Türkiye

Orhan KELLECİ[1]
Gül TEKİNGÜNDÜZ[2]
Süheyla Esin KÖKSAL[3]

Abstract

In this study, sales and marketing of forest products are discussed in order to evaluate the current and future production status of log production in Türkiye. The sales and marketing of forest products are carried out by the General Directorate of Forestry (GDF). The GDF sells a variety of forest products, including logs, pulpwood, mining poles, and wire poles. The most popular product among customers is logs, with 87 % of customers preferring logs. The next most popular product is 4th class (pulpwood) wood, with 40 % of customers preferring 4th class wood. The GDF's log supply is sufficient to meet customer demand, but the supply of 4th class wood is insufficient. The reason for this is that customers often purchase products that are originally offered for different purposes, such as mine poles and wire poles, and use them in the production of thin timber. The GDF should focus on increasing the production of 4th class wood in order to meet customer demand. The study also discusses the reasons why customers demand 4th class wood. The most obvious reason is that customers want to use 4th class wood in other areas besides pulpwood. The study concludes by stating that the GDF's supply possibilities are not sufficient to meet the demand for Class 1 and 2 logs, but the customers' preference for Class 3 logs.

Introduction

With the rapid increase in human population, the ecological balance in the world has been negatively affected. The excessive increase in human population

[1] 1- Asst. prof.; Bolu Abant Izzet Baysal University, Mudurnu Sureyya Astarci Vocational School, Department of Forestry, Bolu, Türkiye, orhankelleci@ibu.edu.tr ORCID No: 0000-0003-4501-0854

2- Asst. prof.; Bolu Abant Izzet Baysal University, Mudurnu Sureyya Astarci Vocational School, Department of Forestry, Bolu, Türkiye, gulakbulut@ibu.edu.tr ORCID No: 0000-0002-0785-6472

3- Asst. prof.; Bolu Abant Izzet Baysal University, Mudurnu Sureyya Astarci Vocational School, Department of Forestry, Bolu, Türkiye, esinkoksal@ibu.edu.tr ORCID No: 0000-0001-7970-8412

(Figure 1) has had the most negative effects on forests. For this reason, the protection and management of forests and the sustainability of forest products have become important. In order to obtain maximum benefit from forest products, the products have been classified and marketed. Forest products are divided into two categories: by-product and main wood product.

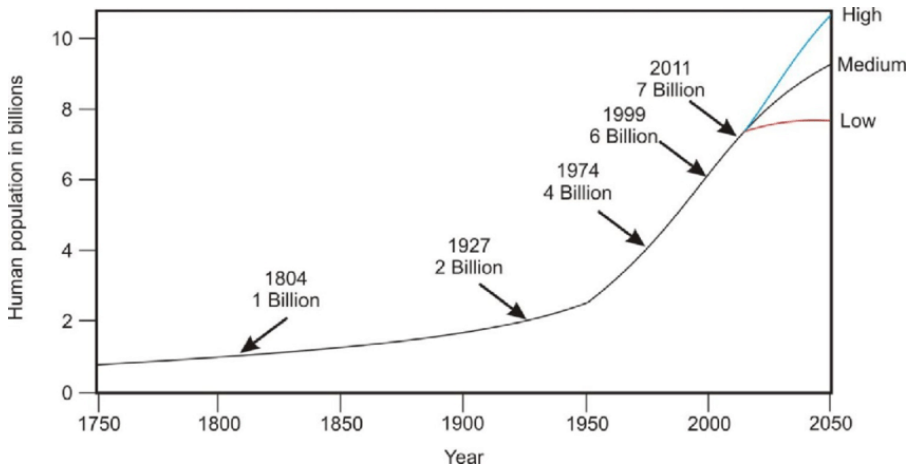


Figure 1. Rapid increase in the world's human population (Elias, 2015)

Wood raw material, one of the main forest products, is produced to meet the market demands of trees that have reached the cutting age and are mature in terms of diameter and height (Figure 2). Wood raw material is the most used raw material in the industry and has up to 10 thousand uses worldwide (Örs & Keskin, 2001; Ünver & Acar, 2005).

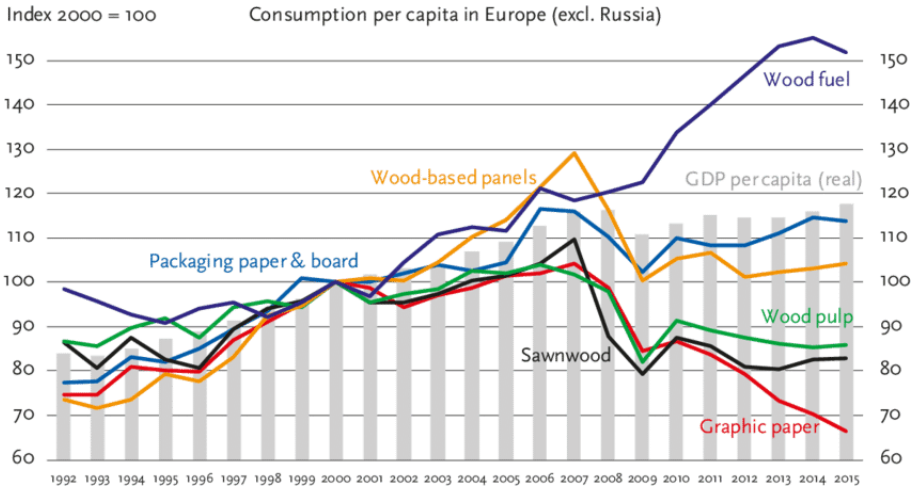


Figure 2. Wood raw material consumption per capita in Europe (Jonsson et al., 2017)

Industrial wood production constitutes 50-55 % of the total wood raw material production of the General Directorate of Forestry (GDF) in the last 20 years. 65 % of the industrial wood raw material demand in the market is met by the GDF This resource constitutes 90 % of the income of forest enterprises. Among industrial wood products, logs, fiber chips and logs used in pulpwood production take the first three places. (Bozkurt & Erdin, 1986).

In Türkiye, 48 % of the 9.9 million m³ industrial wood produced in forest enterprises in 2000 was log, 19 % was fiber-sawdust, 15 % was pulpwood, 4 % was mineral pole, 2 % was wire pole and 12 % is packaging wood (Konukçu, 2001). After 23 years, a total of 25.6 million m3 of industrial wood was produced in 2023; 48 % is log, 19 % is fiber-sawdust, 15 % is pulpwood, 4 % is mining pole, 2 % is wire pole and 12 % is packaging wood. Industrial wood production has increased by 158 percent in the last 23 years. The biggest increase was the increase in pulpwood production (OGM, 2023).

Wood production in the world and in our country is divided into two, industrial wood and fuel wood production, according to the purpose of use. There are three types of production methods of industrial wood.

1. Whole Tree Method: It refers to the transportation of the tree cut in the production area as a whole without removing its branches and top, and the trees felled by chainsaws or felling machines are transported to the roadside with the help of special forest tractors or cable lines. In developed countries, machines called processors are used extensively during this production technique.

2. Whole Trunk Method: In the production area, the tree is felled, its top is cut and its lower branches are removed with a chainsaw. After these are dragged to the roadsides or collection points with various types of forest tractors and air lines, the remaining branches are removed with a chainsaw. At the same time, harvesting machines are also used in this method.

3. Log Direction: Falling the tree, removing its branches and top, and dividing it into logs of certain sizes is carried out at the bottom of the log from which the tree was cut. These operations are done with a chainsaw. The logs are transported from the stand to the edge of the forest road by human power, throwing, carrying and shifting, animal dragging, tractors and aerial lines, forwarders and harvesters. The logging method is widely applied in the forests of our country (Ozturk, 2006).

During the transportation, stacking and sales processes of logs, defects occur in the wood, causing both quality and value to decrease. This degradation is

caused by direct sunlight, constant winds and temperature fluctuations, fungal and insect damage, and climatic conditions (Ay & Güller, 2005; Köse & Kantay, 2008). It is necessary to create appropriate storage conditions to reduce these negative effects and improve log quality and prevent prices from falling.

The classification of trees cut down in the forest is carried out by GDF.

In cases where the number of personnel of GDF is insufficient, help is received from experienced personnel who have worked in wood production in the forest instead of civil servants (Gültekin, 2008).

The following conditions are taken into account during the standardization phase after the tree is cut (Bozkurt and Göker, 1996);

1- The product produced as industrial wood is more valuable than the wood produced as fuel wood. For this reason, more importance is given to industrial wood production.

2- Not only logs are obtained from trees. Care is taken to ensure that the other types of products obtained are of the highest quality.

3- In logs and other wood products, the drying rate of wood is taken into account.

4- The bark of gymnosperm type wood should be peeled, and the bark of angiosperm type wood should not be peeled. Log defects (snags, insect holes, fungal damage, cracks, fiber curl, trunk deformities, curvature) are carefully considered in the classification of logs.

Market demands should be taken into consideration when producing wood products from trees. Wood standardization should be done to provide the highest economic benefit to forest enterprises and buyers (Bozkurt and Göker, 1996).

After the products brought to the main warehouse are unloaded there, they are divided into classes according to product types (1st, 2nd and 3rd class logs, fiber chip wood, fuel wood, etc.) by warehouse workers. If the logs do not have any fungal damage, insect damage or other defects, they are classified as sound (Class II log), if there is 1 defect, they are classified as rotten (Class III log), and if there are 2 or more defects, they are classified as rotten (Class IV – pulpwood log-Figure 3) (Bakır & İmamoglu, 2014). These products are then stacked in certain parts of the warehouse by manpower or loading vehicles. After the information such as wood type, class, length, diameter and volume of the stacked products are recorded, the stack is stamped by giving a stack number. After all operations with the stack are completed, the stack is painted in a single strip with black or white paint with a thick brush and the stack is made ready for sale. Applying a paint strip on the stacks in this way indicates that the stack is ready for sale and is done to ensure the safety of the stack against any loss or

disintegration. Firewood is stacked in the same way; stack information is entered, and it is ready for sale.

Figure 3. Stack of pulpwood logs

The amount of wood production in Türkiye cannot meet the wood raw material needed by the industry. For this reason, 9 % of the industry's needs are met by imported wood. For this reason, care should be taken in log classification in order to obtain the maximum benefit from wood (Ünver & Acar, 2005).

Sales and marketing of forest products

In Türkiye, sales and marketing of products obtained from forests are carried out by GDF in accordance with the forest law number 6831. Forest products are passed through various stages and delivered to the end user (Figure 4).

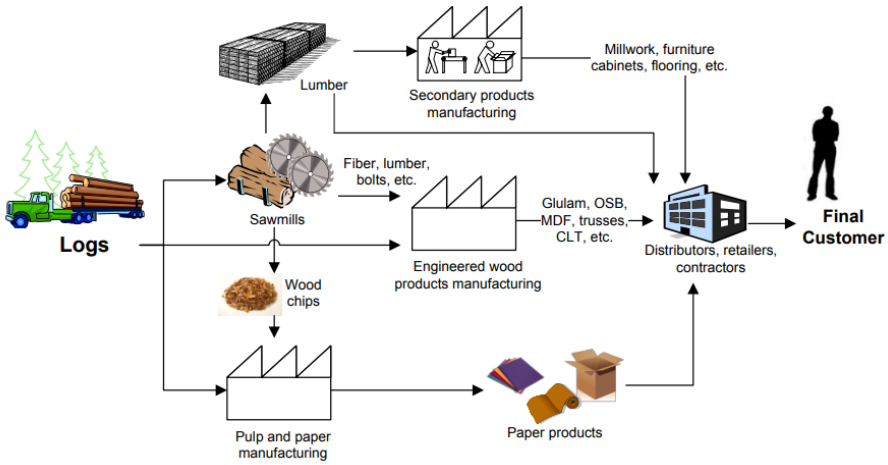


Figure 4. Wood product supply chain (Espinoza & Smith, 2015)

In Türkiye, among the trees to be cut from the forests, which tree will be evaluated in which class and for what purpose it will be sold is carried out by GDF. The forms and principles regarding measurement works issuance and use of transport documents are determined by the GDF.

Unless forestry techniques and evaluation requirements make it necessary, the General Directorate of Forestry cannot produce any kind of finished or semi-finished products, and factories, warehouses and sales points cannot be established in cities and towns outside the forest. If necessary, the establishment and operation of the factory by the General Directorate of Forestry depends on the decision of the President.

Auctioning of trees obtained from forests is essential in the market sale of forest products. If deemed necessary and beneficial for the needs of some government institutions or in cases requiring urgent sale, forest products may be sold privately at market prices. According to the management plan data, the sale of forest products, including planted trees, can be made for years, not exceeding five years (Orman Kanunu, 1956).

Heads of households in need who are registered with the village population and live in the villages permanently in villages with a productive state forest within their borders or who have moved their residence address to another place while living here, or those who have lived in the village for five years uninterruptedly as their residence address, the houses they will build for their shelter and common needs of the village, Citizens and the items they will build for their repair, such as barns, haystacks, warehouses and chicken coops, schools, mosques, health centers, village road bridges and village mansions,

will be purchased from the sales hoarding places around these forests, with one-third of the cost charged. It can be given once in new construction and depending on the need for repair. In the structures within the scope of this article, upon the request of the property owners, compensation will be paid in cash by the administration instead of the goods to be built (Orman Kanunu, 1956).

If log production is carried out by GDF, real persons residing in villages with a state forest within their borders and registered to the population of that place, or forest village development cooperatives established in villages and towns with a state forest within their borders. Up to one hundred percent of the wood they cut from forests, groves and deciduous forests and carry for sale is given to them in exchange for the price within the period determined by the administration, if they request, according to the combined price method.

All kinds of forest products and products other than the forest products included in the annual production program such as logs, wire poles, mining poles, industrial wood, pulpwood, wood, fiber-chip wood, poles, sticks, firewood, resin, sweetgum oil, kindling and boxwood to be extracted from the state forests. Permission is given to the forest village development cooperatives specified in article 40, in order of priority, to collect and remove the residues within the determined areas and periods, by announcing it to the villagers in or around the workplace and on condition that they pay the tariff fee. The people or cooperatives in these places are not willing to do this work or their workforce is not sufficient.

In case of detection and certification, other bidders may be allowed to collect and extract these products and residues under the same conditions, or they may be produced and sold by the forest administration. Bidders may be given permission to remove trees, roots and other forest pests that are harmful to the forest, as determined by the General Directorate of Forestry, from the forest by cutting, rooting, uprooting or collecting, under the conditions to be determined by the forest administration. No money will be collected from those who cut, root, dismantle or collect them.

Wood sales in OGMs are made through tender. Product types that customers prefer when purchasing; The order of preference is logs (87.0 %), wood (40.1 %), mining poles (27.2 %) and wire poles (20.3 %). The log supply of the enterprises is in line with customer expectations but is insufficient in quantity. In response to customer requests for wire poles, mining poles and industrial wood, the company is discontinuing production of these products (Kaya et al., 2023).

Reasons why customers demand 4. class (pulpwood) wood

The fact that almost all of the customers demand logs, and 40 % of them demand firewood or wood for wire poles, mining poles and other products, is due to their desire to use the wood they use for purposes other than its intended purpose. It is a known fact that when log prices are high, buyers purchase wood products such as mining poles and wire poles and use them in the production of thin timber (Ok, 1997; Akkaya et al., 2020).

While none of the buyers in Ankara produce pulp, the reason for the demand for pulp is the desire to use it in other areas. As a matter of fact, by using a material flow analysis technique, researcher Koç (2023) determined that "the products sold by GDF as wire poles, mining poles, industrial wood and paper wood are consumed mainly for logging purposes." Although less than 20 % of wood buyers demand 1st and 2nd class logs, the Regional Directorate's supply possibilities cannot meet this demand.

Conclusions

In log production activities, the continuity of forest resources should be protected and the opportunities to benefit the country's economy should be increased. Reducing losses in product quantity and quality during the production of logs and other forest products in the forest requires the use of advanced production techniques. Wood defects, which are taken into account in grading the quality of wood, occur during production, dismantling and stacking activities. Preventing any disruptions that may occur during the production phase will be ensured by experienced or trained forest workers using appropriate cutting techniques, determining the cutting direction correctly and using a chainsaw. Pruning and peeling of trees must be done with appropriate tools, taking into account the bark thickness of the species.

It has been determined that the problems related to the customers' sales sides arise from supply deficit, compliance with the standard, quality and measurement errors. Ukraine has not banned the export of unprocessed pine logs. The supply deficit, which arose due to OGM's reduction in production level compared to the previous year, is being tried to be eliminated in the following years.

Thus, although the factors affecting the sales and income of forest enterprises are local and controllable, as in insect destruction, they can also arise completely outside the control of forest enterprises, as in the case of an economic crisis. Therefore, in order to reduce the impact of such factors on tender sales, taking into account market conditions and possible demand contraction from the moment they arise;

• Creating tender sales amounts and dates in a coordinated manner at the regional directorate level, while keeping stocks low,

• Relative reduction of supply and therefore increasing sales rates, taking into account market demand,

• It would be beneficial to follow strategies such as shifting the production season as early as possible and meeting market demand with fresh products instead of stocks (Dikilitaş and Öztürk, 2010).

Increasing competition in the forest products market forced OGM to develop new marketing strategies. Sales analyzes are important in developing these strategies. Sales analysis should include price changes, stock status and supply-demand balance.

References

Akkaya, M., Ok, K., Koc, M., Akseki, İ., & Akkaş, M. E. (2020). Sectoral use of imported wood raw material in Turkey. Turkish Journal of Forestry | Türkiye Ormancılık Dergisi, 279–293. https://doi.org/10.18182/tjf.766501

Ay, N., & Güller, B. (2005). Artvin Orman İşletme Müdürlüğüne Ait Istif ve Satış Yerlerinin (Depolar) İncelenmesi. . Kafkas Üniversitesi Artvin Orman Fakültesi Dergisi, 6(1-2)(2005), 1–10.

Bakır, D., & İmamoglu, S. (2014, October 22). Artvin Hamamlı ve Ardanuç Orman Depolarında Bulunan Tomrukların Fakkop 3d Akustik Tomografi (Odun Tomografi) Cihazı İle İncelenerek Kalite Sınıflarının Belirlenmesi. II. Ulusal Akdeniz Orman ve Çevre Sempozyumu.

Bozkurt, A., & Erdin, N. (1986). Ticarette Önemli Yabancı Ağaçlar. İÜ Fen Bilimleri Enstitüsü Yayınları, Yayın No: 4024, FBE Yayın No:12, 2. Baskı, İstanbul, 1986.

Bozkurt, A., & Göker, Y. (1996). Physical and mechanical wood technology. *Istanbul University Publication, 3445*.

Dikilitaş, K., & Ozturk, A. (2010). Artvin orman bölge müdürlüğü son beş yıllık açık artırmalı satışlarının irdelenmesi. III. Ulusal Karadeniz Ormancılık Kongresi, 259–269.

Elias, S. A. (2015). Global Change Impacts on the Biosphere. In Reference Module in Earth Systems and Environmental Sciences. Elsevier. https://doi.org/10.1016/B978-0-12-409548-9.09532-4

Espinoza, O. A., & Smith, R. L. (2015). The U.S. Forest Products Industry. In Business management practices for small to medium sized forest products firms (pp. 3–4). Virginia!Polytechnic!Institute!and!State!University Printing!Services.

Gültekin, Y. (2008). Orman ürünlerinde pazar kayıplarının değerlendirilmesi. In Y. A. M. Gültekin (Ed.), *6. ulusal orman fakülteleri öğrenci kongresi*. Tübitak.

Jonsson, R., Hurmekoski, E., Hetemäki, L., & Prestemon, J. (2017). What is the current state of forest product markets and how will they develop in the future. In Towards a sustainable European forest-based bioeconomy (pp. 1–126).

Kaya, G., Ok, K., & Kulaç, C. (2023). Müşterilerin açık artırmalı tomruk satışlarından beklentileri: Ankara Orman Bölge Müdürlüğü örneği. Turkish Journal of Forestry | Türkiye Ormancılık Dergisi, 272–286. https://doi.org/10.18182/tjf.1312231

Koç, M. (2023). Türkiye'de odun hammaddesine dayalı döngüsel biyoekonomi politikalarının makroekonomik analizi [Doctoral Dissertation]. İstanbul Üniversitesi Cerrahpaşa, Lisansüstü Eğitim Enstitüsü.

Konukçu, M. (2001). Ormanlar ve Ormancılığımız. DPT Yayın No:2630, Ankara, 237s, 2001.

Köse, C., & Kantay, R. (2008). Orman İşletme Depoları ve Depolama Teknikleri. İstanbul Üniversitesi Orman Fakültesi Dergisi, ISSN: 1309-6257, Seri B, 59(1), 75–92.

OGM. (2023). Üretim, Satış ve Stok Faaliyetleri. Https://Www.Ogm.Gov.Tr/Tr/e-Kutuphane/Kitaplik/Uretim-Satis-ve-Stok-Faaliyetleri.

Ok, K. (1997). Aynı yaşlı ormanlarda kesim düzeninin ekonomik analizi [Doctoral Dissertation,]. İstanbul Üniversitesi, Fen Bilimleri Enstitüsü, İstanbul.

Örs, Y., & Keskin, H. (2001). Ağaç Malzeme Bilgisi. T.C. Sanayi ve Ticaret Bakanlığı KOSGEB Küçük ve Orta Ölçekli Sanayi Geliştirme ve Destekleme İdaresi Başkanlığı, Kale Matbaacılık Ofset, ISBN: 975-7608-87-4, Ankara, 2001.

Ozturk, T. (2006). Türkiye'de odun üretiminin iş aşamaları. İstanbul Üniversitesi Orman Fakültesi Dergisi, 56b (2).

Orman Kanunu, T.C Resmi gazetesi 1 (1956).

Ünver, S., & Acar, H. H. (2005). Odun hammaddesi üretim çalışmalarının odun kalite sınıfları üzerine olan etkileri. Kafkas Üniversitesi Artvin Orman Fakültesi Dergisi, 6 (1-2) (2005), 128–134.