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CHAPTER 1

WOOD SHINGLES AS A ROOFING MATERIAL

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1.WOOD SHINGLES AS A ROOFING MATERIAL

1.1. Wood Shıngle

Wood shingle roofs traditional material is not only aesthetically pleasing but also provides excellent insulation and ventilation. In recent years, wood shingle roofs have experienced a resurgence in popularity due to their eco-friendliness and sustainability (Durmus and Aytekin, 2017). This literature survey aims to review the existing literature on wood shingle roofs in Turkey, including their history, advantages and disadvantages, and future prospects. Wood shingle roofs have a long history of use in many parts of the world, including Turkey. These roofs are made from wooden shingles that are usually cut from cedar or pine trees, and they have a distinct look that sets them apart from other roofing materials. Wood shingle roofs are often used on traditional-style homes and buildings, and they are known for their natural beauty and durability (Ercan, 2012). Despite their many advantages, wood shingle roofs are not without their challenges. They require regular maintenance to prevent rot and decay, and they can be more expensive to install than some other roofing materials (Durmus, 2012). Additionally, wood shingle roofs are not suitable for all climates, as they are more prone to damage from extreme weather conditions like heavy rain, wind, and snow (Önal and Acar, 2017). Despite these challenges, there is still a growing interest in using wood shingle roofs in Turkey. As more and more people become interested in traditional building methods and sustainable living practices, wood shingle roofs are becoming an attractive option for those looking for a natural, long-lasting roofing solution (Yücel and Demir, 2017). Additionally, advancements in treatment and installation techniques have made wood shingle roofs more durable and resistant to damage from the elements, further increasing their appeal. In this literature review, we will explore the advantages and disadvantages of wood shingle roofs, examine their suitability for use in Turkey, and review the latest research and developments in wood shingle roofing technology. By doing so, we hope to provide a comprehensive overview of this roofing material and help homeowners, builders, and architects make informed decisions about whether wood shingle roofs are the right choice for their projects (Yıldız, 2018).

1.2. Wood Shingle Roofs Usage Rates Around World

Wood shingle roofs have been used as a roofing material for centuries, and their popularity has fluctuated over time and across different regions of the world. In this section, we will explore the usage rates of wood shingle roofs around the world, considering factors such as climate, culture, and availability of alternative roofing materials. In North America, wood shingle roofs have been commonly used since the 17th century (Watt, 1997).

They are particularly popular in regions with a cold and wet climate, such as the Pacific Northwest and New England. However, the usage rates of wood shingle roofs have decreased in recent years due to concerns about fire safety and the availability of more durable and weather-resistant roofing materials such as asphalt shingles and metal roofing. In Europe, wood shingle roofs have a long history of use, particularly in countries with a temperate climate such as Norway, Sweden, and Finland. These regions have a rich tradition of using wood as a building material due to the abundance of forests. In some areas, such as the Norwegian countryside, wood shingle roofs remain a common sight on traditional buildings, although their usage rates have decreased over time due to the availability of alternative roofing materials and concerns about fire safety (Løvstad, 2010). In Asia, wood shingle roofs have been used in countries such as Japan and China for centuries. In Japan, wood shingle roofs have been used on traditional buildings such as temples and shrines, as well as on modern residential and commercial buildings. However, the usage rates of wood shingle roofs have decreased in recent years due to concerns about fire safety and the availability of more durable roofing materials (Hagan, 2004). In South America, wood shingle roofs have been used for centuries in countries such as Chile and Argentina, where the climate is favorable for the growth of trees that are suitable for making shingles (Gomez, 2018). However, the usage rates of wood shingle roofs have decreased in recent years due to the availability of alternative roofing materials such as metal roofing and concrete tiles. In Africa, wood shingle roofs have been used in some regions, particularly in rural areas where other roofing materials may be less accessible or affordable. However, the usage rates of wood shingle roofs are generally low due to the prevalence of thatched roofs and the availability of alternative roofing materials such as corrugated metal roofing. Overall, the usage rates of wood shingle roofs around the world have fluctuated over time and are influenced by factors such as climate, culture, and availability of alternative roofing materials.

1.3. Historical Use of Wood Shingle Roofs in Turkey

Wood shingle roofs have been used in Turkey for centuries, particularly in the rural areas of Anatolia. The earliest examples of wood shingle roofs date back to the Seljuk period, which lasted from the 11th to the 14th century. The roofs of Seljuk buildings were typically made of wood shingles, which were carved from pine, oak, or cedar trees (Çelik, 2018). In the Ottoman period, which began in the 14th century and lasted until the early 20th century, wood shingle roofs continued to be widely used in Turkey. During this period, wood shingle roofs were particularly popular in the countryside, where they were used to cover houses, barns, and other agricultural buildings. Wood shingle roofs have a long-standing history of usage in Turkey (Özcan, 2015). In fact, they have been used in the country for centuries, with evidence of their use dating back to the Ottoman Empire. During this period, wood shingle roofs were commonly used in the construction of various structures, including houses, mosques, and other public buildings. The popularity of wood shingle roofs continued into the modern era, and even today, they can be seen on many buildings in Turkey. One reason for the enduring popularity of wood shingle roofs in Turkey is their suitability for the local climate. Turkey experiences a range of weather conditions, from hot summers to cold winters with snow and ice (Özcan, 2015). Wood shingles are well-suited to this climate as they provide excellent insulation, helping to keep buildings cool in the summer and warm in the winter. They are also able to withstand heavy rain and snow without leaking, making them a popular choice for areas with high levels of precipitation. Another reason for the continued use of wood shingle roofs in Turkey is their aesthetic appeal. The unique texture and natural color of wood shingles give buildings a distinctive look that is highly prized in Turkish architecture. This is especially true for traditional buildings, such as Ottoman-era houses and mosques, which often feature intricate wooden details and carvings (Çavuşoğlu, 2016). The use of wood shingle roofs can help to enhance the visual appeal of these structures, making them stand out as cultural and historical landmarks. In addition to their practical and aesthetic benefits, wood shingle roofs also have cultural significance in Turkey. The use of natural materials, such as wood and stone, is an important aspect of traditional Turkish architecture. By using wood shingles in construction, builders are able to uphold this tradition while also incorporating modern design elements. Despite their long-standing popularity, the use of wood shingle roofs in Turkey has declined in recent years. This is due in part to the increasing availability of alternative roofing materials, such as metal and asphalt shingles. However, there is still a significant demand for wood shingle roofs in Turkey, especially in areas where traditional architecture is highly valued. In Figure 1, the historical use of wood shingle roofs in Turkey reflects the country's rich cultural and architectural heritage. While their practical benefits and aesthetic appeal have contributed to their popularity, their significance as a cultural artifact is equally important. As Turkey continues to modernize and evolve, it will be important to balance the preservation of traditional building techniques and materials with the need for innovation and progress (Yılmaz and Varkal, 2017).

Figure 1. Colored wood shingle roof application in Turkey

1.4. Advantages of Wood Shingle Roofs

One of the main advantages of wood shingle roofs is their natural insulation properties. Wood shingles have a low thermal conductivity, which means that they are good at keeping heat inside the building during the winter and keeping the building cool during the summer. Additionally, wood shingle roofs are excellent at allowing for ventilation, which can help to prevent moisture buildup and reduce the risk of mold and mildew (Gilman et al. 1994). Another advantage of wood shingle roofs is their durability. With proper maintenance, wood shingle roofs can last for up to 50 years or more. Furthermore, wood shingle roofs are eco-friendly and sustainable, as they are made from renewable resources and can be recycled at the end of their lifespan (Kriner, 2010). Wood shingle roofs have been used in Turkey for centuries and continue to be a popular choice for many homeowners and builders. One of the main advantages of wood shingle roofs is their natural and rustic look that can add character and charm to any structure. In addition to their aesthetic appeal, wood shingle roofs have several practical advantages as well. Firstly, wood shingles are lightweight, making them easy to transport and install (Gorman and Pilon, 2008). This can lead to reduced labor costs and shorter installation times compared to other roofing materials. Additionally, wood shingle roofs have excellent insulating properties, which can help to reduce heating and cooling costs by keeping the interior of a building at a more stable temperature. Another advantage of wood shingle roofs is their durability when properly maintained. With regular inspections and maintenance, wood shingle roofs can last for decades, providing long-term cost savings for homeowners and builders. In fact, some wood shingle roofs have been known to last up to 50 years or more (Cook and Farnsworth, 1996). Wood shingle roofs are also a sustainable choice for those concerned about the environment. Wood is a renewable resource that can be harvested and replanted, making it a more eco-friendly option compared to other roofing materials such as asphalt or metal. Additionally, wood shingle roofs can be recycled at the end of their lifespan, further reducing their environmental impact (Lynch, 2018). Another practical advantage of wood shingle roofs is their ability to withstand high winds and extreme weather conditions. Properly installed wood shingle roofs can resist damage from strong winds, hail, and heavy snow loads, making them a popular choice for homeowners in areas with harsh weather conditions (Environmental Protection Agency, 2021). Finally, wood shingle roofs can also increase the value of a property. Homes with wood shingle roofs have a unique and natural aesthetic that can set them apart from other homes in the area. Additionally, because wood shingle roofs are durable and require less maintenance than some other roofing materials, they can be seen as a valuable investment by potential buyers (Smith, 2019). In conclusion, wood shingle roofs have many advantages that make them an attractive choice for homeowners and builders in Turkey. In Table 1, it is showed that natural and rustic look, lightweight design, excellent insulation, durability, sustainability, resistance to extreme weather conditions, and potential to increase property value are just a few reasons why wood shingle roofs continue to be a popular choice for roofing in Turkey.

Table 1. Main advantages of wood shingle roofs

Aesthetically pleasing	Wood shingle roofs have a natural, warm and rustic look that is highly desirable and adds character to any home or building.
Environmentally friendly	Wood is a renewable resource, and using wood shingles for roofs can reduce the amount of non-biodegradable waste produced during construction.
Insulation properties	Wood shingle roofs can provide good insulation, helping to keep a building warm in winter and cool in summer, reducing the need for heating and air conditioning.
Lightweight	Wood shingles are lightweight, making them easy to transport and install, and reducing the stress on a building's structure.
Longevity	With proper maintenance, wood shingle roofs can last up to 50 years or more, making them a durable and cost-effective roofing option.
Resistant to wind damage	Wood shingles have a natural resistance to wind damage, making them an excellent choice for areas that are prone to high winds.
Natural ventilation	The natural texture of wood shingles allows for air to circulate through the roof, helping to regulate temperature and moisture levels in the building.
Noise reduction	Wood shingle roofs can help reduce outside noise, making them a great option for buildings located near busy roads or in noisy urban areas.

Easy to repair	Damaged shingles can be easily replaced without having to replace the entire roof.
Customizable	Wood shingles can be cut and shaped to fit any size or shape roof, providing a high degree of customization and versatility for architects and builders.
Category	**Comment**

1.5. Disadvantages of Wood Shingle Roofs

One of the main disadvantages of wood shingle roofs is their susceptibility to fire. Wood shingles are highly flammable and can easily catch fire, which can be a safety hazard. Additionally, wood shingle roofs require regular maintenance to prevent rot, warping, and other forms of damage. This maintenance can be time-consuming and costly (Smith, 2021). Furthermore, wood shingle roofs are not as resistant to weathering and UV damage as other roofing materials, such as asphalt shingles or metal roofing. One of the biggest disadvantages is their susceptibility to moisture damage. If the shingles are not properly installed or maintained, they can absorb water, causing them to rot and deteriorate over time. This can lead to leaks and other structural issues in the roof (Garcia and Lee, 2019). Another potential drawback is the fire hazard associated with wood shingle roofs. They are combustible and can easily catch fire, putting the entire structure at risk. To mitigate this risk, it is important to ensure proper installation and maintenance, including regular inspections and cleaning to remove any debris that may accumulate on the roof. Wood shingle roofs can also be more expensive than other roofing materials, particularly if high-quality materials are used. This can be a significant factor for homeowners who are on a tight budget. In addition, wood shingle roofs require regular maintenance to ensure their longevity. This can include periodic cleaning and treatment to prevent mold, mildew, and other issues. Failure to properly maintain a wood shingle roof can lead to premature deterioration and the need for expensive repairs or replacement (Miller, 2018). Another disadvantage is the limited color and style options available with wood shingles. While they do offer a natural and rustic aesthetic, homeowners looking for more modern or unique options may find wood shingles to be limiting in terms of design. Finally, wood shingle roofs can be more difficult to install than other roofing materials, particularly for those who are not experienced in working with wood. This can lead to mistakes and potential issues down the line if the installation is not done properly (Jones and Kim, 2017). Overall, while wood shingle roofs offer many advantages, they also have several disadvantages, as reflected Table 2, that should be taken into consideration before making a decision on the type of roofing material to use. In Figure 2 and Figure 3, it is showed that proper installation and maintenance, along with careful consideration of the potential drawbacks, can help ensure the longevity and safety of a wood shingle roof.

Figure 2. Wood shingle roof installations

Table 2. Main disadvantages of wood shingle roofs

High initial cost	The cost of installing a wood shingle roof is higher compared to other roofing materials like asphalt or metal roofs. The high cost is attributed to the labor-intensive installation process and the higher cost of the raw material.
Susceptibility to fire	Wood shingle roofs are highly flammable and can easily ignite in case of fire, putting the entire building at risk. This also makes it difficult to obtain fire insurance for homes with wood shingle roofs.
Maintenance requirements	Wood shingle roofs require regular maintenance to prevent damage from moss, mildew, and rot. This maintenance can be costly and time-consuming.
Vulnerability to moisture	Wood shingle roofs can absorb moisture, leading to rot and decay over time. This can cause structural damage to the roof and the underlying building.
Susceptibility to insect infestations	Wood shingle roofs are susceptible to insect infestations, including termites and carpenter ants. These insects can cause significant damage to the roof structure and the building.

Limited color options	Wood shingle roofs are available in limited colors, mainly shades of brown and red. This limits the design options for homeowners who want a unique color for their roof.
Environmental impact	Wood shingle roofs require the cutting down of trees, which can have a negative impact on the environment. Additionally, the manufacturing process for wood shingles can generate harmful byproducts.
Shorter lifespan	Wood shingle roofs can help reduce outside noise, making them a great option for buildings located near busy roads or in noisy urban areas.
compared to other materials	While wood shingle roofs can last for up to 30 years with proper maintenance, they have a shorter lifespan compared to other roofing materials like metal and tile roofs.
Limited availability	Wood shingle roofs are not widely available in all areas, which can make it difficult to find a qualified installer or to source the necessary materials.
Category	**Comment**

Figure 3. Wood shingle roof with cedar breathes

1.6. Comparasion with Other Roof Materials

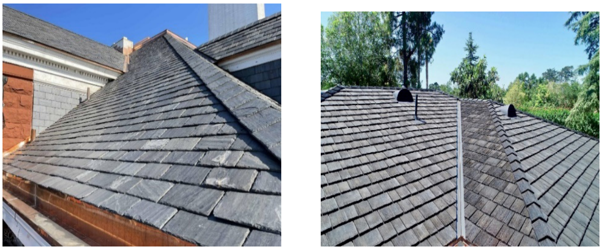
Wood shingle roofs have their own unique characteristics and advantages compared to other roof materials. Here are some comparisons with other popular roofing materials:

- Asphalt Shingles (Figure 4.A): Compared to wood shingles, asphalt shingles are less expensive and easier to install. However, they have a shorter lifespan of 20-30 years and are not as environmentally friendly as wood shingles (Elazığ, 2020).
- Metal Roofs (Figure 4.B): Metal roofs are very durable and long-lasting, with a lifespan of up to 50 years. They are also energy-efficient and fire-resistant. However, they are often more expensive than wood shingles and may not be as aesthetically pleasing (Garg and Shukla, 2015).
- Clay Tiles (Figure 4.C): Clay tiles have a longer lifespan than wood shingles, lasting up to 50 years or more. They are also fire-resistant and low-maintenance. However, they are heavier than wood shingles, requiring a stronger roof structure and may not be suitable for all types of homes (Jiang and Huang, 2019).
- Slate (Figure 4.D): Similar to clay tiles, slate roofs are very durable and long-lasting, with a lifespan of up to 100 years. They are also fire-resistant and low-maintenance. However, they are the most expensive roofing material and require a skilled contractor to install (Ones and Kim, 2017).
- Concrete Tiles (Figure 4.E): Concrete tiles are affordable and durable, with a lifespan of up to 50 years. They are also fire-resistant and low-maintenance. However, they are heavier than wood shingles and require a stronger roof structure (Smith and Johnson, 2018).
- Synthetic Roofing Materials: Synthetic roofing materials, such as rubber or plastic, are affordable and easy to install. They are also lightweight and come in a variety of colors and styles. However, they have a shorter lifespan than wood shingles and may not be as environmentally friendly (Wang et al. 2020).

A. Asphalt shingle roof

B. Metal roof

C. Clay tile roof



***D.**Slate roof* **E.** *Concrete tiles roof*

Figure 4. Different shingle materials applications

Overall, wood shingle roofs offer a unique aesthetic appeal and are environmentally friendly, but they do require more maintenance than some other roofing materials. Homeowners should consider their priorities, budget, and climate when choosing a roofing material.

1.7. Future Prospects of Wood Shingle Roofs in Turkey

Despite their disadvantages, wood shingle roofs continue to be a popular roofing material in Turkey. In recent years, there has been a renewed interest in wood shingle roofs due to their eco-friendliness and sustainability. Additionally, wood shingle roofs are an important part of Turkey's cultural heritage and contribute to the country's unique architectural style (Çakır and Çağlar, 2018). As Turkey continues to prioritize sustainable building practices, it is likely that wood shingle roofs will continue to be a popular roofing material. With an increased focus on sustainability and environmental responsibility, more and more people are turning to natural and renewable materials for their building projects, including roofing (Özkul and Akgün, 2015). Wood shingle roofs offer a unique and attractive option for those looking to embrace this trend. One potential area of growth for wood shingle roofs in Turkey is in the tourism industry. Turkey is home to many historical and cultural landmarks, some of which have traditional wood shingle roofs. The use of these roofs can help to preserve the authenticity and cultural heritage of these sites, while also providing a unique and memorable experience for visitors (Karaduman, 2019). Another area of opportunity is in the construction of new homes and buildings. As more people become aware of the benefits of wood shingle roofs, they may choose this material for their own projects. This could create a ripple effect, as more and more homes and buildings with wood shingle roofs are built, making it a more common and widely accepted choice (Koca and Korkmaz, 2019). In addition, advances in technology and treatment processes have improved the durability and resistance of wood shingle roofs to weathering, pests, and fire. This means that wood shingle roofs are becoming an increasingly viable option in areas where they were previously not considered due to harsh climate conditions or other environmental factors (Yılmaz and Ay, 2021). Furthermore, the production of wood shingle roofs in Turkey can create job opportunities in the forestry and construction industries, leading to economic growth and development. The use of local materials and labor can also have positive impacts on the local economy and reduce the carbon footprint associated with transportation of materials from outside the region. Overall, the future of wood shingle roofs in Turkey looks bright, with increasing awareness of their benefits and sustainability, as well as technological advancements making them a more durable and practical option (Göksel and Gürses, 2020).

1.8. Wood Shingle Roofs as an Investment

Wood shingle roofs offer a range of benefits that make them a cost-effective option compared to traditional roofing materials. The initial cost of installing a wood shingle roof is often higher than other roofing materials such as asphalt shingles or metal roofs, but the long-term cost savings can be significant. One way that wood shingle roofs save money is through their durability. When properly maintained, a wood shingle roof can last up to 50 years or more, while other roofing materials such as asphalt shingles may only last 15-30 years. This means that homeowners with a wood shingle roof will need to replace their roof less frequently, saving them money in the long run. Additionally, wood shingle roofs are more energy-efficient than traditional roofing materials. They offer better insulation and ventilation, which can reduce heating and cooling costs for homeowners. This is because wood shingles allow for natural airflow and help regulate the temperature in the attic, reducing the need for additional insulation and ventilation. Another way that wood shingle roofs save money is through their eco-friendliness. Wood shingles are made from renewable resources, which means that they are a more sustainable option compared to traditional roofing materials such as asphalt shingles or metal roofs (Wood Roofs, 2008). Additionally, wood shingles can be recycled at the end of their lifespan, further reducing their impact on the environment. Homeowners can also save money on maintenance costs with a wood shingle roof. While they do require regular maintenance such as cleaning and sealing, the cost of maintenance is typically lower compared to other roofing materials. This is because wood shingles are less likely to crack or become damaged, reducing the need for repairs. Overall, the money-saving benefits of wood shingle roofs make them a smart investment for homeowners looking for a long-term roofing solution. While they may require a higher initial investment, the cost savings over time can be significant.

2. MATERIAL PROPERTIES

2.1. Chemical Propeterties

Wood shingle roofs are made from wood, which is a natural material composed of organic compounds such as cellulose, lignin, hemicellulose, and extractives. These compounds are responsible for the physical and chemical properties of wood, including its strength, durability, and resistance to decay. Cellulose is the main component of wood and is a long chain polymer made up of glucose units. It provides wood with its strength and rigidity. Lignin, on the other hand, is a complex polymer that acts as a natural adhesive, holding the cellulose fibers together. It also provides wood with its brown color and resistance to decay. Hemicellulose is a polysaccharide that binds cellulose fibers together and gives wood its flexibility. It is less resistant to decay than cellulose and lignin, which makes it an important factor in wood decay. Extractives are organic compounds that are found in wood and can be responsible for its color, odor, and resistance to decay (Elçi, 2015). The chemical properties of wood shingle roof materials can be affected by various factors, including moisture, temperature, and exposure to sunlight. Moisture is one of the most important factors that can affect the chemical properties of wood. When wood is exposed to moisture, it can absorb water and swell, which can cause it to lose strength and become more susceptible to decay. Temperature can also affect the chemical properties of wood. High temperatures can cause wood to lose its moisture and become brittle, while low temperatures can cause it to become stiff and more prone to cracking. Exposure to sunlight can also affect the chemical properties of wood. Ultraviolet (UV) rays from sunlight can cause wood to break down and lose its color over time. This can make the wood more susceptible to decay and other forms of damage (Freeman, 2019). In addition to these factors, the chemical properties of wood shingle roof materials can also be influenced by the type of wood used, as well as the manufacturing process. Different types of wood have different chemical properties, which can affect their strength, durability, and resistance to decay. The manufacturing process can also affect the chemical properties of wood by altering its structure and composition (National Park Service, 2016). Overall, the chemical properties of wood shingle roof materials play an important role in their strength, durability, and resistance to decay. Understanding these properties is essential for ensuring that wood shingle roofs are properly installed, maintained, and protected from the elements.

2.2. Mechanical and Physical Properties

Wood shingle roof material has various mechanical and physical properties that make it an attractive option for roofing applications. Mechanical properties refer to the response of a material to external forces, while physical properties refer to the characteristics that can be observed without changing the identity of the material. In terms of mechanical properties, wood shingle roofs have a moderate strength and stiffness, making them able to withstand moderate loads such as wind and snow. However, they are not as strong as some other roofing materials like metal or concrete, and are more prone to damage from impacts or heavy loads (Bausano and Kozak, 2018). Another important mechanical property of wood shingle roofs is their elasticity. Wood shingles are able to bend and flex slightly without breaking, which helps them absorb shocks and vibrations. This property is particularly important in areas with high seismic activity, as it allows the roof to better withstand earthquakes. In terms of physical properties, wood shingle roofs have a natural beauty and warmth that is difficult to replicate with other materials. They are also a sustainable and renewable option, as wood is a natural resource that can be grown and harvested in a responsible manner (Dietsch, 2013). One of the drawbacks of wood shingle roofs is that they are more prone to decay and insect damage than some other roofing materials. However, proper maintenance and treatment can help extend their lifespan and protect against these issues (Dinius, 2002). Another physical property of wood shingle roofs is their thermal conductivity. Wood is not the most thermally efficient material, meaning it does not insulate as well as some other materials like foam or fiberglass. However, wood shingle roofs can still provide some insulation value, particularly if they are installed with a layer of insulation beneath them. In terms of moisture resistance, wood shingle roofs can absorb moisture if not properly maintained or treated. This can lead to warping, rotting, and other issues over time (Forest Products Laboratory, 2010). However, wood shingle roofs that are properly installed and maintained can provide effective moisture resistance. Overall, the mechanical and physical properties of wood shingle roof material make it a viable option for roofing applications, particularly in areas with moderate weather conditions and a desire for a natural, warm aesthetic. However, proper maintenance and treatment are necessary to ensure its longevity and protect against decay and insect damage (USDA Forest Products Laboratory, 2017).

2.3. Lifespan of Wood Shingle Roofs

The lifespan of wood shingle roofs can vary depending on various factors such as the quality of the wood used, the installation method, and the climate. In general, wood shingle roofs can last anywhere from 20 to 50 years or more with proper care and maintenance (Smith, 2019). One of the most important factors that affects the lifespan of wood shingle roofs is the quality of the wood used. High-quality wood such as cedar or redwood tends to have a longer lifespan than lower-quality wood. This is because these types of wood have natural oils and resins that make them more resistant to decay, insect damage, and moisture. Lower-quality wood, on the other hand, may be more prone to cracking, splitting, and rotting, which can reduce the lifespan of the roof. Another important factor that affects the lifespan of wood shingle roofs is the installation method. Proper installation is critical to ensuring that the roof performs as intended and lasts as long as possible. If the shingles are not properly installed or if there are gaps or other issues with the roof, moisture can seep in and cause damage over time. It is important to work with a skilled and experienced contractor who knows how to install wood shingle roofs properly (Jones, 2018). Climate is also an important factor that affects the lifespan of wood shingle roofs. In areas with high humidity, frequent rain, or heavy snowfall, the roof may be more prone to moisture damage and decay. In hot and dry climates, the wood may be more prone to cracking and splitting. It is important to choose the right type of wood for the climate and to take steps to protect the roof from the elements, such as installing proper ventilation. Regular maintenance is also critical to extending the lifespan of wood shingle roofs (Davis, 2020). This includes cleaning the roof periodically to remove debris and checking for any signs of damage or wear. It is important to address any issues as soon as they arise to prevent them from getting worse and causing further damage to the roof (Garcia, 2017). In summary, the lifespan of wood shingle roofs can vary depending on various factors such as the quality of the wood used, the installation method, and the climate. With proper care and maintenance, wood shingle roofs can last anywhere from 20 to 50 years or more. It is important to work with a skilled and experienced contractor and to take steps to protect the roof from the elements to ensure that it lasts as long as possible.

2.4. Installation Types

Wood shingle roofs can be installed using several different techniques. The installation method used will depend on the type of shingle, the roof’s design, and the climate in which the building is located. Some common installation methods include:

- Nail-On: The most common method of installation is to nail the shingles onto the roof deck. This technique involves using a pneumatic nail gun to fasten the shingles to the deck. The nails are typically placed at the top edge of the shingle, just below the overlap of the next row. This method is relatively fast and easy to install, but it can be susceptible to wind damage and water infiltration if not done correctly (Remick and LeBlanc, 2003).

- Interlocking: This method involves the use of shingles that have a unique interlocking system. The shingles are designed to fit together tightly, which creates a weather-resistant barrier that is less susceptible to wind damage and water infiltration. This method is typically more labor-intensive and time-consuming than nail-on installation, but it offers a higher level of protection against the elements (Knauf, 2004).

- Cedar Breather: The Cedar Breather system involves the use of a breathable underlayment that is installed over the roof deck before the shingles are applied. This underlayment allows for ventilation beneath the shingles, which helps to prevent moisture buildup and prolongs the life of the roof. The shingles are then installed over the underlayment using the nail-on or interlocking method. This system is more expensive than traditional nail-on installation, but it offers superior protection against moisture damage and can extend the life of the roof (Ducharme, 2006).
- Shake-Look Shingles: Shake-look shingles are designed to mimic the look of traditional hand-split cedar shakes, but they are made from composite materials that are more durable and resistant to moisture and insects. These shingles can be installed using the nail-on or interlocking method, and they typically require less maintenance than traditional wood shingles (Downing and Gonzales, 2009).
- Fire Retardant Shingles: In areas with a high risk of wildfires, fire retardant shingles may be required by local building codes. These shingles are treated with a fire retardant chemical that helps to slow the spread of flames in the event of a fire. They can be installed using any of the above methods, but they may be more expensive than traditional wood shingles (Ritter, 2014).

It's important to note that proper installation is critical to the longevity and performance of a wood shingle roof. Improper installation can result in leaks, water damage, and premature aging of the shingles. Therefore, it's recommended that a qualified roofing contractor be hired to install the roof. Additionally, regular maintenance and inspection of the roof should be performed to ensure that it remains in good condition and to address any issues before they become more serious (Faller, 2015).

2.5. Cost of Product

Wood shingle roofs have been used for centuries and continue to be a popular roofing material due to their aesthetic appeal and natural beauty. However, the cost of wood shingle roofs can vary significantly depending on several factors, including the type of wood used, installation method, and availability of materials. In comparison to traditional roofing materials such as asphalt shingles or metal roofing, wood shingle roofs can be more expensive. This is largely due to the fact that the cost of high-quality wood shingles is generally higher than other roofing materials. Additionally, the installation process for wood shingle roofs can be more time-consuming and labor-intensive, which can increase the overall cost of the project (Dubois, 2010). The type of wood used in the shingles can also impact the cost. Cedar is a popular choice for wood shingle roofs due to its durability and resistance to moisture and insects. However, cedar shingles can be more expensive than other types of wood. Redwood is another popular choice for wood shingle roofs, but it is also a more expensive option. While the initial cost of wood shingle roofs may be higher, they can offer cost savings over time. Wood shingles are durable and can last for many years with proper maintenance. This can be more cost-effective in the long run than other roofing materials that may need to be replaced more frequently (Runkel and Huelman, 2013). Another factor to consider when comparing the cost of wood shingle roofs to traditional materials is the environmental impact. Wood shingles are a renewable resource and can be sustainably sourced. Additionally, the manufacturing process for wood shingles typically requires less energy and produces fewer greenhouse gas emissions than other roofing materials. In some cases, the cost of wood shingle roofs may be higher due to local building codes or regulations. Some areas require specific materials or installation methods for roofing to meet safety and fire code requirements. This can impact the overall cost of the project and should be taken into consideration when comparing the cost of wood shingle roofs to other materials. Overall, while wood shingle roofs may be more expensive than traditional roofing materials, they offer several benefits such as durability, natural beauty, and sustainability. The cost-effectiveness of wood shingle roofs can vary depending on the specific project and location, but it is important to consider all factors when making a decision on roofing materials.

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CHAPTER 2

THE UTILIZATION OF CRAYFISH SHELLS AS ALTERNATIVE BIOLOGICAL RESOURCES IN INDUSTRY

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INTRODUCTION

As the world population grows, the demand for animal protein sources, especially seafood, is increasing as a part of a healthy diet (Gomez et al., 2019; Bohnes et al., 2019; Regueiro et al., 2022). Hence, the food production sector, especially animal protein production, plays a critical role in food and nutrition security (Maulu et al., 2022). When it comes to seafood, a very broad food category comes to mind. Namely, these categories are; a) both freshwater and marine finfish species (trout, carps, sea bass, sea bream, tilapia), b) bivalves (mussels and oysters), c) decapods (crabs, shrimp, and lobsters), and d) cephalopods (cuttlefish, squid, octopus). The production sector of these seafood groups is considered to tend to grow faster, showing better environmental performance than land-raised animals (FAO, 2018).

Aquatic product obtained through aquaculture and fishing contain important sources of animal protein and contributes significantly to human health by containing micronutrients and essential fatty acids (FAO, 2020). In addition to their high nutritional content, shellfish are also ecologically beneficial to the environment as they are involved in the nutrient cycle. For this reason, it is assumed that the fishery and aquaculture sector can supply more economic value to production in the future through trade and marketing in ensuring sustainable food production (Cai et al., 2019). Aquatic production, world fisheries and aquaculture production grew by 69.2% in the 2002-2022 period and reached 184.6 million tons in 2022, and more than half of this production is reported to come from aquaculture (FAO, 2022). Molluscs account 13% of the total seafood production, and crustaceans 9% (FAO, 2022). Shellfish are aquatic invertebrates that have a shell or exoskeleton. They are defined as crustaceans and/or mollusks such as mussels, oysters, crab, lobster and shrimp. Chitin, a polysaccharide derived from crustacean shells, is a potential source of antimicrobial agents. Chitosan, which is a derivative, has a wide range of application area, especially in wastewater treatment, cosmetics, toiletries, food, beverage, agricultural chemicals and pharmaceuticals (FAO, 2022; Mazlum et al., 2022).

Mussel and oyster shells have also industrial applications. Shells can be converted to calcium carbonate or calcium oxide, two versatile chemical compounds. The shells can also be used as a calcium supplement in cosmetics and animal feed, as well as for crafts and jewelers. Most of the shellfish species are of marine origin and constitute more than half (52.2%) of the total fish group (FAO, 2022). Crustaceans are the fourth-largest arthropod group among animal groups and are generally considered a sub-phyla (Mazlum and Yazıcı, 2023). Due to their protein content, crustaceans provide important contributions to both the economy and human health by meeting the nutritional needs of people. Global aquaculture production of crustaceans reached 11.2 million tons in 2022 (FAO, 2022). Due to the edible proportion of crustaceans (<50%), a large amount of shell waste is also produced during meat processing, and green recycling of crustacean shells is gaining more and more attention (Sato et al., 2010). Crustaceans, comprising about 50,000 to 75,000 species, are an important group of arthropods. Shrimp, crab, crayfish, lobster and other large crustacean species have an important place in aquaculture in terms of rich food sources. Crustaceans and their derivatives are an important sustainable part of modern culture and commerce, biomedicine and economic development, aesthetics, gastronomy, geology and many other fields (Susanto, 2021; Amiri et al., 2022). Therefore, it is thought that Crustacean will play crucial role in contributing to future global food production. Crustaceans include whiteleg shrimp *Litopenaeus vannamei*, Red swamp crayfish *Procambarus clarkii*, Chinese mitten crab *Eriocheir sinensis*, giant tiger shrimp *Penaeus monodon*, and mud crab *Scylla* species (Tacon, 2020). It should not mean that other crustaceans have less potential as future food. Studies on other species are contemplated to increase the production, consumption and value of these creatures, and therefore they will be among the important food candidates of the future.

According to the data of 2021, the total aquaculture production is 90.9 million tons, and the most grown group of aquatic species is fish (47.1 million tons), shellfish (24.0 million tons) and aquatic plants (27.9 million tons) (Figure 1). Shellfish as the food of the future; It is defined as an affordable, useful, safe, nutritious and sustainable product without harming the environment. In this context, the food of the future is considered to be important in having four characteristics: (i) it must be available, (ii) its production cost is low, (iii) it must be environmentally friendly and friendly, and (iv) it can be obtained through the sustainable use of resources.

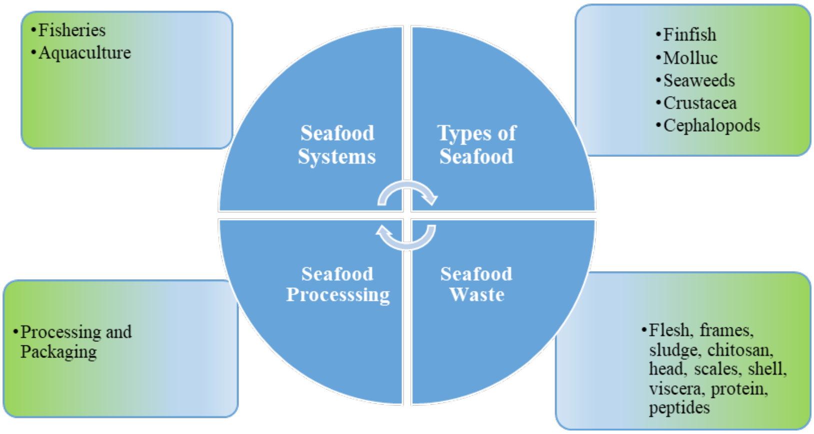

Figure 1. Types of aquatic production system, and types of by-products that are made (Cooney et al., 2023)

Crustaceans are produced in millions of tons worldwide and are the largest seafood production sector, providing a protein-rich (17-20%) food source by humans. More than half of the body mass of crustaceans (40-60%) contains inedible parts such as shells that are simply thrown away as waste (Yan and Chen, 2015; Nguyen et al., 2017). According to FAO (2020) data, shrimp, crab, lobster, etc. such as shellfish are produced about 9.3 billion tons per year. Since the shells or exoskeletons of crustaceans are edible, a significant portion of the crustacean aquatic animals is dumped as waste into landfills or the sea, causing pollution of the environment and endangering health (Santos et al., 2020). Harvesting and processing of shellfish is an important waste generation around the world, and it is estimated that approximately 6-8 million tons of waste is generated annually (Yan and Chen, 2015; Vicente et al., 2022). That is, while 75% of the weight of a tuna fish can be removed as fillet meat, only 35-40% of the mass of a shrimp or crab is meat. In addition, over 12 million tons of mollusk shells are obtained each year. When all these are carefully examined, more than 70% bivalves (oyster, scallop and mussel shells) are represented (Summa et al., 2022). Bivalves, especially mussels, and other shellfish make up 65-90% of live weight depending on the species (Morris et al., 2019; Vélez-Henao et al., 2021). The seafood processing industry, on the other hand, produces large amounts of by-products and discards tons of shells. Some of their waste is used locally as food for aquaculture or animal feeding. In addition, innovative methods for the evaluation of shells are emerging as these wastes are rich in excellent sources of protein, chitin, lipid, pigment, calcium carbonate and small molecule and have great commercial value (Yan and Chen, 2015) (Figure 2).

Figure 2. Crustacean shell and powders obtained from different aquatic organisms

Crayfish shells are used as a chemical source in many commercial applications (Chen et al., 2020) and these shells attract more and more researchers' attention every day. It is also known that chitin and its derivatives, chitosan, show heavy metal removal properties (Yang et al., 2020; Zhang et al., 2021). Chitin and its derivatives have recently been extensively studied for its applications in various industrial areas such as food, health and agriculture due to its antioxidant, antimicrobial and film-forming properties (Kim et al., 2012). Therefore, the wastes of crustacean shells are an important material for chitin. The exoskeleton of crustaceans contains carotenoid pigments of high nutritional value. It also constitutes primary protein or fat-soluble carotenoid pigments, which is more than 40% by weight of the total crustacean waste (Sachindra et al., 2005; Šimat et al., 2022).

ARTHROPOD SHELL

Crayfish shells have significant potential as a novel research topic in the biological utilization of natural resources (Chen et al., 2020; Mazlum et al., 2022). Crayfish shells and derivatives are anticipated to align with new sought-after criteria such as structure, function, diversity, sustainability, and low costs in the realm of biomaterials (Nekvapil et al., 2021; Binnewerg et al., 2020; Araujo, et al., 2021).

Freshwater crayfish, belonging to the phylum Arthropod, class Crustacean, and order Decapoda, encompass over 737 species inhabiting freshwater environments (Crandall and De Grave, 2017). Characterized by a robust yet flexible exoskeleton, crayfish bodies are segmented into three parts: head, carapace, and abdomen. These segments are sometimes divided into 19 paired appendages, known as 19 segments. Being invertebrates, crayfish exhibit adaptability to various habitats such as While some species (*Pontastacus leptodactylus*) breed in oxygen-rich cold waters such as lakes and rivers, others thrive in oxygen-poor (*Procambarus clarkii*), hot water environments. Certain species ((*Astacus leptodactylus and Pacifastacus leniusculus*) have even adapted to saline waters (Mazlum and Yılmaz, 2006; Mazlum and Yılmaz, 2012).

Crayfish play a significant role in the freshwater food chain, consuming other invertebrates, macrophytes, algae, and detritus. Additionally, crayfish display cannibalistic tendencies and possess a selective diet targeting specific invertebrates and macrophytes (Mazlum et al., 2020). In periods of abundance, crayfish contribute substantially to the food chain and species diversity, both as direct consumers and as a consumable entity. They serve as a vital energy source for many predatory animals, thereby occupying a prominent position in the upper trophic levels of the food chain. Therefore, crayfish can be considered an economically important natural food resource (Nystrom, 2002).

Globally admired and recommended as a high-quality food and an integral part of a balanced diet, crayfish, like other crustaceans, have gained prominence. Over the years, the crayfish market has expanded, rendering crayfish a valuable food source for human populations. The shells of crayfish and similar crustaceans can exhibit variations in composition based on species, season, and habitat. Annually, around 100,000 tons of crayfish shells are produced, and the waste generated during crayfish processing typically ranges from 40% to 50%, with chitin constituting 40% of this waste (Peng et al., 2016; Cai et al., 2017). Crayfish shells contain significant proportions of protein, calcium carbonate, chitin (20–30%), omega-3 fatty acids, pigments, and other minerals, rendering them suitable for various industrial applications (Vicente et al., 2022).

Chitin is the most important natural polymer and is the main structural component of the exoskeleton of arthropods (Ngasotter et al., 2023). Chitin is chemically stable and insoluble, converted to chitosan by deacetylation. It has a wide range of uses. Chitin from freshwater crayfish is a biodegradable, biocompatible and non-toxic biopolymer. In general, it finds wide application in different usage areas such as chemicals, pharmaceuticals and food processing (Riva et al., 2011; Parvez et al., 2012). Moreover, crayfish shells contain astaxanthin, a widely used carotenoid with potent antioxidant properties that can enhance immunity and potentially prevent cancer. Apart from these, astaxanthin can protect the central nervous and visual systems, owing to the rich protein content, particularly aspartic and glutamic acids (Visioli and Artaria, 2017; Lim et al., 2015; Huang et al., 2014). Chitin is the second most abundant polysaccharide in the world after cellulose (Mazlum et al., 2022). It has anti-microbial, antioxidant and anti-inflammatory effects. It has biodegradability, biocompatibility and toxic properties. It has environmentally friendly and biodegradable properties. Their use in a wide variety of industrial applications in the fields of biomedicine, medicine, agriculture, food, cosmetics, textiles and enzyme immobilization makes these seashells valuable and attracts the attention of researchers every day (Zheng et al., 2010; Qin et al., 2016; Long et al., 2017; Park et al., 2018; Yan et al., 2018).

APPLICATION AREAS OF ARTHROPOD SHELLS

Due to their contents, arthropod shells have various potential applications in the industry. When arthropod shell wastes are evaluated holistically, they can be valuable raw materials for the production of chitin and chitosan, especially in the food sector (Lukum et al., 2023; Adeyemi and Ojoawo, 2023). It is the only naturally occurring alkaline polysaccharide discovered so far, obtained from the deproteinization and demineralization of crustacean shells, especially from shrimp, crab, lobster, and krill

(Hamed et al., 2016; Iber et al., 2022) (Figure 3). Chitin and its derivatives are valuable compounds that meet consumers' natural product needs with positive effects on health.

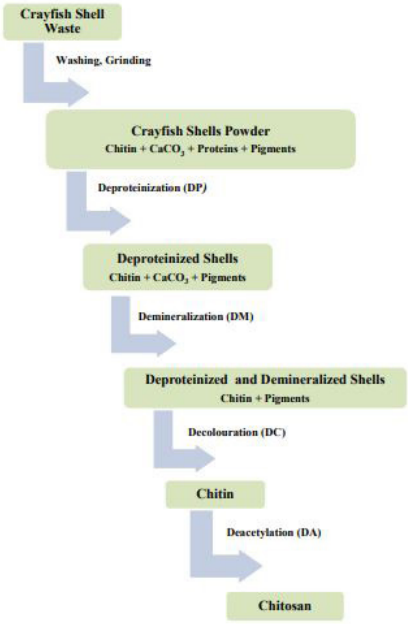

Figure 3. Schematic representation of chitin and chitosan production by biological method (Al Sagheer et al., 2009)

The efficacy of chitin across diverse applications is contingent upon critical factors including its degree of acetylation, molecular weight, and functional modifications (Rameshtangam et al., 2018). Therefore, chitin can find a wide range of industrial applications in biomedicine, pharmaceuticals, agriculture, food, cosmetics, textiles, and enzyme immobilization due to its versatile properties. In addition to health benefits, such as antimicrobial, antioxidant, and anti-inflammatory effects (Muthu et al., 2021), chitin is also environmentally friendly (Casadidio et al., 2019). The shells of crustaceans, particularly crab shells, can be used in the nutrition of poultry and livestock as an alternative to fish meal (Vijayalingam and Rajesh, 2020). Similarly, shrimp heads and shells are processed for use in both animal feeds (Gasco et al., 2018) and biscuit products due to their high chitin content (Adiarsa et al., 2023), and they can also be employed as fertilizers (Baharlouei and Rahman, 2022). The various applications of chitosan derived from shells are illustrated in Figure 4.

Figure 4. Chitin obtained from crayfish (Pontastacus leptodactylus) shell (Mazlum et al., 2022).

BIOMEDICAL APPLICATIONS OF CHITIN: ARTHROPOD SHELLS

Crustacean remnants of arthropods are considered a limited source of chitin (Amiri et al., 2022). Chitin and its derivatives are considered to be safe, biodegradable and environmentally compatible natural polymers (Figure 5).

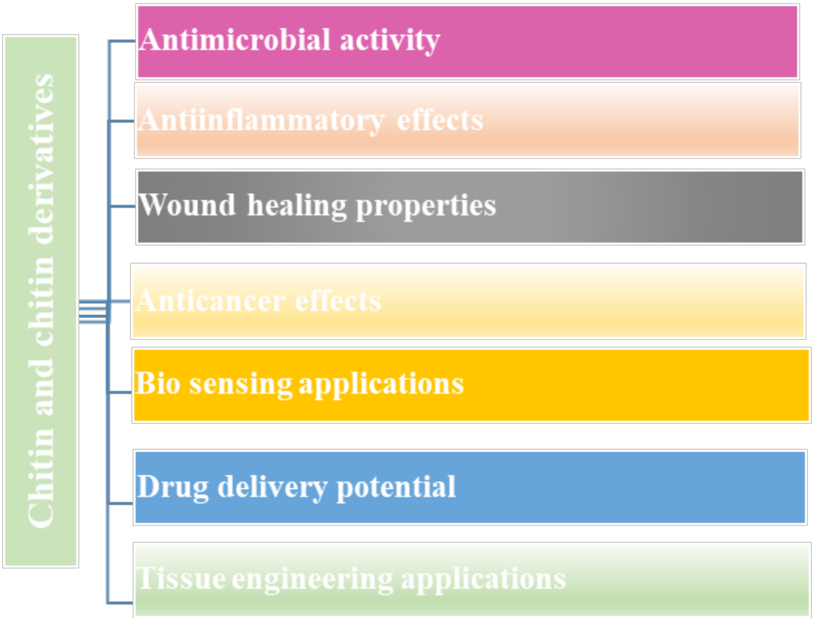

Figure 5. Schematic representation of the use of chitin and its derivatives in the biological field

In the biomedical context, chitin and its derivatives can be found in various forms such as hydrogels, membranes, nanofibers, beads, micro/nanoparticles, scaffolds and sponges. These forms are used in a number of biomedical applications such as wound healing, tissue engineering, and contact lens manufacturing (Azuma et al., 2014; Elieh-Ali-Komi and Hamblin, 2016). The realm of tissue recovery and augmentation has witnessed the judicious utilization of biopolymers to restore compromised tissues (Reddy et al., 2021; Dash et al., 2011). In parallel, chitin and its derivatives have garnered notable attention in the domains of tissue regeneration and scaffolding (Szulc and Lewandowska, 2022). Pertinently, chitin-based wound dressings have demonstrated their efficacy in shielding burns and wounds against bacterial incursions, as noted by Singh et al. (2017). Furthermore, the application of chitosan in burn management showcases a distinct advantage, as its susceptibility to endogenous enzymes facilitates its degradation, negating the need for cumbersome dressing removal, and by extension, the potential infliction of harm and trauma (Dutta et al., 2012). Through the establishment of a microbial barricade, chitin and its derivatives maintain a conducive wound milieu characterized by optimal moisture levels. Consequently, they curtail excessive fluid effusion while concurrently facilitating oxygen permeability and gaseous exchange. It is by virtue of these attributes that these materials stand as prime candidates for dressing applications (Azuma et al., 2014). In addition, chitin and its derivatives can potentially be used in the manufacture of contact lenses as they have unique properties such as immunological compatibility, optical clarity, transparency, gas permeability, wettability, mechanical stability and flexibility. Chitosan has taken the place of synthetic polymers in ophthalmological applications due to the safety and comfort it provides during use (Dutta et al., 2012). Also, chitosan-based lenses with antimicrobial and wound-healing properties may be beneficial for injured eyes (Figiela et al., 2018).

Antimicrobial Activity

Antimicrobial agents are substances capable of inhibiting the proliferation of microorganisms. The emergence of antimicrobial-resistant microorganisms has significantly escalated concerns within both public health and the food industry. This elevation in concern is attributed to their rapid adaptability and diminished responsiveness to synthetic antimicrobials. The spectrum of antimicrobial agents encompasses both bacteriostatic and bactericidal attributes contingent on their origin, concentration, and efficacy (Olatunde et al., 2018). Recent years have witnessed a mounting fascination with antimicrobial compounds derived from natural reservoirs. Bioactive agents hailing from marine origins encompass a diverse array of biological functions, encompassing roles as antioxidants, antimicrobials, anti-inflammatories, antihypertensives, and even agents with anticancer potentials. Investigations into the antibacterial potency of chitin and chitosan sourced from shrimp exoskeletons have unveiled their efficacy against bacterial strains like Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa (Abdel-Rahman et al., 2014; Jiang et al., 2014). Notably, chitosan displaying a heightened degree of deacetylation has been proven to exhibit more pronounced antibacterial effects compared to chitin (Ardean et al., 2021).

Anti-Inflammatory Effect

Conventional synthetic anti-inflammatory agents, while efficacious, often entail undesirable consequences encompassing gastric irritation, ulceration, and compromised host resistance. This predicament has spurred the quest for natural anti-inflammatory compounds characterized by biocompatibility and biodegradability, prompting active investigations (Khanal et al., 2001). Optimal outcomes have been observed with the administration of a specific dose, 8 mg/kg, of this compound, signifying its efficacy in averting lung damage. Similarly, the harnessing of rutin within chitosan microspheres has yielded heightened anti-inflammatory potential. Noteworthy inferences propose the prospective application of rutin-loaded chitosan microspheres in addressing mucosal inflammation, encompassing regions such as the synovial, pulmonary, and intestinal domains (Kulkarni et al., 2022).

Wound Healing Potential

Chitosan can be used as a wound dressing to promote rapid epithelial cell renewal and collagen synthesis. Furthermore, advancements in nanotechnology have enabled the targeting of cancer and wound healing through the use of chitin and chitosan nanoparticles. A wound is a type of injury that starts as a result of a simple cut or a hard break in the dermis and can spread to the adjacent tissues, muscles, subcutaneous tissues, and tendons, disrupting the anatomical order. Wounds are classified into two main categories, acute and chronic. Acute wounds occur on the superficial part of the skin or tissues, usually leave minimal scarring and heal in about 12 weeks. The healing process of chronic wounds is longer and often recurs. Wound healing, an intricate process encompassing hemostasis, inflammation, proliferation, and remodeling, necessitates meticulous intervention to orchestrate intricate cell-cytokine interactions during its distinct phases (Kawasumi et al., 2013; Tabuchi et al., 2016; Abdel-Mohsen et al., 2016; Marei et al., 2017). Biomaterials, including alginates, collagen, pectin, hyaluronic acid, and derivatives of chitin, play pivotal roles as wound dressings, catalyzing the expeditious progression of wound closure. Among these derivatives, chitin emerges with profound wound healing attributes. Minagawa et al. (2007) have scrutinized the effects of chitin/chitosan molecular weight and degree of deacetylation, unveiling that heightened deacetylation coupled with lower molecular weights augments wound healing efficacy (Yazıcı et al., 2022).

Anticancer Effects

Cancer-related mortality rates persist at elevated levels, underscoring the pressing need for effective interventions. Presently, chemotherapy retains its prominence as a primary modality in cancer treatment. However, its clinical effectiveness remains hindered by obstacles such as suboptimal drug accumulation within malignant cells and undesirable drug retention within healthy tissues, undermining its therapeutic potential (Tsai et al., 2016; Barusrux et al., 2020). The biocompatibility of chitin nanogels has been systematically explored across diverse cell lines, elucidating its viability for potential applications (Rejinold et al., 2012). In the context of cancer, chitooligosaccharides displaying maximal acetylation and minimal molecular weight have exhibited discernible anticancer attributes, most notably against human myeloid leukemia cells (Kim et al., 2012). Noteworthy findings by Huang et al. (2012) shed light on the cell-specific anticancer efficacy inherent to highly charged chitosan oligosaccharides, exhibiting effectiveness across distinct cell lines. Intriguingly, it has been observed that heightened charges in chitosan derivatives confer substantial reduction in cancer cell viability, irrespective of positive or negative charge polarities. Further insights unveil the capacity of low molecular weight chitin to impede the action of glycoproteins bearing anti-apoptotic effects. Collectively, the anticancer responses elicited by chitin and its derivatives contribute to the burgeoning landscape of novel anticancer agents under exploration (Salah et al., 2013).

Biosensor Applications

Electrochemical methodologies present notable advantages in the scrutiny of pharmaceutical compounds and biological molecules in human bodily fluids. The preeminence of electrochemical detection arises from its commendable attributes encompassing sensitivity, cost-effectiveness, and comparably brief analysis durations when juxtaposed with conventional analytical techniques. The protonation of the acetylamide moiety within chitin stands out as an efficacious mechanism for segregating and amassing specific anions from the sample matrix, facilitated by electrostatic interactions. This distinctive attribute lends itself to the immobilization of enzymes and diverse materials, amplifying analytical prospects (Sugawara et al., 2000; Dvoretsky and Dvoretsky, 2023). The chitosan membrane derived from the exoskeleton of the soldier crab Mictyris brevidactylus, as illuminated by Chen et al. (2006), emerges as a compelling case of sound electrochemical and mechanical properties, rendering it apt for enzyme immobilization. Kumar and collaborators (2010) have underscored the augmented mechanical properties and electrical conductivity stemming from the integration of carbon nanotubes into chitosan matrices, culminating in the fabrication of carbon nanotube-polymer nanocomposites. This ingenuity has found application in the immobilization of functionalized carbon nanotubes onto chitosan matrices via cross-linking agents, exhibiting proficiency in detecting organic molecules like hydroquinone, dipyron, and glucose (Pauliukaite et al., 2010). These collective insights substantiate the potential of chitin and its derivatives in pioneering sensor development for the detection of diverse chemicals, biomolecules, and pharmaceutical agents.

Drug Delivery Potential

Drug distribution within the body involves a complex process that requires overcoming various barriers such as drug elimination by the liver and kidneys, rapid degradation in the bloodstream, and limited permeability across biological membranes. An ideal drug delivery vehicle should possess several key features, including biocompatibility, biodegradability, and controlled release properties. In modern times, polymer-based materials are considered a promising platform for transporting bioactive macromolecular drugs (Desai et al., 2023). Among the various intriguing characteristics of drug carriers are mucus and bioadhesiveness, the capacity to bind and release therapeutic macromolecules, as well as biocompatibility, low toxicity, biological solubility, and mucosal and bioadhesive properties. Due to these attributes, it is a well-known molecule in drug delivery platforms (Goycoolea et al., 2009; Cover et al., 2012; Nascimento et al., 2014).). Controlled release capabilities enable the gradual and controlled release of drugs over a specific period, allowing for the maintenance of continuous therapeutic levels and reducing dosing frequency. Chitosan, owing to its unique properties, holds significant promise for drug release applications. Chitin-derived nanoparticles have been employed not only for drug molecules but also for the transportation of RNA, proteins, and peptides (Nascimento et al., 2014).

Tissue Engineering

The combination of chitosan hydrogel and chitin nanoparticles could facilitate the targeted delivery of anticancer drugs, inhibiting cancer cell proliferation. In light of promising applications for nanofibers in tissue engineering, the focus has shifted towards the development of chitin-derived fibers as biological replacements for nano-scale body tissues (Shoueir et al., 2021; Satitsri and Muanprasat, 2020). Tissue engineering presents a fundamental approach to regenerate or replace damaged or diseased tissues and organs. However, various challenges such as limited graft availability, potential disease transmission, graft site discomfort, inadequate fusion, donor site complications, and cost-related factors impose restrictions within the realm of tissue engineering. Consequently, biomaterials possessing appropriate physiological and biochemical attributes have been employed to achieve favorable survival rates in tissue engineering endeavors (Anitha et al., 2014). Recently, chitin and its derivatives have exhibited promising potential within the field of tissue engineering. Kumar et al. (2013) developed a nanocomposite scaffold for tissue engineering using a lyophilization technique, employing a blend of pectin, chitin, and nano $CaCO_3$. The researchers assessed cytocompatibility on human dermal fibroblast (HDF) cells, evaluating cytotoxicity on murine fibroblast cell lines. The results confirmed minimal cytotoxicity of the scaffold material towards cells. Subsequent studies focused on cellular seeding and proliferation. In another investigation, bioactive composite scaffold structures were created based on graphene oxide (GO)–chitosan (CS)-hyaluronic acid (HA), incorporating simvastatin as a drug to trigger osteogenesis for bone tissue engineering applications. In vitro results exhibited substantial impacts of the scaffold material on osteogenesis and biomineralization, alongside remarkable biocompatibility, thereby emphasizing its potential utility as a scaffold in bone tissue engineering (Liu et al., 2016; Unnithan et al., 2017; Zhou et al., 2023). Liu et al. (2016) effectively employed dispersion-based freeze-drying to produce CS/chitin nanocrystal (CNC) composite scaffolds, which demonstrated a notable enhancement in mechanical strength under compression when utilized as scaffolds for MC3T3-E1 osteoblast cells. These scaffolds displayed exceptional biocompatibility and minimal cytotoxicity. The study's findings further indicated that CNCs can significantly enhance cell adhesion and osteoblast proliferation within CS, suggesting their potential application in the realm of bone tissue engineering (Liu et al., 2023)

THE KEY INDUSTRIAL APPLICATIONS OF CHITIN, CHITOSAN, AND THEIR DERIVATIVES: ARTHROPOD SHELLS

Agriculture Area

Chitosan is a versatile compound offering a wide range of applications. This compound finds use in various fields ranging from fertilizers to food preservatives. Its utilization as a seed coating material to enhance plant defense mechanisms and control harmful organisms has been documented in the literature (Zeng et al., 2010; Vicente et al., 2022). Studies have established the impact of chitosan on germination and growth processes of ajowan (Trachyspermum ammi) seeds (Mahdavi and Rahimi, 2013; Ngasotter et al., 2023). Moreover, chitosan has been observed to be effective in soybean (Glycine max) production, significantly increasing yield, germination rate, and plant growth when applied as a seed coating (Zeng et al., 2012).

Traditionally, chemical pesticides have been widely used for pest control in agriculture. However, due to the high toxicity and resistance development risks of these chemicals, research has been conducted on the use of chitin and its derivatives as an alternative (Badawy and Rabea, 2011). Many studies indicate that Chitin, chitosan, and their derivatives have as plant protection properties, offering potential applications in various fields against harmful organisms (Ramírez et al., 2010).

Industrial Area

Food processing operations yield substantial quantities of by-products. While these waste materials could pose environmental and health concerns, they often hold value and can be transformed into beneficial products. For instance, the shells of crustacean seafood products like shrimp, crab, and lobster contain a polysaccharide called chitin. Managing these shell wastes and utilizing them as chitin allows the evaluation of this compound with diverse biological effects. Chitin and its derivatives exhibit biological activities such as cancer prevention and antioxidant effects, suggesting potential applications in various sectors like medical, cosmetic, food, and textiles. The shellfish processing industry generates significant waste annually, posing an environmental threat. The management of shell waste and chitin extraction offer a potential solution to reduce waste and obtain valuable compounds. It is imperative to consider non-food utilization options for these waste materials as well (Hamed et al., 2016; Amiri et al., 2022).

Textile Applications

Chitin-based compounds have the ability to interact with textile materials composed of natural fibers and synthetic fibers (Gao and Cranston, 2008; Zhou et al., 2019). In addition to their positive charges, these compounds possess favorable properties such as water solubility, bio-adhesiveness, biocompatibility, biodegradability, non-toxicity, and antimicrobial activity, suggesting their potential application in textiles for antimicrobial purposes (Mourya et al., 2011). The growth of microorganisms that show growth on the textile surface can cause a decrease in the mechanical strength of the fabric and cause unpleasant odors both on the fabric itself and on the wearer (Ying et al., 2015). Furthermore, the non-allergenic and anti-microbial attributes of chitin fibers make them suitable for garments designed for individuals with sensitive skin, such as babies and the elderly (Pillai et al., 2009).

Wastewater Treatment

Crustacean shells are good biosorbent due to their non-toxic nature. Chitin and chitosan are organic compounds and can be acetylated to produce metal complexes (Al Balushi et al., 2021). Generally, heavy metals are among the most persistent pollutants found in wastewater. Dyes, coloring textile auxiliaries and chemicals used in the textile industry produce colored wastewater. Chelating agents and flocculants, such as chitosan, have the ability to effectively bind heavy metals, serving as metal scavengers (Abu Hassan et al., 2009; Dutta et al., 2004). In wastewater treatment, chitosan and its derivatives have a wide range of use in the textile industry. Many studies have shown that shells can be an effective biosorption for heavy metals in surface waters (Esguerra et al., 2018).

Food Industry

Each year, more than 80,000 tons of chitin are manufactured from sectorial waste, primarily sourced from the seafood processing sector (Kim et al., 2007). It is recognized that chitin and its derivatives encompass a broad spectrum of biological functionalities, which encompass antioxidant and antimicrobial properties among others. These functionalities have the potential to be harnessed within the food sector to bolster food safety, elevate quality, and extend shelf life (Zhao et al., 2022).

a. Antioxidant Activity

Oxidative stress, triggered by reactive oxygen species such as hydrogen peroxide, hydroxyl radicals, and superoxides, is linked to various pathologies that result in detrimental outcomes (Muthu et al., 2021; Šimat et al., 2022). These include conditions like cancer (Manda et al., 2009), cardiovascular diseases (Zhang et al., 2022), premature aging (Cui et al., 2012), inflammation, and rheumatoid arthritis (Filippin et al., 2008). Notably, chitin is among the compounds that exhibit antioxidant effects (Park & Kim, 2010). Consequently, its incorporation into the production of functional foods holds potential for curbing age-related and diet-associated ailments (Kerch, 2015). In the realm of food, elevated levels of lipid oxidation can lead to adverse taste and bitterness. In addressing this concern, synthetic antioxidants like butylated hydroxytoluene and butylated hydroxyanisole have historically been employed. However, in light of emerging health considerations (Younes and Rinaudo, 2015), a shift towards safer and natural antioxidants has been favored. Chitosan emerges as a candidate capable of retarding lipid oxidation, thus mitigating the pro-oxidant activity of iron ions or impeding their conversion into ferric ions (No et al., 2007).

b. Food Preservatives

Chitin and chitosan find utility as effective food preservatives within the food industry (Sethulekshmi, 2014; Barikani et al., 2014; Amiri et al., 2022). Their application extends to conferring antimicrobial attributes, safeguarding consumables against the onslaught of microbial spoilage. The antimicrobial function of chitin materials hinges on a mechanism wherein the cell wall's negative bacterial charges undergo conversion into positive charges upon microbial intrusion (Khoushab and Yamabhai, 2010). The incorporation of chitosan into food products serves to hinder the proliferation of microorganisms, thus curbing undesirable manifestations encompassing appearance, taste, and consequential economic detriments. El-Diasty et al. (2012) notably exhibited that the integration of chitosan into cheese formulations effectively suppressed mold and yeast proliferation, thereby protracting the product's shelf life and enhancing its overall quality.

c. Antimicrobial Packaging

Chitosan's inherent antibacterial attributes render it a valuable candidate for packaging applications (Muzzarelli and Muzzarelli, 2005; Singh et al., 2016). The formulation of biofilms using chitosan has yielded extended storage possibilities for food items. The application of antimicrobial coatings to vegetables, fruits, grains, and fish acts as a safeguarding shield, retarding microbial incursion, consequently augmenting both the sensory and nutritional facets of the food (Sinha et al., 2014; Olatunde et al., 2020). Beyond its protective function, edible biopolymer films have emerged as versatile carriers for bioactive compounds, thereby elevating the quality of foodstuffs. Polymeric bioactive films containing organic acids, bacteriocins, plant extracts, proteins, among other constituents, act as barriers against food spoilage instigated by pathogenic microorganisms, leading to prolonged shelf life (Dutta et al., 2004). Notably, chitosan-based edible films, distinguished by their biological degradability, offer the unique advantage of being consumable alongside the packaged contents. Furthermore, the creation of transparent films exhibiting robust mechanical properties fosters a protective cocoon, effectively preserving the visual appeal and integrity of the enclosed foodstuff (Park et al., 2014).

d. Dietary Fiber Source

Both chitosan and chitooligosaccharides can serve as sources of dietary fiber (Xia et al., 2011). Their resistance to digestion by intestinal enzymes renders them functional foods with prebiotic effects. They stimulate beneficial bacteria (*Bifidobacterium and Lactobacillus sp.*) in the gastrointestinal tract (Morganti et al., 2011; Prashanth and Tharanathan, 2007; Kipkoech, 2023). Additionally, they can function as thickeners and stabilizers (Arvanitoyannis, 2008).

CONCLUSION AND FUTURE PERSPECTIVE

Food, being a fundamental necessity for human survival, and aquatic products, in conjunction with the geometric increase in population, stand out as fundamental drivers of the continuous rise in demand for marine products. Particularly, within this context, shellfish and other marine products, assume a paramount position among critical protein sources on a global scale. The advancement of shellfish culture plays a significant role in ensuring sustainable food supply and security. Thus, the shells should be recognized not as mere waste, but as potential byproducts, warranting meticulous and comprehensive exploitation.

Waste management holds intrinsic economic value. However, the disposal of waste, which may lead to the wastage of valuable resources and contribute to environmental issues, poses a substantial concern. The imperative of technology lies in devising appropriate systems and procedures to hinder or delay decomposition. The shellfish processing industry, primarily due to its significant chitin content, emerges as a substantial potential source of byproducts. Yet, the utilization of these byproducts remains relatively unexplored, demanding further investigations into diverse applications. Simultaneously, it is crucial to promote the incorporation of these applications into commercial sectors. Notably, the implementation of sustainable practices remains pivotal within aquaculture, whereby augmenting established methodologies can yield enhanced sustainability outcomes.

The shells of shellfish hold the potential to serve as soil conditioners or fertilizers, and ongoing endeavors aim to harness this potential. Given the millions of tons of crab, lobster, and shrimp shells discarded annually, the vast untapped potential of chitosan, synthesized from these shells, becomes evident. Chitosan finds utility across various sectors, including water treatment, textile production, and food preservation. Moreover, it's potential for enhancing plant growth and increasing crop yield has been demonstrated through empirical studies.

The numerous benefits of chitin and its derivatives, coupled with their environmentally-friendly characteristics such as biodegradability and biocompatibility, have engendered substantial interest. These compounds hold considerable promise for diverse industrial applications, spanning biomedicine, pharmaceuticals, agriculture, cosmetics, textiles, and enzyme immobilization. This versatility not only underscores the value of these shell byproducts but also suggests a potentially lucrative avenue for processing marine waste. Additionally, the valuable components offer health benefits such as antimicrobial, antioxidant, and anti-inflammatory effects. In light of chitin's inherent eco-friendly nature and innate capacity for biodegradation, its integration, alongside its derivatives, within environmental remediation initiatives emerges as a promising avenue for the evolution of avant-garde techniques and materials to counteract environmental pollutants. Although the potential applications of chitins enzymes and chitin derivatives display promising horizons, their comprehensive deployment remains relatively unexplored across various scenarios. This underscores the exigency for sustained inquiry and empirical substantiation, essential for realizing their transformative potential in both medical and environmental arenas. Conclusively, the pragmatic exploitation of residual shellfish resources and the extended adoption of compounds like chitosan necessitate the cultivation of sophisticated technologies and applications. The forthcoming trajectory may conceivably embrace an expanded purview, facilitated by intricate amalgamations such as nanotechnologies and compound synergies, thus fostering a more expansive and diversified realm of possibilities.

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CHAPTER 3

AGRICULTURE VALUE ADDED IN TÜRKİYE AND IN THE WORLD[1]

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[1] The opinions and contents of the article remains the responsibility of the author, not of the Turkish Statistical Institute.

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1. Introduction

Agricultural production activities, which are necessary to meet the nutritional needs, which are one of the basic human needs, started with the beginning of human history and have been a strategic issue for all humanity in every period in order to meet the food demand, which has been increasing with the increasing population since then. Self-sufficiency in food, that is, the ability of countries to meet the nutritional needs of their populations when their connections with the outside world are cut off, has become increasingly important, especially after the first and second world wars. The pandemic and the Russia-Ukraine war in recent years have made access to basic agricultural and food products even more difficult, and this situation has once again demonstrated the strategic importance of agricultural production.

The structural transformation that occurs as a result of the development process a country means that the agricultural sector's part of the domestic product among basic services falls, while the contribution of the industry and services sectors increases. When the structural transformation processes of industrialized countries are analyzed, it is evident that the agricultural sector's share of overall production and output is declining (Soyyiğit and Yavuzaslan, 2019). However, the importance of agricultural production has been maintained for countries due to the strategic importance mentioned above.

This importance given to agricultural production has brought about an increase in the added value of agricultural products and has made agricultural economy an area of emphasis. The contributions of agriculture to economic development, which is defined as transforming a country's production structure to produce high value-added products and increasing living standards by distributing the resulting product fairly among the income groups that make up that society (Kaynak, 2011), can be summarized as follows: product and market contribution, responding to increasing food demands, population and labor contribution, obtaining foreign currency income through the export of agricultural products, contribution to the industrial sector, contribution to national income, contribution to foreign exchange trade through capital accumulation and expansion of the domestic market (Erbay, 2013). This contribution is more evident in underdeveloped and developing countries where the share of the agriculture value added in the total domestic product is high.

Agriculture value added and its share of GDP, which estimates the total gross value added by all institutional units resident in the economy, at producers' prices, plus import taxes, less import subsidies, and non-deductible value added tax (FAOSTAT, 2023a), are two common indicators used for measuring and following the contribution of agriculture to the economy. The value added is defined as the difference between the value of output and the value of intermediate consumption (gross value added) (Li et al., 2022).

In this study, agriculture value added, which is an important strategy issue to both agricultural entrepreneurship and rural development (Coltrain, Barton and Boland, 2000; Kilkenny and Schluter, 2001; Womach, 2005; Lu and Dudensig, 2015), and its share of GDP was analyzed in the world, regions and Türkiye for the years between 1970 and 2022 for agriculture sector. Agriculture sector comprises forestry, hunting, and fishing, as well as agricultural cultivation and livestock production, and corresponds to divisions 1-5 of the International Standard Industrial Classification (ISIC, revision 3). These analyses were conducted at constant 2015 prices in US dollars in order to adjust for inflation, using data from the Food and Agriculture Organization of the United Nations (FAO), which compiles aggregate figures at the regional and global levels (FAOSTAT, 2023b).

2. Agriculture[1] Value Added in the World

From USD 948 billion[2] in 1970 to USD 3.870 billion in 2022, global agriculture value added increased by 2,8 percent each year on average (Figure 1). However, over the last decade, its annual growth rate has decreased to 3,1 percent on average, from USD 2.997 billion to USD 3.870 billion, with a peak of 4,7 percent in 2013. There was no decrease in annual growth in the last twenty years. The growth in global agriculture value added was minimum in the years of 2012 and 2018 by 1,8 and 2,2 percent, respectively.

The value added contribution of agriculture to global GDP slightly declined from 5.2 percent in 1970 to 4.2 percent in 2019. It increased to 4.4 percent in 2020, then slightly decreased in 2021 and increased to 4.9 percent in 2022 (Figure 1). The relative reduction until 2019 was related to nonagricultural activity growing faster than agriculture. Because of the COVID-19 pandemic, agriculture's share climbed in 2020, since the value added of the industries and services sector declined while agriculture's increased (FAO, 2023a).

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[1] Agriculture includes agriculture, forestry and fishing (ISIC Rev. 4, A 01-03).

[2] All values are measured in 2015 constant USD.

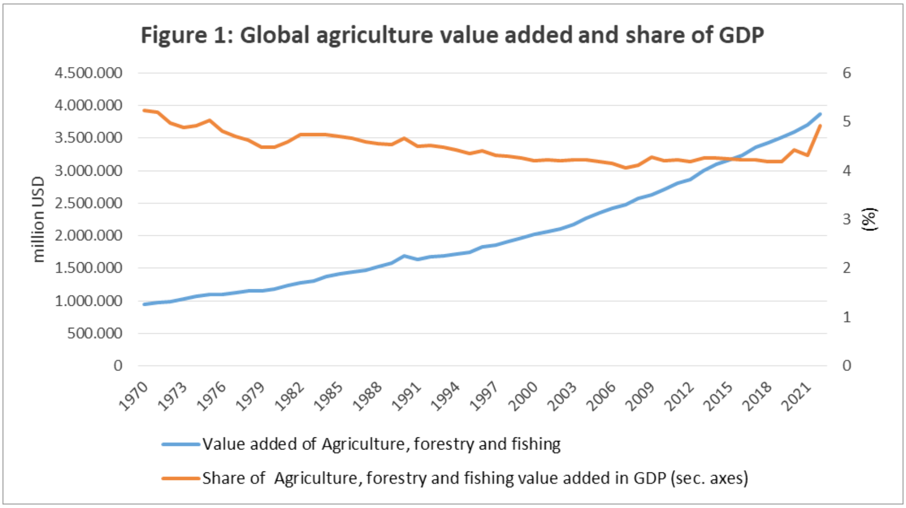


Figure 1: Global agriculture value added and share of GDP

Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

The decade 1980-1990 recorded the greatest increase in global agricultural value added (43,7 percent), followed by 2000-2010 (34,2 percent). Over the last decade (2013-2022), the global agricultural value added rose by 29,1 percent. Asia has experienced the greatest increase in this decade, at 35,8%, followed by Africa (35,7 percent), Oceania (24,3 percent), Americas (10,5 percent), and Europe (9,1 percent). Regarding the last year (2022), the change ratio compared to the previous year was 4,4 percent for the world and 5,2, 3,1, 4,9, 1,3, and 3,0 percent for Africa, Americas, Asia, Europe, and Oceania, respectively (Table 1). Yearly fluctuation by region from 1970 to 2022 is shown in Figure 2.

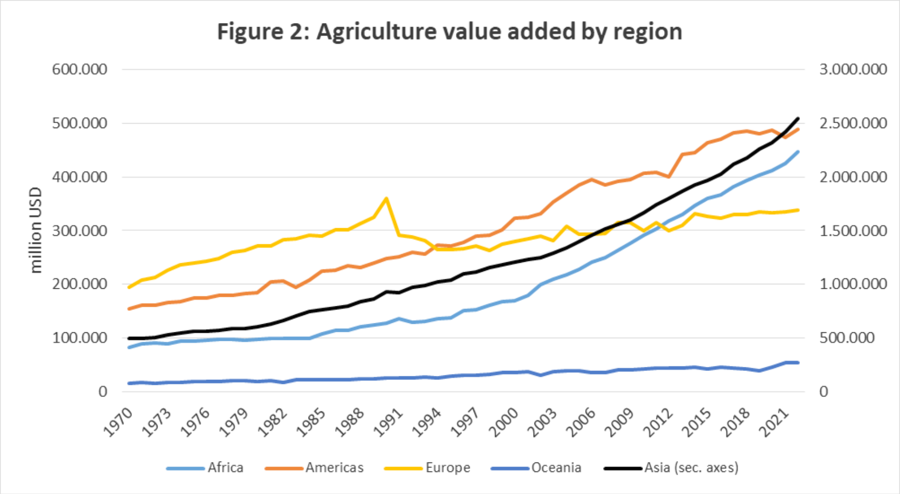


Figure 2: Agriculture value added by region

Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

The value added contribution of agriculture to GDP in Africa decreased between 1970 and 1984 from 17,2 to 13,0 percent, then fluctuated between 1984 and 2022 and slightly rose from 13,0 to 15,8 percent. In Asia, the agriculture value added share of GDP sharply decreased between 1970 and 2022 from 17,2 to 7,4 percent. This demonstrates that nonagricultural activities increased faster than agriculture in Asia than in other regions. In Europe, Americas and Oceania, the fluctuation was relatively low compared to other regions. The agriculture value added shares of GDP in these regions slightly decreased from 2,6 to 1,6 percent, from 2,2 to 1,6 percent, and from 4,2 to 3,2 percent, respectively (Figure 3).

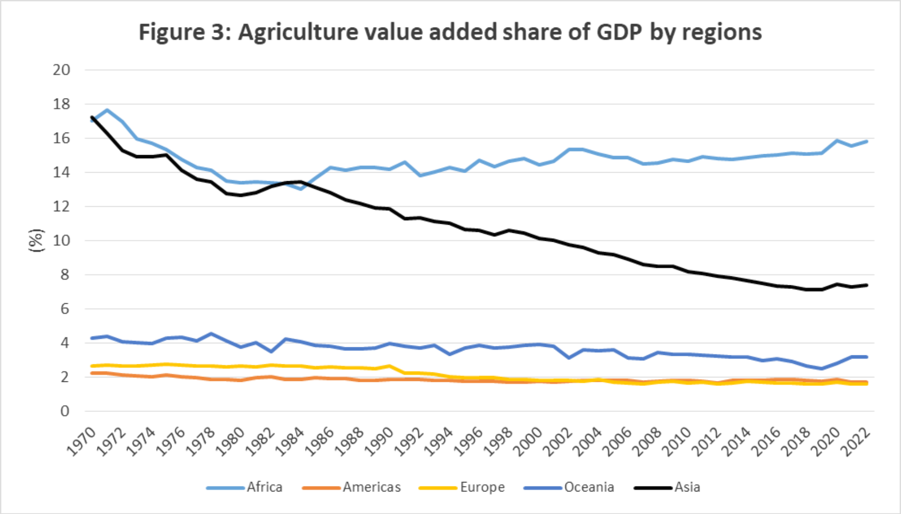


Figure 3: Agriculture value added share of GDP by regions

Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

Table 1: Agriculture value added by region (million USD), 1970-2022

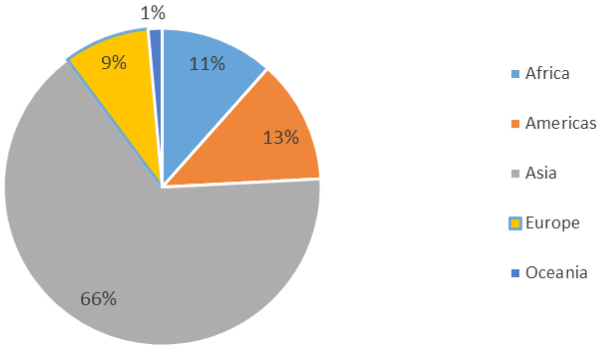
	1970	1980	1990	2000	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
World	947.571	1.178.870	1.694.335	2.019.814	2.709.633	2.996.931	3.090.728	3.163.254	3.237.034	3.352.722	3.426.505	3.515.119	3.596.885	3.707.576	3.870.050
Türkiye	26.807	31.459	35.295	40.899	49.937	54.039	54.335	59.364	57.825	60.669	61.959	64.003	67.679	65.687	68.588
Africa	83.158	98.246	128.700	170.279	291.753	329.834	346.597	360.071	366.873	381.926	393.471	403.390	412.496	425.299	447.554
Americas	155.302	185.280	247.393	323.454	407.030	441.447	445.839	463.106	470.465	481.991	485.850	480.776	486.348	472.957	487.794
Asia	498.101	605.387	931.836	1.208.427	1.667.752	1.870.618	1.921.832	1.970.063	2.029.507	2.114.003	2.174.954	2.256.034	2.318.804	2.421.090	2.540.664
Europe	194.557	270.906	359.766	280.656	300.552	310.523	330.931	326.707	323.965	329.628	329.698	335.216	333.455	334.501	338.695
Oceania	16.453	19.051	26.640	36.999	42.547	44.509	45.530	43.307	46.223	45.174	42.532	39.704	45.781	53.730	55.343

Change in agriculture value added by region (%), 1970-2022

	1970-1980	1980-1990	1990-2000	2000-2010	2010-2020	2013-2022	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
World	24,4	43,7	19,2	34,2	24,7	29,1	3,1	2,3	2,3	3,6	2,2	2,6	2,3	3,1	4,4
Türkiye	17,4	12,2	15,9	22,1	26,2	26,9	0,5	9,3	-2,6	4,9	2,1	3,3	5,7	-2,9	4,4
Africa	18,1	31,0	32,3	71,3	29,3	35,7	5,1	3,9	1,9	4,1	3,0	2,5	2,3	3,1	5,2
Americas	19,3	33,5	30,7	25,8	16,3	10,5	1,0	3,9	1,6	2,4	0,8	-1,0	1,2	-2,8	3,1
Asia	21,5	53,9	29,7	38,0	28,1	35,8	2,7	2,5	3,0	4,2	2,9	3,7	2,8	4,4	4,9
Europe	39,2	32,8	-22,0	7,1	9,9	9,1	6,6	-1,3	-0,8	1,7	0,0	1,7	-0,5	0,3	1,3
Oceania	15,8	39,8	38,9	15,0	7,1	24,3	2,3	-4,9	6,7	-2,3	-5,9	-6,6	15,3	17,4	3,0

In 2022, Asia had the world’s largest agricultural economy, accounting for 66 percent of global agricultural value added, followed by the Americas (14 percent), Africa (11 percent), Europe (9 percent), and Oceania (1 percent) (Figure 4).

Figure 4: Share of agriculture value added by region, 2022



Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

3. Agriculture Value Added in Türkiye

The agriculture value added in Türkiye fluctuated and increased from USD 26.807 million in 1970 to USD 68.588 million in 2022. Over the last decade, its annual growth rate has increased in all years except for 2016 and 2021. The increase was 2,7 percent on average, with a peak of 9,3 percent in 2015. The value added contribution of agriculture to GDP in Türkiye fluctuated and declined from 23,0 percent in 1970 to 5,8 percent in 2022 (Figure 5). Although agricultural added value has increased at constant prices in Türkiye over the years, large drops in agricultural added value computed using basic prices have been recorded in years when foreign exchange and inflation have increased significantly (Figure 6).

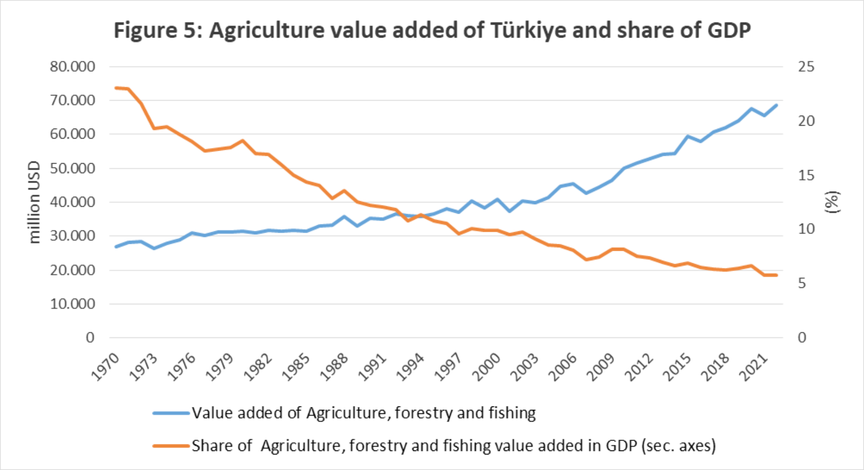


Figure 5: Agriculture value added of Türkiye and share of GDP

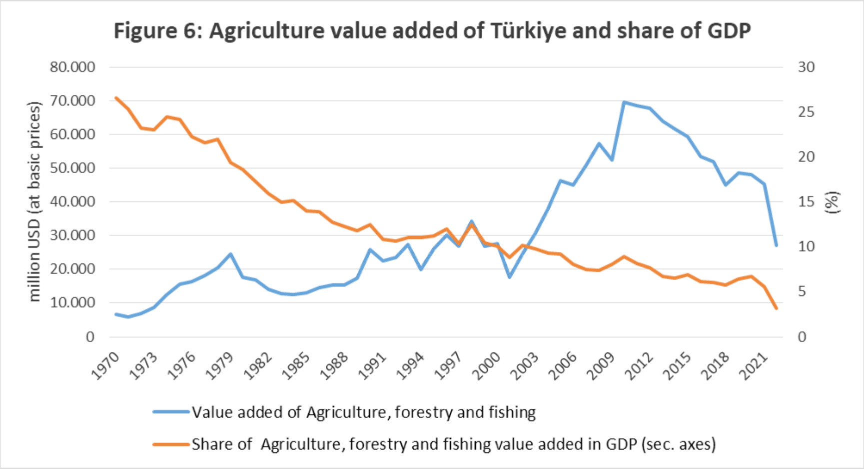
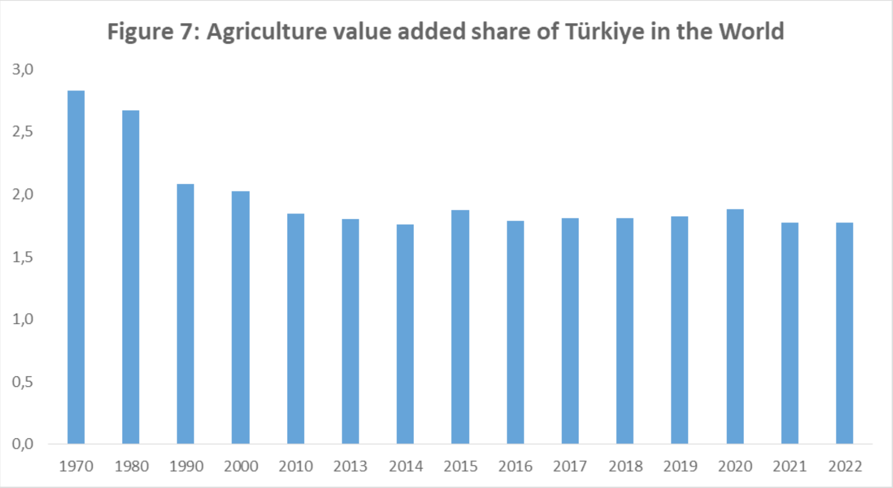


Figure 6: Agriculture value added of Türkiye and share of GDP

Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

The change ratio in agriculture value added for Türkiye was close to that of the world between 1970 and 2022, except for the period of 1980-1990. In the period of 1980-1990, the change ratio in agriculture value added in the world was almost 3,6 times that of Türkiye. And it was 29,1 percent in the world, while it was 26,9 percent in Türkiye in the last decade. The change ratio in agriculture value added in 2021 compared to the previous year for Türkiye was -2,9 percent, while it was 3,1 percent in the world and 4,4 percent in Asia (Table 1).

The agriculture value added share of Türkiye in the world decreased from 2,8 percent to 1,8 percent between 1970 and 2014. Then, it fluctuated but did not vary so much in the last decade, reaching a peak of 1,9 percent in 2015 and 2020 and being 1,8 percent in 2022 (Figure 7).



Source: FAOSTAT: Macro Indicators. http://www.fao.org/faostat/en/#data/MK

4. Conclusion and Discussion

Agriculture, according to Erbay (2013), is the first activity that should be encouraged in the development process, especially in developing countries, both as a source of income and to meet food demands correctly. In this regard, viewing agriculture as secondary to the economic development process will lead us to embrace a disruptive approach to development. To avoid making this mistake, agriculture emphasizes the importance of properly examining the land and its requirements, as well as carefully selecting regulations (Erbay, 2013).

It is important to increase the agriculture value added in Türkiye, where the share of agricultural employment in total employment is 15,8 percent (TurkStat, 2023). To achieve this, necessary policies should be produced and applied by all parts of the society. Özertan (2020) made the following suggestions for increasing agriculture value added in the value chain in Türkiye; preparation of legislation on ensuring fair trade; infrastructure development to ensure formality at the value chain level; preparation of legal legislation for contract production and regulation of audit, binding and contract structures in contract production practices; implementation of the local publication system, which takes into account the characteristics of the region and product, in public-private sector cooperation; completing needs assessment studies to increase the skill level of producers and agricultural workers and developing and implementing local training programs; establishment of partnerships with producers and other players in the supply chain with public support to determine and raise quality and standards in the production of agricultural goods; prioritizing increasing the producer's share of added value by using traditional and/or emerging methods according to the nature of the product; revising foreign trade policies regarding agricultural and food products; directing a qualified workforce to agricultural production and supporting qualified agricultural entrepreneurship; preparing a strategy document and road map by the public sector that takes into account the structure of Turkey's agriculture and food sectors; creation of sustainable agricultural technologies.

Soyyiğit and Yavuzaslan (2019) stated that developed countries have completed the structural transformation, which is expressed as the change of the manufacturing structure from the agricultural sector to the industrial sector and then from the industrial sector to the service sector, in a healthy way over time, by transitioning from simple products with low added value to products with high added value (Can and Doğan, 2017), when the examples of developed countries are examined, they particularly point out that while the share of the agricultural sector in economic indicators decreased in the mentioned structural transformation process of these countries, policies and structural reforms were implemented to increase the quality of agricultural production. In order for Turkey, an agricultural country, to take firm steps towards becoming a developed country, it is of great importance to implement the above-mentioned policies aimed at increasing the added value of agriculture while implementing this transformation.

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CHAPTER 4

CROP ROTATION IN PEA CULTIVATION

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1.INTRODUCTION

One of the most important cultural practices of field agriculture is crop rotation. A well-chosen crop rotation not only reduces the density of diseases, pests and weeds, but also improves the physical and chemical structure of the soil and increases productivity by providing many advantages such as deeply increasing soil vitality, benefiting from various layers of the soil equally and preventing erosion; As a result, it increases the productivity of the grown product. (Uzun et al, 2005).

In crop production, providing the nutrients that plants need largely depends on soil fertility. Soil fertility is largely achieved through appropriate cropping rotations and green manuring, as well as fertilizer applications. These practices only yield positive results when long-term planning is carried out in an integrated manner (Chirinda et al., 2008). It is known that crop rotation has many positive agricultural effects such as erosion control, contribution of organic matter to the soil, improvement of soil structure, nitrogen fixation, cycle of unused soil nitrogen, suppression of disease, pest and weed populations (Hartwig, 2002).

Crop rotation is defined as the sequence of operations applied to that field within the product or vegetation period following any product planted in a field. It is the cultivation and application of different plants in the same field, one after the other, in a certain order. The aim of crop rotation is to leave better soil for each plant planted in the field than when it was planted (Büyüktavşan and Naneli, 2020).

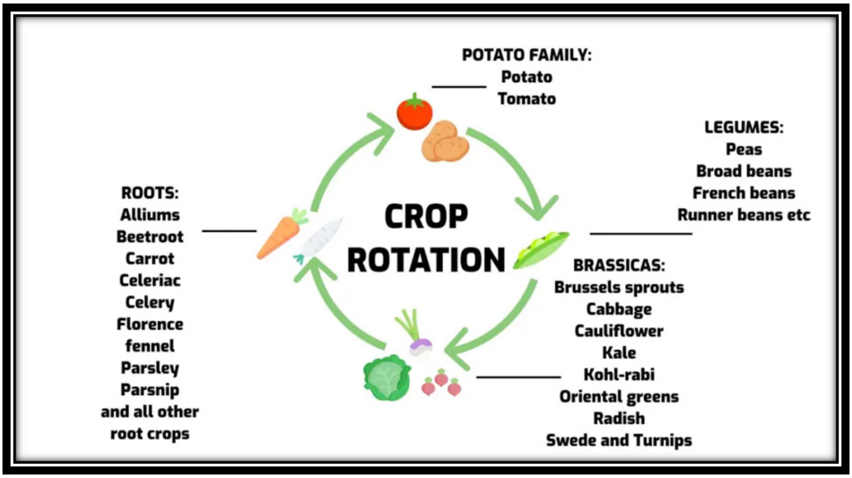

Figure1. *Peas in crop rotation.(https://psci.princeton.edu/tips/2020/3/21/agriculture-101)*

Growing plants from the same family and having similar characteristics sequentially in the same field is called monoculture. Sequential cultivation of plants grown in the same soil, at the same time, in the same way and exposed to similar diseases, weeds and pests, disrupts the soil structure and increases the presence of diseases, pests and weeds. When cultivated plants are replanted in the field where they were harvested, their cultivation becomes difficult and their yield and quality decrease significantly. For this reason, growing plants that get along well with each other in the field one after the other is beneficial in many ways.

Crop rotation is an agricultural method that means not planting the same products consecutively in a field, but planting different plants one after the other in an order. In some cases, crop rotation is also implemented by dividing a field into several parts and planting different products in each part. Crop rotation practices have many purposes, such as increasing soil fertility, preventing soil erosion, reducing weed and disease formation, supporting biodiversity and increasing economic efficiency.

It is very important to include legume plants in crop rotation, which enrich the soil with nitrogen with the nodosites in their roots. Pea, which fixes up to 15 kg of pure nitrogen per year to the soil through its root tubers, is also a good rotation plant. Peas, which belong to the legume family, like cool climates and are relatively resistant to low temperatures. In regions with a temperate climate, winter planting can be done in November and December. In Turkey, winter planting is done in the Aegean and Mediterranean regions. In the Central Anatolian regions, pea planting is done in the summer months in February and March.

The aim of this study is to include peas in the crop rotation system, to enable the cultivation of the land that is left empty as fallow land every year, to support sustainability in agriculture, and to explain the benefits of both the soil, nature and the productivity of the product.

2. THE IMPORTANCE OF PEA IN CROP ROTATION

Peas are a highly nutritious food source. It is a nutrient-rich food, containing protein, carbohydrates, and vitamins A, B, and D. Pea grains are composed of 18-20% dry matter, which is made up of 10-12% carbohydrates and 20-30% protein. Peas are one of the legumes with the highest protein content. The stubble, stalks, and straw residues left over after harvest are used as animal feed.. Peas are a beneficial rotational crop because they add nitrogen to the soil through the Rhizobium bacteria in their roots, improving the soil quality for the next crop. According to data from the Turkish Statistical Institute (TUIK), 8,873 hectares of peas were planted in Türkiye in 2023. The average yield was 270 kilograms per hectare, and the total production was 2,392 tons. (Uskutoğlu and İdikut, 2023).

Peas have thin main roots and side roots. The first lateral roots develop as much as the main root in terms of length and thickness. The elongation of the roots continues until flowering. It reaches its highest level in this period, and root development slows down with the formation of pods. Depending on the physical conditions, moisture and nutrients of the soil, pea roots grow to a depth of 110-120 cm and 50-75 cm laterally. Tubers form on the roots. Pea roots have bumps called nodules on them. Bacteria of the genus Rhizobium form round or nearly round nodules on legume roots. Thanks to these nodules unbound nitrogen in the air is bound to the soil. Rhizobium type bacteria, which enter into symbiosis with the root of the pea, fix nitrogen, which is free in the air but cannot be directly utilized by living things, to the environment in which they live. Nitrogen, taken from the atmosphere and accumulated in the nodules formed by bacteria in plant roots, is broken down by microorganisms and converted into elemental form after the harvest of the plant. In this way, peas enrich the soil layers where their roots spread with organic nitrogen, and the plants planted later benefit from this nitrogen. Including peas in crop rotation is of particular importance in terms of both monetary and soil and soil water pollution, as it will reduce the use of commercial nitrogenous fertilizers (Adak et al., 2015).

Figure 2. *Root system of peas.(The photo was taken by Research Assistant Duygu USKUTOĞLU)*

It is known that soil organic matter with a high nitrogen content decomposes more quickly. Studies have shown that legume roots with a C/N ratio of 13:1 decompose in 1-2 weeks under suitable conditions, while cereal roots with a C/N ratio of 80:1 take 4-8 weeks to decompose (Munzur and Sakin, 2018). Thus, legume roots accelerate microorganism activities with the high content of organic matter they leave in the soil and increase soil vitality in the root spreading area. They contain plants that yield not only human food, but also animal feed, timber, textiles and various other products, and are used as green manure in the soil. As it is known, nitrogen and water are the two main factors that restrict agricultural products the most. Plant species in this family form a perfect symbiosis with Rhizobium bacteria, which infect and settle in their roots and fix nitrogen in the root nodules they form (Uyanık et al., 2011).

Figure 3. Nodules formed on pea roots.(The photo was taken by Research Assistant Duygu USKUTOĞLU)

3.BENEFITS OF INCLUDING PEAS IN CROP ROTATION

3.1. Disease and Pest Management

Crop rotation with peas after winter cereals such as wheat and barley does not cause significant damage to the fungal pathogens that cause important damage to winter cereals, such as stem rust, yellow rust, and leaf rust. The inclusion of peas in the rotation in areas contaminated with these pathogens helps to control diseases and pests. Insect pests such as the Hessian fly, aphid, and stem weevil, which are particularly harmful to wheat in winter cereals, do not cause damage to peas. In areas where these pests are widespread, crop rotation with peas instead of growing winter cereals in succession can disrupt the life of the pests and help to control them to a certain extent (Akan et al., 2007).

3.2. Benefiting from Various Soil Layers to the Same Degree

The root depths of plants are as different as the variety and quantity of plant nutrients they take from the soil. For example, while the roots of barley can reach up to 90 cm, the root depth of peas can reach up to 110-120 cm depending on the species and soil structure, as it is a taproot plant. In addition, the nutrients taken from the soil by each plant are quite different in both variety and quantity. Unlike cereals, which remove nitrogen from the soil, peas bind free nitrogen from the air to the soil through bacteria in their roots.

When the same crops are grown in the same field in succession, they consume the same nutrients from the same layers of the soil. In this case, both the soil is damaged and the yield and quality of the plants decrease significantly. When plants with different root depths are grown in succession in the same field, the soil is well-utilized because the utilized root depths and the nutrients taken from the soil are different in variety and quantity. Deep-rooted crops such as peas benefit from the nutrients in the lower layers of the soil and leave a significant portion of these nutrients in the layers close to the soil surface after harvest. When they are rotated with cereal crops, cereal crops will take up the nutrients in the upper layers of the soil.

3.3. Weed Control

When the same crop is grown in the same field in succession, the amount of weeds that are parallel to the cultivation technique applied to this crop increases significantly (Sirat, 2016). As long as the same crop is continued to be grown, the weed problem increases significantly every year, causing a significant decrease in yield. In regions where winter wheat cultivation is carried out, when winter wheat is grown in succession in areas with sufficient rainfall, it is not possible to mechanically combat weeds that develop and complete their lives in the wheat field. If the weed is narrow-leaved and also belongs to the same family as the wheat family, it is not possible to combat it with chemical herbicides. In this case, over time, weeds multiply and it becomes difficult to grow wheat in the field. In such cases, it is recommended to rotate the planting of the legume plant, which is a member of the wheat family, with peas. Since wheat is narrow-leaved and peas are broad-leaved, when grown one after the other, weed control can be achieved with chemical weed killers.

3.4. Improving the Physical, Chemical and Biological Structure of the Soil

In a good crop rotation, the goal is for each crop planted in the field to leave a better soil for the crop that will be planted after it than it was when it was planted. When different crops are grown sequentially in the field in harmony with the region, it significantly improves the physical, chemical, and biological structure of the soil. When a suitable crop rotation is applied, on the one hand, high quality yields are obtained, while on the other hand, soil productivity is preserved and increased. When a good crop rotation is applied for the region, the soil's organic matter increases significantly. The physical, chemical, and biological structure of the soil with a balanced increase in organic matter also improves significantly. Instead of continuously growing the same crop, the physical, chemical, and biological structure of the soil is improved by applying crop rotation (Karakurt, 2009). When wheat and peas are rotated in a field that is continuously planted with wheat, it improves the physical properties of the soil, such as its structure, granulation, bulk density, aeration, and permeability, as well as its chemical properties, such as the balanced and accessible forms of plant nutrients in the soil. Microorganisms that find a sufficient amount of organic matter in the soil significantly improve their quantity, number, and activity, and raise soil vitality, thus significantly improving their biological properties.

3.5. Maintaining And Increasing Soil Productivity

Sustainable agriculture is based on crop rotation, in which each crop leaves the soil in better condition than it was when it was planted. When this is done, soil productivity increases every year. When winter cereals are planted in the aftermath of peas, the winter cereals develop well and produce high-quality and high-yield grain. As long as the appropriate crop rotation is applied for the region and there are no errors in the crop rotation, the amount of organic matter in the soil increases every year. As the amount of organic matter in the soil increases every year, the structure of the soil improves, the soil becomes granular, and its vitality increases, all of which lead to increased soil productivity (Aksakal, 2004). In addition to all these benefits, biological balance will be preserved and environmental and soil pollution will be prevented as a result of wheat and pea crop rotation systems.

3.6. Preventing Erosion

As a result of the wheat and pea crop rotation carried out in a way that is appropriate for the region, the soil surface is less exposed to erosion because it is covered with plants for most of the year. Plants protect the soil surface from erosion with their above-ground parts, while their roots protect the depths of the soil from erosion. When crop rotation is applied in a proper and planned manner, productivity increases, which leads to an increase in the amount of organic matter in the soil and, consequently, soil vitality. Because soil vitality increases, soil structure improves and the soil becomes granular. Granular soil is more resistant to horizontal water and wind erosion, and vertical water erosion. Soil that is protected from erosion preserves its structure and texture, making it more suitable for providing water and nutrients to the plants that are grown in it and that are included in the rotation.

4. PLANNING CROP ROTATION

The crop rotation to be applied in a region depends on the economic conditions of the region, the type of crop to be grown, and economic conditions. It is not possible for plant species, species, and varieties that are not allowed to grow in the ecological conditions of the region to be included in the crop rotation in that region. It is appropriate to grow plant species that are adapted to the region where crop rotation will be applied. The inclusion of the pea plant, which can be planted in summer and winter depending on the region, in the crop rotation system will provide the producer with a high level of benefit. We can briefly summarize the planning of crop rotation as follows:

Climate: The climate of the region is an important factor in determining the crop rotation system. For example, crop rotation can be applied to grow winter crops in cold climates.

•Soil structure: The soil structure of the land is also an important factor in determining the crop rotation system. For example, legumes that retain nutrients in the soil better can be grown in sandy soils.

•Water availability: Water availability is also an important factor in determining the crop rotation system. For example, drought-resistant crops can be grown in areas with limited irrigation.

•Cultivable plant species:The types of cultivable plants are also an important factor in determining the crop rotation system. For example, different types of plants can be grown to prevent the same field from being planted with the same crop every year.

•The spread of weeds, diseases, and pests: The spread of weeds, diseases, and pests is also an important factor in determining the crop rotation system. For example, crops resistant to weeds, diseases, and pests can be grown to prevent the same field from being planted with the same crop every year.

•Economic conditions such as transportation, storage, and marketing: Economic conditions such as transportation, storage, and marketing are also important factors in determining the crop rotation system. For example, crops that are suitable for storage and transportation conditions can be grown for products to be sent to distant markets.

Figure 4. Pea plant in crop rotation.*(The photo was taken by Research Assistant Duygu USKUTOĞLU)*

The crops included in the crop rotation should be at a high economic level that will provide the yield that will not reduce the income level of the producer. It is the selection of plants suitable for the region that do not cause any problems during cultivation. It is also necessary to consider the ease of selling and evaluating the product obtained. The selected plants should not require special tools and machinery and should not impose a significant economic burden on the business. The yield of the crop that is the main product in the region should not decrease with the application of crop rotation.

5. PEAS AND CROP ROTATION SYSTEMS

Peas are a cool-season crop. They can tolerate low temperatures close to freezing. In its early stages of development, it can withstand temperatures as low as -5°C. Pea seedlings are quite resistant to frost. Even if the main stem is killed by frost, side branches emerge from the nodes under the ground. Flowers and immature pods are sensitive to frost. At temperatures of -1°C or higher, flowers and immature pods fall off. The temperature should be above freezing during the growing season. Although it grows very well in conditions where the weather is cool and humid, it does not like hot and dry weather. Yield increases if there is sufficient coolness in the vegetative phase and warm spring in the reproductive phase. Pea seeds can germinate at 2°C, but germination is very slow. It does not like high temperatures and long hours of sunshine during the growing period. It needs a cool and humid environment during this period. High temperatures and drought during the growing period cause the plant to spend all its energy on generative development. The plant remains stunted and the fruits do not reach their normal size. Yield and quality decrease due to rapid and forced ripening. Seed sowing time depends on the climatic conditions of the region. Seed can be sown from November to May. In Turkey, seed sowing is usually done in February and March. For early varieties, sowing should be done from the beginning of February to March 15, for semi-early varieties until the beginning of April, and for heat-resistant varieties after April 15. In the Aegean and Mediterranean coastal belt, winter sowing is done in November or December, and sowing can be done in the Central Anatolia and transition regions in late winter and early spring. Seed sowing should not be delayed in spring sowings. Delaying sowing in spring leads to yield losses. Seed sowing is done in the fall and spring in temperate regions, and in the spring in cold regions. This makes peas a good crop for crop rotation.

Uzun et.al., (2005) reported that in the pea + corn crop rotation systems they conducted in Bursa conditions, the corn plant planted after peas had the highest cob length and they saw an increase in corn grain yield. Bengisu (2011) emphasized that in Şanlıurfa, where cotton cultivation is widespread, agricultural lands are left empty between November and April. He added that, taking into account the animal population of the region and the development of intensive dairy cattle farming in the future, cultivation of winter intercropping crops such as vetch, mallow, fodder peas, vetch, annual clovers, Alexandria clover, fodder rapeseed and their mixtures with cereals should be encouraged. He stated that it is beneficial to cultivate annual legumes suitable for the region, such as peas, which can also be planted in summer, as a second crop after winter crops such as wheat, barley and rapeseed, which are grown as the main winter crop, both for increasing the nitrogen content of the soil and for improving soil properties.

Açıkgöz et.al., (2005) reported that vetch, fodder peas, some annual clover species are grown in fallow areas or in crop rotation with plants grown as the main crop in the region, either alone or in mixture with cereals, and that the physical and chemical properties of the soil can also be improved by growing these plants in fallow areas or taking them into crop rotation. In general, peas are included in the rotation after wheat in temperate regions as a second crop, and before corn when sown as a main winter crop.

6. CONCLUSION

To reduce the negative impacts of monoculture farming, farmers should rotate different crops in the same field over time. This helps to improve soil health, reduce pest and disease problems, and improve biodiversity. When planning a crop rotation system, farmers should consider the specific characteristics of their region, including the types of crops that are adapted to the local climate and soil conditions, as well as the logistical challenges of transporting, storing, and marketing different crops. Crop rotation systems in agricultural areas should be implemented and planned with the goal of increasing soil water holding capacity, organic matter content, and fertility to create a more favorable environment for cultivated plants. Rotation can be used to plan labor in businesses. Crop rotation techniques can help to minimize risks and achieve maximum yield by allowing for efficient and uninterrupted sowing, maintenance, harvesting, threshing, and pre-sowing soil preparation processes during the plant's vegetative period. It has been determined that especially the rotation of legume plants has positive effects on soil quality, such as plant residues quickly breaking down in the soil and turning into humus, increasing soil organic matter, and increasing soil N content. Pea is a plant belonging to the legume family. Legumes contain bacteria in their roots that increase the amount of nitrogen in the soil. Therefore, planting peas in rotation, which is an important step for sustainable agriculture, helps maintain the fertility of the soil. Peas are a valuable crop for crop rotation systems. They can help to improve soil fertility, reduce pest and disease pressure, and provide a green manure. By including peas in a crop rotation system, farmers can improve the sustainability of their farms and reduce their input costs.

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CHAPTER 5

SEA CAGE AQUACULTURE IN MARINE ENVIRONMENTS TROPHIC INDEX (TRIX)

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Introduction

In the pursuit of economic development, the preservation of natural resources assumes significance for sustaining aquaculture activities. Ensuring the enduring availability of these resources, without degradation, is a fundamental pillar of sustainable economic development. These changes maintain the academic tone while making the text even more concise and precise. Turkey, surrounded by seas on three sides and possessing significant inland water resources, also holds substantial potential for aquaculture production (Baki, 2021). Globally, aquaculture has emerged as one of the fastest-growing sectors in recent years. The production of aquaculture products has increased nearly twelvefold worldwide over the past three decades, with an average annual growth rate of approximately 8.8% (FAO, 2022). The Food and Agriculture Organization (FAO) of the United Nations acknowledges it as a rapidly evolving and continually expanding sector within the food industry. According to FAO data, global aquaculture production continues to rise steadily, reaching 87.5 million tons in 2022 (46.4% of total seafood production), up from 21.8 million tons in 1990. Of this, 33 million tons are sourced from marine environments, while 54 million tons come from inland waters.

Intensive cage culture of high-value fish species is rapidly expanding worldwide. This growth and the transformation of the sub-sector carries significant social and environmental implications. Similar to global trends in livestock production, intensive and rapid growth in aquaculture could marginalize small-scale producers and pose environmental degradation risks if high production levels are not appropriately planned and managed. Considering that most cage aquaculture activities take place in fragile coastal environments that are already under significant pressure, there is a growing consensus on the need for specific attention to the environmental sustainability of this sub-sector.

It is important to repeat here that aquaculture (including the use of cage farming systems) has also numerous important social, economic and environmental benefits, including increased food security and poverty alleviation impacts, increased employment opportunities within rural communities, increased seafood supply and availability, improved human nutrition and well-being, increased foreign exchange earnings, improved waste water treatment/water reuse and crop irrigation opportunities, and improved nutrient recycling all of which need to be taken into consideration and weighed by importance in a balanced comparison of food production systems (Hambrey et al., 2001; Tacon, 2001; FAO, 2006; Halwart and Moehl, 2006; Tacon and Halwart, 2007).

In recent years, the expansion of aquaculture production has generated significant socio-economic benefits, yet it has also led to notable ecological changes. The nature and extent of these ecological changes depend on factors such as aquaculture production methods, production volume, and the coastal area's physical, chemical, and biological characteristics. While previous studies have generally acknowledged that aquaculture has had minimal adverse effects on ecosystems, some researchers have reported environmental disturbances in certain operations (Barg, 1992; Koca et al., 2011).

Aquaculture holds substantial potential for Turkey, and it is imperative to continue this process as informed producers, ensuring its sustainability. To assess the environmental effects of aquaculture activities and determine the ecological quality, trophic level, and thus the feasibility and sustainability of production in areas designated for aquaculture, the TRIX Index has been developed based on scientific data and recommendations from relevant management mechanisms.

The present study underscores the significance of the trophic index (TRIX) in elucidating changes in nutrient levels and environmental effects in marine areas where aquaculture is practiced to ensure sustainable aquaculture production.

Environmental Effects of Aquaculture

The predominant environmental concerns from waste generated in cage fish farming are inherently point-source in nature. The production of waste and its environmental repercussions in fish farming depends on various factors such as fish size, water temperature, the farming method employed, feed composition and quantity, the species being cultivated, stock density, background nutrient concentrations in the receiving water body, water mass dynamics, and the quantity of emissions per fish farm unit (Pillay, 2004; Yıldırım and Korkut, 2004; Fisheries and Oceans Canada, 2006).

Due to the effect of cage farming on water quality, plankton, benthos, nekton biomass, and species diversity in the areas where it is practiced, it is observed that environmental effects affecting other users of water bodies may occur. These environmental effects vary depending on factors such as the farming method, production capacity, hydrography of the region, stock density, farm management, feed content, and the biological, chemical, and physical characteristics of the area where the farming is conducted (Davies, 2000; Beveridge, 2004; Yıldırım and Korkut, 2004). In areas with limited water circulation, nutrient enrichment can become a problem.

To assess the environmental effects of waste generated from fish farming, it is essential to have knowledge of nutrient concentrations in the production area, water dynamics, and the emissions of nutrient elements from the production area per unit of time before establishing a fish farming facility. Additionally, stratification in the area and waste dispersion are critical considerations (Baki and Baki, 2021).

The primary environmental issues from waste generated by cage fish farming include anoxic conditions in water and sediment environments and algal blooms. These waste sources consist of organic solids, dissolved waste, and inorganic nutrient elements. When the entry of these components into the receiving environment exceeds the natural assimilation capacity of the aquatic ecosystem, environmental problems such as eutrophication, oxygen depletion, and changes in biological diversity can occur both in the water column and sediment (IUCN, 2007).

The majority of solid waste generated from fish farming consists of feces, waste feed, scales, mucous, and similar materials. Depending on the feeding activity, the amount of accumulated waste is affected by the feed composition, water flow in the area, and cage system. Digested feed becomes fecal waste. Fecal waste is estimated to constitute approximately 15-30% of the consumed feed. The feed content determines the composition of fecal waste, and the quantity of fecal waste is determined by the undigested feed component (Podemski and Blanchfield, 2006). The phosphorus content of raw materials used in fish feeds affects aquatic ecosystems through uneaten feeds and settling fecal waste (Baki and Baki, 2021).

Phosphorus and nitrogen are the primary components in fish farming that affect the environment. These forms of nitrogen and phosphorus are compounds readily used by algae and aquatic plants (Reid, 2007).

In assessing the environmental effects of waste generated from feeding and metabolic activities in aquaculture, it is crucial to consider the feed/fecal matter sedimentation rate, benthic sediment composition, and changes in fauna. When evaluating the effect of cage fish farming on sediments and the nutritional status of water bodies, considering eutrophication events caused by these factors is crucial (Baki and Baki, 2021).

It is widely acknowledged that intensive fish farming in cages has significant global, regional, and local environmental effects (Folke and Kautsky, 1989).

Knowledge of the polluting species is necessary to study the effects of waste generated from aquaculture. Regardless of the aquaculture technique and facility location, three fundamental pollutant types exist (Mac Alister Elliott et al., 1993):

- Organic matter from uneaten feeds and feces that consume oxygen.
- Excessive amounts of dissolved nutrients (nitrate, nitrite, ammonia, phosphate, silicate).

- Antibiotics and other chemical pathogens (Özbay, 2008).

Various chemical substances and pharmaceuticals are employed in intensive aquaculture practices to manage diseases. Malachite green and formaldehyde are commonly utilized to prevent fungal and parasitic infections. Additionally, various antibiotics are added to fish feeds to prevent bacterial infections. Consequently, various chemical agents and medications are introduced into the aquatic environment. Over time, these substances begin to pose a threat to the flora and fauna of the aquatic ecosystem. Research indicates significant qualitative and quantitative alterations in bacterial, protozoal, planktonic, benthic, and fish populations in waters used for fish production. Thus, particularly in waters where intensive aquaculture is practiced, changes in native fish populations can occur, associated with the fact that no matter how effective preventive measures are, the dispersion of cultured fish into the environment cannot be entirely prevented. Furthermore, certain diseases not previously present in cultivation areas can be transmitted to cultured fish (Şen, 1998; Özbay, 2008).

The increase in dissolved nutrients in water leads to deterioration in water quality. Dissolved nutrients include NO_3, NO_2, NH_4, PO_4 (nitrite, nitrate, ammonium, phosphate), and vitamins. These substances enter the environment through discharges from hatcheries, cages, and ponds where non-consumed feed, feces, excretory products, and industrial and animal fertilizers are used to enhance productivity (Şen, 1998).

Limiting Nutrient Elements in Aquatic Environments

In ecology, the concept of limitation refers to substances or limiting elements that constrain biological development when insufficiently present in the environment. The German agricultural scientist Justus von Liebig, through his research, determined that the nutrient element required for plant growth, present in the minimum amount in the environment, restricts plant development. This theory or concept is called Liebig's Law of the Minimum (Vlasov and Trifonov, 2005).

Simplifying the concept of limitation to a single nutrient element or factor is a way to comprehend a complex system. It is crucial to consider the interaction of numerous factors in an ecosystem. The presence or concentrations of other factors or substances can affect how the limiting factor restricts growth. For instance, plants' zinc (Zn) requirement decreases in shade but increases in sunlight. In this case, the concentration of Zn can be limiting for plants in the presence of sunlight (Anonymous, 2023).

While some nutrient enrichment may be beneficial, excessive enrichment may result in large algal blooms and seaweed growths, oxygen depletion and the production of hydrogen sulphide, which is toxic to marine life and can cause high mortality, red tide events, decreasing fishery yields, and nonreversible changes in ecosystem health (Daoji and Daler, 2004). Coastal areas are intense in terms of nutrient input due to the population increase, and the increase in nutrient level produces higher probability of eutrophication which causes serious problems (Officer and Ryther, 1980). Nutrients are among the essential chemical components of life in the marine environment (Bizsel and Uslu, 2000), and are the common limiters of primary production, especially in nitrogen and phosphorous coastal ecosystems, fresh water and estuarine regions (Hecky and Kilham, 1988).

The inputs of nutrient elements, referred to as nutrients, into coastal areas and aquatic environments typically originate from point and anthropogenic sources known as non-point sources. The quantification of pollutant loads from point sources is generally more controlled and manageable than non-point sources. Nutrient inputs from aquaculture facilities can exhibit characteristics of both point and non-point sources, occasionally posing challenges for intervention. Therefore, conducting site assessments in compliance with relevant regulations and exploring the TRIX trophic index's feasibility is crucial to proactively addressing these issues.

The primary substances released from farms into aquatic environments include phosphorus, nitrogen, organic matter, and suspended solids. Nitrogen, found in abundance in waste from cages, exerts a more limiting effect in marine environments than phosphates (Bugdale, 1967). Inorganic nitrogen (N) and phosphorus (P) are the fundamental nutrients restricting growth. These essential elements, called macronutrients, are pivotal in organism development. When these elements become depleted in aquatic ecosystems, algal growth ceases. Conversely, when introduced into the system, algal populations (primary production) increase until another environmental factor limits their growth or until they are once again constrained by nutrient availability. While phosphorus is typically the limiting nutrient in stagnant water bodies, nitrogen can become limiting in marine ecosystems (Tokgöz Yayan, 2015).

Inorganic nutrients serve as the chemical building blocks of life in aquatic ecosystems. Some require substantial quantities for cell growth and are thus termed macronutrients. These include carbon, oxygen, nitrogen, phosphorus, sulfur, silica, and iron. Micronutrients, such as manganese, copper, and zinc, are essential nutrients but are needed in smaller quantities. However, within the context of water quality modeling, the focus centers on four macronutrients (Chapra, 2015).

Phosphorus

Phosphorus is an essential element for all forms of life. Among its various functions, it plays a critical role in the genetic system and the transfer and storage of cellular energy. Despite its scarcity, phosphorus can be discharged into natural waters due to various human activities. Both human and animal waste contain significant amounts of phosphorus (Chapra, 2015). Like nitrogen, phosphorus is a necessary nutrient for the growth of algae and other microorganisms. Therefore, removing compounds containing phosphorus is paramount before they are introduced into receiving environments (Duran and Demirer, 1997). Phosphorus can enter aquatic environments from both point and non-point sources. Human activities can introduce phosphorus into natural waters despite its natural scarcity, with one source being aquaculture activities. It is essential to determine the phosphorus content in marine environments. Phosphorus can be measured through several methods, with total phosphorus (TP) measurement being commonly used to assess eutrophication, as specified in relevant regulations (Chapra, 2015). Phosphorus is referred to as a limiting element in aquatic environments due to its lowest atomic number within the stoichiometry of nutrient elements (C:N:P, 106:16:1). Therefore, phosphorus is the primary nutrient controlling eutrophication in aquatic environments (Chapra, 2015).

Nitrogen

Like phosphorus, nitrogen also serves as a crucial nutrient in microbial growth. Nitrogen, like phosphorus, can lead to unwanted algal blooms and eutrophication in water sources. Nitrogen, like phosphorus, can enter natural waters due to anthropogenic activities, including aquaculture. Both human and animal waste contain significant amounts of nitrogen. Fish feeds typically contain around 0.9-1.5% phosphorus and 7-8% nitrogen. The amount of nitrogen taken through feeds varies depending on fish species, typically accounting for about 20-30%, with the remaining 70-80% being released into the water. Phosphorus, nitrogen, organic matter, and suspended solids in the water are factors contributing to pollution in fish farms (Yıldırım and Korkut, 2004; Koca et al., 2011).

N:P Ratio and Its Effect on Eutrophication

The ratio of nitrogen to phosphorus in aquatic systems also significantly affects algal growth in freshwater and marine ecosystems. This ratio, also known as the Redfield Ratio is 16:1, representing the ratio of nitrogen to phosphorus atoms in an organism’s dry matter. In other words, an organism’s dry matter contains 16 nitrogen atoms for every 1 phosphate atom. In natural systems where the ratio of other elements’ atomic numbers to phosphorus atomic number is greater than the Redfield Ratio, it is assumed that algal growth or biomass is limited by phosphorus or, at least, algal growth rates will significantly decrease in such systems (Karpuzcu, 2007).

Carbon

Similar to phosphorus and nitrogen, carbon is also considered a nutrient. In water quality modeling, carbon serves three roles: as a nutrient, biomass, and pollutant effect.

Eutrophication

When examining the trophic conditions of water bodies, they are typically classified based on their trophic status. In this regard, general terms include:

* Oligotrophic (poorly nourished)

* Mesotrophic (moderately nourished)

* Eutrophic (well-nourished)

* Hypertrophic (excessively nourished) (Chapra, 2015).

These classifications are generally developed for lakes but are also suitable for rivers and estuaries.

Rich in nutrient elements, eutrophic stagnant water masses are characterized by:

- The water surface being heavily covered with blue-green algae or experiencing excessive algal blooms.

- The color of the water mass is green/brown.

- Very low or zero oxygen levels at the bottom points of the water mass (excessive algal growth prevents sunlight from penetrating the water surface, inhibiting photosynthesis, which results in dead algae sinking to the bottom and reducing dissolved oxygen levels in the benthic environment).

- Dense algal masses, which, when wind-driven, wash up on the shores of water bodies and, as they decompose, cause foul odors (Muslu, 2001; UNEP, 2015).

The effects of nutrient elements resulting from fish farming depend not only on factors related to the operations, such as production capacity and the content of the feed used, but also on the characteristics of the water body where aquaculture is practiced (depth, temperature, current, etc.) (Pillay, 2004).

Marine habitats are subject to increasing pressures (nutrient discharge, eutrophication, etc.) due to population growth, agriculture, industry, tourism, fishing, and aquaculture. Coastal water eutrophication is considered one of the greatest threats to the health of marine ecosystems. It is defined as a change in the marine food web resulting from nutrient enrichment of seawater, which can alter carbon pathways and increase oxygen consumption (Vollenweider et al., 1992; Ferreira et al., 2011).

Various EU directives (such as the Urban Waste Water Directive [UWWTD, CEC 1991a], the Nitrates Directive [ND, CEC 1991b], the Habitats Directive [HD, CEC 1992], the Water Framework Directive [WFD, CEC 2000] and the Marine Strategy Framework Directive [MSFD, CEC 2008]), the Oslo Paris Convention (OSPAR 2003a, b), the Helsinki Commission (HELCOM, Andersen and Laamanen, 2009) and TRIX (Vollenweider et al., 1998) all consider the assessment of eutrophication through measurement of key indicators such as concentrations of nutrients, Chl-a and DO (Devlin et al., 2011).

Trophic Index (TRIX)

Water eutrophication in the 1980s and the first half of the 1990s was caused by the enhanced use of chemicals in agriculture and exerted a strong negative effect on all the trophic levels of the Black Sea ecosystem (Oguz and Gilbert, 2007). Though the conditions have become better in recent decades (Kideys, 2002), the continuous monitoring of the water eutrophication rate seems very important, in particular, in the coastal area subjected to a great anthropogenic impact. In order to make the evaluation universal and convenient, the parameters used at conventional monitoring approaches and reflecting the status of the main ecosystem components, affecting the eutrophication, should be applied. The trophic index of an ecosystem (TRIX) is based on the parameters of the concentration of the main nutrients (nitrogen and phosphorus), saturation rate of water with oxygen, and chlorophyll concentration (Vollenweider et al., 1998). The European Environmental Agency has evaluated this index and suggested that TRIX scales at regional level should be developed. TRIX values are very sensitive and any slight change of oxygen, chlorophyll a, dissolved inorganic nitrogen and total phosphorus concentrations results in changed index values (Boikova et al., 2008). This simple index seems to help synthesize key eutrophication variables into a simple numeric expression to make information comparable over a wide range of trophic situations (Balkıs et al., 2012). The advantage of this index consists in the fact that the water reservoir status may be not only qualitatively but also quantitatively evaluated. It enables the classification of the trophic status of an ecosystem according to a ten-point scale from “excellent” (low productive clean water, the absence of anoxic conditions, and the index lower than four) to “bad” (high-productive opaque water, episodic hypoxia, and the index higher than six) (Romanova et el., 2016).

The Trophic Index (TRIX) is an eutrophication index recommended by Vollenweider et al. (1998) for characterizing the trophic condition of marine waters along the Emilia-Romagna coastal region (northwestern Adriatic Sea). Data collected along the Emilia-Romagna coast from 1982 to 1993 have been used as a reference to develop and validate this proposed trophic index. These data encompass a broad range of trophic conditions, ranging from generally eutrophic near the coast to oligotrophic conditions in open waters (Vollenweider et al., 1998).

Eutrophication assessment indicators should incorporate multi-variable water column status variables encompassing physical, chemical, and biological variables. TRIX is defined by four state variables strongly associated with primary production: chlorophyll-a, oxygen, dissolved inorganic nitrogen, and total phosphorus.

TRIX encompasses a wide range of trophic conditions from oligotrophic to eutrophic and has been applied to coastal marine waters in several European seas (Fiori et al., 2016). These include the Adriatic Sea and Tyrrhenian Sea (Giovanardi and Vollenweider, 2004), the Baltic Sea (Vascetta et al., 2004), the Black Sea (Kovalova and Medinets, 2012; Baytut et al., 2010; Dyatlov et al., 2010; Medinets et al., 2010; Moncheva and Doncheva, 2000; Moncheva et al., 2002; Zaika, 2003), the Eastern Mediterranean (Tuğrul et al., 2011), the Aegean Sea (Yucel Gier et al., 2011), the Marmara Sea (Balkis et al., 2012), the Caspian Sea (Shahrban and Etemad-Shahidi, 2010), the Mar Menor (Salas et al., 2008), the Persian Gulf (Zoriasatein et al., 2013), and the Gulf of Finland (Vascetta et al., 2008).

Equation and Parameterization of TRIX

A Trophic Index (TRIX) was then proposed; it is defined by a linear combination of the logarithms of four state variables: chlorophyll-a (ChA), Oxygen as absolute percent deviation from saturation (aD%O), mineral nitrogen (minN) and total phosphorus (TP). This Index has been adopted by the Italian national legislation, in the frame of the monitoring activities requested to control coastal marine environment (Giovanardi and Vollenweider, 2004).

The TRIX index, developed using data collected by the “Daphne” oceanographic division of the Emilia-Romagna Regional Environmental Protection Agency (ARPAE-Daphne) from 1982 to 1993, as described by Vollenweider et al. (1992), is based on four state variables directly related to productivity:

- Chlorophyll a (Chl, mg m^{-3})

- Oxygen as the absolute deviation percentage from oxygen saturation (DO, %)

- Dissolved inorganic nitrogen (DIN, mg m^{-3})

- Total phosphorus (TP, mg m^{-3})

The usable components of the trophic index are elucidated as follows (Vollenweider et al., 1998):

(a) Factors that directly express efficiency:

Chlorophyll a: [Ch: mg/m^3]

Oxygen as absolute [%] deviation from saturation: [abs | 100±%0 | =aD%0]

(b) Nutritional factors:

(i) Totals

Total nitrogen: [NT: mg/m^3]

Total phosphorus: [PT: mg/m^3]

(ii) Available

Dissolved inorganic nitrogen as N-(NO_3 + NO_2 + NH_3): [DIN = mN: mg/m^3]

Dissolved inorganic phosphorus as P-PO_4: [DIP = PO_4: mg/m^3]

(c) Supplementary water quality factor:

Transparency: [Secchi depth: m]

DIN=N-NO_3+N-NO_2 +N-NH_4

DO = 100 - Ox, where Ox represents oxygen saturation.

The variable under consideration is scaled using the maximum (Ui) and minimum (Li) values in the time series data and is denoted as TRIX.

$$TRIX = \frac{k}{n}\sum_{i=1}^{n}\frac{(\log Mi - Log\ Li)}{(log Ui - log Li)}$$

In this formula, k represents another scaling factor; n denotes the number of considered state variables, and Mi represents the observed values of Chl, DO, DIN, and TP. Building upon the data utilized, Vollenweider et al. (1998) assumed that the logarithm of Ui minus the logarithm of Li is equal to 3 for all state variables, further simplifying the TRIX formula as follows:

$$TRIX = \frac{1}{1{,}2}\left[\log(Mchl\ MDO\ MDIN\ MTP) + 1{,}5\right]$$

$$TRIX = [\log 10(Chl - \alpha * Do\% * TN * PO4 + 1{,}5]/1{,}2$$

Chl-α : Chlorophyll-α concentration as micrograms per liter

$D\%O_2$: The % deviation of the oxygen concentration from saturation conditions

TN : Mineral nitrogen; dissolved inorganic nitrogen, DIN = N (as N - NO_3 + N - NO_2 + N - NH_4) as micrograms per liter

PO_4 : Total inorganic phosphorus as P–PO_4 (micrograms per liter)

The TRIX index utilized by ARPAE-Daphne ranges from 0 to 10, specifically designed for coastal waters. A value of 0 corresponds to extremely oligotrophic conditions, whereas 10 indicates highly eutrophic conditions. Additionally, TRIX values have been categorized into four trophic regimes: “high,” “good,” “moderate,” and “poor” (see Table 1) (Rinaldi and Giovanardi, 2011).

Tablo 1. The trophic index (TRIX) developed by ARPAE in Emilia-Romagna and its associated reference values for water quality and trophic conditions, as established by Rinaldi and Giovanardi (2011), are presented herein.

Conditions	TRIX units	Trophic state	Water quality conditions
Oligotrophic	<4	Elevated	– Scarcely productive waters – Good water transparency – Absence of anomalous water colors – Absence of oxygen undersaturation in the bottom waters
	4 < < 5	Good	– Moderately productive waters – Occasionally water turbidity – Occasionally anomalous water colors – Occasionally bottom waters hypoxia episodes
	5 < < 6	Mediocre	– Very productive waters – Low water transparency – Frequently anomalous waters colors – Hypoxia and occasionally anoxia episodes in the bottom layers – Suffering of the benthic communities
Eutrophic	> 6	Bad	– Strongly productive waters – High water turbidity – Diffuse and persistent anomaly in the water colors – Diffuse and persistent hypoxia/anoxia episodes in the bottom waters – High mortality rate of benthic organisms – Alteration of the benthic communities and strong decrease of the biodiversity

Considering the advantages and certain drawbacks of applying the Trix index, it is noted that it serves as a useful method for the preliminary assessment of the trophic status of coastal areas (Primpas and Karydis, 2011).

(a) TRIX is a multimetric index and therefore can be used without the uncertainties and risks of univariate procedures,

(b) the variables involved in the index are intercorrelated and this fact can lead to an underestimation of the eutrophication problems under certain conditions,

(c) oligotrophic, mesotrophic, and eutrophic intervals of TRIX should not be defined arbitrarily but should be derived from sets of data of known trophic status,

(d) it does not seem possible that a universal TRIX scale can satisfactorily describe trophic conditions. It has to conform to specific water bodies (estuaries, bays, and transitional waters) and intercalibration of the index should be encouraged. Other indices and community structure indicators should also be calculated and an overall assessment should be drawn,

(e) A single index value should never be the final diagnosis of ecosystem quality especially if expensive programs for ecosystem remediation and upgrading are going to be applied

Conclusion

In recent years, aquaculture in cages for the cultivation of aquatic products has witnessed rapid global expansion. The aquaculture sector is undergoing significant changes in response to the pressures of globalization and the increasing global demand for aquatic products. The growth in current production has led to the development of more intensive farming systems and their utilization in larger areas. Notably, the need for suitable areas for production has resulted in the exploration of new potential areas for cage aquaculture, such as lakes, ponds, rivers, coastal brackish waters, and offshore waters. Recognizing the significance of cage aquaculture today, it is acknowledged that cage-based production will play a pivotal role in the future growth of the aquaculture sector.

Aquatic product cultivation worldwide relies on increased production, expansion of production areas, growth in aquaculture enterprises, and increased production capacities. Large-scale enterprises are often located in marine environments, but since coastal nations share marine areas, the freedom of individual countries to act independently in utilizing these areas is constrained, necessitating collaborative efforts with other nations.

Waste sources in fish farming encompass unconsumed feed and undigested or water-soluble substances. When these substances exceed the assimilation capacity of the aquatic ecosystem, environmental issues such as eutrophication, oxygen depletion, and changes in biological diversity can occur, both in the water column and sediment. These effects vary depending on factors such as the species being farmed, fish size, stock quantity, depth, currents, physicochemical properties of the water, farming methods, feed content, feed quantity, and other factors affecting the receiving water.

The excessive presence of organic solids, dissolved waste, and inorganic nutrient elements, primarily nitrogen and phosphorus, resulting from fish feeding can lead to eutrophication when they exceed the ecosystem's carrying capacity. Eutrophication initially provides nutrient richness but subsequently leads to ecosystem impoverishment. Therefore, monitoring the trophic status of production areas should be conducted from the establishment of production areas.

Ecological indices used in water quality monitoring provide indicators of ecosystem quality in coastal areas and offer valuable information on essential parameters for all coastal users. The Trophic Index (TRIX) identifies the primary cause-and-effect relationships of eutrophication. In this context, the European Environmental Agency recommends defining TRIX intervals for different regions or areas to enhance index sensitivity. Determining data to be obtained using TRIX calculations (annual averages, seasonal averages, several years' seasonal averages) is crucial to reducing index sensitivity to natural meteorological variations. The European Environmental Agency suggests that the TRIX general approach holds high potential for monitoring and assessing trophic conditions by identifying eutrophication trends in marine and coastal waters, facilitating its applicability and comparability.

The environmental effect of production is also linked to the physical and chemical characteristics of the fish feed used and the feeding management applied. Successful fish farming with minimal environmental effects involves minimizing unconsumed feed, reducing feed phosphorus and nitrogen content, and maximizing feed digestibility. Based on the applied production system, strategies need to be developed for all factors that contribute to deteriorating water quality. Improving the physical and chemical quality of feeds and implementing appropriate feeding strategies will contribute to making the environmental effects of aquaculture waste more sustainable.

In conclusion, to ensure the sustainable production of aquaculture facilities while preserving aquatic ecosystems, the "Ecosystem-Based Fish Farming Strategy" should be implemented by all producers. At the outset of this process, the importance of the TRIX trophic index in site selection and the evaluation and application of the TRIX index have been emphasized. Sustainable development in fish farming is defined as integrating it into a broader ecosystem that supports equity and the harmony of social and ecological systems. At this stage, determining assimilation capacity alongside the TRIX trophic index in aquaculture facilities is a correct and sustainable approach.

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CHAPTER 6

ECOLOGICAL MATERIAL: PROTECTIVE PERFORMANCE OF STRAW OIL/ THERMO WOOD OIL ON WOOD

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INTRODUCTION

Wood Wooden material has been one of the indispensable main materials of humanity since the beginning of the historical process. Synthetic and chemical-based materials release carbon and have a negative impact on human health, especially in indoor spaces. The naturalness of the wooden material, its texture-color-form diversity, its machinability, and the superior properties of this raw material against many materials (steel, concrete, iron, etc.) have increased its usage area [1]. It is reported that the human population increases rapidly in the ecological cycle and, in parallel, forest resources continue to decrease rapidly. It has become of great importance to provide wider usage areas by protecting the wooden material at the highest level, but to fully identify the factors that damage wood, and in parallel, to develop organic preservatives and methods that are protective, restorative, provide strength, and are also reusable and compatible with the ecological structure [2]. Human beings have used wood to meet one of their basic needs, which is shelter. With the advancement of technology; Properties such as methods of protecting wooden material, its ability to be easily shaped, its resistance to fire and earthquake, and its mechanical strength are improving day by day [3]. Samples prepared from different trees were impregnated with paraffin-linseed oil and then kept in water to measure the amount of water uptake. It was determined that samples impregnated with paraffin-linseed oil retained less than 50% water [4]. Aleppo pine was impregnated with wax and paraffin, and it was determined that as the concentration of water-repellent impregnation materials increased, the amount of water repellency increased [5]. Impregnation Environmental organizations state that impregnation materials should be banned due to their environmental damage. In recent years, the use of human and environmentally friendly materials has been increasing. Resin/natural oils prevent the growth of fungi as they reduce the amount of water in the wood to below 10%. The most commonly used oil groups are reported to be linseed oil and tall [6,7]. Three types of wooden materials (fir, beech, spruce) used in park and garden construction were subjected to three types of impregnation (dipping, hot oil, brush) with waste oil. The highest weight increase rate (%) was detected in dipping, while the lowest was brushed. While the lowest water uptake rate was determined in the dipping method, it was determined that waste oil improved the physical properties of the wood [8].

They subjected poplar wood to hot oil treatment with linseed oil and determined that while an 80-106% increase in the weight gain rate was determined, the water uptake rate was low due to the significantly reduced amount of moisture [9]. In another study, they determined that the modification process of poplar wood with poxidized linseed oil/carnauba wax provided significant dimensional stability/water repellency [10]. Organic vegetable oils are recommended to be used as glitter because they create a hydrophobic layer on the cell wall and reduce the amount of water uptake [11]. They impregnated Chinese fir with silicone oil and reported that water uptake decreased and dimensional stability increased as a result of the experiment [12].

Impregnated Wood linseed oil darkens the color of the wood and makes the wood grains more visible. Linseed oil can be used as a first primer on wooden surfaces before painting. By itself, it penetrates deep into the wood and preserves its natural texture for a long time. It helps prevent decay by increasing the resistance of wood exposed to water and moisture [13]. Miklecic et al. (2010) impregnated various types of wood thermally treated with teak oil and reported that it provided protection against UV effects on wood samples left in outdoor conditions [14]. He prepared mixtures (concentrations) by treating natural linseed oil with various chemical solvents (alcohol, thinner, etc.) and reported that water uptake decreased significantly when Scots pine wood was subjected to impregnation [15]. In our century, where human/environmental health comes to the fore within the ecological cycle, the preservation of wooden materials for a longer period of time, the reuse of impregnated wooden materials, the use of straw oil/thermowood oil, the most effective organic impregnation material in all human spaces, in the process of drought, climate change and rapid decrease in water resources, are used in interior decoration. It is aimed to make the use of these materials more active in outdoor areas. In the restoration of historical wooden works, especially children's toys, outdoor furniture, and wooden plates/cups in restaurants/cafes, their protection levels (physical properties) against water and other factors have been tried to be determined.

1. MATERIAL and METHOD

1.1. Wood Material and Treatment

In this research, red pine (Pinus brutia) and beech wood (Fagus orientalis Lipsky L.) were used as wood materials. Based on TS 2470, 2471 standards, samples without ridges, fungi, knots and rot were preferred [16,17]. In my impregnation process, organic impregnation materials Straw Oil and thermowood oil were used. The drying time of Thermowood oil is 8-12 hours, and full hardening is 24 hours [18]. Absorption of straw oil usually occurs within 24 hours [19].

1.2. Preparation of Experiment Samples

Samples with air-dry moisture (12%) were prepared from the sapwood parts of the tree, with annual rings perpendicular to the wide surface, in a size of 20 × 20 × 30 mm, according to the principles of TS ISO 3129 [16]. All samples were free of cracks, knots, twigs, mold and rot. etc. Care was taken to avoid any defects; Care was taken to ensure that the annual ring structure of the samples obtained from the sapwood was towards the surface (radial) [20,21,22].

1.3. Density and Retention

In determining air-dry and fully dry specific gravity, processes were carried out based on (TS ISO 13061-1, TS ISO 13061-2) standards, and the retention amount of linseed oil/teak oil on the wood material (remaining solid matter (% compared to the weight of fully dry wood amount) was determined by the following formula [16,23,24].

1.4. İmpregnation Method

The wood samples, which were made completely dry during the impregnation process (103±5 °C), were impregnated by the immersion method (medium term: 3 hours, long term: 24 hours) [25].

1.5. Evaluation of Data

In the study, 4 tree species and 2 types of impregnation materials were used and multiple analysis of variance (MSTAT-C) was used to determine the differences between the groups. Whether the difference was significant between groups was determined with the help of the "Duncan Test".

2. RESULTS AND DISCUSSION

2.1. Retention Amount (% Retention)

Duncan test results for % retention are given in Table 1, and their change chart is given in Figure 1.

Table 1. *Percentage Retention (%)*

İmpregnation Material	Wood	Immersion Time (Middle-Long)	Retention (%)		
			Mean	St. Dev.	HG
Straw Oil	Pinus	3 Hours	7.73	2.12	D
		24 Hours	9.78	1.67	C
	Fagus	3 Hours	10.37	5.79	B
		24 Hours	12.66	4.16	A
Thermowood Yağı	Pinus	3 Hours	4.28	2.37	D
		24 Hours	6.64	3.45	C
	Fagus	3 Hours	14.76	6.74	B
		24 Hours	17.37	4.44	A

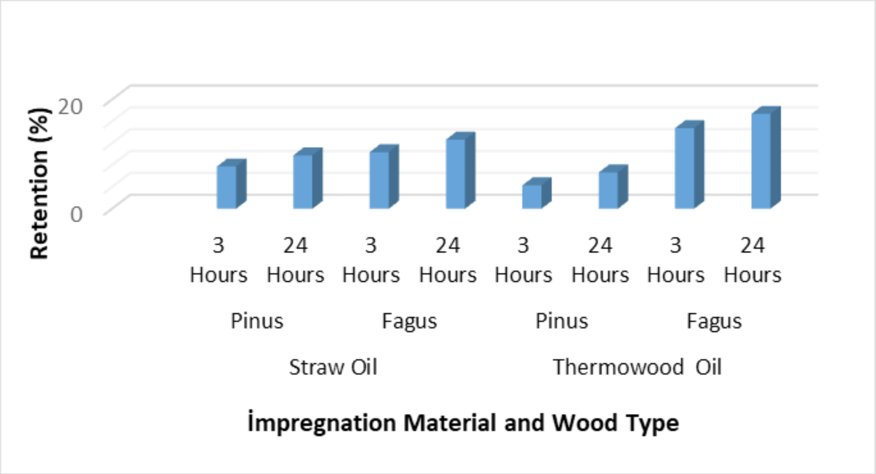

Figure 1. *Retention (%)*

The highest retention in straw oil impregnation was 24 hours (12.66 %) on beech wood, the lowest retention was 3 hours (7.73%) on red pine wood; The highest retention in thermowood oil impregnation occurred in beech wood for 24 hours (17.37%), and the lowest in red pine wood for 3 hours (4.28%). Alkan (2016) subjected various types of wood to the impregnation process, compared natural preservatives among themselves, and reported that kebracon provides twice the retention than tara [26].

Atılgan et al. (2012) impregnated beech wood with 9% concentration (cement + borax) and found that they obtained the highest retense amount (42.43 kg/m3) value, while the lowest value was in Scots pine (1% ammonium tetraflu borate) [27]. Sarıca (2006) impregnated oriental beech wood with borax and determined the maximum adhesion amount (29.65 kg/m^3) in sessile oak wood impregnated with boric acid [28]. Özçifçi et al. (2009) found the highest retention amount in Scots pine (19.39 kg/m^3 - 21.81%) and the least in oak (8.742 kg/m^3 - 9.15%) [29].

2.2. Air/Full Dry Specific Density (g/cm^3)

Specific density change results are given in Table 2, and the change graph is given in Figure 2.

Table 2. *Air Dry and Full Dry Specific Gravity (g/cm³)*

İmpregnation Material	Wood Type	Immersion Time (Middle-Long)	Air Dry Density		Full Dry Density	
			Mean	HG	Mean	HG
Straw Oil	Pinus	Kontrol	0,48	D	0,46	D
		3 Saat	0,49	D	0,46	D
		24 Saat	0,54	C	0,52	C
	Fagus	Kontrol	0,63	B	0,61	B
		3 Saat	0,62	B	0,59	C
		24 Saat	0,64	B	0,61	B
Thermowood Oil	Pinus	Kontrol	0,48	D	0,46	D
		3 Saat	0,52	C	0,48	D
		24 Saat	0,47	D	0,44	D
	Fagus	Kontrol	0,63	B	0,61	B
		3 Saat	0,66	B	0,63	B
		24 Saat	0,72	A	0,70	A

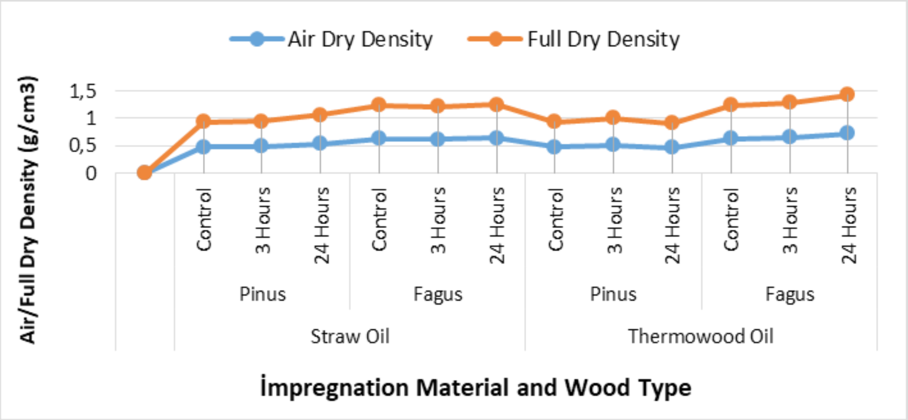

Figure 2. *Air/Full Dry Density*

Straw oil and thermowood oil impregnation provided an increase in the specific gravity value of both wood types. The increase is especially evident in the 24-hour period. The highest air-dry specific gravity value for straw oil was determined in beech wood at 24 hours (0.64 g/cm³), and for thermowood oil at 24 hours (0.72 g/cm³) in beech wood. The difference in air dry density values of impregnated wood materials may be due to the air gap ratio (porosity), annual ring width and type of impregnation material depending on the anatomical structure of the wood materials.

Kılıç (2012) impregnated beech and spruce wood with silicone (silane) and determined that the specific gravity values did not change significantly compared to the control groups, as 0.44 g/cm³ in spruce control samples and 0.43-0.56 g/cm³ in impregnated samples [30]. Gür (2003) reported that the density value of Scots pine and red pine woods increased by impregnation with various substances [31]. Var et al. (2017) reported that there was no significant change in density/tangential expansion after impregnating red pine (*P. Brutia* Ten.) wood with various geothermal waters [32]. Kaplan et al. (2019) impregnated red pine wood with various geothermal yanka waters and reported that the density increased by 16.64% [33]. Özkan et al. (202) reported that impregnation of various wood types with waste oils showed positive performance in physical properties [34]. Şimşek (2013) reported that Scots pine wood was impregnated with valexin and its physical properties were negatively affected [35].

3. CONCLUSION

The highest retention in straw oil impregnation was 24 hours (12.66%) on beech wood, the lowest retention was 3 hours (7.73%) on red pine wood; The highest retntion in thermowood oil impregnation occurred in beech wood for 24 hours (17.37%), and the lowest in red pine wood for 3 hours (4.28%). Straw oil and thermowood oil impregnation provided an increase in the specific gravity value of both wood types. The increase is especially evident in the 24-hour period. The highest air-dry specific density value for straw oil was determined at 24 hours (0.64 g/cm^3) for beech wood, and for thermowood oil at 24 hours (0.72 g/cm^3) for beech wood.

The difference in air dry density values of impregnated wood materials may be due to the air gap ratio (porosity), annual ring width and type of impregnation material depending on the anatomical structure of the wood materials. Since straw oil and thermowood oil are new ecological (natural) products, they can be preferred in a wide variety of usage areas. It has started to be widely used in the kitchen sector (restaurants, cafes, etc.), on yachts (in places with water contact), and in various interior spaces. Indoor children's toys can be impregnated with a wide variety of natural materials (plants, etc.) combinations, and their burning, water absorption and technological properties can be investigated, especially in the century when human/environmental health awareness comes to the fore.

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