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PREFACE

Plant science is a basic disipline of biology that deals with diverse fields on plants. In this book, there are eleven chapters related with some special topics in plants. The chapters provide wide knowledge on general aspects of the fields, main literatüre and recent research advances to academicians, researchers, graduate and undergraduate students. This book was prepared with the contributions of expert academicians in their fields. I would like to thank the authors of the chapter for their scientific contributions, referees and the Livre De Lyon Publishing House for printing the book.

I hope that the book will provide new perspectives to the readers.

Assoc. Prof. Dr. Neslihan KARAVİN

CONTENT

CHAPTER I

THE ROLE OF BIOCHAR ON PLANT GROWTH

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1. Introduction

Energy consumption and food need are increasing rapidly parallel with the increase in the world population. The human population in the world expected to be 9.4-10.1 billion by 2050 and 0-2.7 billion by 2100 (Giller et al., 2021). Therefore, new methods of energy supply and food production are needed. The first step towards more food supply is receiving higher yields per unit area rather than opening new farmlands. Fertilizers, hormones, and pesticides are commonly used to increase productivity in agricultural crops.

Although the biochar industry is a new process, the formation of it in nature has continued spontaneously for centuries. When plant wastes remain under the ground, they spontaneously carbonized by grass fires for a very long time and biochar is naturally formed (Akgül, 2017).

In the recent years, biochar applications became popular because of its advantage in reducing the greenhouse gas emissions. The applications of biochar vary from the flue gas, power and heat production, metallurgical applications, building material, medical, material production, cleaning to improving the agricultural activities and animal husbandry (Weber and Quicker, 2018).

Biochar is well described as a “soil conditioner” organic material produced various organic feedstocks (Verheijen et al. 2010). The effectiveness of biochar on plant fitness and soil features depends on feedstock and soil structure, plant species and environmental conditions (Luo and Gu, 2016; Prapagdee and Tawinteung, 2017; Günal and Erdem 2018). These factors determine the role of the biochar applications, i.e., whether their beneficial or not. The roles of these factors in biochar applications were indicated in several studies.

This chapter focused on the effect of biochar threatments on plant fitness. The popularity of the biochar applications for plant growth is related with the several soil-improving properties of biochar such as rich carbon content, rich porous structure, pH, large surface area, capacity of ion exchange, electrical conductivity, microbial activity, water retention, metal adsorption from soil and water (Wang and Wang, 2019).

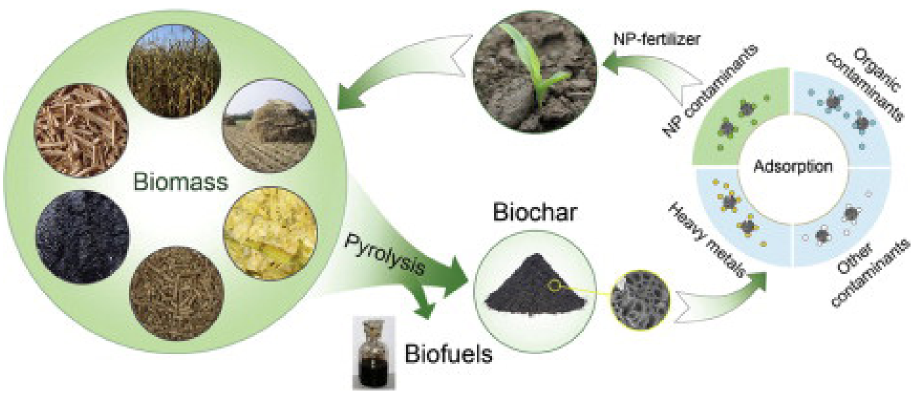

Figure 1. Production and use of biochar (Source: Tan et al., 2015)

2. The Application of Biochar for Plant Growth

It is known that biochar applications in agriculture have been used since ancient times. The effects of biochar application on plant growth were examined from several perspectives. Of course, the initial step of biochar applications is occurred in the soil.

2.1. The Effects of Biochar Addition on Soils

Enhance the soil fertility and improvement of the habitat conditions have become an essential requirement for plant growth in many regions of the world. At this point, biochar become prominent as the most suitable material in terms of both environmental pollution and global climate change. The first findings on the using biochar in order to improve soil fertility are based on studies on Terra Preta de Indio soils discovered in the Amazons (Günal and Erdem, 2018). The popularity and usage of biochar in agricultural activities increased in recent years due to gain more crop yield.

Although there were several studies on the effects of biochar applications on soil structure and function, the knowledge is still unclear. Because the effects of biochar treatments strongly related with soil conditions, the feedstock structure of the biochar and production methods. However, related studies gave important information about the role of biochar treatments on soils.

Biochar addition to the soils provides multiple advantages by changing soil conditions such as nutrient and water supply, pH, porosity, cation exchange capacity, concentrations of toxic materials and microbial activity. The Figure 2 which was made by Murtaza et al. (2021) summarized the benefits of biochar to the soil properties. It was determined that the addition of biochar to the soil improves the microbial activities, which is useful for plant growth in the soil, by providing suitable nutrients and habitat for the microorganisms, improving soil conditions such as pH, ion exchange capacity, soil temperature, water supply etc. (Thies and Rilling, 2012).

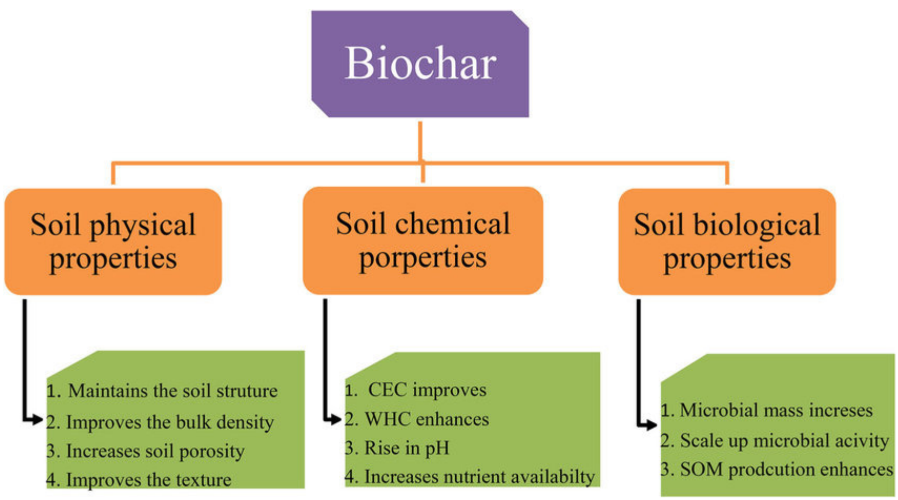

Figure 2. Benefits of using biochar on soil properties (Source: Murtaza et al., 2021)

In the light of literature, the effect of the biochar addition to the soil properties and their benefits were summarized in Table 1.

Table 1. Impacts of the biochar addition to the soils

Effect	**Benefits**	**Literature**
Its porous structure and large surface area increase the soil water holding capacity	Beneficial in low-water habitats or for growing plants that need more water and supports soil aeration	Ajayi et al. 2016, Wu et al. 2022
Increase the ion (cation) exchange capacity of soils by this way it provides easier nutrient uptake	Supports plant growth usually in infertile habitats	Lorenz ve Lal, 2014, Domingues et al. 2020
Due to its high oxygen content, it increases the adsorption of the toxic substances	It is useful in the removing pollutants and the remediation of the polluted soils	Yang et al. 2019, Li et al. 2020,
Because of its high C content, it is used in soil improvement	Increases organic carbon content which promotes soil structure and microbial activity	Rajalekshmi and Bastin 2019,
Reduces CO2 emission from soil to atmosphere	Prevent the release of global climate change by reducing the greenhouse gases	Altıkat and Alma 2021
Regulates soil pH and electrical conductivity	Improves the soil conditions	Bai 2022, Calcan et al. 2022
Due to its highly porous structure, it provides good aeration of the soil	Enhances microbial activity and growth of organisms	Singh et al. 2019, Kocsis 2022
High surface area and water retention of biochar improves soil conditions	Supports plant growth, promotes decomposition.	Ahmad Bhat et al. 2022, Kang et al. 2022.
Decreases wind and water erosion	Provides soil stability	Tang 2022, Vahidi et al. 2022
Improve infiltration of water and soil temperature	Removes harmful substances from water, enhance soil conditions and improve plant growth.	Ahmad Bhat et al. 2022, Chen et al. 2022
Darkens the colour of soils and changes the albedo of the soil surface	Reduces evaporation from the soil surface and increases soil moisture	Altıkat and Alma 2021

2.2. The Effects of Biochar Addition on Plants

The addition of the biochar to the soils changes various factors related with plant growth. In addition to be a habitat, soils are the main nutrient and water resources for plants. Therefore, the soil structure, characteristics and conditions have an important role in plant growth. There are several applications to improve the soil characteristics, but much of them are not natural and generally cause environmental pollution. Biochar is preferred to minimize the negative environmental impacts due to its naturality and various benefits. The various benefits of the biochar addition to the soils were summarized above (Table 1). It is clearly seen that many soil properties can be improved with only the application of biochar.

The chances in soil properties based on biochar addition to the soil affect plant growth directly or indirectly. There are numerous factors that are effective on plant growth. Thus, the role of biochar applications in plant growth were discussed in terms of effects on germination, on plant anatomy, morphology and physiology, crop yield and environment in this chapter.

2.2.1. Seed Germination

Generally, the first stage in plant growth is seed germination which is the main process of emerging a new plant individual from a seed. Seed structure, environmental factors and conditions play important roles on seed germination success. For the occurrence of seed gemination: seeds must be viable and capable of germination, must have emerged from dormancy, should be placed in suitable environmental conditions (suitable temperature, water, oxygen, and sometimes light supply. While the viability, germination capability and the dormancy status of the seeds are internal properties and usually are not regulated by external factors, the suitable environmental conditions required for seed germination may be enhanced. There are numerous ways to improve environmental factors for seed germination. One of them is the biochar application.

Many of the examinations expressed that biochar application to the soil has a positive effect on seed germination (Solaiman et al., 2012; Gascó et al., 2016; Das et al., 2020; Dani et al., 2022). Yılmaz (2018), it was concluded that the germination of pepper, tomato, cucumber, watermelon, melon, and lettuce plants accelerated by using biochar obtained from apple pulp. However, biochar does not always have the same effect on plants, low doses in some plants and high doses in some plants were effective. For example, earlier germination was seen in pepper and tomato seeds treated with biochar. The seed germination of cucumber increased in low doses of biochar while high doses of it caused a delay in germination. In general, biochar applications provided earliness in lettuce, melon, and watermelon seed germination.

In the study of Das et al. (2020), while the germination rate of seed in black gram and maize is increased with biochar addition at lower concentrations of biochar, it has no significant effect or decreased seed germination at higher concentrations. The impact of biochar on germination was differed based on biochar type. It was thought that because of their lignin-rich feedstock, the biochar of pine needle did not satisfactorily improve seed germination. However, the seed germination rate increased by black gram biochar addition.

These results explained that the feedstock and concentration of biochar are determinant factors in seed germination performance of plants as reply to biochar application. As an evidence Solaiman et al. (2012) found similar results. High rates of tree different biochar addition inhibited seed germination in wheat. Variations in their response to biochar application were determined among plant species. It is clear the seed type and chemical content of biochar are also important factors in response of germination.

Gascó et al. (2016) examined the phytotoxicity effects of biochar on germination. They reported that the phytotoxic effects of biochars on germination are strongly related with plant species, concentration, and feedstock of biochar. It was determined that tomato and lettuce seem to be more sensitive to the toxic substances that present in biochars. However, some of the biochars did not improve seed germination.

Dani et al. (2022) studied the effect of different sewage sludge biochars, which were produced at 400 and 500°C, on the germination of *Solanum lycopersicum* seeds. According to the results, germination index and the germination (%) in *Solanum lycopersicum* were enhanced by the additions of both biochars. The maximum germination (%) and germination index were determined in sewage sludge biochars produced at 500°C.

These results indicated that the production method of the biochars were also effective on the impacts of them to seed germination and the plant growth. It was seen that from the literature survey, multiple factors play role on the impact of biochar addition on germination. As a summary, seed type, plant species, biochar feedstock, production methods of the biochars and environmental factors are major determinants. More study was required on the effect of seed biochar applications on germination to understand all aspects.

2.2.2. Plant Anatomy and Morphology

The biochar addition to the soils as a soil conditioner directly or indirectly affects plant status in many ways. There are various studies on the impacts of biochar on plant anatomy and morphology. Here, we discuss the results of some studies.

In the study of Yılmaz (2018), biochar applications significantly decreased the pepper plant diameter. The dry matter of green parts was not affected by biochar treatment in pepper. A significant increase was not determined in shoot growth in tomato. The stem thickness of cucumber plants increased parallel with increasing doses. However, the root growth was not affected by biochar application. The biochar applications did not have a important effect on root growth of melon.

Nikpour-Rashidabad et al. (2019) investigated the variations in the anatomical characteristics in mung bean roots based on biochar applications during the salt stress. The biochar treatment positively affected the root characteristic in mung bean only in saline media. While the shoot/root ratio, total root area, density and specific root length, vascular cylinder and cortical parenchyma areas were improved by biochar under saline conditions, the biochar were not significantly effective on root density and diameter under the non-saline media. Biochar treatment improved shoot growth more than root growth under the saline conditions. These results indicated that habitat conditions also have an impact on the role of biochar treatments.

Beig et al. (2020) stated that the fresh shoot weight and dry shoot weight, maximum leaf area and root volume were determined at 5 g/kg level of biochar made from rose. Except diameter and height of shoots, the increase in biochar concentration from 5 to 10 g/kg decreased all parameters.

The biochar treatment led to increase in the chlorophyll content, amount of leaves and plant height according to results of the study of Hafez et al. (2020). The use of biochar moderated the negative effects of drought on barley plants.

In the study of Lerison Miranda Melo et al. (2022), the effect of biochar addition on anatomy and morphology of young *Eucalyptus urophylla* plants were examined. It was determined that the anatomical features of the root such as vascular cylinder diameter, root epidermis thickness, root cortex diameter, root metaxylem diameter and root endodermis thickness. The best effect of biochar on root was in the treatment with 7.5% biochar addition. Results were associated with an increase in water retention which support the rigidity, integrity of the cell wall and volume. In addition, biochar addition leaf structure properties such as increased epidermis thickness from adaxial and abaxial leaf side, palisade and spongy parenchyma thickness and photosynthetic pigments. It was reported that these increments were related with the increase in nutrient and water supply due to biochar addition. Li et al. (2022) expressed that the biochar treatments increased the total root surface area and total root length of soybean individuals. But increased concentrations of biochar did not always change these parameters. Therefore, biochar the application method and rate were important determinants in the role of it on plant growth.

The results of Egamberdieva et al. (2021) demonstrated that maize-derived biochar improved root and shoot biomass, root architecture and nodule formation of *Glycyrrhiza uralensis* Fisch (Figure 3). The medium concentration of biochar added to the soil mostly improved the root structure. However, the higher concentration treatments of biochar may lead to unfavourable conditions in the soil.

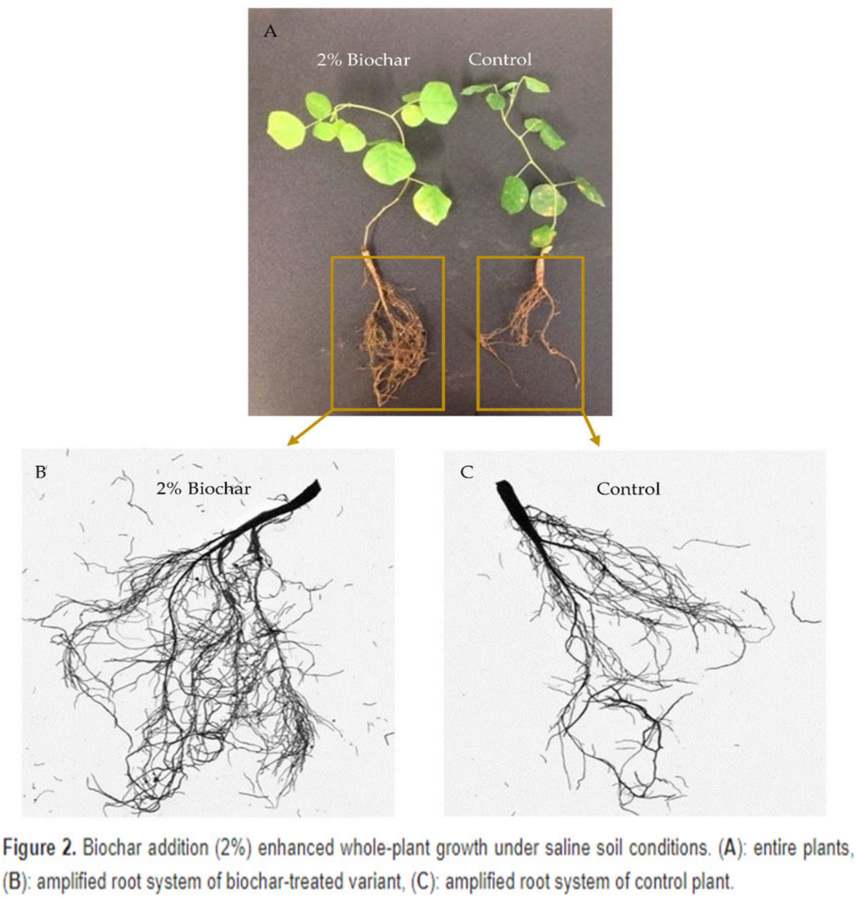

Figure 3. Differences in plant growth in the study of Egamberdieva et al., (2021) (Source: Egamberdieva et al., 2021).

2.2.3. Biomass Production, Nutrient and Water Supply

Generally, moderate concentrations of the biochar enhance nutrient and water uptake of plants and improve growth due to its beneficial effects on the soil conditions. As an example, Case et al. (2012) expressed that the application of biochar to the soil reduces the bulk weight of the soils and increases its water holding capacity. Similarly, Akgül (2017) stated that biochar increases the soil water holding capacity up to 6 times, and thus plants can more easily absorb elements useful for plant growth, such as phosphorus and nitrogen, from the soil. Kara (2016) concluded that the application of biochar obtained from different feedstocks such as eucalyptus, poplar pruning wastes, cotton harvest waste and olive pomace enriches the soil organic matter content and provides significant benefits in the uptake of micro and macro nutrients of plants from the soil.

Warnock et al. (2007) explained that biochar also increases the yield of plants by means of positively affecting beneficial microorganisms that live in plant roots and the soil and have an important role in plant development.

Namlı et al. (2017) the effect of the biochars produced from chicken manure and hazelnut shell was examined as soil conditioner. It was determined that the biochar obtained from chicken manure was more effective in the growth and development of wheat grain. It was concluded that the use of biochar obtained from the chicken manure increased the amount of phosphorus concentration more than the biochar derived from the hazelnut shell. It was observed that biochar application positively affected the height of the wheat plant. In addition, the application of these two biochar types with chemical fertilizers is very beneficial and effective on plant development and soil structure.

In the study of Akpirinç (2017), it was determined that biochars, obtained from the wastes of tobacco and cotton plants, had positive effects on plant growth and fruit formation in pepper and tomato cultivation.

It was determined that biochar produced from goat manure had positive effects on the nutrient content of the curly lettuce and onion plants and increased the benefit rate of the inorganic fertilizer (Mounirou, 2019). In a study on corn and wheat plants, it was concluded that the application of *Eucalyptus* and green waste biochar had a positive impact on the uptake of K from the soil by plants (Uysal, 2019).

The biochar obtained from *Eleagnus* waste was applied on maize plants increased the soil fertility by improving nutrient solubility, availability and uptake. The biochar applications in this study increased the plant height, stem diameter, above-ground fresh biomass and leaf chlorophyll content of the maize plant and also promote the Ca, Fe, P, N, K, Zn and Mg uptake of plants (Manirakiza, 2019).

Yamato et al. (2006) and Schmidt et al. (2015) expressed that combined addition of biochar with fertilizer was more effective on plants and increased crop yield.

Çakmakçı et al. (2020) determined the highest plant height, fruit length and stem diameter in biochar-applied pepper plants. Similarly, by the addition of biochar, approximately 150% increase in corn yield (Uzoma et al., 2011), 96% increase in radish yield (Chan et al., 2008) and 13% increase in tomato yield were determined (Akhtar et al., 2014).

Huang et al. (2019) stated that the addition of dredged sediments and biochar improves rhizosphere soil characteristics and supports plant growth. In this study, biochar treatment enhanced available phosphorus content of *Phragmites communis* (Cav.) Trin. ex Steud.

Egamberdieva et al. (2021) indicated the positive effects of biochar, produced from maize, on nutrient uptake and growth of *Glycyrrhiza uralensis* Fisch. due to increased soil microbial activity, improved root growth, availability of nutrients based on biochar addition. Günal and Erdem (2018) told that the benefits of biochar on plant fitness and growth are quite high, and it can even be used against plant diseases.

2.3. The Effects of Biochar Addition on Environmental Factors

Biochar applications not only have positive effects on soil and plant individuals, but also have significant contributions to environmental conditions. The biochar become prominent as the most suitable material in terms of both environmental pollution and global climate change. There are various environmental benefits of the biochar such as remediation of soil and water, C sequestration, increase in nutrient and water bioavailability, NO_2 suppression (Field et al., 2013). Because it reduces CO_2 from soil to atmosphere and remediate the contaminated soils and waters, biochar does not lead to pollution such as chemical conditioners. Biochar reduces the phytotoxicity and bioavailability of much of pollutants, especially metals and improve the soil properties in saline media.

Several studies indicated that biochar applications are beneficial for most of the environmental factors. In the study of Beig et al. (2020), the rose biochar has enhanced the growth parameters of lettuce by decreasing the availability of Pb and Cd in the soil.

The protective effects of biochar against Cd stress were determined by García et al. (2020) (Figure 4). They reported that biochars can be used as an alternative for improving defences against abiotic stresses.

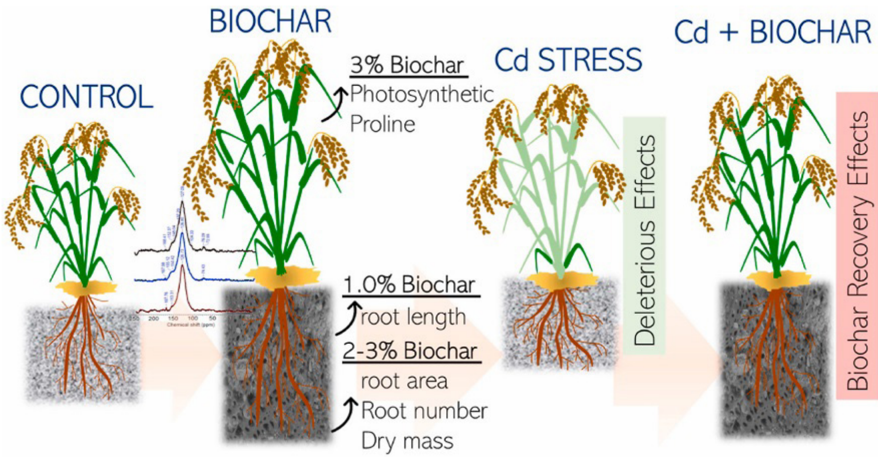

Figure 4. The results of the study of García et al. (2020) on protective benefits of biochar on growth of rice in sandy fragile soil polluted with cadmium (Source: García et al., 2020)

Atılgan (2021), animal-derived biochar, obtained by various processes from the fish scales, presented as an effective alternative for Cd^{+2} removal from the aqueous medium. Thus, cadmium ions, which are toxic even at low concentrations dissolved in water, are economically removed from the aqueous solution. This showed that biochar can be used not only in soil and plant improvement, but also in practical treatment applications of aqueous environments.

The effect of biochar and wheat straw application on GHG emissions for 15 months examined by Hu et al. It was found that addition of biochar decreased CO_2 and N_2O emissions (Zhang et al., 2019).

In the study of Durukan (2021), green part dry matter production, which decreased with drought stress applications, increased with biochar doses. The same is true for tuber yield. The decrease in antioxidant enzymes, which increase with drought stress, resulted from biochar application in the first year, has created that biochar can eliminate or reduce the symptoms of drought stress on sugar beet plants.

Özyavuz (2017) examined the plant stress due to changing environmental conditions and its negative impact on growth. It was determined that the stress can be reduced relatively by biochar applications (tobacco stalk and cotton stalk) compared to the control group, but it could not provide a significant improvement in fruit formation in the eggplant. It was determined that biochar additions in salty and saltless soils caused significant differences in plant growth. Nikpour-Rashidabad et al. (2019) explained that the biochar application enhanced the plant growth of mung bean in saline media. Studies that reported the positive contribution of biochar applications to the plant growth and reduction of stress in saline habitats were explained detailed in the previous sections.

The production and usage of the biochar have an important environmental role in reducing the pollution levels in both terrestrial and aquatic ecosystems. The organic waste management support the mitigation of global climate change by reducing the methane emissions, industrial energy use, emissions based on recycling, producing energy from waste, and reducing the costs of waste disposing (Lehmann and Joseph, 2015).

In the light of the studies on the effect of the biochar applications, it is clear biochar has important positive impacts on plant growth, soil structure and environmental management. The impacts of biochar mainly vary according to feedstock, production method and concentration of biochar, soil type, plant structure and environmental conditions. Besides the positive effects some negative effects of biochar on soils and plant growth were reported. These were generally related with chemical compounds of biochar feedstock and application concentrations of biochar. In the big picture the biochar application is useful for plant growth and can be primarily preferred as a soil conditioner.

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CHAPTER II

HALOPHYTE PLANTS: ECOLOGICAL DEMANDS AND POTENTIAL USAGES

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1. Introduction

Salinity is a significant issue in arid and semi-arid regions. Inadequate precipitation and significant evaporation are the main causes of salt creation in these regions. (Greenway and Munns, 1980). However, because to overirrigation brought on by human activity, it also happens in areas that can be irrigated (Hanson et al. 1999). Due to inadequate drainage and overuse of irrigation, groundwater levels rise. The soil becomes salinized when the water in it evaporates due to the high temperature, but the salts that were dissolved in it remain on the surface.

Different ecological conditions for plants are prevalent in soils with a lot of salt in them. Edaphic variables are the most significant ecological element in these soils In addition, the chemical properties of the soil (nutrient content, electrical conductivity and salinity in the soil) impose restrictions on the growth, development and distribution of plants (Markert, 1992).

Salt sensitive plants and even some halophytes may experience a quick drop in growth rate and total growth as a result of excessive soil salinity, water scarcity, ion toxicity, and nutrient deprivation, which can result in numerous metabolic alterations that cause molecular damage (Zhu, 2002; Flowers, 2004; Sobhanian et al., 2011).

Halophytes are xerophytes that grow in very salty soils. Plants in these environments cannot get enough water due to high osmotic density (Öztürk and Seçmen, 2004). Halophytic plants have one or more specific adaptations that allow them to survive in a salty environment. They have specific tolerances for widely fluctuating salt concentrations (Khan, 2002).

In this study, the ecological demands of halophyte plants, some adaptation mechanisms and how these special plants cope with stress, which category they are classified according to, potential usage areas and effects are mentioned.

2. Ecological Demands of Halophytes

The most widely known definition of halophytes is “ plants that can thrive and complete their life cycle in soil with at least 200 mM NaCl salinity” (Flowers et al., 1986; Flowers and Colmer, 2008). Many halophytic plants can actually grow and thrive above this concentration (200 mM NaCl) (Gallagher, 1985). With around 350 taxa dispersed across various families and genera, halophytes make for 0.25 percent of angiosperms (Flowers et al., 2010).

Halophytes’ requirement for and tolerance of high salt concentration is so great that sometimes if the amount of salt demanded by the plant is not found in the environment, the development of the plant slows down and the plant is damaged. Very few of the halophyte plant species have this feature (Aronson and Whitehead, 1989).

In salty areas like the shoreline, the region around tiny lakes, and occasionally the interior of the land where soil salinity is higher, halophytes, or salt-tolerant plant groups, live. When the soils where halophyte plants are distributed are examined, it is seen that most of them are salty-sodium soils (Greenway and Munns, 1980).

The bedrock layer (Markert, 1972), evaporation (Waisel, 1972), tides and flooding (Leendertse et al., 1997), and salt spray at the seaside (Odum, 1960) affects the amount of salt in the soil.

Salt marshes near the sea are common worldwide and are subject to occasional sea floods. Halophytic plant groups predominate in this type of marshland, deltas at estuaries, islands and bays that are well preserved in terms of environmental conditions (Bertness, 1991).

From coastal regions to alpine valleys, halophytes are found in a variety of environmental settings (Khan, 2002). Edaphic rather than biotic factors are the fundamental forces dictating how species are distributed in salt marshes. Floods may also negatively affect halophte plants' ability to disseminate in salt marshes (Vince and Snow, 1984).

All halophytes are adapted to environmental constraints that govern their development and geographic distribution in arid regions. These restrictions include soil's physiological dryness, which is brought on by a high ion content in the soil solution, and moisture shortages induced by salts' harmful and osmotic effects on plants (Walter, 1968).

Halophytes essentially have two issues to deal with. They must first be able to endure high salt levels in their habitat. The other is that it must absorb water from a soil solution with a low water potential. Halophytes must maintain their water intake and turgor state in these circumstances by keeping their water density lower than the soil solution. If the plant achieves this by the accumulation of inorganic ions, which can easily take the ions from the soil, this is an advantage (Flowers et al., 1977).

Plants can withstand environmental stresses like salt and temperature in one of two ways. According to this theory, the first of these methods is "Escape" from stress, and plants use changes to their morphology and chemical composition to do this. The second method is called the "Endurance" mechanism, and it is well known that efforts are being made to lessen the impact of the stress factor by altering cells and tissues (Avcıoğlu et al., 2003).

The most important adaptations of halophyte plants are the secretion of salts to the environment and the preservation of a balanced salt concentration in the cytoplasm of cells. The plants control the mineral composition of their tissues by removing excess salts from tissues with the aid of the salt-releasing mechanism (Mahajan and Tuteja, 2005; Sanchez et al. 2008; Shabala and Mackay, 2011; Slama et al., 2015). Many halophytes, including *Halostachys* species and *Halocnemum* species, release salts with the aid of salt-accumulating vacuoles when the salt concentration is higher than in mesophyll cells. Another way to modify salt level is to remove salt-accumulating organs (Boyko 1968; Batanouny, 1977; Munns, 2005). Some succulent halophytes are capable of accumulating salts with large concentrations in the cellular fluid. Cell hypertrophy happens during water absorption as a result (Greenway et al., 1965; Jennings 1968).

Increased ion and low-molecular organic component content (glycine betaine, proline) in cells of halophytes leads to the formation of high osmotic pressure. Water scarcity typically increase halophytes' biological processes that are important in saline environments from an ecological standpoint. One of the distinguishing reactions is the increase of proline (Batanouny and Ebeid, 1981; Bohnert and Sheveleva, 1998; Taban et al., 1999; Öztürk and Demir, 2002; Kishor et al.,2005; Gupta and Huang, 2014). It influences osmoregulation, guards against dehydration, and provides energy and nitrogen for metabolic functions. Because it is believed to be a crucial physiological characteristic that increases the effectiveness of water absorption, a high osmotic pressure is needed in the root and shoot tissues. Therefore, a plant's general water regime may be accurately estimated using the osmotic pressure measurement, which also serves as a water balance indicator.

Among the variety of plants found in natural and cultivated flora, three distinct forms of photosynthesis are recognized: C3, C4, and CAM (Crassulacean acid metabolism). Plants that use C4 photosynthesis make up the vast majority of halophytes (Gamalei and Voznesenskaya, 1986; Glenn and Watson, 1993). Salinity decreases the net photosynthesis rate, transpiration rate and stomatal conductivity in plants and increases stomatal resistance. In higher plants, salinity changes net photosynthesis, photosynthetic parameters and pigment composition. The decrease in photosynthesis in plants exposed to salinity is due to the decrease in CO_2 fixation due to stomatal closure (Parida and Das, 2005; Stepien and Johnson, 2009; Uzilday et al., 2015).

Halophytes are often tiny in structure and bluish-green in color. They are more or less resistant to different salts in the soil (such as NaCl, Na_2SO_4) and the density of salt concentrations. Leaf colors are a result of their high content of chlorophyll, and the fact that they are rarely covered with a thick wax layer. Halophytic plants have developed these traits as a way of reducing the amount of moisture their leaves and shoots use (Black, 1973; Kılınç and Kutbay, 2008).

In the life cycle of halophytic plants, seed germination is the most important phase (Ungar, 1995). Environmental elements as light, temperature, and salinity regulate the germination of halophyte seed under natural settings (Khan et al., 2002; Guma et al. 2010, Orlovsky et al. 2011, Wang et al. 2013). Like glycophytes, halophytes can germinate more effectively in non-saline environments (Khan et al., 2004; Wang et al., 2008; Zhang et al., 2015; Çınar et al., 2016; Terzi et al., 2017; Çınar et al., 2021; Çınar and Tuğ, 2021).

Survival capacity (seed bank) without losing its vitality in high salinity soil, germination ability in extremely high salinity and capacity to complete its life cycle in very saline environments are among the most important features of halophyte plants (Khan, 2002).

3. Different Classifications of Halophyte Plants

The first scientific studies on halophyte plants started in the nineteenth century (Chapman, 1960). Waisel (1972) conducted the first investigation on the biology of these unique plants in the literature. Although halophyte plants have long been known, they were not thoroughly investigated until the 20th century. (Huchzermeyer and Flowers, 2013). However, Flowers et al. (1977) carried out the important research to comprehend the processes of salt tolerance in halophytes.

Halophytes have been classified in different categories by many researchers.

Halophyte plants were categorized into three classes by Henkel and Shakdov (1945) as follows: "Euhalophytes (salt accumulators)", "Crynohalophytes (salt expellers)", and "Glycohalophytes (salt impermeable)".

Based on how successfully the halophytes adapted to saline soils, Sen et al. (1982) categorized the halophytes into the following three classes: "True (obligate) halophytes" are plants that can only thrive at their best in saline soil (soil with a NaCl content of at least 0.5%). *Suaeda fruticosa* (L.) Forssk, *Cressa cretica* L., *Haloxylon recurvum* Bunge ex. Boiss, *Salsola baryosma* (Schult.) Dandy, *Zygophyllum simplex* L. and *Aeluropus lagopoides* (L.) Trin. are a few examples of true (obligate) halophyte plants. "Facultative halophytes" are plants that, like true halophytes, thrive best in saline soil (0.5% NaCl level) but can also grow in non-saline soil. Examples of facultative halophyte plants are *Tamarix dioica* Roxb. ex Roch, *Trianthema triquetra* Rottler & Willd., *Eragrostis ciliaris* (L.) R. Br., *Launaea nudicaulis* L., *Eragrostis pilosa* (L.) P. Beauv. and others. "Glycophytes or transitional halophyte plants" growing only at the transition of saline and non-saline areas and achieve optimal growth at non-saline habitats of the salt basin. Glycophytes or transitional halophytes: *Haloxylon salicornicum* Moq., *Sporobolus helvolus* (Trin.) Th. Dur. & Schinz, *Dactyloctenium sindicum* Boiss. and the other.

Some researchers (Woodell, 1985; Keiffer and Ungar, 1997) have classified halophyte plants as Type 1, Type 2 and Type 3 according to their relationship with inundation along a salinity gradient. The Type 1 plant species are typically only very rarely exposed to inundation. Species in the Type 2 group are exposed to more inundation than the first group. The impacts of inundations are severely exposed to species in the Type 3 category. These researchers' classifications may change depending on the geographic area, ecological conditions, ecological tolerance of the species, and competition between intraspecific and interspecific species.

According to the levels of chlorine in their root zones, Ellenberg et al. (1992) classified halophyte plants into nine categories, ranging from glycophytes to hyperhalophytes. However, Kutbay and Demir (2001) stated that it would not be possible to adapt this type of classification to all halophytes since the anion and cation types that dominate in the areas where halophytes live change.

Akjıgıtova (1995) divided the halophyte plants into four groups. Halophyte plants with a very high salt content are called "Hyperhalophytes". "Euhalophytes" are halophyte plants that are generally adapted to saline soils, but live in relatively less saline habitats. Plants known as "Hemihalophytes" have adapted to moderately salinity-containing soils. "Haloglycophytes" are halophyte plants adapted to soils with high sand content.

Halophytes can be examined under three groups within themselves (Flowers and Colmer, 2008). "Succulent halophytes" have the capacity to store salt in a variety of organs. With an increase in cell sap, they are plants that are resistant to high chloride concentrations. "Non-succulent halophytes" are plants that adapt by secreting excess salt in their tissues from the salt glands. "Salt-accumulating halophytes" have not developed special mechanisms to remove salt from the plant body. Until the plant dies, the salt they consumed is retained in the tissues.

Depending on the environments in which they grow and develop, halophyte plants are further separated into "Hydrohalophytes" and "Xerohalophytes". Water or moist soil are necessary for hydrohalophytes to grow. When halophytes germinate and reproduce in high-salinity environments (≥500 mM NaCl), they are referred to as extremophiles. Xerohalophytes are plants that can thrive in dry habitats with salty soils (Gul et al., 2013; Yuan et al., 2019).

Halophytic plants can be categorised as "'Facultative halophytes" and "Obligate halophytes" based on their tolerance and requirement for salts. While "Facultative halophytes" can thrive in non-saline environments and even in strict freshwater conditions, salt is required for the growth and development of "Obligate halophytes". "Glycophytes", on the other hand, are salt sensitive plants. Accordingly, the classification of plants according to their ability to tolerate salt is given in Table 1 (Von Sengbusch, 2003; Parida and Jha, 2010; Jimenez-Lopez, 2020).

Table 1 Plant classification based on salt tolerance (Von Sengbusch, 2003; Jimenez-Lopez, 2020).

Types	**Features**	**Examples**
Obligate Halophytes	Growth in saline habitats and stimulating the growth with salt (≥ 200 mM NaCl)	*Arthrocnemum* spp. *Frankenia* spp. *Kochia* spp. *Prosopis* spp.
Facultative Halophytes	Their growth is best under conditions of low or no salt, but they can grow under situations of moderate salt concentration (≤ 200 mM NaCl)	*Aster tripolium* L. *Atriplex* spp. *Plantago* spp. *Chenopodium quinoa* Willd.
Habitat-indifferent	Growth preferently on salt-free soils, but in salt soils has a better growth compared to glycophytes	*Salsola* spp. *Festuca rubra* L. *Juncus bufonius* L.
Glycophytes	Salt-sensitive plants (< 100 mM NaCl)	Most Agricultural crops

According to the salinity of the substrate and the texture of the soil, all halophyte species are categorized into a number of ecological groups. “Hyperhalophytes” make up about 45% of the total, followed by “Xerohalophytes” (about 29%), “Psammohalophytes” (about 16%), and other categories (weeds, chasmophytes, and phreatophytes), which make up about 6% (Aronson and Whitehead, 1989).

4. Potential Usages of Halophyte Plants

Halophyte plants are used in many areas with economic value. They can be used as food, animal feed, fuel, essential oils, gum, medicines, fiber, bread and among many other things (Somers, 1982).

The importance of halophytes in terms of food cannot be underestimated. These plants can be eaten in a variety of ways, including cooked, raw, pickled, with vegetable oil, crushed powder, salt, and salt alternatives. Consumable halophyte plant parts include leaves, fruits, young shoots, roots, seeds and flower buds. Some of the plant genera with the highest consumption rates of halophytes include *Salsola*, *Chenopodium*, *Bassia*, *Suaeda*, *Plantago*, *Salicornia*, *Portulaca* and *Atriplex* (Tug and Yaprak, 2017).

In the world's flora, there are around 150 halophyte species of feed value. Halophytes are distinctive as forage crops because they have a high enough nutritional value. These characteristics enable the use of halophytes as a feed source for camels, sheep, and goats in arid regions. In particular, *Atriplex* spp. are evaluated as fodder, oil and ornamental plants (O'Leary, J.W. 1985; Aronson and Whitehead, 1989; Shamsutdinov et al., 2017).

The salt-tolerant *Grindelia camporum* Greene plant contains gum and is used in glue, polish, paper, ink, soap and many industrial areas. Some of the halophytes have taken their place in many fields, such as ornamental plants (*Frankenia hirsuta* L.), wares (*Juncus* spp.), and cosmetics (*Simmondsia chinensis* (Link) Schneider) (O'Leary, 1984; Kılınç and Kutbay, 2008).

Halophyte-based landscape design is a method of regulating harsh climatic conditions. It reduces adverse environmental impacts and is often more cost effective than solutions to protect structures such as light, wind and noise. It would be highly beneficial to promote an attractive crop production program for halophytic plants in hot, arid areas with limited drinking water resources. Approximately 240 species of halophytes, representing different types of life, have varying degrees of decorative appeal (Aronson and Whitehead, 1989; Shamsutdinov, 2003).

Some halophytes (For example, *Salsola baryosma* (Schult.) Dandy, *Zygophyllum simplex* L., *Salsola kali* L., *Kochia indica* Wight,) which originate and flourish in naturally saline environments, are commonly employed in medicine (Dagar, 2005). *Glycyrrhiza glabra* L. and *Glycyrrhiza uralensis* Fisch. are mesohalophyte plants and are used commercially as a medicine, feed and bioremediation product (Shamsutdinov et al., 2017).

Halophytic plants are used as wood fuel. The production of fuelwood frequently involves the use of salt-tolerant trees and shrubs such the *Tamarix*, *Prosopis*, *Casuarina*, *Kochia*, *Acacia*, *Salsola*, *Capparis* and *Salvadora* species. Some halophytes such as *Casuarina*, *Tamarix* and *Haloxylon* are suggested as energy inputs in salt water irrigation. Halophytic plantations serve as both energy storage and energy-producing renewable biological resources (O'Leary, 1984; Dagar, 2005; Shamsutdinov et al., 2017).

Halophytes have habitat-forming and habitat-optimizing roles, and as a result, they improve salinized soils (Shamsutdinov, Z.S. and Shamsutdinov, N.Z., 2002). The plants' fresh organic matter serves to alter the soil's pH, electrical conductivity, and hydraulic conductivity while also enhancing its physicochemical characteristics and biological activity.

5. Conculusion

Halophytes are extremely unusual and unique plants that can grow and thrive in a variety of climate and soil salinity conditions around the world. These plants have many functions, especially the protection of ecological balance. Although they are often neglected, studies on halophytes in recent years have emphasized the importance of halophytes in many areas and provided their value to be understood.

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CHAPTER III

CONVENTIONAL EXTRACTION TECHNIQUES FOR PLANTS

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1. Introduction

Extraction is one of the most important step for the separation of the desired compounds from plant or animal tissues. The process is widely used in many fields such as modern and alternative medicines, food supplements, pharmaceutical intermediates, nutraceuticals, folk medicines, etc. Plants are the most common raw materials that used in the extraction of therapeutic compounds. Owing to the fact that, plants contain beneficial phytochemicals at low concentrations, extraction efficiency plays an important role in terms of obtaining of the targeted compound.

It is known that, plants have been used in folk and alternative medicine since ancient times due to their curative and protective properties. Nearly, 50% of clinical drugs are derived from natural sources and 25% of the total constituted from plants (Van and Prinsloo, 2018; Hayta et al., 2014). In developing countries, a large part of the population benefit from plant-based products for health-care needs and in developed countries natural medicines have gained interest due to rising health-care costs (World Health Organization, 2013).

Curative properties and diverse biological activities of plants mainly depend on their secondary metabolite contents. Different parts of plants such as roots, fruits, seeds, leaves, flowers, and stems contain various bioactive compounds including phenols, flavonoids, tannins, alkaloids, fixed oils, volatile oils, steroids, glycosides, and resins (Li et al., 2006).

These beneficial phyto-compounds possess therapeutic effects and have been used in the prevention and treatment of chronic, cancer, and cardiovascular diseases. On the other hand, plants contain low quantity of active natural compounds (Zhang et al., 2018). Therefore, it is important to select the most effective extraction technique/solvent/extraction time etc. for the targeted compound. Although new and greener technologies are gained interest in recent years, conventional extraction techniques are still widely used by many researchers. Conventional extraction techniques are low cost, simple and easy to apply and extensively used in daily life routine. So, in this chapter, conventional extraction techniques along with their advantages and disadvantages are discussed in order to determine the most suitable extraction method.

2. Conventional Extraction Techniques

The conventional extraction techniques include percolation, maceration, decoction, infusion, digestion, reflux and Soxhlet extraction. These methods generally require long extraction time and high quantity of solvents. Conventional extraction techniques can be divided into two main groups: Cold extraction methods and hot extraction methods.

2.1. Cold Extraction Methods

2.1.1. Percolation

Extraction of active compounds is performed with a percolator that usually made of glass, porcelain, enamel, or stainless steel. Dried and powdered plant material is soaked with the extraction solvent and then placed into the percolation tank (Figure 1). After sufficient amount of solvent addition, the mixture is kept for 4 h (Abubakar and Haque, 2020). Percolation is a continuous extraction method, i.e. the saturated solvent is replaced with fresh solvent and therefore, it is more efficient than maceration method (Zhang et al., 2018). Solvent addition is maintained until the total volume of solvent reached 75% of the desired amount of entire preparations. The crude extract is obtained after filtration and evaporation processes. Percolation is used in the fields of material science, physics, epidemiology, geology, and other fields. It is also applied for coffee brewing in daily life.

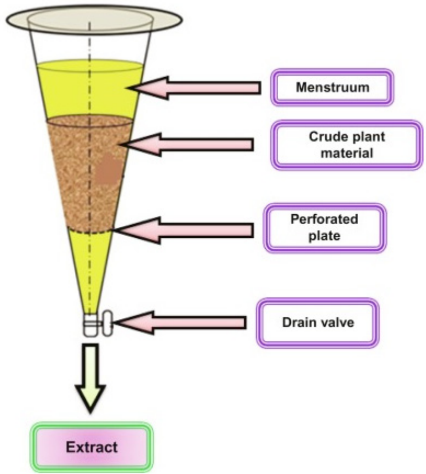

Figure 1. Schematic diagram of percolation process (Mukherjee, 2019)

2.1.2. Maceration

In this technique, the solid material is pulverized, kept for a certain period of time (at least three days) by mixing with a certain amount of solvent in a container at room temperature (Figure 2a). After the end of the extraction, the mixture is filtered and the mark is pressed. Finally, filtrates are combined and subjected to straining process in order to obtain clear solution (Azwanida, 2015; Ingle et al., 2017; Majekodunmi et al., 2015). This technique is generally applied to overcome possible difficulties that may be encountered in filtration processes in the presence of gums, balsams, resins, soap, etc. Water, aqueous and non-aqueous solvents can be used in this method. Polarity of the natural compound depends on the extraction solvent (Zhang et al., 2018).

2.2. Hot Extraction Methods

2.2.1. Decoction

Decoctions are prepared by adding water to the herb following by heating process for 20-30 min (Figure 2b). After cooling to about 40°C, the marc is pressed and filtered. The prepared decoction is used entirely or diluted, as well (Nagalingam, 2017). It is generally suitable for hard herbal drugs such as root, stem, bark, wood, etc. Water is used as a solvent and the plant material is cut into small pieces and boiled with water for the stated time. Water soluble compounds and heat-stable components can successively extracted with this method.

2.2.2. Infusion

This extraction method is similar to the maceration method. In infusion method, it is possible to extract flavors and other chemical compounds from plant using alcohol, water or oil as a solvent which allows to suspension of the material in course of time. The powdered plant material is placed into a container. The solvent (cold or hot) is added to the container and let for incubation for a period of time (Figure 2c) (Ingle et al., 2017). Maceration or percolation methods are modified in order to obtain concentrated infusions. For the preparation of infusions, generally 1:10 plant material/water ratio is used.

2.2.3. Digestion

Digestion is a kind of maceration technique. The main difference is the extraction temperature. Extraction with digestion method includes relatively higher temperature than maceration method. It is generally used for woods and hard barks that are difficult to penetrate with water. It includes a gentle heating process. When a moderately elevated temperature is required, this technique is used increase the effectiveness of the solvent (Mehta, 2003). The process is performed in a metal vessel which known as "digestor". The material is placed into the digestor and extraction is carried out at a definite pressure and temperature, as well.

a b c

Figure 2. Conventional extraction techniques
a) Maceration b) Decoction c) Infusion

2.2.4. Reflux Extraction

The plant material is placed in a round bottom flask containing the extraction solvent. The round bottom flask which is surrounded by a heating mantle is conjunct with a condenser (Figure 3). The system is started to heat and when the solvent reach its boiling point, evaporation and condensation processes occur consecutively. Condensation of the extraction solvent facilitates to perform extraction process without loss of solvent.

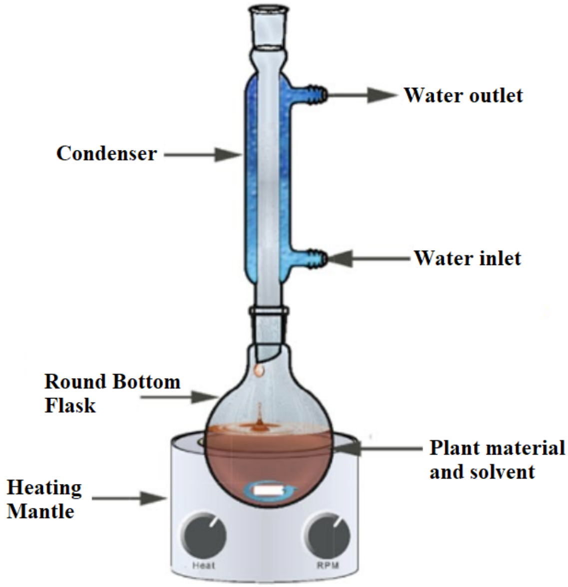

Figure 3. Schematic diagram of reflux extraction (Aditha et al., 2016)

2.2.5. Soxhlet Extraction

Soxhlet extraction system (Figure 4) is a simple and effective extraction technique that has been used for the extraction of wide range of samples including plant tissues, animal, sediments, and soil with various solvents (De Boer, 2001). A Soxhlet extractor system consist of a heater, thimble of thick filter paper, siphon mechanism, and condenser. The crushed plant material is put in thimble. Soxhlet extractor which is conjunct with a condenser is placed onto the solvent flask and started to heat. As the temperature of the solvent starts to increase, vapor moves towards to the distillation arm, floods into the chamber. The plant material in the thimble soaks with the solvent slowly and the soluble compounds dissolve in the extraction solvent. After the siphon tube fills with the solvent, the extract (solvent and dissolved compounds) syphons away from the Soxhlet extractor and runs back down to the distillation flask (Raynie, 2019). The cycling process may maintain several times. Finally, the solvent is removed by means of a rotary evaporator to obtain the extract.

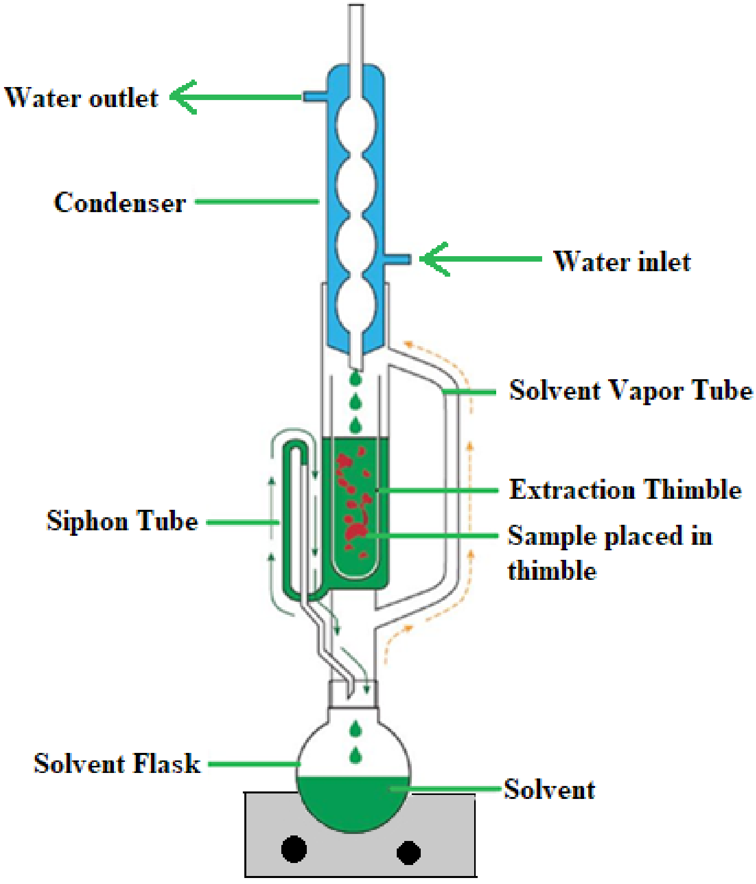

Figure 4. Schematic diagram of soxhlet extraction (Guimarães et al., 2021)

Advantages and disadvantages of the conventional extraction techniques are given in Table 1.

Table 1. Advantages and disadvantages of the conventional methods (Wang et al., 2020; Rasul, 2018; Zhang et al., 2018; Devgun et al., 2010; Khan et al., 2005)

Technique	**Advantages**	**Disadvantages**
Maceration	The method is simple	Extraction time is long
	It is used for thermolabile components	Extraction efficiency is low
	It doesn't require equipment	The process is slow
	It is performed at room temperature	Large volume of solvent is required
Percolation	The process is easy	It needs long extraction time
	It is suitable for wide range of natural products	Large volume of solvent is used
	Extraction of unstable compounds can be performed successively	Particle size is an important parameter
	It is suitable for costly drugs	Energy consumption is high
Decoction	It is suitable for heat stable compounds	Not suitable for volatile or thermolabile compounds
	Application is easy	Adjustment of final volume is necessary
	No need expensive equipments	Further filtration process is required
Infusion	It can be used for preparation of fresh extracts	Infusions are sensitive to bacterial and fungal growth
	Extraction of well-soluble bioactive compounds can be achieved easily	Fresh infusions must be used in a short period of time
	There is no need to adjust the final volume	It requires a filtration process
Digestion	It is proper for the extractions which performs at moderately elevated temperatures	It is not suitable for thermolabile compounds
	Efficiency of solvent can be incresased	Further filtration process is needed

Reflux extraction	It can use for toxic reagents	Requires a large volume of solvents
	It performs efficient extraction	Extraction time is long
	The equipment is not complex	Thermal degradation may be occur due to the high extraction temperatures
	Insoluble impurities can extract successively	It needs a filtration process after extraction
Soxhlet extraction	It provides quite efficient extraction	Extraction process is long
	It facilitates to perform extraction multiple times	Requires a large volume of solvents
	The process is simple	It has limited extraction efficiency
	It doesn't require further filtration	The process is labor intensive
	The method is generally used for as a benchmark in the comparison of new extraction techniques	Extraction of polar lipids is poor

3. Recent Developments

There are three important points in the industrial application of extraction techniques: energy, plant material, and solvent consumption. It is important to choose the best extraction method to obtain active compounds from plants. The incontrovertible reasons for improving new extraction technologies are reducing solvent consumption, performing extraction process in a short time, and restraining decomposition of the active compounds (Mohammad Azmin et al., 2016; Ameer et al., 2017). Therefore, in recent years, modern and greener technologies have taken the place of conventional extraction techniques providing less time extraction, less energy requirement with higher selectivity (Zhang et al., 2018). These are Pressurized Liquid Extraction (PLE), Supercritical Liquid Extraction (SLE), Ultrasound Assisted Extraction (UAE), Microwave Extraction (ME), Pulsed Electric Field Extraction (PEF), Enzyme Assisted Extraction (EAE), Water Distillation and Steam Distillation, and Ohmic Heating Extraction (OHE).

4. Conclusion

The demand for extraction of bioactive components with high efficiency, less solvent and time consumption canalized people to develop and/or combine various extraction techniques. In this point of view, there isn't any standard extraction technique for ideal extraction that covers all plants, i.e. extraction techniques are authentic to the plants. It depends on the chemical structure, solubility, polarity, physical and chemical properties of the targeted compound. Therefore, it is important to decide the most convenient technique for the desired compound.

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CHAPTER IV

ACQUISITIONS AND RISKS OF GENETICALLY-MODIFIED ORGANISMS IN PLANT PRODUCTION

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1. Introduction

The beginning of science and technologies regarding Genetically-modified Organisms has found its place in the depths of history depending on the developmental process of previous civilizations. Approximately 10.000 years ago, when civilizations were established and developed, human beings started to cultivate animals and plants to cover their organic needs (Merdol Kutluay, 2012). It is already known in the first inscriptions about the old and new world that observation-based selections were made in terms of yield and quality in cultured plant and animal populations. The industrialization of various societies, identification, and culture of microorganisms were developed with the development of the methods for agricultural production. The selection of microorganisms and their use in the classical fermentation industry are known examples of the first biotechnological applications, especially in the food sector

(Budd, 1993). The use of Mendel's inventions in the 1860s in plant genetics in plant cultivation prepared the ground for developments called the "green revolution" in history and made significant contributions to the development of new hybrid plant genotypes (Yaşar et al., 2017). However, changing environmental conditions over time and the rapidly increasing world population made it necessary to obtain higher yields and better quality products per unit area in agriculture. Increasing crop production is possible by expanding the production areas or increasing the yield obtained from a unit area. Agricultural areas are not expanding in parallel with the increasing world population. To increase the yield per unit area, on the one hand, the genetic structure of the plants must be improved and on the other hand, the agricultural techniques used in cultivation must be applied well. Although the chemicals used in fertilization, irrigation, and the fight against diseases and pests in plant production in the last century provided great increases in yield, it was found that these applications, also have negative impacts on the ecological balance on the earth in the long term, especially when used unconsciously. In this regard, it turns out that yield increases in plant production can be achieved by improving the genetic structures of plants and applying the inputs more consciously (Özgen et al., 2005).

As a plant production material, seeds have strategic importance for the agricultural sectors of the countries and are the basis of the agricultural development mechanism. They are also the reproduction material of many plants and constitute the first link of the food chain and the structural indicator of biological and cultural diversity. In parallel with the transformation of agriculture from a form of livelihood into economic activity and a contemporary industry, the reproduction method of seeds, which are the most basic input of plant production, has undergone a similar evolution. As one of the sub-sectors providing input to agriculture, seed growing directly or indirectly provides several contributions to the national economy, especially in terms of increasing production and quality, employment, added value, foreign exchange savings, or export revenues (DPT, 2007). Seeds that do not carry the high yield potential genetically may not show high performance even if the environmental conditions are suitable. For these reasons, the development of hybrid varieties provides great benefits in terms of seed development. Recent developments in hybrid cultivar production, the advances in genetic engineering, the selection, identification, and development of new cultivars by using molecular methods, and regulations in the use of GMOs have brought the industry into an important competitive setting.

It is already known that the quality and quantity of crops will be increased with the studies in the field of biotechnology, and the resistance of crop plants to negative conditions such as salinity and drought, especially diseases and pests, will be acquired. Modern methods were developed as well as classical cultivation methods to obtain plants with these qualities. Classical cultivation requires a very long time to collect the genes that determine the desired characteristics in a genotype and brings great labor and expense. The low number of species that can be hybridized with classical cultivation methods is an important factor that limits success in this area. Biotechnology, on the other hand, can use the genetic resources that exist in nature without any limit. The necessity of cross-cultivation in gene transfer between different species and breeds will be eliminated because an isolated gene is directly transmitted with the application of new biotechnological techniques, and it will be not necessary to hybridize in the gene transfer between different species and genera, the problem of sterility and incompatibility, in other words, natural isolation, which is the most important obstacle in utilizing wild gene resources in classical cultivation, is resolved. After these transferred genes are placed in the organism, they work like natural plant genes and produce proteins (Özgen et al., 2005). The process applied for this purpose is called gene transformation, and the obtained plants are called genetically-modified plants or transgenic plants (GMOs). The use of transgenic plants has opened many new areas that encourage agricultural advances in plant biotechnology after the 1980s when the first transgenic plants were produced (Sağıroğlu, 1999; Kaynar, 2009). Many transgenic agricultural plants were planted in large areas and their products have taken their places on the shelves after the beginning of the production of these plants. Differences in the cultivation or consumption of genetically-modified crops have begun to emerge between countries over time within the framework of biosafety laws. In our country, in line with the "Biosafety Law" that entered into force in 2010, the consumption of transgenic products as "animal feed and supplementary food (baby formulas) was allowed, but its cultivation and use as human food were prohibited (Biosafety Law, 2010). Many products developed with biotechnological methods are commercially available in our present day.

Fields, where commercial transgenic plants are produced, are basically grouped under three generation classes (i.e., primary, secondary and tertiary generation genetically-modified organisms) (Smith, 1996; Briggs and Koziel, 1998; Holmberg and Bülow, 1998; Ölçer, 2001). Studies that were conducted in the first years of commercialization of genetically-modified products focused on input-oriented characteristics (e.g., herbicide tolerance, insect and pathogen resistance), directly regarding the farmer, helping to grow agricultural plants resistant to biotic and abiotic stress factors, and were defined as first-generation genetically-modified organisms (Öktem, 2004a; Öktem, 2004b; Yuzbasioglu et al., 2017). The production purpose of first-generation genetically-modified organisms in the production phase was to increase the farmer's profit rate and crop yield (Korth, 2008). The widely acquired herbicide tolerance characteristic reduces farmers' crop costs at significant levels. Also, pesticide use decreases during the production of plants in which the CRY gene from *Bacillus thuringenis* (Bt) is transferred, which is effective against harmful caterpillars that damage crop yield, especially in areas where corn and cotton are grown. This application, which provides economic conditions, will eliminate the negative impacts of chemical drugs applied on the environment and human health (Rahman et al., 2015; James, 2016). Second-generation genetically-modified organisms, which are herbal products developed for the use of consumers, are not very common in the market yet because they are under development (Meriç, 2012). Studies continue to change or improve the nutritional values of plants through biotechnology methods. Rice called "golden rice", which contains increased beta carotene/vitamin A, is the most recent example of second-generation genetically-modified organisms (Ricroch et al., 2018). Third-generation genetically-modified organism products can also be defined as green factories. Two main characteristics come to the forefront in these genetically-modified generation products. The first is to give the plants medicinal characteristics by transferring the genes that contain very expensive drugs and vaccines, which are very important for human health, to plants. The second is the studies to obtain plants suitable for biofuel production by transferring genes to oilseed energy plants such as camelina (*Camelina sativa* L.), corn, sorghum, canola, soybean, and sunflower. It is considered that the third-generation GMOs, whose R&D studies are continuing today, will yield successful results in the future and the production stage will start (Nofouzi, 2013). The most important transgenic plants traded are Cabbage (*Medicago sativa*), apple (*Malus domestica*), canola (*Brassica napus*), corn (*Zea mays* L.), cotton, (*Gossypium hirsutum* L.) papaya (*Carica papaya*), potato (*Solanum tuberosum* L.), soybean (*Glycine max* L.), pumpkin (*Cucurbita pepo*), rice (*Oryza sativa* L.), and sugar beet (*Beta vulgaris*) (ISAAA, 2019).

In this chapter, the purpose was to discuss the acquisitions and risks of genetically-modified organisms in plant production by reviewing the literature data in this respect.

2. Acquisitions in Genetically-Modified Organisms

2.1. Impacts on Human Health

2.1.1. Increasing Nutrient Contents of Plants

An increase in plant yield and quality can be achieved with biotechnological applications. An increase in plant quality means increased taste, structure, appearance, and nutritional value of the plant. Applications such as increasing the dry matter ratio in tomatoes and the unsaturated fatty acid ratio in soy are beneficial for health. Increasing the nutritional value of plants is an important application in the protection of human nutrition and health. According to previous studies, 14 million children face incurable eye damage because of vitamin A deficiency (Ergin and Yaman, 2013). According to WHO data, 30% of the world population has iron deficiency, which creates problems such as reducing learning ability and increasing infection risks. Scientists produced a type of rice that increases the amount of vitamin A and the iron content was doubled in another type of rice (van den Bergh, 2002). The level of antioxidant vitamins and minerals, which are the cause of the development of some cancers, heart disease, and blindness, and which are compounds that slow down or prevent biological oxidation, which is a harmful chemical reaction, in the products are increased with the gene transfer technology. The level of vitamin C, which is very important for human nutrition, has been increased in strawberries with genetic modification technology (Sarıca and Kılınç, 2004). Increasing the antioxidant level of plants will reduce the rate of certain cancers and other chronic diseases in the community. Lycopene, which is an important antioxidant, is abundant in genetically-modified tomatoes, tomato products, and peppers. Fats that have high saturated fat content cause high cholesterol in humans. The cholesterol ratio in the body can be controlled by increasing the unsaturated fat ratio in genetically-modified soybean and rapeseed varieties (Çiçekçi, 2008; Spök, 2006). Potato varieties that had high starch content, wheat varieties with increased gluten and bread quality and cereal varieties with increased amino acid ratio were also produced (Çiçekçi, 2008). It was ensured with transgenic methods that fish secreted more growth hormone and thus increased meat yield (Kulaç et al, 2006).

2.1.2. Edible Vaccine Production

Vaccination is the most effective method in preventing many diseases and is often expensive and requires special storage conditions. Research conducted with transgenic plants offers the opportunity for large-scale production of safe, pure, and highly potent therapeutic proteins. Plants synthesizing various proteins of pathogenic microorganisms are obtained utilizing the genes to be transferred to the plants we consume and these plants are tried to be used as vaccines. Genetically-modified fruits and vegetables are used against Hepatitis B, diarrhea, cholera, measles, and many other diseases (Le et al., 2004). The lineage of some tropical plants (e.g., bananas) was altered to produce proteins that can be used against intestinal diseases common in developing countries (e.g., Hepatitis, rabies, dysentery, cholera, and diarrhea). Studies conducted on using plants for vaccination, which is an effective method for the prevention of diseases that threaten people's lives, continue (Kartal and Onbaşılı, 2013). A vaccine has been developed from yeast for the Hepatitis B virus, which causes chronic liver disease, but the expensive cost of the vaccine has limited its use in the present day. Genetically-modified potato and tobacco plants producing Hepatitis-B surface antigens were obtained by using biotechnological methods in the USA. The Hepatitis-B gene was successfully expressed in potatoes, then the potato tubers that contain this gene were fed to mice and it was observed at the end of the experiment that the defense systems of the mice responded as expected (Korkut and Soysal, 2013). Similar studies on the banana plant are conducted in developing countries such as India (Kumar et al., 2005; Nofouzi, 2013).

2.1.3. Treatment of human diseases

Increasing the nutritional values of plants (e.g., vitamins A and C) has a positive impact on human health. The levels of antioxidants, vitamins, and minerals in foods are increased with gene transfer technology for the treatment of some diseases. Vitamin C is important for human nutrition. Increased levels of vitamin C were achieved in strawberries with biotechnological methods (Sarıca and Kılınç, 2004). Increasing the level of antioxidants, especially in fruits and vegetables, will lead to a decrease in some cancers and other chronic diseases in society. Lycopene, which is an important source of antioxidants, was increased in tomatoes, tomato products, and peppers produced with genetically-modified biotechnological methods. The rate of unsaturated fat can be increased by changing the genetics of soybean and rapeseed and the cholesterol ratio in the body can be controlled in this way (Çelik and Balık, 2007). Genetically-modified vegetables and fruits are effective against Hepatitis B, cholera, measles, diarrhea, and many other diseases. Some animals are cloned and used in the field of healthcare by producing suitable fetal cells of some organs (heart, kidney, liver) required for transplantation to humans (Ergin and Yaman, 2013).

2.2. Importance in terms of agricultural practice

2.2.1. Endurance to insects and herbicides

Herbicides are chemicals that manufacturers cannot stop using and it is desirable that a good herbicide can control all undesirable plants other than agricultural products, be safe for the environment, and have a minimum amount of residue in the soil (Öktem, 2004a). The majority of transgenic plants developed for plant health are herbicide-resistant plants. The most important step in the development of herbicide-resistant crop plants is to understand the herbicide's impact on the plant at the molecular level. In our present day, there are many studies conducted on herbicide resistance. Successful results were obtained from some of them and they were put into practice. For example, genetically-modified tobacco resistant to Dalapon herbicide was obtained by transferring a gene from *Rhizobium sp* by using recombinant DNA technologies to the tobacco plant (Kaya et al., 2013). Another study was conducted to evaluate the possibilities of obtaining Imidazolinone group herbicide-tolerant (IMI) cotton (*Gossypium hirsutum* L.) genotypes through mutation. As a result, it was shown that IMI-tolerant cotton varieties can be developed through mutations (Atıntaş, 2020).

2.2.2. Increasing the yield of plant and animal products

The inability to cover nutritional needs is an important problem because of the lack of arable lands in parallel with the increasing world population. Also, freshwater resources that can be used in agricultural production are rapidly decreasing. Product yield per unit area must be increased for this reason. The use of gene transfer technology in plant and animal cultivation studies has become inevitable because classical cultivation methods are costly, require intensive labor, and a long time (Kıyak, 2004). Genetically-modified plants can be used to increase crop yield and reduce crop loss by producing plants resistant to various environmental factors (e.g., insects, weeds, herbicides, viruses, salinity, pH, temperature, frost, drought, and weather) (Uzogara, 2000; Kıyak, 2004). The increase in global production can be achieved by increasing efficiency and decreasing product losses. Important annual grain crops can be genetically-modified to turn into perennial crops through which erosion can be reduced by less treatment of the soil, and also crop yields can be obtained throughout the year

(Uzogara, 2000; Hemmer, 1997). Also, the drought resistance of genetically-modified plants may reduce the use of water in agriculture, which will make these plants suitable for cultivation in some tropical and arid regions where water is insufficient. Increasing the resistance of crops to other environmental stress factors (e.g., extreme pH, salinity, insects, temperature, etc.) helps re-use the cropland around the world that is currently unsuitable for crop production. In this way, the pressures on natural resources that cannot be compensated (e.g., rainforests) are reduced (Uzogara, 2000). Resistance to environmental stresses may be the result of complex interactions of many genes. For this reason, it may take time to bring these characteristics to plants (Zülal, 2003).

Cloning has largely led to the production of livestock animals to meet the demand for protein products and meat. Milk production in dairy cows given rSBH (recombinant bovine growth hormone), which was approved by the U.S.A. Food and Drug Administration in 1993, was increased. For this reason, it is considered that these products can be produced in abundance to export these products to countries with insufficient meat and milk resources. Genetically-modified animals can be used for purposes such as lactose-free milk, low-fat milk, low-fat meat, special protein meat, special quality meat, and milk production (Uzogara, 2000).

2.2.3. Improving Organoleptic Characteristics and Extending Shelf Life of Fruits and Vegetables

Flavr Savr Tomatoes are the first genetically-modified crop that was approved by the U.S.A. Food and Drug Administration. These tomatoes are plants with a long shelf life by delaying ripening, softening, and rotting processes (Uzogara, 2000). Ripening and softening are largely dependent on ethylene production by fruit cells (Arda, 1995). Ripening in fruits and vegetables can be delayed by controlling the genes that play roles in ethylene production or, as a different strategy, by suppressing the enzyme polygalacturonase, which is an enzyme disrupting the cell wall, by delaying pectin degradation (Arda, 1995). In this way, high-quality organoleptic characteristics (e.g., odor, flavor, softness/hardness, and longer shelf life) can be achieved. Slowing or delaying ripening can also be achieved on crops such as raspberries, strawberries, pineapple, and peaches. Extending the shelf life of the products will facilitate transportation, storage, and processing for the manufacturer and the seller, and will provide the consumer with the opportunity to use the product for a long time without spoilage. The ability of products to withstand transportation and processing will also be beneficial for farmers and consumers in developing countries where cooling systems are unsafe and expensive and the transportation network is insufficient (Uzogara, 2000).

2.3. Impacts on the Environment

The most important environmental benefit of genetically-modified organisms is that they allow less use of chemicals that cause environmental pollution. Also, petroleum and its derivatives and Polycyclic Aromatic Hydrocarbons (PAH), which are produced as a result of industrial development, pose great risks to soil and water resources. PAHs contaminated with the environment are primarily degraded by bacteria and fungi. However, microorganisms alone can metabolize hydrocarbons at limited rates. By using Recombinant DNA Technology, the genes that determine the ability to degrade harmful compounds existing in nature can be added to plasmid DNA, which can be transferred from other organisms by transformation or conjugation. For example, it is already known that the phthalene, salicylate, camphor, octane, xylene, and toluene-degrading characteristics of *Pseudomonasspp* bacterium were encoded on plasmids. The transfer of PAH-degrading plasmid or gene fragments to bacteria by using recombinant DNA technology contributes to the emergence of new strains in cleaning the environment from hydrocarbons in a shorter time (Vines, 2002).

3. Damages of Genetically-Modified Organisms

3.1. Damages to Human Health

3.1.1. Allergy

The most common negative impact of genetically-modified organisms on humans is allergic (van den Bergh., 2002). Allergies can occur in the form of swelling of the tongue and lips in the mouth, itching on the skin, eczema, and rashes, or in the form of redness and edema in the eyes. There might also be difficulty in breathing in the lungs or abdominal cramps, diarrhea, and vomiting in the gastrointestinal tract. Even small changes in protein sequences in foods can cause allergic conditions. The body does not recognize these newly taken proteins for the first time, and for this reason, produces allergic conditions and different responses in the immune system. Also, the protein gene, which is allergic in a person, can be transmitted with foods that people can trust and consume safely (Ergin and Karababa, 2011). In previous studies, it was reported that the transgenic change of foods with low methionine content to different types of foods rich in methionine causes allergies in those who are allergic to methionine-rich foods (Nordlee et al., 1996). Allergic conditions were also encountered in people working in the cotton industry producing Bt toxin in India, which is an Asian country. Allergic symptoms such as eye, and skin reactions and respiratory distress were also observed most frequently (Conner et al., 2003).

3.1.2. Toxic impacts

One of the problems caused by genetically-modified organisms on living organisms is toxic impacts, which include new gene products transferred and secondary products that occur depending on these genes. Lethal genes in GMO plants accumulate in the cell and tissue systems of living organisms and cause toxic impacts. In gene transfers, important metabolic events are seen in cells. The most important of these metabolic events is the differentiation of enzymes and proteins in the cells of living organisms, which suggests that the reason for this change may be because of their toxic impacts (Bruetschy, 2019).

3.1.3. Antibiotik resistance

Controversially, the problem caused by genetically-modified organisms on living organisms is antibiotic resistance. Foods with genetically-modified organisms create resistance to antibiotics with the genetic materials they have. The genetic materials reaching the bacteria in the gastrointestinal tract of living organisms can cause significant problems. Antibiotics develop because of such a transfer (Şahin, 2003). These genetic materials pass on to the bacteria in the body of living organisms and become resistant to antibiotics. However, such a transition could not be proven experimentally (Gücükoğlu and Küplülü, 2006). WHO released a decision in 2004 regarding this genetic material transfer in line with the abandonment of methods of adding marker genes to the cell. However, it was observed that the biotechnology partners did not comply with this decision. It was determined that antibiotic-resistance genes with popular performance are still in use (Ergin and Karababa, 2011)

3.1.4. Cancer risk

It was reported in previous studies that genetically-modified organisms may have direct or indirect carcinogenic impacts. It is already known that chemicals such as “bromoxynil” and “glufosinate” that are used in cotton, soybean, corn, and rapeseed varieties that provide resistance to herbicides are directly carcinogenic (Haspolat, 2012). Also, it is an important question what the consequences of transferring a plant, animal, virus, or bacterial DNA particles to a human or animal genome will be in terms of human health. Although the DNA that is taken with diet is generally fragmented in the mammalian gut, this fragmentation is not complete and instantaneous, and sometimes DNA can remain stable. For this reason, it was reported that it is theoretically possible for foreign DNA fragments taken through food to pass into the circulatory system without being fully digested in the digestive system, and from there to human or animal cells (Hemmer, 1997). For example, in maize-fed cattle and chickens, maize chloroplast DNA was reported to enter various tissues (Hemmer, 1997; Einspanier et al., 2001).

3.2. Alterations in nutritional value

Transgenes that are transferred to food products can reduce the level of some nutrients when giving plants desired characteristics. It was shown in a study that compared the phytoestrogen level of herbicide-resistant transgenic soybean and conventional soybean that the phytoestrogen level in genetically-modified soy was significantly reduced by 12-14% (Lappè et al., 1998). It was also found that the level of tocopherol decreased significantly in genetically-modified canola, whose carotene content was increased by 50 times when compared to non-GMO controls. Although gene transfer increased the vitamin A content of canola, it caused a decrease in vitamin E levels (Spök, 2006).

3.3. The destruction of biological diversity

The most important problem with transgenic plants is the danger of destroying the natural structure of countries. It was reported in previous studies that genetically-modified organisms may affect the species distribution in the ecosystem, disrupting the balance, and for this reason, causing a global environmental and nutrient crisis (Hails, 2000). The geographical location, climate, fauna, and flora characteristics of the country must be known in detail to examine the environmental impacts caused by the cultivation of transgenic plants. It is considered that transferred genes to natural plant species may cause loss of genetic diversity in the natural species of their environment, deviations in the natural structure of wild species, and disruption of the balance and species distribution in the ecosystem by promoting one-way evolution as a result of one-way chemical application (Özgen, 2015).

3.4. Increasing endurance to harmful organisms

New genetic traits that are transferred to plants, (e.g., herbicide and insect resistance) may escape to native species, wild species, and insects during cross-pollination. Transgenic plants contain the insecticidal protein, although Bt toxin is only transiently present in the plant when applied by spraying. This continued exposure can increase the likelihood of resistant insect formation. Also, plant DNAs are destroyed during the decay of genetically-modified plants and various resistance genes can be taken up by soil microorganisms. It is considered that these situations may lead to the emergence of resistant weeds and insects. Although it is considered that genetically-modified plants will reduce the use of herbicides, pesticides, and artificial fertilizers soon, it is also considered that this may cause an increase in environmental pollution by increasing the dependence on agricultural chemicals even more because of the increase in resistance of long-term pests (Çelik and Balık, 2007).

3.5. Transition of GDO genes to the soil, water and ecosystem

Dead zones occur in the soil around the seed and the microbial balance of the soil is disturbed when seeds are planted with tetracycline to activate the terminator gene. For this reason, it is considered that as a result of applications with chemicals, the soil becomes polluted, various microorganisms living in the soil die, and the structure of the soil may be damaged (Anonymous, 2010).

3.6. Genetic contamination

Genetically-modified pollen from the regions where genetically-modified organisms are effective is carried by wind, birds, and insects to areas where both organic and classical agriculture are made, which causes contamination in the DNA of cultivated plants. Traits transferred from transgenic plants to their wild relatives through pollen may cause the genetic structure of valuable plant gene resources to deteriorate. Agricultural warfare may become impossible because of the "super weeds" that will be formed as a result of passing the herbicide resistance gene to weeds (Haspolat, 2007).

3.7. Damage to beneficial organisms

All transgenic plants that contain insecticidal crystal protein can also affect another organism in their environment. For this reason, the target of the transgene can be a pest or pathogen, or non-target organism. Non-target organisms affected by insect-resistant varieties are collected under 5 headings; Beneficial species (natural enemies of pests and pollinators), Soil organisms, Non-target herbivorous insects, Non-hazardous and neutral species, and other species that contribute to local diversity. In a previous study conducted on the monarch butterfly, which is one of the important insect species of America, it was stated that the larvae that eat the pollen-covered leaves of transgenic corn varieties are damaged (Losey, 1999).

4. Conclusion

The distribution of genetically-modified plants and the food obtained from them is increasing rapidly on a global scale. However, the short and long-term impacts of these products on human health are not known sufficiently. Transgenic products must be investigated more thoroughly and in detail before they can be used for human nutrition. Also, the irreversible negative impacts of these products on agricultural lands, food safety, and the environment must be considered and, if they threaten genetic diversity, an irreversible process will also be faced. For these reasons, such products must be offered for consumption after sufficient scientific studies are conducted, and their use must be constantly controlled within the legal framework.

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CHAPTER V

GRAPE POMACE: ITS IMPORTANCE AND USAGE IN CEREAL PRODUCTS

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1. Introduction

Due to their high nutritional content, grapes are widely grown and consumed around the world. In 2020, 7.8 million tons of grapes were produced worldwide and 4.2 million tons in Turkey (Anonymous, 2022a). In terms of grape production, Turkey ranked sixth in the world with this production value. 39% of the grapes produced in our country are used to make products such as molasses, 33% are dried, 25% are consumed as table grapes, and only 3% are processed into wine (Aktaş, 2002; Semerci et al., 2015). When grapes are pressed for wine or molasses, the remaining pomace is around 25%. 25% of grape pomace is stem and seed, whereas 50% is grape skin (Kılıç, 1996; Yu and Ahmedna, 2013). In other words, the pomace obtained from the pressed grapes needed to produce 6 liters of wine is around 1 kg. of 1000 kg pomace, 425 kg grape skin, 249 kg stalks, and 225 kg grape seeds (Spinei and Oroian, 2021).

Grape pomace contains 9% ash, 11% protein, and 10% sugar, in addition to a high level of dietary fiber, antioxidants, total phenolic compounds, and anthocyanins. On the other hand, grape seed includes 16% oil, around 4% ash, and health-promoting phenolic compounds and antioxidants (Acun and Gül, 2014).

2. Phenolic Compounds of Grape Pomace and Their Biological Properties

Chemicals of phenolic compounds structure characterized by the presence of one or more aromatic rings containing hydroxyl groups. According to their structural properties, these compounds are divided into five main types. phenolic acids, stilbenes, flavonoids (flavanols or catechins, flavanols, flavones, flavanones, isoflavanoids, anthocyanins), tannins, and lignans are classified together (Çağlar and Demirci, 2017). These components defend the plant from pathogen growth, disease, UV radiation, and drought, and play a positive role in its adaptation. The concentration of phenolic compounds found in fruits and vegetables varies based on storage, transportation, maturity level, and production method. Grapes phenolics are anthocyanidins, flavonol glycosides, cinnamic acid derivatives, catechins, and protonocyanidins (Söylemezoğlu, 2003; Balbaba and Bağcı, 2020).

Anthocyanidins, one of the most prevalent phenolic compounds in grapes, are particularly plentiful in red and black grapes, but are either inadequate or absent in white grapes. While black grapes such as Yusufağa, Koşkuran, and Papaz Karası cultivated in Tunceli had between 358.5 and 1192.1 mg/kg of anthocyanins, the white grape variety Hasani contained none (Sanyürek et al., 2018). The amount of anthocyanin in Oküzgozü grape pomace, which is most preferred for red wine production and is produced primarily in Elaziğ and Adıyaman, is 5754 mg/kg, whereas the amount of anthocyanin in Narine grape pomace, which is preferred for white wine production, is 616.58 mg/kg (Gül et al., 2013). In addition to differences across cultivars, the amount of anthocyanin may also differ depending on whether the pomace is present in the skin or the seed (Gül et al., 2013).

The skins of red grapes contain more hydroxycinnamates, catechins, and procyanidin dimers than the skins of white grapes, which include anthocyanidins. On the other hand, white grapes have more flavonos.

The phenolic content of red and white grape seeds is comparable, while white grape seeds contain more catechin, epicatechin, and procyanidin B1. Furthermore, grape seed contains a higher concentration of catechin and procyanidin than grape skin (Yu and Ahmedna, 2013).

The interest in anthocyanin-rich fruits with high antioxidant capacity, which are essential for human health, has expanded significantly worldwide, particularly in industrialized nations (Çağlar and Demirci, 2017).

In order to reduce the detrimental effects of free radicals on human health, it is essential to increase the proportion of naturally antioxidant-rich foods in the daily diet. Phenolic compounds have antiulcer, anti-inflammatory, anti-carcinogenic, and antioxidant properties (Sağlam et al., 2021; Tahmaz Karaman et al., 2022). Grape phenolic compounds contribute positively to human health. Anthocyanins, particularly in black grapes, contribute to the protection against Alzheimer's disease, heart disease, diabetes, cancer, and the development of viruses within the cell (Mohammadi et al., 2019; Sağlam et al., 2021).

Tannins such as catechin, epicatechin, and epigallocatechin, which are found in the stem, peel, and pomace of grapes, are also essential antioxidant phenolic components. Tannins, which reduce the nutritional value of foods by reacting with various components (such as protein and carbs), regulate blood pressure and cholesterol levels, provided they are not consumed in overabundance (Sağlam et al., 2021).

Carotenoids that influence the color of grapes, such as p-carotene and lutein, have anti-cancer effects (Cabaroğlu, 2003; Sağlam et al., 2021). White grapes are especially rich in flavonoids like myricetin, quercetin, and kaempferol, which contribute positively to health by preventing cardiovascular problems, cancer, and diabetes. Additionally, these ingredients exhibit antiviral, antiallergic, and anticancer properties (Arakawa et al., 2002; Keskin et al., 2017; Sağlam et al., 2021).

In white grapes, the most common phenolic acids are ferulic, caffeic, and coumaric; in black grapes, the most common phenolic acids are laricitrin and syringin. The seeds and peel contain nine out of ten of the phenolic acids found in grapes. More than half of this is in the seed, whereas one-third is on the skin (Mattivi et al., 2006; Gülcü, 2008). Hence, grape pomace is abundant in phenolic acid. Particularly, resveratrol, which is synthesized by plants under stress, has a positive effect on lowering LDL cholesterol and avoiding heart disease (Yaman et al., 2013). This component, which is likewise synthesized in grapes, varies with grape variety, similar to melatonin. (Iriti and Faoro, 2009). As with other phenolic compounds, melatonin retards aging, prevents cancer, and helps in life extension by lowering stress (Atasoy and Erbaş, 2017).

2.1. Dietary Fiber Content of Grape Pomace and Its Effect on Health

Hispley developed the term “dietary fiber” in 1953 to refer to plant-derived components that cannot be digested or resist absorption because they are not affected by digestive enzymes in the human small intestine, but can be partially or totally fermented in the large intestine. (Devries et al., 1999; Arslan and Erbaş, 2014; Ergene and Bingöl, 2019). Dietary fibers can be classified depending on their physicochemical qualities (such as solubility, viscosity, and fermentation) or their source of origin. Components such as cellulose, hemicellulose, and pectin, known as soluble and insoluble dietary fibers based on their solubility, contribute significantly to health. Particularly, insoluble fibers increase the volume of waste in the large intestine and control and accelerate the transition of the intestines; soluble fibers catch sugar, cholesterol, and fat, slow the digestion of these substances, and cause a sense of fullness (Burdurlu and Karadeniz, 2003; Dulger and Sahan, 2011; Zuleta, 2013; Ergene and Bingöl, 2019).

Eighty percent of the dry weight of grape pomace is made up of nutritional fibers. The majority of these are insoluble dietary fibers (Valiente et al., 1995; Zhu et al., 2015). Grapes contain insoluble fiber comprised of clason lignin, neutral sugar, and uronic acid. Regardless of grape cultivar, the percentage of insoluble fiber to soluble fiber is higher. However, the ratio of dietary fiber in white wine grapes is between 17.2 and 20%, whereas it is between 51 and 57% in red wine grapes (Deng et al., 2011; Zhu et al., 2015; Antonić et al.,2020).

Grape pomace dietary fibers show antibacterial, anticarcinogenic, anti-apoptotic, and antioxidant properties. In addition, it prevents cardiovascular disease and enhances digestive health (Zhu et al., 2015).

The nutritional value of many foods is increased by the addition of grape pomace. Grape pomace, which improves the nutritional value of all foods to which it is added, facilitated the development of functional qualities in the products (Tolve et al., 2020; Tolve et al., 2021; Balli et al., 2021; Rainero et al., 2022).

2.2. Grape Seed and Grape Seed Oil

The study of bioactive components in grape seed extracts began at the turn of the 20th century. Since its discovery in 1936, the composition and health effects of proantocyanidine have attracted the interest of numerous scientists (Unusan 2020).

The grape seed is composed of 35% dietary fiber, 29% other extractable compounds, including phenolic compounds, 11% protein, 7% water, and 3% mineral compounds (Badavi et al., 2013; Gupta et al. 2020). Although the amount of oil in grape seed varies by variety, it ranges between 10 and 16% by dry weight. The grape seed contains essential oils such as linoleic and linolenic acids, which have high levels of unsaturated fatty acids. These are advantageous for lowering LDL levels and preventing cardiovascular disease, cancer, hypertension, and autoimmune disorders (Gupta et al., 2020). In addition, dietary fibers, which comprise 35% of the seed's composition, help to reduce the risk of diseases like diabetes, obesity, and colon cancer (Anderson et al., 2009; Badavi et al., 2013; Gupta et al., 2020).

Grape seed extract has anti-aging, anti-inflammatory, anti-apoptotic, anti-necrotic, cardiovascular, anticancerogenic, and wound-healing properties due to the phenolic compounds it contains (Johnson and Wilgus 2014; Farzaei et al. 2015; Hosseinzadeh 2017; Kwatra, 2020).

2.3. Cereal Products and Its Importance

Cereal products produced from grains such as rye, corn, and oats, particularly wheat, play a significant role in human nutrition. Wheat-based foods, including bread, pasta, cakes, and crackers, comprise a large amount of the daily diet. In

2020-2021, approximately 29 percent of the total land planted in Turkey was reserved for wheat cultivation (Taş and Salan, 2017).

In Turkey, bread is the most consumed oven product. However, if the bread's basic food components are consumed in excess, there are negative significant health consequences. It is known that breads produced by adding wheat bran, rye, or oats have developed functional properties of bread and contribute positively to health (Serra-Majem and Bautista-Castaño, 2015; Aune et al., 2016; Gültekin et al., 2019).

The most consumed cereal product after bread is pasta. Pasta, which dates back 1200 years, was consumed at a rate of 8.5 kilograms per person in Turkey in 2021 (Anonymous, 2022b). Pasta, which is rich in protein, vitamins, and minerals, is consumed, especially by children and students (Muslu et al., 2021).

Due to its high nutrient content cake, which contains more sugar than bread and pasta, is one of the first preferred cereal products in meals to be quickly consumed. However, this food is low in fiber, minerals, and vitamins despite its high nutrient content (Baltacıoğlu et al., 2020).

Biscuits are another cereal product with a high nutritional quality that students prefer for breakfast (Alıç, 2022). Due to their high sugar and oil content, biscuits, such as cakes, should be replaced with healthier options.

In recent years, consumers have required the production of functional alternatives to cereal goods with high consumption rates in daily nutrition, due to their desire to know the origin of the foods they consume and their preference for healthier options. Several scientists are attempting to enrich cereal goods, lower their sugar content, and improve their functionality. In cereal goods, the inclusion of fruits and vegetables high in dietary fiber, which are called useful ingredients, has become widespread for this reason (Koyuncu, 2021).

In order to prevent environmental pollution and evaluate high-nutritional by-products, cereal products are enriched with functional food wastes such as grape pomace, grape seeds, palm seeds, pomegranate seeds, and olives (Topkaya, 2017; Šporin et al., 2018; Karić et al., 2020; Nakov et al., 2020; Temkov et al.,2021).

3. Using of Grape Pomace in Cereal Products

In order to increase the nutritional value of foods, three different applications are made: enrichment, fortification, and replacement. In functional food production, fortification is one of the most used methods. Addition of foods that may be lost during the storage and processing of foods; the addition of components such as vitamins, minerals, diet fiber, and antioxidants, which are limited in some foods, is defined as the fortification of foods. Thus, it is aimed at contributing positively to human health by preventing micronutrient deficiencies (Aydın, 2018; Mete and Altıner, 2018). In addition to its high nutritional value, grape pomace, which has many positive contributions to health, is very important in fortifying foods. The fortification of cereal products, which are consumed more than other foods in the daily diet, is important for the protection of health. There are many studies on the use of grape pomace in grain products, which are loved and consumed by different age groups and income levels, such as bread, pasta, cake, and biscuits (Acun and Gül, 2014; Sharma et al., 2018; Lukinac et al., 2021; Boff et al., 2022). In this section, some information about the effect of grape pomace on product quality will be given in order to fortify cereal products.

Adding the grape pomace to the flour leads to a change in the properties of the dough. The type of grapes has an effect on dough reology. Although the dietary fiber content is lower than red grapes in white grape pomace, the development time and dough stability of the dough prepared with red grape pomace are longer (Šporin et al., 2018). Grape pomace also reduces the extensibility of the dough and deformation energy. Accordingly, the specific volume of bread decreases (Tolve et al., 2021). Adding grape seeds, grape pomace, or seedless grape pomace to the dough also increases its water absorption, development time, and dough stability. Since the dietary fibers in its structure hold water, the water absorption of the dough increases. Since the dough integrity is broken due to the components of the grape pomace structure, the pomace ratio to be added to the dough must be less than 10 %. (Lou et al., 2021a).

In the bread consumed, consumers expect homogeneous pore structure and high volume. The volumes of the breads with grape pomace are low, but the fiber and antioxidant content are high. The amount of grape pomace added increases the dietary concentration. This situation leads to the deterioration of the dough integrity in the bread (Tolve et al., 2021). The percentage of grape pomace used to increase nutritional value while maintaining bread quality is 5%. The dietary fibers in the grape pomace on this value are not recommended as they will cause bread volume to decrease. Using the glucose oxidase enzyme (100 ppm) can help improve bread quality (Amoah et al., 2020; Gül ve Ödeş, 2020). In addition, the addition of grape pomace obtained from white grapes to the bread is more sensory acceptable. The dark colour of the pomace from red grapes changes the colour of the bread, and its acceptability by consumers is low (Smith and Yu, 2015).

The biscuit consumed by university students to quickly pass their breakfast is a cereal product consumed by young children and elders (Suher, 2007). Grape pomace is added to improve the nutritional value of the preferred biscuit in rapid meals. The fundamental nutritional components of biscuits, such as protein and fat, rise proportionally with the addition. In addition, antioxidant and total phenolic substance values increase. (Acun and Gül, 2014). However, the technological properties are adversely affected due to the increased addition of pomace. For example, the spread rate and sensory acceptability of biscuits are reduced. Therefore, the addition of grape pomace is not desired to be more than 10 %. (Acun and Gül, 2014; Kuchtová et al., 2018; Maman and Yu, 2019; Boff et al., 2022). In addition, increasing the amount of pomace added increases the dough stability and water absorption. When more than 15 % pomace flour is added, the development time decreases (Lou et al., 2021a).

Many fruits or vegetables are used to fortify the pasta, which has a very rich diversity in terms of production method and shape. Especially in the production of fresh and filling pasta, which has become more popular in recent years, the pomace of these products has been used. Also, research has been done on grape pomace to improve how the component of the product is made. As with other cereal products, it is very important to add enough pomace so that the product keeps its technological properties. As a result, grape pomace should not be added to pasta in amounts greater than 6% to preserve the shape and sensory acceptability of the pasta. One of the most important quality features in pasta production is the amount of cooking loss. Increasing the amount of pomace added in pasta production increases the transition of the starch to the water when the dough integrity is impaired, which causes a decrease in pasta quality (Tolve et al., 2020; Balli et al., 2021).

In the production of cakes, the use of red grape pomace causes the product color to darken more, whereas white grape pomace is more sensitively accepted (Bender et al., 2017). Even if the increase in nutritional value increases with the addition, the increasing dietary fiber ratio causes a decrease in cake volume. (Nakov et al., 2020). Increasing diet fiber increases the hardness of the product, reducing chewiness. (Walker et al., 2014).

In general, the addition of grape pomace improves the nutritional value of the products and increases antioxidant activity, total phenolic content, and the dietary fiber ratio. However, the addition of grape pomace can affect the technological properties of the products and cause deterioration. This requires the addition of grape pomace in certain proportions. The effect of grape pomace added to some cereal products on product quality is summarized in Table 1.

Table 1: Effects of The Use of Grape Pomace on Some Bakery Products on Product Quality

Product	Application	Effect	References
Bread	Narince (white) and Öküzgözü (red) grape seed flour were used to produce bread at a ratio of 0 %, 5, 10 and were used 50-100 ppm glycosoxidase enzymes to improve quality.	When the Narince grape seed is added at 10 %, bread hardness is 1207.8 g; When Öküzgözü flour is added, 1458.0 g. When 10 %seed powder is added without using enzymes, the bread volume is 388.67 cm^3 and 256.67 cm^3. Depending on the additional rate, crumb and crust color are darkened and chewness value decreased.	Gül and Ötleş, 2020
Bread	Added to bread as a micropower in 1 %	The volume of bread and the hardness of the crumb decreased and the hardness of the crust increased. No significant change was observed in the total number of microorganisms at the end of 4 -day storage.	Valková et al., 2020
Bread	5 %and 10 % *Vitis Vinifera cv*. Corvina pomace	The amount of antioxidant activity and diet fiber increased as the additional rate increased, while bread volume and sensory acceptability decreased.	Tolve et al., 2021
Cookie	Addition of different particle-size grape seed flour between 2.5-10 %	104 µm in size seed flour reduced consumer acceptability and was recommended to use 209 µm in size seed flour	Maman and Yu, 2019

Cookie	Muscat grape pomace was added to the biscuit dough at a rate of 2.4.6.8 %	With the increase in the additional rate, the spread rate of the cookies increased, the nutritional value was increased, and the energy value decreased because the fiber rate increased. At the end of 60 days of storage, the hardness value of the cookies, which added 6 % of the grape pomace, decreased by only 8 %. It has increased its functional characteristics without making a significant change in the sensory characteristics of the cookies added at the 6 %level.	Theagarajan et al., 2019
Biscuits	It is added at different rates—between 0 and 20 % to the flour according to the principle of displacement of grape pomace.	As the additional rate increased, the total phenolic substance, antioxidant activity, protein, ash, and fat value increased, while consumer acceptability decreased as more than 10 % was added. In addition, when the addition rate is increased by up to 15 %, the hardness and chewable value increase, while the specified value decreases when the additional rate is at 20 %.	Lou et al., 2021b
Pasta	The pomace of Vitis cinifera L. cv. Corvina was used at 0%, 5%, and 10%.	Optimum cooking time has decreased due to the increased additional rate; cooking loss and hardness have also increased. The color darkened, and the total amount of phenolic content increased.	Tolve et al.,2020
Pasta	7 % Gamay grape pomace extraction has been added.	The antioxidant activity value and total phenolic content both increased.	Balli et al., 2021

Pasta	White (Fiano) and two red (Agliianico and Lambrusco) grape pomace were used in pasta production at rate of 5 %.	The use of both white and red grape pomace has increased the nutritional value of pasta and the total amount of phenolic substances. 5 % use did not adversely affect the quality of pasta.	Gerardi et al., 2021
Noodle	Grape seed powder at 1%, 2%, and 3% rates were added.	The nutritional value increased with the increase in the additional rate, but the best textural features were observed in which added 1 % level grape seed powder noodle	Chen et al., 2021
Cake	The seedless pomace of Tannat and Riesling grapes was added at 5 %, 7.5%, and 10%.	The bioactive component ratio of cakes increased; depending on the additional rate, the crumb and crust colors darkened. In addition, cooking loss decreased as the additional rate increased.	Bender et al., 2017
Cake	White and red grape pomace were used in 0%, 10%, and 20% concentrations.	With the increase in the additional rate, cooking loss decreased, color darkened, and hardness increased. In cakes with red grape pomace, the hardness value was higher than in those with white grape pomace.	Ortega-Heras et al., 2019

3.1. Usage of Grape Pomace in Gluten-Free Baked Products

In recent years, as a result of people's desire to eat more consciously, interest in gluten-free nutrition has increased, and many people, as well as celiac patients, have started to demand gluten-free foods. For this reason, cereal-like products have been more involved in the production of gluten-free foods. Thus, the product variety has increased. In addition, due to the increasing demand, increasing the technological quality of these products has become as important as improving their nutritional value. (Aguiar et al., 2021; Simonato, 2021; Mir et al., 2022; Acun et al., 2022).

It is very important to fortify the foods consumed by people who have to eat gluten-free due to gluten sensitivity or gluten allergy. Increasing the protein content of these foods is very important. Increasing the phenolic components and dietary fiber content is as important as fortifying it with protein. Grape pomace is a good source for fortifying gluten-free foods due to its composition. Grape pomace, which is used in the production of gluten-free bakery products such as bread, pasta, cake, and biscuits, increases the nutritional composition and affects the technological properties of the product. In this section, the effect of grape pomace used in gluten-free bakery products on product quality will be discussed. In recent years, gluten-free pasta production has increased. Protein content is important for the production of high-quality pasta. Gluten affects how chewiness and elasticity the pasta is. Since gluten-free pasta doesn't have gluten, the quality of the dough is affected, and the structure of the final product is worsened. For this reason, different protein additives are made in order to maintain the quality of pasta production. Increasing the proportion of grape pomace used in pasta making reduces the dough's hardness and darkens its colour. When pasta is cooked with more than 3% pomace, the texture becomes firm. In addition, when cooking loss increases, so does sensory acceptance (Ungureanu-Iuga et al., 2020).

Pomace from grapes, a common ingredient in gluten-free biscuits, increases the nutritional value of the product. Depending on the variety of grape, the ratio of dietary fiber in its structure affects the product quality differently. For instance, when the addition rate of Alibernet grape pomace increases, biscuit hardness increases, and as the addition rate of Cabernet grape pomace decreases, biscuit hardness reduces. Because of this, 5% grape pomace should be used in biscuit making to keep the quality of the biscuits (Matejová et al., 2016).

Cake is another popular and widely consumed bakery product. The fact that it is satisfying, and alternatives can be produced affects the preferences of consumers. Gluten-free cakes lose elasticity as a result of the absence of gluten during manufacture. The cake's volume, one of the most crucial characteristics, is low. The addition of grape pomace is intended to improve the product's quality and nutritional value. In cakes with grape pomace added, as the ratio of pomace addition increases, the nutritional value such as fat, protein, and ash increases. For sensory acceptability, it is not recommended to add more than 20 % pomace (Baldán et al., 2021).

Grape seed is utilized in the production of gluten-free cakes to improve antioxidant activity and phenolic content. Consequently, a useful product can be obtained. Due to the fiber structure of the grape seed, the cakes' volume is reduced. It also decreases the value of hardness by changing the textural qualities. In order to maintain the product's quality and flavour, cakes produced with grape seeds should contain no more than 5 percent grape seed powder (Levent et al., 2022). In addition, the crust and crumb colour of the cakes produced by adding grape seeds become darker, and the cooking loss increases. (Levent et al., 2021).

The use of grape seed flour in gluten-free bread production is a good choice for improving the nutritional value of the product and producing functional bread. According to the replacement principle with flour, the production of grape seed powder up to 9 % increases the total amount of phenolic compounds and the antioxidant activity. Regardless of the grape variety, there is an increase in the nutritional composition (Kapcsándi et al., 2021).

4. Conclusion

Grapes are one of the most produced and consumed fruits in the world. While countries like France, which has a high production rate around the world, primarily use grapes for wine production, the number of grapes used in wine production in our country is quite small. Grapes, which are predominantly consumed as table grapes in our country, are also used to make wine, grape juice, and molasses. The pomace, that has a high nutritional value and is rich in antioxidants, is wasted after these processes that use grape juice.

The total amount of waste in Turkey in 2020 is approximately 105 million tons, and the recovery of these wastes is very important. (Anonymous, 2022c). One of these wastes, of which 69.4% is recyclable, is grape pomace left over from the production of wine, molasses, or grape juice (Yaman, 2012; Odabaşıoğlu et al, 2022). It is very important to evaluate this pomace using different methods. Particularly due to its high nutritional content, it is preferred for fortified foods.

Fortification of the most consumed cereal items in the daily diet is useful for enhancing public health. Today, as the creation of functional foods gains popularity, the manufacturing of bakery items with high antioxidant activity has attracted more attention. In bakery products, grape pomace, which is rich in phenolic compounds and dietary fiber, has been used extensively for this purpose.

Fortification of widely consumed bakery products, such as bread, pasta, cake, and biscuit, with grape pomace increases the nutritional value of the product while also fortifying it in terms of total phenolic content, antioxidant activity, and dietary fiber. The use of grape pomace enables the bakery products to gain functional properties, while negatively affecting their technological properties. Therefore, it is important to determine the ratio to be added. Which form of grape pomace will be used in the production of bread, pasta, biscuits, and cakes is important in terms of determining the amount to be added.

Gluten-sensitive people should have a nutritionally diet, so it is crucial to improve their food. In addition, according to some research, consuming 1 mg of the proanthocyanidins found in grape seeds on a daily is helpful to one's health (Dias et al., 2021). For this reason, adding grape pomace to their daily diets will make a positive contribution to their eating habits.

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CHAPTER VI

ADVANCES IN FOOD RELATIONSHIPS BETWEEN PLANTS AND INSECTS

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1. Introduction

The living organisms interact with each other in terrestrial and aquatic ecosystems. The most of them need each other for various factors such as food, reproduction, habitat. Plants and insects have lived together in nature since their existence. The relationships between plants and insects are as diverse as the plant and animal species. The main relationships between plants and insects are feeding, pollination, egg laying, habitat use, mutualistic relationships and mimicry. These relationships were monitored and examined with numerous studies. Although the studies done so far have explained the basic relationships between plants and insects, it is thought that there are still many unknown relationships that and waiting to be discovered.

There are different approaches to insect-plant relationships. Jermy (1993) reported that the evolutionary studies on the interrelations between plants and insects are based on two assumptions that, "(1) phytophagous insects reduce plant fitness, and that (2) insect-plant relationships are the result of unconstrained selection." These assumptions were not fully demonstrated by previous studies. In the other hypothesis, the evolution of insect-plant interactions was primarily explained by autonomous evolutionary occurrences which derived from heritable changes within the insect genome. According to this hypothesis the ecological factors have not a primary role (Jermy,1993).

Depending on the development of the technology, the use of satellite systems, new analysis and monitoring methods allow to be revealed and examined the relations between plants and insects in more detail. In this chapter, the food relationships between plants and insects were discussed in the light of recent studies.

2. Evaluation of Food Interactions in Terms of Insects

Food is the primary need for all living organisms due to its importance on health and life. Most of the relationships between living organisms are based on food supply in the nature. The basis of insect-plant interactions is food for insects and production for plants. Since insects can move, they take an active role in these relationships. In fact, food supply, which is the basic need for insects, has also been a mechanism for reproduction of plants.

Similar with most of the other organisms, insects diverse in their food preference. In order to clearly understand the relationships between plants and insects based on food availability, a brief information about the food preferences of insects is presented below.

Herbivores: Living organisms that use plant species as food are called herbivores. Most of the insects feed on plants. Insects that feed on plants are classified according to their food preferences as follows:

Phytophagous: A group of organisms that feed on plants.

Monophagous: The insects that feed on only one plant species. These type of insect species shows strict attachment to their hosts.

Oligophagous: The insects feed on several closely related plant species or genera.

Polyphagous: Insects that feed on a wide variety of plants are called polyphagous.

Insects must have some anatomical structures to feed on plants. Insects have different mouth structures (Figure 1) according to their diet. For this reason, the mouth structures of insects give information about the feeding styles of them.

Chewing Mouth: It is the basic mouth structure of insect species. It has mandibular mouth instrument. The individuals of Orthoptera, Isoptera and Coleoptera orders have chewing mount. Chewing insect individuals would be small or large. They may cause several damages and can be exposed to hard-to-digest compounds and toxins.

Piercing-sucking Mouthparts: Galea, one of the mouthparts, showed a high degree of elongation and took the shape of a proboscis. These types of insects immerse their oral instruments in the xylem and phloem and suck the plant sap from these areas. They generally avoid toxins and compounds that are difficult to digest. They can also transmit disease. There are 2-3-4 and 6-needle types according to the number of needles formed by changing the mouth parts. It is seen with mosquitoes and some flies, Hemiptera and Thysanoptera specimens.

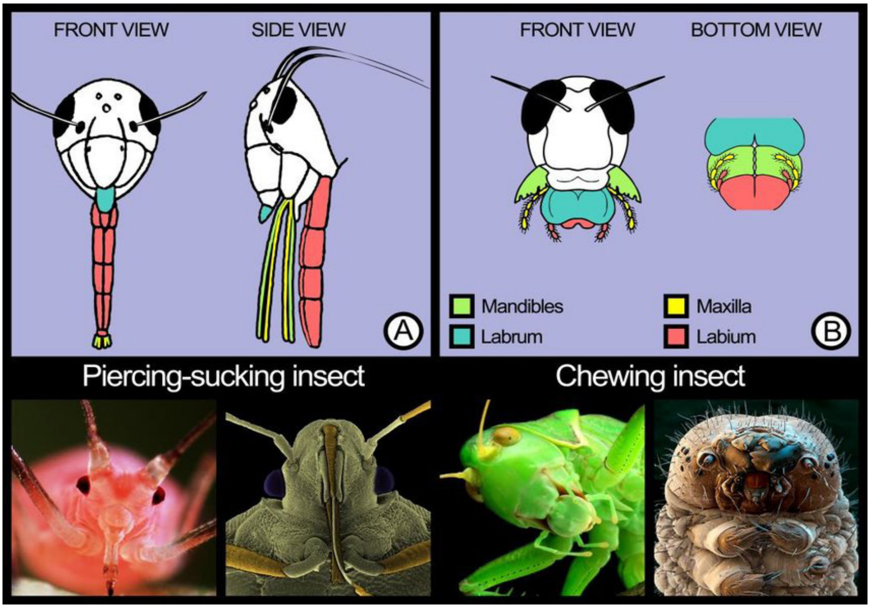


Figure 1. Examples of mouthparts of phytophagus insects.
(A) piercing-sucking insects, (B) chewing insects (Body, 2013).

Licking-Sucking Mouthparts: It is the mouth type seen in honeybees (Hymenoptera). A special mouth type is seen in the housefly (*Musca domestica*). In fact, the needles are lost in the mouth, which is a piercing-sucking type with 2 needles, and there is a structure consisting of 2 small plates called "labellum" at the very end.

Siphoning mouthparts: It has a long tube that generally curled up and provide to insert deep tisues of plant such as tubular flowers to drink nectar. Seen in butterflies and moths.

According to the subject of the chapter we focused on phytophagous insects. With at least 500,000 insect species, diversity of phytophagous insects is very high. The main phytophagous insect orders are Coleoptera Orthoptera, Heteroptera, Lepidoptera, Diptera and Hymenoptera (Bernays, 2009). The main insect pests in forest are belong to Phasmatodea, Hymenoptera, Diptera, Orthoptera, Hemiptera, Lepidoptera, Coleoptera, Isoptera and Thysanoptera (URL 1). Phytophagous insects feed on almost all green plant species. Some of them preference only one plant species and called monophagous such as some aphids. The insects which live within plant parts and feed on tissues internally are called as endophytophagous. These are gall-forming, leaf-mining and stem-boring insects (Body, 2013). Ectophytophagous insects feed on externally.

Variation in mouth structure of insects shows the variation in feeding preference of insects (Figure 2). Herbivorous insects usually feed on plants by sucking plant sap, chewing and piercing plant tissues or tearing plant parts. Because the food preferences and feeding type of insects are very diverse, the food relationships between plants and insects are very variable.

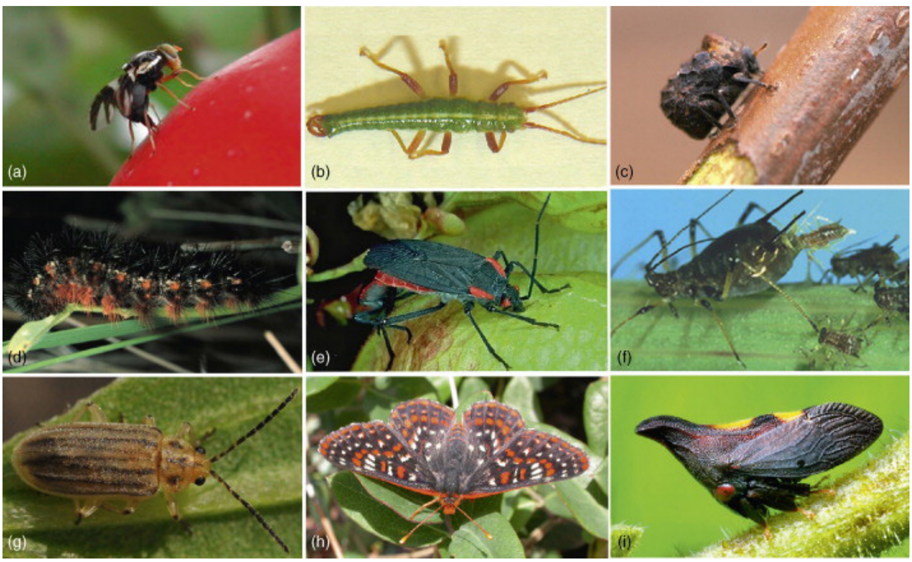


Figure 2. Samples of insect herbivors (a) *Rhagoletis pomonella,* (b) *Timema cristinae* (c) *Neochlamisus bebbianae* , (d) *Grammia crotalaria* caterpillars, (e) *Jadera haematomola* (f) *Uroleucon ambrosiae,* (g) *Ophraella notulata,* (h) *Euphydryas editha,* (i) *Enchenopa binotata* (Source: Funk, D. J. 2010).

Damages in plants caused by insects decimate plant production and crop yield. Thus, farmers take precautions against insects and commonly use the insecticides which are hazardous substances for organisms and abiotic factors of the ecosystems. The insecticides use cause a reduction in insect populations and treats the species diversity in most ecosystems. Due to important roles of insects on plant damages and yield loss, the food relationships between plants and insects were tried to examine. The studies related with food relationships of insects were usually focused on economically important insect species. Jones and Rader (2022) studied on nutrition of insect pollinators and the factors which affect the health of insect pollinators. They reported that in addition to the importance of crop yield, it is also important to protect the health of pollinator organisms such as bees, non-bee taxa in terms of plant development and agricultural activities. The health of pollinators was defined as "multilevel, spatio-temporally unconstrained measure of the wellbeing, resilience and ecological functionality of individuals through to populations of pollinators" (López et al., 2020; Jones and Rader, 2022).

As pollinators visit the plants more for feeding, the crop yield increases, and higher quality products are obtained. Some of the studies expressed that the number of floral visitors increased with presence of additional non-crop floral resources (Albrecht et al. 2020; Jones Rader, 2022). But it cannot be certainly said that the presence of non-crop plants will increase the crop yield. Presence of noncrop plant resources provides additional food supply such as pollen and nectar, and support health and growth of polinators by this way (Vaudo et al., 2015; Rodríguez-Gasol et al., 2020; Jones and Rader, 2022). Since nutrient contents and secondary compounds in plants vary according to species, it is not known exactly which plant species is more beneficial for the nutrition of pollinators. Adler et al. (2021) reported that while supporting the feeding of the insect pollinators by of non-crop plants, attention should be paid to pathogen contamination for insect health. To provide appropriate food support for insect pollinators it is important to know which type of nutrients they need. Thus, the feeding behaviours of insect species should be well observed, and appropriate plant species may be determined. In addition, since the nutrient content and the concentration of secondary compounds in plants change depending on environmental conditions, the ecological characteristics of the habitat become an important factor. The environmental factors of habitat indirectly affect insect pollinator health.

The term genetically modified organism has emerged based on the developments in biotechnology. An organism whose gene sequence has been changed by gene alteration or inter-species and intra-species gene transfer called as genetically modified organism. The organisms gain new characters by this application. The modification of gene sequences and characteristics of organisms affects interactions among living organisms. Due to costs and toxic effects of pesticides and produce more crop yield, the genetic modifications are usually applied crop plants such as maize, soybean, pumpkins, watermelon, tomato, potato etc. These applications may cause changes in plant properties such as nutrient content, secondary metabolites. Because of these differences food relationships among organisms may also change. There was an argument on the negative effects of genetical modification of organisms on the food webs in the ecosystems. Insects as the herbivore, carnivore and detritivore organisms have important role in ecosystems and the negative effects of genetically modified foods on insects may have indirect impacts on other organisms by changing insect resistance, biodiversity, emergence of new species and natural enemies (Ögür and Tuncer, 2012). Currently, there are two commercially modified genetically modified plant type as insect-resistant or herbicide-resistant plants and a combination of both. Insect-resistant plants secrete the poisonous Cry protein (Figure 3), by means of the gene transferred from the *Bacillus thuringiensis* (Bt) *bacterium*, and these toxins kills the insects (Hagvar and Aasen, 2004; O'Callaghan et al., 2005; Ögür and Tuncer, 2012). Insects have developed resistance to many insecticides over time, and it is thought that if transgenic plants are used uncontrollably, insects may also develop resistance against them in the coming years. It is also stated that the use of transgenic plants may cause the emergence of new pests. Not all pests are sensitive to plants with *Bacillus thuringiensis*.

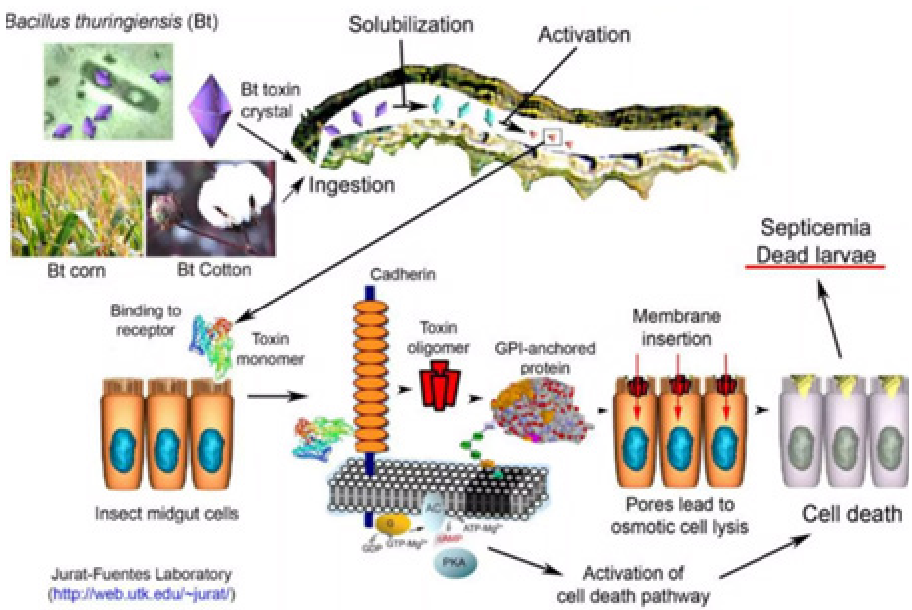


Figure 3. Effect of insect resistant crop with BT on insect larvae (URL 2)

Therefore, secondary pests gain advantage due to reduced competition with the main pest. These insect species, which are not main pests before, may cause economic loses (Hagvar and Aasen, 2004; Ögür and Tuncer, 2012). As an example for this situation in USA, *Striacosta albicosta* (Lepidoptera: Noctuidae) population and spread increased with production of transgenic maize with *Bacillus thuringiensis*. These species became a new pest and caused economic loses (Ögür and Tuncer, 2012). Another negative effect of transgenic plants use is related with biodiversity loss. According to the hypothesis, the transferred genes may be pass to natural plant species and this may cause genetic diversity loss in native species. It is thought that it may cause changes in the natural structure and characteristics of wild species. This leads to reduction in competition power of the natural species and threatens genetic and species diversity. In addition, the insects feed on the pollens of transgenic plants, and their enemies may be damaged because of toxic substances (Çelik and Balık, 2007; Ögür and Tuncer, 2012).

Previous studies showed that nutrient and secondary compounds of plants, plant structure, species and environmental factors directly affects herbivore insects. Contamination of plants with hazardous substances also have negative impacts on insects. Food preference of insects are mainly based on internal factors of insect species. But environmental factors also play role in the food preference of insects. Environmental conditions such as noise, light, temperature and environmental pollution have important role on insect feeding and health.

3. Evaluation of Food Interactions in Terms of Plants

3.1. Pollination

For fertilization of flowering plants, pollen grains must reach the stigma from the anthers and this process is called as pollination (Figures 4-5). The pollination by insects is called entomophily. Insects are major pollinators such as bees, butterflies, ants, flies, wasps and beetles.

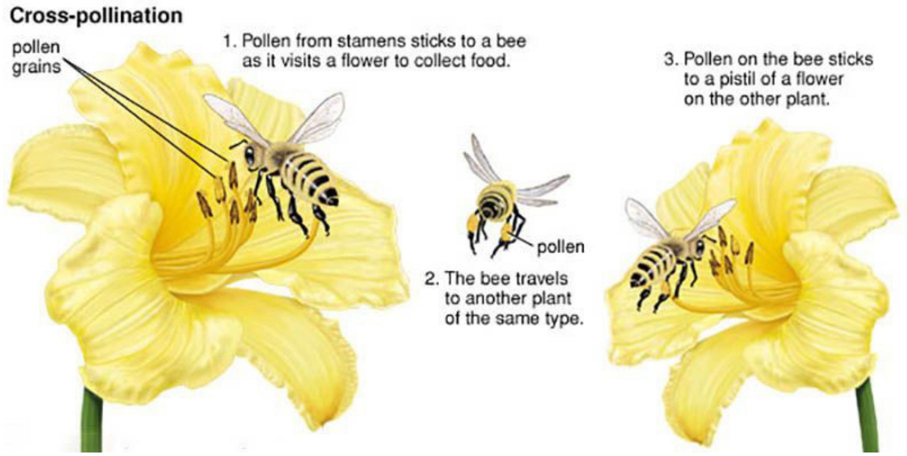


Figure 4. Pollination process (Source: URL 3)

During pollination, plants secrete delicious nectar, fragrant scents or show attractive colours and shapes in order to attract the insects. There are even plants that have flowers like insects that enable them to pollinate by means of mimicry. There are various mimicry patterns of plants and insects in the nature. Most popular one is mimicry of bee orchid (Figure 6) While the insects feed on plants, it also carries the pollens of the flowers to the stigma. Thus, sexual reproduction is achieved in plants. Insects play important role in pollination process of insects by which the continuation of their progeny is ensured.

Figure 5. Bees feeding on flower and pollination (Sources: URL 3 and 4)

Figure 6. An example for mimicry, a bee is feeding on bee orchid (URL 5)

Not only the plant fitness but also the pollinator health was important for sustainability of pollination process. Factors and threats, which are effective on pollinator health such as agricultural processes explained based on feeding behaviour in the Evaluation of Food Interactions in Terms of Insects section in this chapter.

In the worldwide, 7-8% of the food crop production is contributed with pollination by insects and the 70% of whole crop plants needs insect pollinators (Klein et al., 2007; Potts et al., 2016; Ryalls et al., 2022). The importance of the insect pollination in reproduction of plants and food crop production is clear. But there are some environmental threats for insect pollination such as heavy metal pollution, aerial particulate matter pollution, tropospheric pollutants (CO_2, NOx, volatile organic carbon and ozone etc.) which are derived from exhaust gases, industrial and domestic flue gases, and agricultural activities (Figure 7). These pollutants may directly affect health of pollinator insects or decrease pollen foraging efficiency of pollinators (Girling et al. 2013; Reitmayer et al., 2019; Fuentes et al., 2016; Ryalls et al., 2022). In addition, the stigma and pollen tubes may be clogged by the particulate matters, and this prevents the fertilization of plants. The atmospheric gaseous pollutants may mask volatile compounds secreted by plants to attract pollinators (Ryalls et al., 2022).

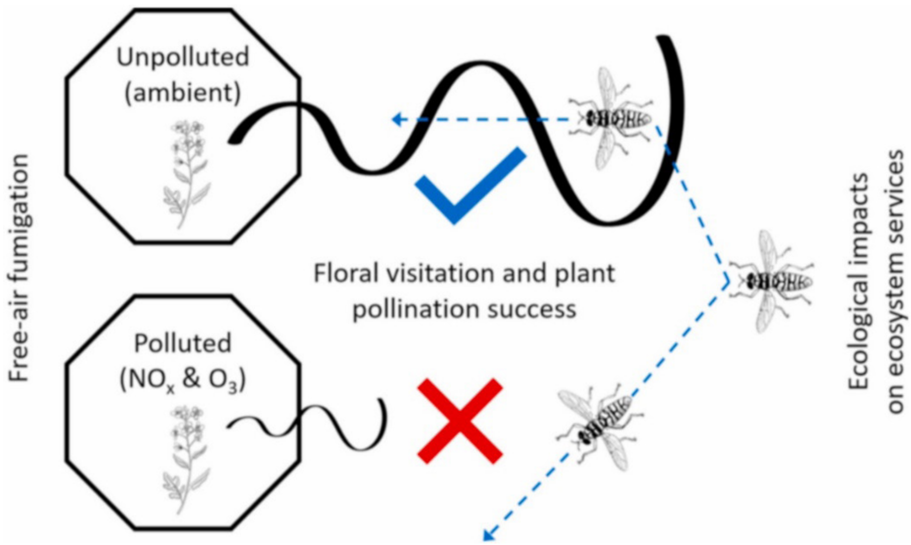


Figure 7. Effect of atmospheric pollutants to pollination process (Source: Ryalls et al., 2022)

Ryalls et al., (2022) studied the effects of some tropospheric pollutants caused by anthropogenic factors on pollinator foraging and the pollination ecosystem service provided by the insects. They indicated that exposure of pollinator insects to separate and combined diesel exhaust and ozone gases decreased the total amount of managed and native insect pollinators by 62–70%. Their flower visits are also reduced by 83–90% due to applied atmospheric pollutants (Figure 8). The pollination ecosystem service was also declined based on exposure to pollutants.

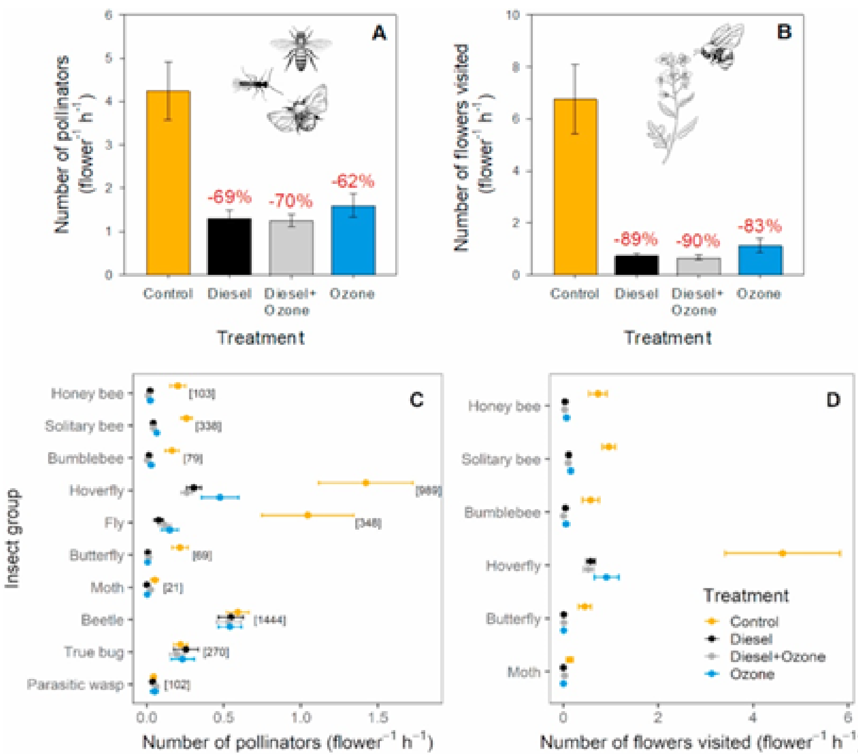


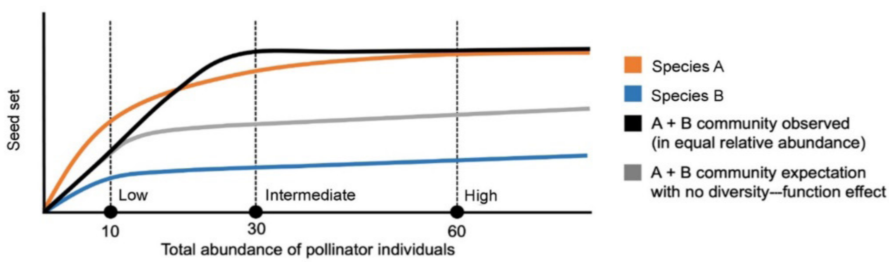
Fig. 2. The effects of diesel exhaust and ozone pollution on pollinator foraging behavior. Means (±SE) of pollinator abundance (A), flower visitation frequencies (B), abundances per insect group (C) and flower visits per insect group (D) were scaled according to the number of flowers within each observation unit and survey duration. For part C, numbers in square brackets represent the total number of individuals counted for each group. If an insect landed on a flower within the observation unit, that insect was counted as '1' for abundance. If that same insect landed on five flowers within the observation unit, the number of flower visits was recorded as '5'. Flower visitation (B and D) was recorded for bees, hoverflies, butterflies and moths only.

Figure 8. Results of the study on the effects of diesel exhaust and ozone on on pollinator foraging on obtained by Ryalls et al., (2022).

The response of the pollinator insect groups to the pollutants varied. The abundances of solitary bees, honeybees, bumblebees, hoverflies, other flies, moths, and butterflies decreased. The abundances of these pollinator groups were higher in unpolluted control groups than those in pollutant treatments. Similar trends were determined for the amounts of visited flowers by hoverflies, bees, moths, and butterflies. However, the abundance of true bugs, beetles and parasitic wasps did not vary due to exposure to pollutants. Differences in the responses of pollinator groups to pollutants are due to variation in the phenotypic plasticity and ecological tolerance of the insect species.

Biodiversity has an important role in functional processes of ecosystems such as pollination (Maynard et al., 2017; Winfree et al., 2018). Reduction in abundance and diversity of pollinator organisms directly affects plant reproduction and accordingly ecosystem productivity. Because of this, the determination of factors that cause declines in pollinator diversity and abundance has vital importance for sustainability of ecosystems. Loy and Brosi (2022) studied on the impacts of pollinator diversity on pollination process. It was thought that the pollinator diversity may improves plant reproduction (Figure 9). Rollin et al. (2022) also reported the negative effects of ozone on the improvement of crop yield by pollinators.

It is thought that the pollinator species in the ecosystem may have different niches and these various functions may be an advantage for pollination and increase reproduction of plants based on increase in community function. It was reported that the competition among pollinators is not necessary (Loy and Brosi, 2022). To better understand how pollinator diversity functionally affects pollination process, we need to know which mechanisms manage the community functions.



Comparing function within similar pollinator abundances	Detectable complentarity/enhancement
When considered in isolation, species A (orange) is more functionally effective than species B (blue) at similar abundances (e.g. A = 10, B = 10). Single-species treatments are used to calculate the expected A + B community function (gray), which can then be compared to the observed A + B community function (black), both at the same total abundance (e.g. 5A + 5B = 10).	**1.** When observed community function (black) exceeds that of the expectation (gray) **OR** **2.** Within range of abundances when community observed function (black) exceeds the function of the higher performing species alone (Species A, orange)
LOW ABUNDANCES (e.g. 10 pollinator individuals) When function is extremely low, it may be difficult to detect a diversity-function effect.	**Neither 1 nor 2**
INTERMEDIATE ABUNDANCES (e.g. 30 pollinator individuals) Species B has saturated its functional niche. Here there is a detectable diversity—function relationship, as the observed A + B community function (black) is greater than expected (blue), due to functional complementarity or functional enhancement. In addition, observed community function exceeds species A alone, even though there are half the number of individuals of this higher performing species.	**1 and/or 2**
HIGH ABUNDANCES (e.g. 60 pollinator individuals) Species A and species B are not able to further increase pollination as all ovules accessible to both species have been pollinated.	**Only 1**

Figure 9. Schematic hypothetical explanation of the effects of diversity and abundance of pollinator species on seed set (Source: Loy and Brosi, 2022).

Meireles et al. (2022) investigated the impacts of pollination on the volatile compound composition in the roasted coffee beans. Results indicated that the concentration of volatile substances such as chlorogenic acids, proteins and some alkaloids significantly increased with pollination.

There are various threats to pollination process in the ecosystems such as environmental pollution, agrochemicals, fire, fragmentation, non-native species, urbanization, diseases, genetical modification of plants and climate change. These globally threats the health and function of pollinator insects, plant reproduction and ecosystem productivity.

Teixido et al. (2022) reported that while global climate change has important effects on pollination, the non-native species mostly affects seed dispersal. As an example, nutrient content and secondary compounds may be change due to genetical modifications of plants.

Changes in food structure and characteristics may leads to malnutrition of pollinator insects or increase pests. These differences also affect population dynamics of organisms in the community and change species composition. Changes in species composition also affect functional processes in the ecosystem. Thus, due to an interference on the natural state, many factors may change in the ecosystem, like domino effect.

Besides the environmental pollutants and the hazardous events, some of the natural mechanisms such as chemical compounds and nutrient content of plants, and habitat destructions also negatively affect pollination process and health of pollinators (Stevenson et al. 2022).

Recent studies reported that abundance and diversity of pollinator are at risk. Considering the pollination process as a vital function for continuity and sustainability of organisms and ecosystems, studies on identification and explanation of the threats to pollination are required.

3.2. Damages in Plants

There are various feeding behaviours of herbivore insects. Herbivore insects may be classified as defoliators, leaf feeders, stem feeders, root feeders, leaf mining, sap suckers, bark feeders, dead-wood feeders, gall makers, flower, nectar seed and pollen feeders, shoot borers according to their feeding behaviours (URL-1). These insects cause numerous damages in plants (Figure 10).

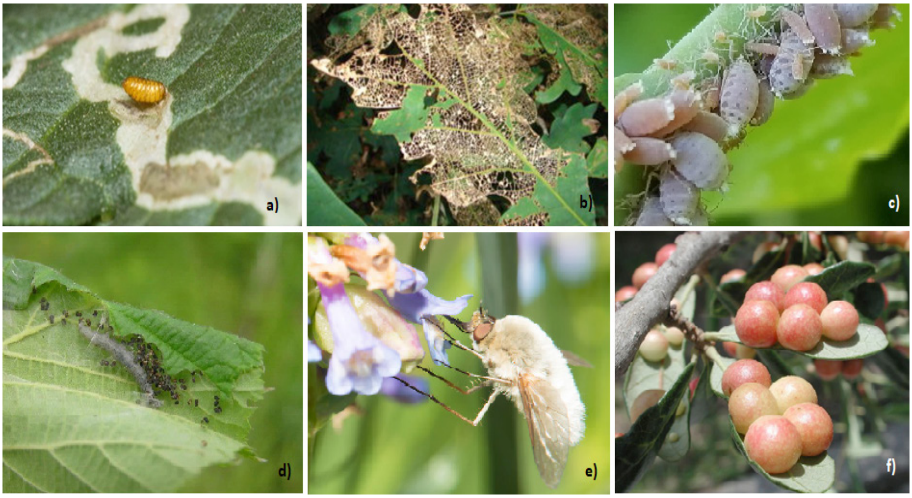


Figure 10. Some examples of plant pests and damages a) leaf miners (URL 6), b) leaf skeletonizer (URL 7), c) sap sucker (URL 8), d) leafroller (URL 9), e) nectar feeder (URL 10) f) gall maker (URL 11)

Damages in plants caused by insects may be explained as below:

1. Loss of plant tissues and reduction of photosynthetic parts of plant. Defoliation may be seen in plants
2. Seedlings or plant destruction
3. Tunnelling or boring of stems of plants, weakness in the stem, sap flow interruption and stem breakage.
4. Destructing of the buds, seeds, flowers, shoots, and fruits of plants
5. Gall formation
6. Boring or eating the tubers and roots
7. Leading to tissue wilt
8. Causing leaf curl
9. Removing sap
10. Stunting
11. Death of plant
12. Fitotoxicity. The toxic saliva of insects may cause death of the cells, tissues, and whole plant
13. Disease (for vector insects for pathogens) (URL 12)

The type of damages in plants are closely related with feeding behaviour of insects (Figure 11). And some of the damages are specific to insect species such as gall formations.

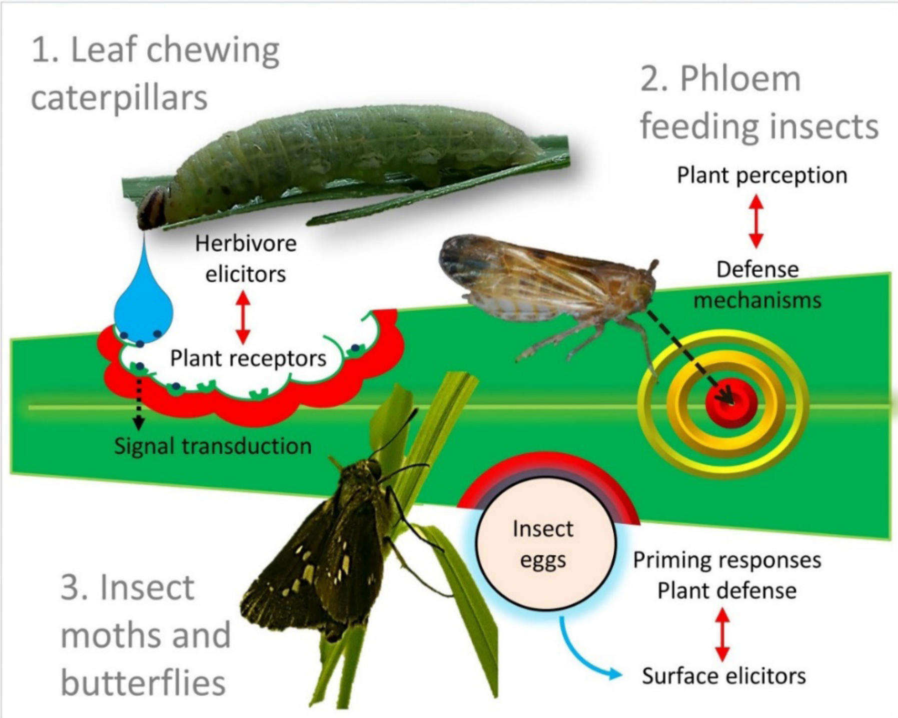


Figure 11. An example of the effects of feeding insects on plants (Source: https://www.gels.okayama-u.ac.jp/en/intro/dept/area/areas07_pstress_e.html)

When the herbivore insect attack to a plant tissue for feeding, several physiological processes start in order to reconfigure the metabolism. An example for physiological restructuring process in plant tissues against to insect attack were shown and summarized in Figure 12 (Body, 2013).

The effect of toxic chemicals transferred to the plant during the feeding of insects is called phytotoxicity. phytotoxicity may cause necrotic tissues, discoloured tissue, local lesions, cork formation, pits, scabs, premature leaf and fruit fall, malformation or curling of plant organs. These formations are very similar to symptoms of plant disease.

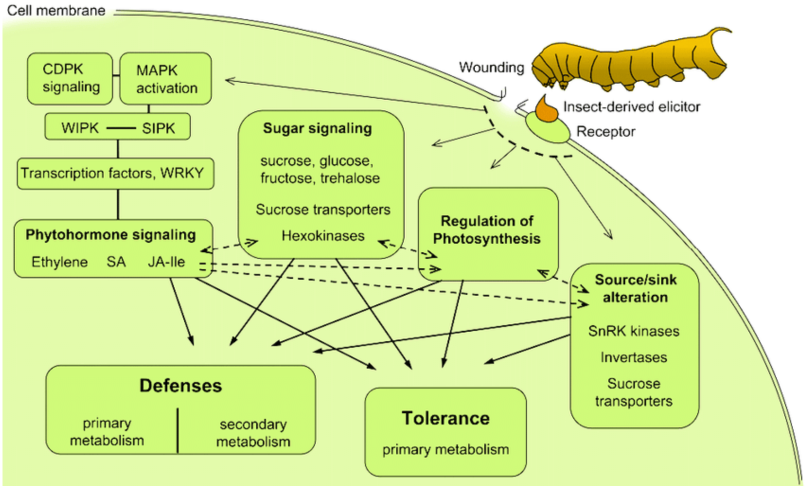


Figure 12. Physiological restructuring process after insect attack. (Source: Schwachtje and Baldwin, 2008; Body, 2013).

Gall is made by abnormal development of plant cells caused by insects. Insect secretions act as plant growth hormones and stimulate plant tissue to form galls. Gall can also occur due to mechanical damage to the plant by insects while feeding. Galls are formed in response to stimuli during feeding and egg laying by insects and mites. Galls can be in the form of simple swellings on the leaf or stem, and it can be quite complex in the anatomical structure of the plant. But it is always in a structure specific to gal builder insects. Galls have specific dimensions, shape and colour. Galls are mostly on leaves, stems and flowers. Aphids, cynipids, thrips, psylids and moths maggots and beetles are most-known gall builders. Leaves with gall fall before other leaves. They give the fruit a rotten appearance and the fruits become useless. Vascular bundles dry up on the trunk and branches. Galls formed on newly emerging shoots and sprouts inhibit growth. As it has many harms to the plant, it also has many benefits for other living things. It is used as food, as well as in the dye industry, leather industry and flower industry (URL 13).

The primary metabolism of plants is affected by insect herbivory. According to the factors such as the insect and plant species, the feeding type, duration of feeding, the type of plant tissue, various plant defence mechanisms play role to provide optimal plant fitness against insect attack. Some of the insect change plant metabolism for their benefits (Zhou et al. (2015).

It was determined from the fossil records that the damages of the insects changed due to past extinctions and climate changes (Carvalho et al., 2014).

Carvalho et al., (2014) hypothesised that the relationships between the leaf-chewing damage types and damager insect richness is determinable in forests. They observed significant relationships between the numbers of damage types made by same species in experiments and collected leaf chewing insect species (Figure 13). The richness of the damage type closely related with insect species. Results showed that the leaf damages caused by insect herbivore might be used for interpreting insect richness and species composition.

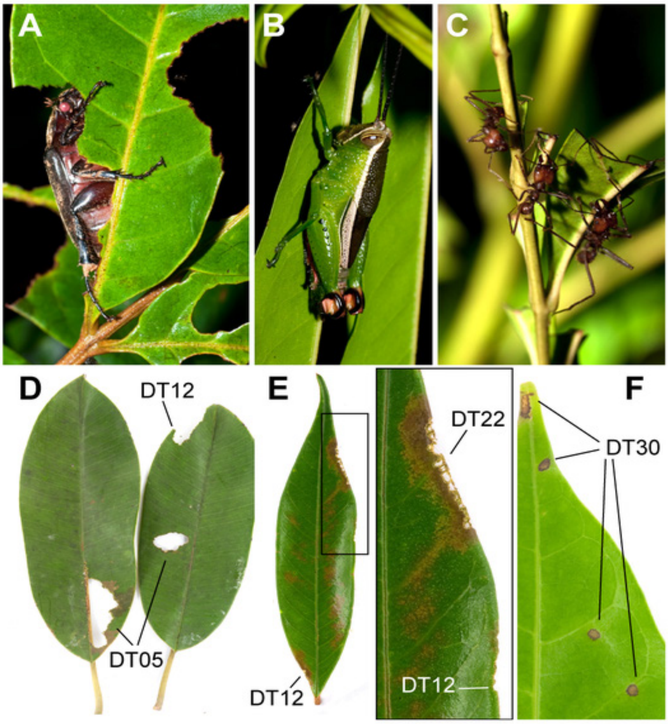


Figure 1. Selected leaf-chewing insects collected from two Panamanian forests, and induced external leaf damage resulting from insect feeding experiments. (*A*) *Phyllophaga* sp. 2 (Coleoptera: Scarabaeidae) observed inducing margin feeding DT12 and DT14 on *Tapirira guianensis* Aubl. (Anacardiaceae). (*B*) Tettigoniidae sp.4. (Orthoptera) on leaves of *Guatteria dumetorum* R. E. Fr (Annonaceae). (*C*) *Atta* sp.1 (Hymenoptera: Formicidae) on leaflets of *Jacaranda copaia* (Aubl.) D. Don (Bignoniaceae) causing margin feeding DT13. (*D*) Hole and margin feeding DT05, DT12 on leaves of *Manilkara bidentata* (A. DC.) A. Chev. (Sapotaceae) induced by Tettigoniidae sp.5 (Orthoptera). Sample 09-216. (*E*) Margin feeding DT12 and skeletonization DT22 on leaves of *Vochysia ferruginea* Mart. (Vochysiaceae) induced by multidamaging species Cryptocephalinae sp.1 (Coleoptera: Chrysomelidae). Sample 09-131. (*F*) Surface feeding damage DT30 on leaf of *T. guianensis*, inflicted by monodamaging species *Homeolabus analis* Illiger (Coleoptera: Attelabidae). Sample 09-135.
doi:10.1371/journal.pone.0094950.g001

Figure 13. The leaf-chewing insect species collected from two Panamanian forests, and leaf damages obtained from feeding experiments (Source: Carvalho et al., 2014).

3.3. Insect-Eating Plants:

Carnivore plants, which form a small part of the plant kingdom, have a completely different diet from other kingdoms. Insect-eating plants, of which approximately 400 species are known all over the world, are a death trap for insects, small birds, and mice. They catch these organisms with their sticky hairs, slippery pitcher-shaped or moving trap leaves (Figure 14). These plants especially grow in nutrient-poor soils such as swamps, peatlands and volcanic masses where nitrogen and other nutrients are deficient. They are also autotrophs and can perform photosynthesis with their green leaves. In addition, they also have special structures suitable for catching and digesting small animals, especially insects. Thus, they take the nitrogen that they cannot provide enough from the soil. If they get the mineral nutrients they need, especially nitrogen, these plants can develop normally without digesting insects. Prey distribution of some carnivorous plant are given in Figure 15. Insect-eating plants growing in both tropical and temperate regions and have a wide variety of apparatus for catching and digesting small organisms (Kılınç and Kutbay, 2008).

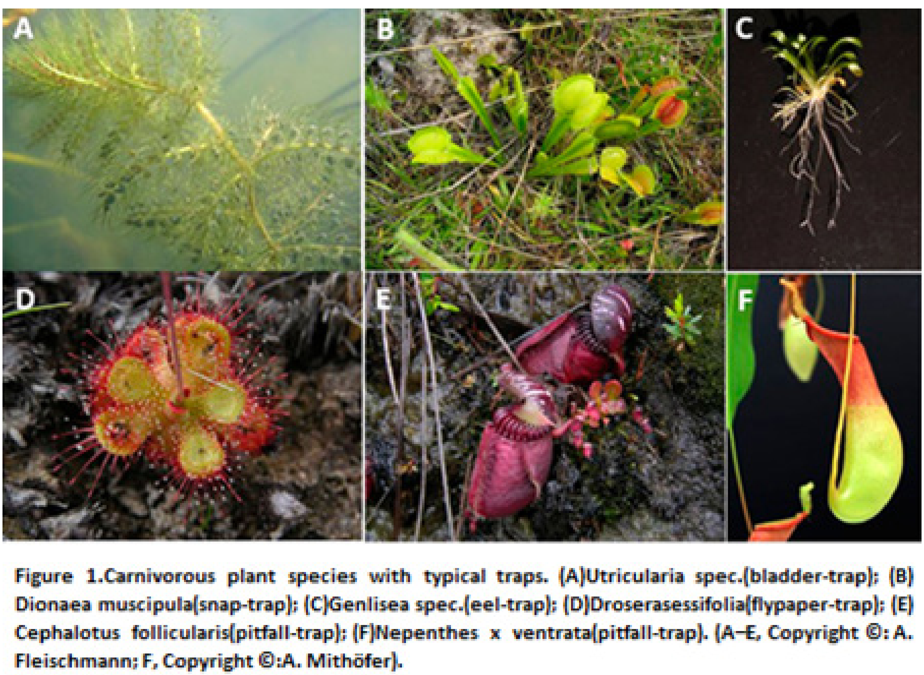


Figure 14. Examples of carnivore plant species (Source: Mithöfer, 2022)

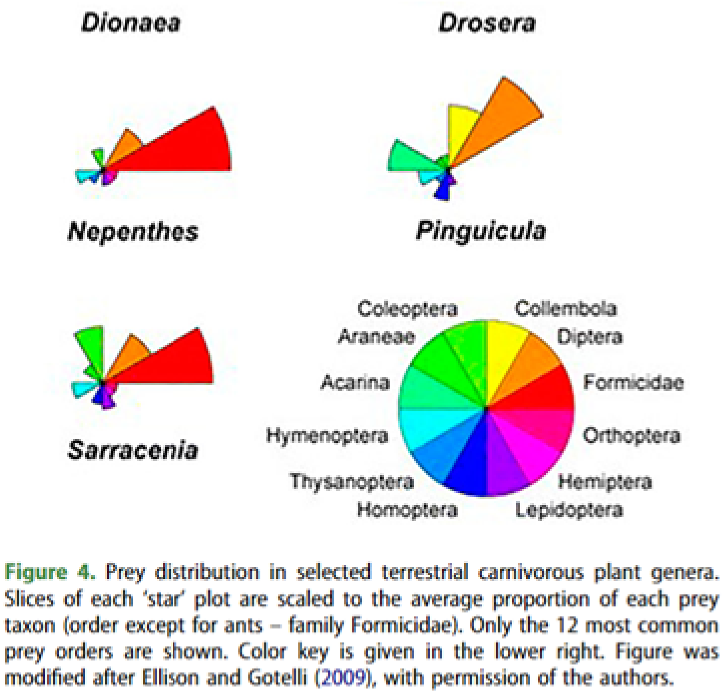


Figure 15. The distribution of preys of the *Nepenthes*, *Sarracenia* and *Pinguicula* according to orders (Source: Mithöfer, 2022).

As a conclusion, there are various interactions between plants and insects in nature. Main relationships were identified but there are still unknown webs between them. The relationships between plants and insects are quite extensive and include many subtopics. In this chapter, advances in food relationships between plants and insects were explained in the light of recent studies. There is a need for detailed studies to clearly identified interactions between plants and insects.

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CHAPTER VII

ENCAPSULATION TECHNIQUES FOR PLANT EXTRACTS

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1. Introduction

Plants are natural sources of various components such as minerals, vitamins, amino acids, lipids, fibers, polyphenols, beneficial oils, flavors, fragrances and pigments (Rubio et al., 2013). Plant materials have bioactive compounds, so there is a need for appropriate extraction methods for the extraction of active compounds (Chuo et al., 2022). In order to increase the extraction efficiency, processes such as drying and grinding are applied before extraction. The solid-liquid extraction method forms the basis of traditional extraction techniques used to extract active compounds from herbal substances. Traditionally used extraction methods include Soxhlet extraction, hydrodistillation and maceration (Idham et al., 2017).

Valuable structures incluede phenolic compounds in plants are both protected and made more functional with the encapsulating technology. Foods gain functional properties by adding phenolic substances, antioxidants, dietary fibers, phytoestrogens and plant sterols to foods. Through to encapsulation technology, it is possible to take the target compound in required amounts. There are several encapsulation techniques. Some of these are; spray drying, spray cooling, extraction, coacervation, lyophilization and emulsification. In the selection of these technologies; The choice of coating materials that are not harmful or toxic to health and the method that will keep the quality parameters at the highest level should be determined and applied. In this chapter, plant extraction and the methods used in the encapsulation of these extracts are discussed.

2. Extraction for plants active compounds

Methods such as microwave, high pressure, high voltage ultrasound and mechanical forces have been used to extract bioactive substances from plants. These methods increase the extraction efficiency, reduce the amount of using solvent and extraction time and enable more greener processes (Cong et al., 2017; Qi et al., 2014; Wu et al., 2017; Siti et al., 2014).

Extracts produced by different methods may have different structural properties (Abuduwaili et al., 2019). Hence, extraction techniques must be carefully determined to obtain the desired extracts. In order to provide optimum extraction conditions, extraction efficiency should be increased, solvent, energy and costs usage should be reduced (Chemat et al, 2019; Perino and Chemat, 2019).

Various plant-derived polyphenols, oil components and other bioactive compounds are structurally different. It is very difficult to find a method that will separate all the components at the same time. The extraction efficiency of bioactive components depends on the characteristics of the plant such as growing conditions, collection time, part of the plant and physicochemical properties of the components.

In addition, extraction conditions; solvent type, solid-solvent ratio, processing time, temperature, pressure, pH and the chosen extraction technique also affect the extract yield. (Mustafa and Turner, 2011, Dent et al., 2013; Jovanovié et al., 2017).

Many traditional extraction methods are used today. The advantages, disadvantages and possibilities of use of these methods differ among themselves. In general, traditional extraction methods are one of the easy-to-use techniques for plant materials. However, its major disadvantages are the large consumption of solvents and the long processing time (Chuo et al., 2022). The advantages and disadvantages of the methods used in herbal extracts are given below. Parameters such as the used plant, extracted the bioactive compound and the extraction time are important parameters in determining methods.

Ultrasound assisted extraction method is among the most used extraction methods in recent years with advantages. These advantages are ease of use, cheapness of the device used, less amount of solvent used, shortening the extraction time, increasing the extraction efficiency and being an environmentally friendly method (Rouhani, 2019; Chen et al., 2018; Chemat et al., 2017).

Also supercritical fluid extraction method is one of the methods used in recent years. The method is an environmentally friendly method with high selectivity, safe and usage of inexpensive solvent, easy extraction conditions and low operating temperature. This method should be considered if the goal in the extraction is maximum purity of the active compounds and the overall yield is not important (Matsuyama et al., 2019; Rafinska et al., 2019).

The positive aspects of microwave-assisted extraction are less extraction time and using to less solvent. Pressurized fluid extraction and subcritical water extraction use the special properties of subcritical liquids to increase the extraction of active compounds from plant materials (İbrahim et al., 2018; Mustapa et al., 2015). Enzyme assisted extraction is safe and environmentally friendly extraction method to obtain bioactive compounds in the structure of the plant. In this method, hydrolysis of the plant cell wall is supplied by the action of enzymes that release bioactive compounds and high extraction efficiency is achieved.

The high voltage assisted extraction method can be used to shred plant structures in a short time to active components. It is an extraction method using ionic liquids or deep eutectic solvents. IL- and DES-based solvents are used, which increase the extraction efficiency of active compounds. These solvents help to increase the solubility of the desired components. In addition, these solvents are safer and more environmentally friendly solvents than other solvents (Chuo et al., 2022).

Many methods can be used in the extraction of plants. Appropriate extraction method disrupts the structure of the plant and ensures the release of active compounds. Microwave, heat, chemical reaction, mechanical movements, ultrasound, high pressure and other methods cause plant structures to deteriorate. The method used should also use solvents that can quickly penetrate and dissolve plant bioactive components. In general, solvents should have similar polarities as bioactive compounds to ensure maximum effectiveness. In order for the extracts obtained to be suitable for consumer use, solvents must be on the generally safe (GRAS) list.

According to recent research, ultrasound assisted extraction and supercritical fluid extraction are the most famous and improved extraction techniques. Microwave assisted extraction, pressurized liquid extraction and subcritical water extraction are also among the frequently used methods.

However, traditional extraction techniques such as heat assisted extraction, maceration, Soxhlet extraction and hydrodistillation are still widely used today. One method alone cannot isolate all active ingredients from plant materials. Finally, combinations of extraction methods should be considered together to produce the desired extracts (Chuo et al., 2022).

Plant extraction with ultrasound system is among the most widely used methods. The ease of use of the ultrasonic bath and the short duration of the extraction process increase the use of this method. The extraction of plants by ultrasound system is shown schematically in Figure 1. Naturally derived extracts are often unstable, bitter, difficult to use, store, or consume. Therefore, natural extracts should be converted into forms that are easier to process, with reduced stickiness. In addition, the extracts must be consistent under varying storage conditions without affected their bioactivity. Encapsulation is an effective method to eliminate all these negativities.

As a result, encapsulation technique putting a barrier in between plant extract and its environment is effective method.

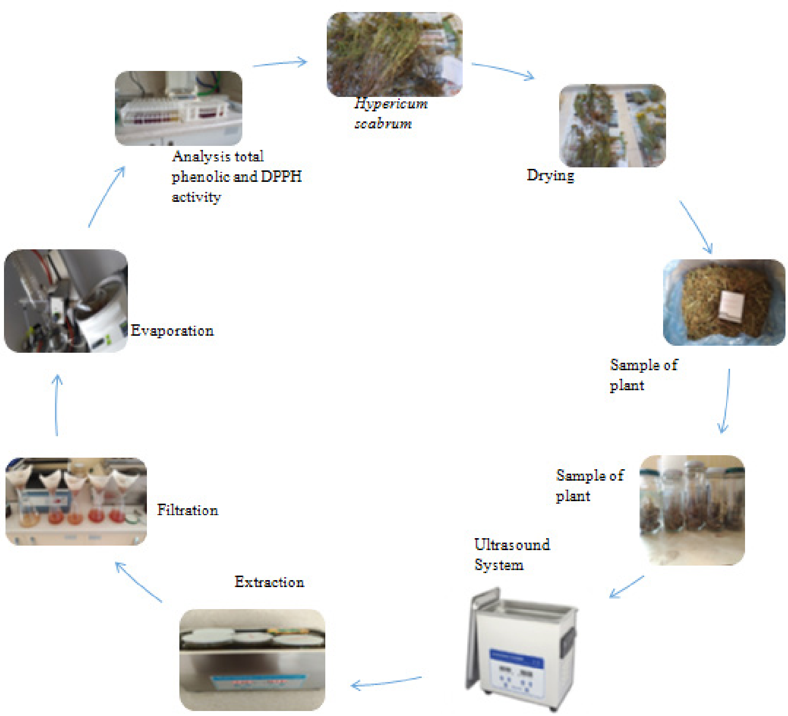


Figure 1: Extraction stages of *Hypericum scabrum*

3. Encapsulation

Extracts with high added value, phenolic compounds, antioxidant compounds, vitamins, microbial cells are obtained from plants, vegetables, fruits or waste materials. Encapsulation technology provides the protection, controlled release and stabilization of these components. It is a common technique used to preserve or increase the bioactivity of natural extracts (Nikmaram et al., 2017).

Encapsulation is the most successful method in terms of protecting aroma substances, masking undesirable odors, increasing their thermal and oxidative stability, limiting their high volatility, controlling their rapid release, increasing their bioavailability and use in food systems (Saifullah et al., 2019). Some problems arise in the use of bioactive components obtained from herb extracts as functional food ingredients. These problems are; undesirable taste, problems caused by factors such as light, temperature, oxygen during food production and storage, or the presence of pH and enzymes in the gastrointestinal tract, rapid intestinal metabolism, low permeability and/or solubility. Encapsulation technology is an effective technique for the preservation and bioavailability of bioactive compounds (Fang and Bhandari, 2010; Đorđevié et al., 2015). Benefits of encapsulated bioactive components in food applications; superior handling, taste masking, visual and textural are effects (Zuidam and Shimoni, 2010). In general, encapsulation described as the process of imprisoning bioactive compounds in a carrier material (Nedović et al., 2011). Nowadays, techniques such as extrusion, coacervation, spray drying, emulsification and spray cooling techniques are used to maintain and increase to stability. These technologies are used both in the food industry and medical, cosmetic and pharmaceutical industries. Spray drying is the most common of the various encapsulation technologies.

The spray drying method is used for the stabilization of plant extracts and in the production of food ingredients. The reasons for using the method are low processing costs, maximum production rates, easy use and cheap-accessible equipment (Gharsallaoui et al., 2007; Đorđevié et al., 2015). Microencapsulation is the process which placed of target material in the center of a shell material and coated with thin coating materials (Hu et al., 2020).

Encapsulation technology is the process of encapsulating core material components, also known as active ingredients, using coating material. There are different views on the distinction between microencapsulation and nanoencapsulation. However, the size of nanoparticles should be between 1-100 nm. Both techniques use a physical barrier to protect the active ingredient from environmental factors and goal to allow controlled release of the active ingredient (Paulo and Santos, 2017). Nowadays, microencapsulation technology is used in the fields of food, cosmetics, medicine, agriculture, textile, biomedical and electronics. Microencapsulation technique is used to increase the effectiveness of the selected active substance (Paulo and Santos, 2017).

The particle size of the microcapsules ranges from 1-1000 μm. The structure of microcapsules; single-core coating, multi-core coating and small matrix type formed by the dispersion of the coating material in drops is classified as. Hydrophobic reactions and van der Waals interactions stabilize lipids. Proteins associate by hydrophobic interactions and covalent disulfide migration. Metal alkoxides and silica are hydrolyzed and condensed to form dense matrices. Therefore, core material release can cause physical, chemical or enzymatic degradation (Ye et al. 2018). Many factors such as the molecular structure, physical properties, biological structure, solubility and surface activity of the core material are important for it to be active and beneficial. In addition, the coating material used in the miroencapsulation process should be biocompatible, non-toxic, cost-effective and biodegradable (Ye et al. 2018).

The properties of the microencapsulated extract can be affected by many factors. These factors may be the properties of the active substance, the properties of the formulation and the processing conditions. These factors affect the particle size, distribution, morphology, yield of the microcapsule and encapsulation efficiency (Paulo and Santos, 2017).

The technology that provides to encapsulation of substances in nano dimensions is called nanoencapsulation. In other words, it refers to bioactive packaging at nanoscale (Lopez et al., 2006). Nanoencapsulation technology increases the bioavailability and release of the bioactive compound. Also this method provides to obtain smaller capsules than microencapsulation (Mozafari et al., 2006). The diameters of nanoparticles range from 10 to 1,000 nm. These nanoparticles expressed as both nanocapsules and nanospheres (Konan, 2002). Nanocapsules are vesicular and matrix systems in which the bioactive compound is covered with a polymer membrane and the bioactive compound is evenly dispersed (Couvreur et al., 1995). Encapsulation types in the literature are given in Table 3.1.

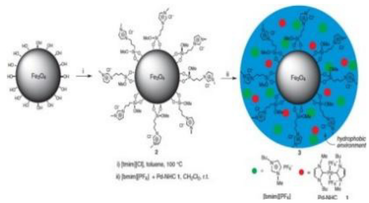
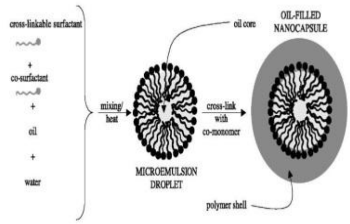
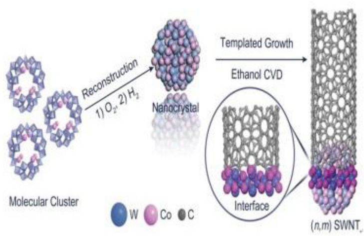
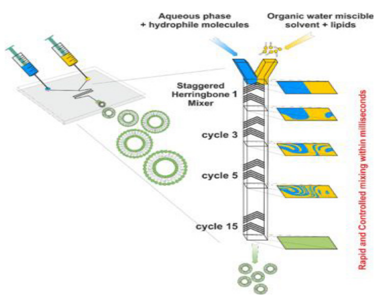
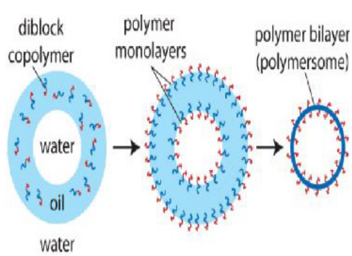
4. Encapsulation Techniques

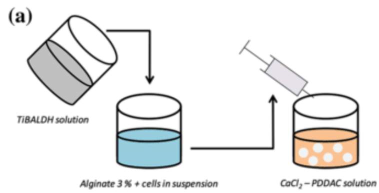
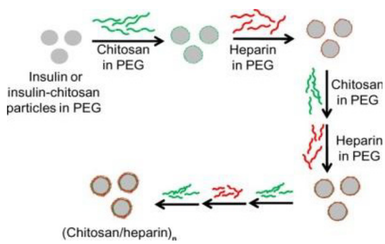
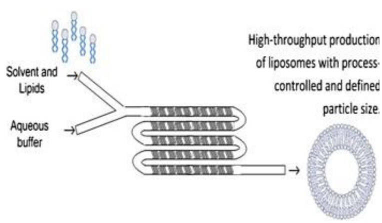
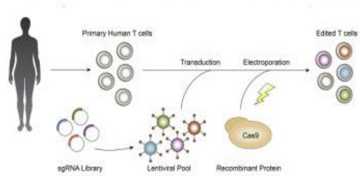
Encapsulation methods basically consist of three parts; mechanical, chemical and physicochemical these are spray drying, polycondensation, insitu polymerization and ionic gelation respectively (Jyothi et al., 2010; Sahlan & Rahman, 2017).

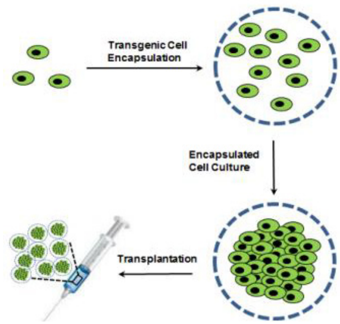
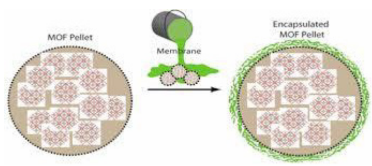
4.1. Spray drying

Spray drying method frequently is used in liquid extracts today. The method can product continuously and obtain standard quality product (Yerlikaya and Arslan, 2019). In addition, this drying method has a short application time and easily controllable process conditions. The spray drying process stands out as an ideal drying system for products that can preserve their color, taste and nutritional value at high level and have the potential to process various product groups (Haque et al., 2015). This technology is an economical method and provides ease of control on parameters such as particle density, bulk density and crystallization degree in powder products. (Haggag and Faheem, 2015). Spray drying involves the atomization and subsequent drying of aqueous or organic solutions with the help of a fluid such as hot air or inert gas (Haque et al., 2015). The fluid in the system is sprayed into the drying environment as smaller droplets and these droplets dry by moving towards the hot gas/air environment (Nuzzo et al., 2015). Depending on the feed composition and processing conditions, the final particles can be very different.

Table 3.1: Encapsulation types and different structures

Types of Encapsulation	Encapsulation Structure	Encapsulation Formation	Reference
	Nanoparticles		He and Alexandridis, (2017)
	Nanocapsules		Url-1, (2020)
Nano-encapsulation	Nanotubes		Yang, (2014)
	Nanoliposomes		Kotouček et al., (2020)
	Polymersomes		Hayward et al., (2006)

Types of Encapsulation	Encapsulation Structure	Encapsulation Formation	Reference
Micro-encapsulation	Microcapsules		Leroux et al., (2020)
	Microparticles		Song et al., (2014)
	Microvesicles (Liposome etc.)		Kastner et al., (2014)
	Adding Genes to Cells		Shifrut et al., (2018)

<table>
<tr><th>Types of Encapsulation</th><th>Encapsulation Structure</th><th>Encapsulation Formation</th><th>Reference</th></tr>
<tr><td rowspan="2">Macro-encapsulation</td><td>Cell, Stem Cell and Tissue Encapsulation</td><td>
</td><td>Zhang, (2015)</td></tr>
<tr><td>Membrane Coated Adsorbent</td><td>
</td><td>Hossain et al., (2018)</td></tr>
</table>

These particles can be classified as; nano-sized powders (210-280 nm), micron-sized fine powders (10-50 µm) or agglomerates (up to 3 mm) (Gharsallaoui et al., 2007). The quality of the powders produced by the spray drying method depends on the properties of the solution fed to the system, the drying air, the contact rate or the distance between the hot air and the drying chamber, the type of atomizer and atomizer's speed (Shishir & Chen, 2017).

The characteristic of the dried product are determined depending on the physical and chemical properties of the fed product, as well as the dryer system design and process parameters (Keshani et al., 2015). Therefore, the quality of spray-dried powders varies depending on flow properties, compressibility, bulk density, dispersibility, solubility, product composition and spray-drying process parameters (Haque et al., 2015). Figure 2 shows the production of microcapsules from herbal extracts by spray drying. Figure 3 shows the production of microcapsules from herbal extracts by spray drying and then their addition to the foodstuff.

The spray drying process basically consists of four parts. 1- Atomizing the liquid to be fed into the system as fine droplets, 2- Contact of the droplets with hot air, 3- Drying the atomized droplets and 4- Separation of the dried droplets from the moist air (Malamatari et al., 2020).

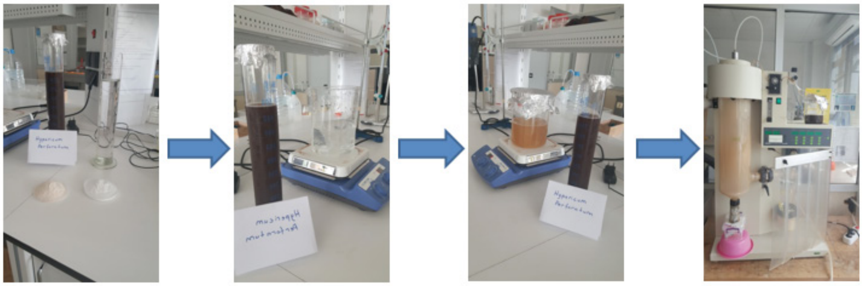


Figure 2: Flow chart of microcapsule production from plants

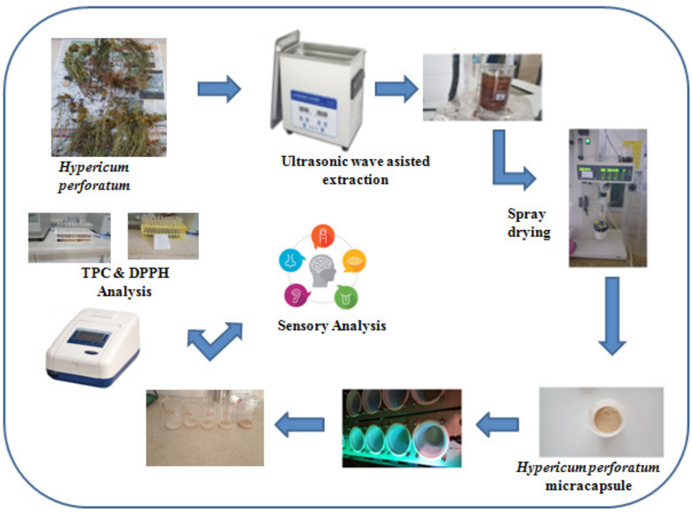


Figure 3: Production of encapsule from the plant extract

The system also have some disadvantages these are non-uniform size and shape of particles, and aggregation tendencies (Đorđević et al., 2015). Makoni tea (Fadogia ancylantha), thyme (Origanum vulgare), thyme (Thymus vulgaris), melisa (Melissa officinalis), coltsfoot (Tussilago farfara) and green tea (Camellia sinensis) have high phenolic content, antioxidant and antimicrobial activities and therefore these plants are very attractive for the food industry. A new form was obtained from these plants by using the spray drying technique. And then these use as an additive in food was investigated (Sansone et al., 2011; Belščak-Cvitanovié et al., 2015b; Bilušić et al., 2020).

Coating agents such as pectin, alginate, inulin, protein isolates and gums have been used in spray drying systems. The obtained powders have improved organoleptic properties, physicochemical, technological and functional features.

In general, microencapsulated extracts have showed reduced stickiness, masking of unpleasant odor and improved free dissolution rate. It has been observed that bioactive substances which sensitive to degradation are preserved even after heating or photodegradation (Nedović et al., 2017).

No significant change was observed between the powders obtained by spray drying and the extract. All these advantages provide that spray drying to be preferred in the production of microcapsules from plant extracts. Plant materials such as anthocyanins, carotenoids, betalains, betaxanthin, betacyanins have been extracted and stabilized in a spray dryer. (Kalušević et al., 2017b, c; Ćujić-Nikolić et al., 2018, 2019; Vulić et al., 2019; Šeregelj et al., 2019).

4.2. Freeze drying

Freeze drying, also known as lyophilization, is a drying method based on freezing the food to be frozen before drying and then sublimation of the water in the food directly under low pressure (Nireesha et al., 2013). In order to perform a successful lyophilization process, the pressure in the drying chamber should be kept at an maximum pressure of 40 Pa (Toledo, 2007). In this process, low temperature and pressure are applied together. Thus, the preservation of color and aroma is ensured with rehydration. (Ceballos et al., 2012).

Freeze drying has become an significant process for drying and increasing the stability of valuable products, including nutrients and pharmaceuticals (vaccine, protein, peptide, colloidal carrier, etc.) (Kumar et al., 2011). Additionally, freeze drying have supplied high quality products, long shelf life and improved rehydration properties.

Since foods naturally contain heat-sensitive components such as vitamins and proteins, drying can cause, oxidation, enzymatic browning and thermal decomposition (Marques and Freire, 2005). For this reason, the use of special techniques such as freeze drying provides additional advantages to these products during the drying (Menon et al., 2020). Lyophilization process is used especially for drying products with high added value due to its high investment cost and energy consumption (Schössler et al., 2012). There are basically three stages in the freeze-drying process 1- Freezing the component, 2- Removal of frozen water by sublimation, and 3- Further heating of the product (Searles et al., 2017).

The freeze-drying process preserves the nutritional values of the extract or food well. Thus, the parameters such as rehydration, texture and color of the obtained capsule are very close to the fresh product. (Voda et al., 2012). However, freeze drying is a process that requires a lot of energy because of freezing the products, providing sublimation in frozen samples and reducing the pressure of the dehydration chamber (Donsì et al., 2001). Therefore, the usability of freeze drying in the food industry is limited to valuable product groups incluiding some fruits, vegetables and meat products. (Schössler et al., 2012).

There are many studies comparing the properties, advantages and disadvantages of capsules obtained with spray and freeze drying method. For example, in order to encapsulate the bioactive compounds of red pepper, freeze-drying gave better results considering its technological properties (Šeregelj et al., 2019).

In the literature, freeze-drying technique has been used in many herbal products. Later, these encapsules have added to foodstuffs. In the encapsulation of plant extracts and essential oils in different systems such as hydrogel beads, freeze drying has been used as an additional technique after application (Balanč et al., 2016; Ćujić et al., 2016; Kokina et al., 2019). Cherry pulp (Šaponjac et al., 2016), capsicum waste (Šeregelj et al., 2019), beet pulp (Hidalgo et al., 2018), grape skin or soybean rind (Kalušević, 2017) are wastes and by-products. These plants compounds obtained from of different plant and fruit-vegetable. Waste-derived extracts which rich in polyphenols, polysaccharides and protein have been encapsulated with freeze-drying. And then encapsules were added to various food products such as cakes, cookies, biscuits, yogurt. (Popovic et al., 2019). Finally, these waste materials were lyophilized and evaluated with encapsulation.

4.3. Electrostatic Extrusion

The extrusion technique is economical and does not harm the environment. Not using organic solvents and high temperatures during the process saves energy and water. Polysaccharide gel which immobilizes the nucleus when in contact with a multivalent ion, is the basis of the method. The extrusion core is incorporated into a sodium alginate solution. And then added to a hardener solution such as calcium chloride via a low gauge pipette. In the extrusion method, it is ensured that the aromas are stable against oxidation. Components such as sucrose, maltodextrin, glucose syrup, glycerin and glucose are commonly used as carrier materials. Thus, oxidation is prevented and products are preserved for a longer time (Gürbüz et al., 2020).

Some essential oils (almond, cinnamon, basil) were encapsulated by extrusion technology and the encapsulation efficiency were determined as 56, 82 and 84%, respectively (Karakaya and Yılmaztekin, 2021). The extract of Carqueja (Pterospartum tridentatum L.) rich in various bioactives such as alkaloids and flavonoids has been coated by electrostatic extrusion (Balanc et al., 2016). Hydrogel loaded microparticles containing calcium alginate and calcium alginate inulin were produced. Phenolic compounds and antioxidant activity were significantly preserved during long-term storage. The presence of inulin preserved the structure of the microcapsules. Moreover similar results have been observed in capsules of anthocyanin-rich chokeberry extracts (Ćujić et al., 2016). Also, this method has been applied successfully with coating plant extracts (e.g. thyme, *Thymus serpyllum L.*) with chitosan (Stojanovic et al., 2011; Trifković et al., 2014).

4.4. Liposome Compression

Liposomes are method used to encapsulate hydrophilic and hydrophobic materials. Liposomes, known as spherical lipid sacs consisting of bilayers of polar lipids, are used in many fields. Soy, sunflower lecithin and eggs are sources of natural. Mechanical and non-mechanical methods can be used in liposome production. Extrusion, high pressure homogenization, high intensity ultrasonication and homogenization are mechanical methods. Reverse-phase evaporation and freeze-drying methods are non-mechanical methods.

Encapsulated antioxidants, antimicrobials, vitamins with liposomal systems remain more stable in various processes (such as drying, pasteurization, frying and cooking). Liposome encapsulation forms a structurally similar coating to the cell membrane. Thus, bioactive compounds can reach the determined areas in the body and their bioavailability increases. It has been determined that the toxic effect of vitamin A, which is coated with liposomal systems, is eliminated even when consumed too much. In addition, they do not change the rheological properties of the system as they are not in polymer structure. Liposomes are at low energy levels due to their structure. Liposome globules coalesces to precipitate and terminate dispersion (Gürbüz et al., 2020).

The cost of liposomal systems limits their use. These excellent coating systems should be used in herbal extracts and studies in the literature should be increased.

4.5. Inclusion Complex

Cyclodextrins are compounds used in inclusion complex formation. It exhibits edible, homogeneous, pure, hygroscopic and non-toxic properties. These compounds have a chemically stable structure and increase water resistance. In this method, a bond is formed between the cyclodextrin and the particles, resulting in precipitation. The use of this method is seen in the food industry. In particular, it preserves the stability of vitamins, flavor, aroma substances, coloring agents and unsaturated fats and extends the shelf life of food (Gürbüz et al., 2020).

The three-dimensional structure of cyclodextrins enables the active substances to be encapsulated within their cavities preserves the properties of bioactive substances (Mura, 2014). The inclusion complex is based on the precipitation of one substance with another substance. Cyclodextrins and aqueous solution of the active ingredient precipitates with stirring, sonication or heating to form an inclusion complex. In addition, spray drying and freeze drying are used to prepare amorphous and rapidly dissolving compounds (Đorđević et al., 2015).

St. John's wort (*Hypericum perforatum*) was extracted by inclusion complex method. And extract was coated with ß-cyclodextrin and then lyophilized (Kalogeropoulos et al., 2010). It is concluded that this method can be used successfully. Especially *Hypericum perforatum* capsules have been added to heat-treated foods. It was observed that the amounts of bioactive compounds in foods and the amounts of bioactive components of *Hypericum perforatum* extract were similar.

5. Conclusion

Plants have very valuable compounds such as phenolics and antioxidants. These compounds can also be used on many of areas for their antioxidant and antimicrobial activity. Similarly plant extracts can be evaluated in many industries. However, the structure of the extracts is affected by environmental conditions such as temperature, oxygen and pH. In this situation, extract's structure can deteriorate and decrease bioactive components. Also there may bitter taste or undesirable color changes. In this case, the encapsulation technology eliminates all these negativities effects and protects the plant extracts against environmental conditions. Methods such as spray drying, freeze drying, extrusion technology, liposomal systems and inclusion complex are used in plant extracts. However, spray and freeze-drying techniques have been used the most in the literature.

The encapsulation of herbal extracts increases their usage in many areas. There are studies in which bioactive compounds and essential oils are encapsulated and added to many foods. Thus, it is seen that successful results are obtained in functional production. The use of different encapsulation methods in herbal extracts should be evaluated and introduced to the literature. More studies should be carried out on plants that are beneficial for health. Encapsulation of these herbal extracts should be studied detailed. The usability of herbal extracts should be evaluated in all areas.

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CHAPTER VIII

MAJOR PESTS OF STORED PLANT PRODUCTS

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1. Introduction

Nutrition, which is the basis of life, offers different alternatives for different life forms according to the way of working. Although plant-based nutrition is one of these alternatives, it is of vital importance for a wide variety of living things, especially humans. Main and complementary nutrients, especially energy sources to be obtained from plants, are indispensable elements in the preservation of vitality. Plant products grown in different geographies of the world are very important not only for humans but also for many different living species, especially insects, due to their different structural nutritional contents. For many insect species, using different plant products in the same area is sufficient for survival, while for some insect species, lifespan depends on a single plant product. Especially in many types of stored plant products, harmful insect species specialized for the stored product are frequently encountered (Boyer et., 2012).

Human beings grow millions of tons of various grains and legumes every year in different geographies of the world. In order to consume such a large amount of plant products grown at different times during the year, these grown products are stored in suitable large warehouses. The first difficulties in the adventure of hidden plant products that will last until our tables begin in this storage process. Because plant products, which are stored for many different living things, especially harmful insects, are an indispensable food source and host for new generations. For this reason, it is meaningless to be able to fight with these pests without recognizing the harmful insects in the stored plant products. The characteristics of these pests have been determined by observations and researches over the years, their biology has been revealed, and many different methods of control have been developed against these pests over the years. Although there are many stored product pests known today, most of them are species of families belonging to the order Coleoptera. However, some species of families belonging to the order Lepidoptera are also quite harmful in stored products (Boyer et., 2012). These stored crop pests infest grains and legumes stored in warehouses, causing quality and quantity losses in crops (Athanassiou et al., 2011).

In this section, the definitions and brief biology of 15 insect pests belonging to the order Coleoptera and 5 moth pests belonging to the order Lepidoptera, which are defined as pests of stored grains and legumes, are discussed. In addition, different control methods used in the fight against these pests are explained in general terms. This information will help us to know these stored product pests better and have very useful information to combat them in the warehouses.

2. Major Stored Product Pests of The Order Coleoptera

Coleoptera is an order containing the largest number of insect species among the insect orders, and its members have a very hard, protective, elegant sheath called the elytra. Individuals that hatch from eggs are called larvae and become adults after completing the larval and pupal stages. Both adults and larvae have biting chewing mouths. About 45 insect families and many related insect species have been identified in stored products (Rees, 2004; Kumar, 2017; Tripathi, 2018).

Table 1. Major stored product pests of the order Coleoptera

Species	Commoun Name	Family
Acanthoscelides obtectus (Say, 1831)	Bean weevil	Chysomelidae
Callosobruchus chinensis (Linnaeus, 1758)	Southern cowpea weevil	Chysomelidae
Callosobruchus maculatus (Fabricius, 1775)	Cowpea weevil	Chysomelidae
Sitophilus granarius (Linnaeus, 1758)	Granary weevil	Curculionidae
Sitophilus oryzae (Linnaeus, 1763)	Rice weevil	Curculionidae
Sitophilus zeamais (Motschulsky, 1855)	Maize weevil	Curculionidae
Tribolium castaneum (Herbst, 1797)	Red flour beetle	Tenebrionidae
Tribolium confusum (Jacquelin du Val, 1863)	Confused flour beetle	Tenebrionidae
Tenebrio molitor (Linnaeus, 1758)	Mealworm	Tenebrionidae
Latheticus oryzae (Waterhouse, 1880)	Longheaded flour beetle	Tenebrionidae
Lasioderma serricorne (Fabricius, 1792)	Cigarette beetle	Anobiidae
Rhyzopertha dominica (Fabricius, 1792)	Lesser grain borer	Bostrichidae
Trogoderma granarium (Everts, 1898)	Khapra beetle	Dermestidae
Cryptolestes ferrugineus (Stephens, 1831)	Rust-red grain beetle	Laemophloeidae
Oryzaephilus surinamensis (Linnaeus, 1758)	Saw-tooth grain beetle	Silvanidae

2.1. Chrysomelidae Family

These pests specialize in mature and maturing legume seeds and use them as food and hosts. They are the most popular and most destructive storage pests of stored products. These pests do not attack cereal grains, cereal products or cereal-based products (Rees, 2004; Kumar, 2017).

Acanthoscelides obtectus: Although it is common in the world, it is a pest mostly seen in subtropical regions. It attacks almost all bean varieties, but has also been reported to attack other legumes. It infects and attacks seeds both in the fields and in warehouses. Adults are oval-shaped, 3-4 mm long, with brown or brownish-grayish hairs on elytra, with sawtooth-like segmented antennae, elytra shorter than abdomen. Adults do not feed, they just mate and lay eggs on seeds, fly fast and well. Adults fake death for a short time when disturbed and then quickly flee. The female lays about 65-75 eggs on the seeds before or after harvest. The eggs first become transparent, then their color becomes dull and slightly yellow. The larvae grow and develop inside the bean grains, they are off-white in color. The larvae form a pupal chamber near the top of the seed. Average minimum life cycle is 28-32 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Tripathi, 2018; Ahmad et al., 2021).

Callosobruchus chinensis: This pest has a cosmopolitan distribution and has been frequently detected in countries with beans and chickpeas. This pest, which is frequently seen in the tropics and subtropics of Asia, is the dominant pest of legumes in Asia. It is a common and important pest of stored legumes and has been reported to damage cowpeas, peas and lentils, as well as beans and chickpeas. Adults are a small hardy pest reaching a length of about 3.5-4.5 mm. It is a pest with hard, short-haired brown spots with black and gray spots on its adult body. Adults have a good flying ability and can easily disperse in planted fields and areas where crops are stored. Females are larger than males, antennae are sawed in females, pectinate in males. Males have stronger flying abilities than females. The eggs of this pest are adhered to the chickpea seeds one by one, and the eggs are quite transparent at first and turn a yellowish dull color over time. A female has the capacity to lay 80-90 eggs. The eggs usually hatch after 4-6 days, and the resulting larvae spend the rest of their developmental stages in the nucleus, feeding on an empty stomach. The larvae are off-white to yellowish-whitish and have small legs. Larva completes its development in 12-20 days. Pupae are dark brown and remain in this form for 6-8 days. Adult pests live up to 8-12 days. Total development time varies between 28-38 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Kumar, 2017; Tripathi, 2018).

Callosobruchus maculatus: This pest, which is common in the world, is an important pest of legumes in landfills. It is extremely harmful to important legumes such as chickpeas, lentils, beans, cowpea, black and green gram, which are economically important. Adults are oval, brown, chocolate brown or dark reddish brown. Adults are 3-4 mm long, covered with very hard and dense hairs.

They fly very well and move fast. The adult elytra is shorter than the rest of its body, leaving the last part of the abdomen exposed. The antennae are serrated, the adult male is smaller than the female and has a more rounded shape. The pest actively breeds from spring to late autumn. Females produce an average of 70-80 small, oval, transparent eggs. Eggs are attached to the seed one by one, but sometimes more than one egg can be seen on a single seed. The eggs are transparent, shiny and smooth when laid, but later, as the larvae begin to form, they turn yellowish-white and eventually turn a dull dark yellow. The incubation period is between 4-7 days. The first larva that emerges from the egg pierces the seed and begins to greedily feed inside the seed. The developmental larval period is 17-20 days until the white, off-white tiny larvae become pupae. It spends its pupal period in a small chamber just below the seed coat, and this period is about 5-8 days. Adult males live 9-11 days, females 11-14 days. The total life span is between 28-40 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Kumar, 2017; Tripathi, 2018).

2.2. Curculionidae Family

True weevils are the largest known insect family. They can be found in many different habitats around the world, where agriculture, forestry, and horticulture are practiced in many different ways. They cause serious damage by attacking the stems, branches, roots and seeds of plants. They are immediately recognizable by their elongated snout structure. Among them, the genus Sitophilus is among the most important pests of stored grain (Rees, 2004; Kumar, 2017; Tripathi, 2018).

Sitophilus granarius: It is a common grain pest in temperate regions of the world. It contains wheat, oats, barley, corn, sunflower, rice, millet, peanuts, chickpeas, rye, sorghum, broad beans and various dried stored products. They do not perform well on floured or heavily cracked grains. The body is bright reddish brown, dark brownish or brownish blackish brightly colored, 3-4 mm long, it is a flightless insect because it has no wings. They have a long, slender snout and a pair of thick jaws, as well as strong chewing mouths. Adults briefly pretend to be dead when disturbed. Adults and larvae greedily feed on infested grain. The grain beetle female lays 250-350 eggs one by one in the holes they have made in the grains. Eggs are laid on a slightly sticky one or two, the incubation period is 4-8 days. Each egg develops into a white, legless larva that eats the grain from the inside. The larva is fleshy, legless and creamy or whitish in color, legless and tan-headed, staying in this period for about 18-24 days. One larva develops in each grain, and the larva tunnels forward and takes the form of a pupa at the end of four larval stages. A single pupa per grain completes this period in approximately 5-8 days. The development period from egg to adult varies between 32-42 days. Since the hairy structures of newly emerged adults do not harden immediately, they remain in the grain for a certain period of time and feed on grain. Adults live up to 6-8 months and can give 3-4 offspring per year (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

Sitophilus oryzae: This pest is the most destructive insect of stored grain products and is seen in all geographies of the world where hot and humid climates are common. They cause serious and irreversible damage by invading wheat, corn, bulgur, barley and all other grain and grain products, especially rice. They can attack crops not only in warehouses, but even while the crop is still in the field. Adults and larvae cause serious damage in their warehouses and cause serious quality and quantity losses in the product within a few months if precautions are not taken. Adults are winged and can fly, elytra with four orange-brown, reddish-brown pale cross-elliptical spots. They are about 2-3 mm long, have a long nose, reddish brownish blackish hard structure. Females lay about 300-400 eggs, a small white egg is laid in the cavity created by the female on the grain, which is then filled and sealed with a gelatinous material. Eggs hatch in 5-7 days, young larvae burrow directly into the grain and begin to greedily feed. Larvae are white, off-white, fleshy and legless. The larval period lasts 20-25 days, followed by a 6-10 day pupal stage. The development period from egg to adult varies between 25-35 days. Adults can live an average of 3-5 months (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

Sitophilus zeamais: It is a cosmopolitan pest that is distributed worldwide in tropical and temperate environments. They feed on most of the whole grain cereals, especially corn, rice, barley, wheat, rye and cause serious losses. It has also been reported to cause serious damage to dry foods such as pasta and noodles obtained from grains. Life cycle similar to rice louse, but slightly larger than rice louse, 2.5-4 mm long. They are more volatile than rice lice and four orange-red spots appear on the elytra. Long proboscis with familial features are highly developed, reddish brown, dark brown blackish and brighter insects. Both adults and larvae feed directly on the seed and cause tremendous irreversible damage. Females lay about 300 to 400 eggs on cereal grains in the field before harvest or in post-harvest storage. Eggs are white, creamy white and hardly visible to the naked eye. Usually one egg is laid per grain, but if more than one egg is laid, the larvae will damage each other with active aggression due to competition within the grain. The females lay an egg in the cavity they have dug on the grain and seal this hole with a sticky and quick-drying secretion. Within a few days, the eggs hatch, a legless, creamy-white-fleshed larva emerges and greedily feeds on grain. At the end of the four larval stages, the larva develops into a pupa and then emerges as an adult insect. It takes a minimum of 28-36 days for this pest to pass through the stages of egg, larva and pupa. Adults can live for 3-6 months and can give 4-5 offspring per year (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Tripathi, 2018; Ahmad et al., 2021).

2.3. Tenebrionidae Family

It is a large insect family with adults 3-10 mm long and with approximately 10,000 described species. Although they are known as scavengers, and some are partially predatory, they become harmful by tunneling under bark or in trees. However, *Tribolium* species are among the most damaging pests of stored products. The elytra of these pests always completely cover the abdomen. Larvae resemble the elateriform form (Rees, 2004; Kumar, 2017; Tripathi, 2018;).

Tribolium castaneum: *Tribolium castaneum* is the most common pest of stored grains and is cosmopolitan in nature. This pest does not harm whole grain, it feeds and survives mainly grains that have been processed, broken or destroyed by other insects and almost any food. Serious damage occurs in the products attacked by both adults and larvae, and bad odor and an undesirable bitter taste in the products occur in the warehouses where the invasion is intense. Since this situation is not suitable for human and animal consumption, products should be destroyed in such cases. This pest is known for its reddish-brown colour, young adults who have just completed their pupal stage are pale brown in color and become darker and brighter with age. Adults are winged and 2.5-4 mm long and can fly, spending their entire life cycle among broken or floury cereal grains. Females can lay an average of 400-500 eggs and this number is reported to increase depending on climate and food. Eggs are transparent white, matting over time. Eggs are left with a slightly sticky substance between flour or broken grains. Thanks to this sticky substance on the eggs, the eggs are covered with flour and become invisible and protected. Eggs complete their development in 5-11 days. Larvae are yellowish-white, elateriform, about 10 mm long, active, have three pairs of legs that move by hiding among broken grains and flours. There are six to seven larval stages, depending on climate and diet, and the larval stage is between 25-35 days. Pupae are off-white, gradually turn yellow over time, the back surface is hairy, hidden in the flours. The pupal period lasts about 6-10 days. Adults can live from a few months to a year depending on temperature and food, adults have the ability to reproduce for a lifetime (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

Tribolium confusum: It is a cosmopolitan pest and is usually found in temperate regions. Harmful in ground and floury grain products, it is also commonly found in cracked grains, some dry foods, and museum specimens. T. confusum is bright reddish-brown in color, elongated and oval, with a flattened body, with projections on the eltra. It is biologically very similar to the T. castaneum pest, but this species is flightless, so its infestation is slower and more controlled. Just like T. castaneum, they cause serious and irreversible damage to the products in the warehouses and mills they occupy. An unpleasant bitter odor occurs in the products they feed and they mediate the formation of some types of mold, they cannot grow in full and healthy products. Eggs are small, transparent or creamy white in color. The female lays sticky eggs between cracked and baked goods, where the egg clings to dust particles around her, making it sheltered and invisible. The larvae are cylindrical and worm-like, the pupae are small, white at first and turn yellowish-brown over time. The egg stage lasts 5-9 days, the larval stage 20-30 days and the pupal stage 6-9 days. Adults can live from several months to several years, depending on climate and nutritional conditions (Aitken, 1975; Arbogast, 1991; Haines, 1991; Hagstrum et al., 2012; Tripathi, 2018; Ahmad et al., 2021).

Tenebrio molitor: They are pests that feed on the dried and aged organic residues of a wide variety of stored grains, sometimes eating small insects, and are a common pest in the world. Its larvae are widely cultivated around the world and sold as pet food or fish food. Adults are 12-20 mm long, with parallel sides and flattened bodies, usually bright reddish brown or brownish black. Adults and larvae leave a very foul-smelling odor arising from their secretions in the warehouses or areas where they feed. For this reason, it is necessary to remove the products in the areas where these pests are seen, to do the hygiene of those areas and to clean them. Females lay 300-500 sticky white eggs in sheltered areas. The larvae are initially white, later turn yellow, and are long and cylindrical. When the larvae grow, they are about 25-30 mm long and their color becomes darker. Eggs complete their development between 6-9 days, larval period is between 150-200 days, pupal stage is between 6-11 days. Adults can live very long, more than 100 days depending on temperature and nutritional status (Aitken, 1975; Arbogast, 1991; Haines, 1991; Hagstrum et al., 2012; Tripathi, 2018; Ahmad et al., 2021).

Latheticus oryzae: This small pest, about 3 mm long, attacks bulgur, rice, corn and grains, which are more common in crumbled products. Both adults and larvae feed on ground products and are often found in warm climates. Unpleasant odor in the product has been reported to be caused by these insects. Adults are long-lived and can fly. Their bodies are thin, flattened, parallel-sided, light tan, brownish insect. Females produce about 300 eggs in their lifetime, the sticky eggs are laid randomly in the food medium and surrounded by particles of flour and grain. The eggs are translucent, thin and cylindrical in shape and smooth, with an incubation period of 7-14 days. Larvae, which are elateriform and whose color can vary from white to bronze, usually spend 5-7 periods and this period is between 20-80 days. Pupae are naked and are also found among food. The pupa is white and naked among the food, and the pupal form persists for 5-10 days. The life cycle of this pest is completed in 25-40 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Tripathi, 2018; Ahmad et al., 2021).

2.4. Anobiidae Family

Members of this family are cylindrical, small and oval insects with a strongly bent head under the thorax. They damage dry products of vegetable and animal origin in warehouse (Rees, 2004; Kumar, 2017).

Lasioderma serricorne: Cigarette beetle is a pest that spreads all over the world. It is known as the tobacco beetle because of its damage to stored tobacco products. Both adults and larvae of the cigarette beetle are omnivorous pests with high adaptability. It can be fed with almost all kinds of products in the warehouses and kitchens of the houses. In addition, since dried animal products and dead insects are also on their menu, they have a wide variety of foods in their diet. An adult smoking beetle is reddish yellow or brownish, about 2-4 mm long, about 1.5 mm wide, oval, small and fat. These insects, which pretend to be dead for a few minutes when disturbed, have a hunchbacked appearance when viewed from the side. The insect is active throughout the year in environments in temperate and subtropical regions. Average lifespan is about 18 days for females and about 20-22 days for males, generally females are larger than males. Adult females can lay about 100 eggs on foodstuffs. The eggs are oval in shape and white in color and in 7-10 days the larvae hatch from the eggs. The larvae are yellowish-white, worm-shaped, less than about 1 mm long, covered with fine hairs, and have a brown head capsule. Larva turns into pupa after feeding for

35-50 days. The color of the newly formed pupa is bright white at first, then turns reddish brown. After the pupal stage, which lasts 8-10 days, they become adults. The period from egg to adult is approximately 40-50 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

2.5. Bostrichidae Family

Most of the pests of this family are important tree, timber and forest pests. However, species belonging to several genera have adapted to feeding on stored cereal grains and dry food (Rees, 2004; Kumar, 2017).

Rhyzopertha dominica: This pest has a wide distribution in the world, it is an important pest of whole grains, especially wheat. In addition, they are very harmful in dried foods and ready-made foods. *R. dominica* can survive and reproduce in a wide variety of climatic conditions, they like to feed on gluttony. They have a high flying ability and are able to migrate to start new invasions. Adults are cylindrical, slightly flattened, reddish brown or blackish, 3-4 mm long and less than 1 mm wide. When viewed from the side, the insect's mouthparts and eyes are tucked under the thorax. Females can lay between 300 and 500 eggs. Eggs are adhered to the grain individually or in batches. Eggs are white at first, then turn a slightly linear pink color, this period can vary between 5-15 days depending on the temperature. Newly hatched larvae feed on fresh or damaged grains and cause considerable damage if not controlled. Larva is about 3 mm long, light brown head, long narrowed off-white body. Depending on the temperature, the larval stage lives for 23-50 days, the pupal stage for 4-6 days, and the adult stage for about 40-80 days (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

2.6. Dermestidae Family

The bodies of the species belonging to this family are oval or round, and their length is between 2-12 mm. They have colored scales of varying lengths on their bodies, and some species have distinctive patterns (Rees, 2004; Kumar, 2017)

Trogoderma granarium: Khapra beetle is a very serious pest of all other grains, especially stored wheat, as well as dry foods of animal and sometimes plant origin. Adults do not feed, but the larvae are a grinding beast. Adults are reddish brown, oval shaped, 2-3 mm long, females are larger than males. After mating, females lay about 100-120 eggs and it takes 4-6 days to lay eggs. Eggs are laid among the food, the eggs are transparent or dirty transparent in color, turn pale yellow over time. The larvae initially feed on shredded damaged grain, but as the larvae grow they can attack whole grains and the extent of the damage becomes extreme. The larvae are quite hairy, their body color changing to golden red or reddish brown as they grow. Larval period is 20-30 days, pupal period is 4-7 days. Adults are short-lived and cannot fly. There are 4-5 generations per year (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

2.7. Laemophloeidae Family

They are small and rather flat insects that live under the bark of trees and cause little economic damage. Species belonging to the genus Cryptolestes are among the most important pests of grain and cereal products (Rees, 2004)

Cryptolestes ferrugineus: It is one of the most destructive insects of warehouses and is widely found around the world. Rusty grain beetles are one of the most cold tolerant stored crop beetles and can fly quite well. Adults walk with a characteristic rocking motion, feed on cereals and cereal products. Its main hosts are corn and wheat grains, but it also attacks other grains and their milled products. This pest prefers grain or rotting food with moist, high humidity, prefers food with mushrooms. Adult rusty grain beetles are reddish brown and about 1.5 to 2.2 mm long. Females can lay 200-500 eggs, spawning continues up to 34 weeks, eggs are white, on average 0.5-0.8 mm long. Females may lay their eggs in cereal grains, crevices in cereals, on or between debris. Larvae are 1-4 mm long, white or yellowish-white, with a brownish head. The larvae, especially the young ones, feed on the seed coat and burrow into small cracks in the seed coat. In their final stages, the larvae spin cocoons by secreting sticky secretions and gluing the grain pieces together for the pupal stage. A full life cycle takes 3-5 weeks, and adults can live up to 1 year (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Tripathi, 2018; Ahmad et al., 2021).

2.8. Silvanidae Family

They are flat, small-bodied insects and mostly feed on moldy food. Oryzaephilus species are among the most important pests of stored products (Rees, 2004)

Oryzaephilus surinamensis: The sawtooth grain beetle is the most common secondary pest in the world and does not attack whole grains but instead feeds on shredded crumbled produce. It has also been reported to attack oilseeds and dried fruits. Both adults and larvae are voracious exterminators in infested areas. Adults are characterized by slender, straight bodies with six saw-like conical structures on the sides of the thorax. It has reddish brown, chocolate red, dark brown body colors. The population growth rate of sawtooth grain beetles depends on the type and quality of food, humidity and temperature. The female insect may lay between 100-500 eggs loosely spread in the crevices of infested grain pieces. The eggs are small, transparent white and elongated. The period of the eggs is between 3-10 days depending on the temperature. Larvae have black spots on white color and flat-shaped bodies with three pairs of legs. In the last stage, the food particles in the environment are brought together and the larva is prepared for the pupal cocoon. Larval period is 14-20 days, pupal period is 7-21 days. Adults continue to feed throughout their lives, they live an average of 6-8 months, but this period can sometimes be up to 10 months (Aitken, 1975; Arbogast, 1991; Haines, 1991; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

3. Major Stored Product Pests of The Order Lepidoptera

Adult insects with two pairs of wings covered with very distinctive and strikingly colored scales are called Lepidoptera. They are divided into two main groups, butterflies and moths. The mouth of adults consists of a flexible, tube-like structure specialized for sucking up liquid foods. Forms that hatch from eggs are larvae and love to greedily feed until the pupal stage. The mouthparts of the larvae have the ability to bite and chew, and many larvae feed on vegetable products. The group that damages the stored products is moths, and the most important families are Pyralidae and Gelechiidae (Rees, 2004; Kumar, 2017).

Table 2. Major stored product pests of the order Lepidoptera

Species	Commoun Name	Family
Sitotroga cerealella (Olivier, 1789)	Angoumois grain moth	Gelechiidae
Plodia interpunctella (Hübner, 1813)	Indian meal moth	Pyralidae
Ephestia kuehniella (Zeller, 1879)	Mediterranean flour moth	Pyralidae
Pyralis farinalis (Linnaeus, 1758)	Meal moth	Pyralidae
Cadra cautella (Walker, 1863)	Warehouse moth	Pyralidae

3.1. Gelechiidae Family

Adult moths of this family have very long, strong and curved labial palps. Larvae feed on dried and growing plant material in a wide variety of environments (Rees, 2004).

Sitotroga cerealella: This pest is the most important and most destructive insect belonging to the order Lepidoptera, and it causes great damage to stored products, especially cereals. This moth pest, which can be seen almost all over the world, has a strong flying ability. Adults do not feed in stores, are short-lived (5-10 days), have long fringes on the fore and hind wings, wingspan of 6 to 9 mm, are light-focused, most active at dusk and at night. Each female can lay 50-200 eggs, eggs are laid singly or in groups at night, cracks and crevices are preferred especially for spawning, the color darkens and turns red as the eggs develop. Egg development can take five to 10 days, respectively, depending on the temperature. The larvae are 5 mm long, off-white, with a brown head, yellowish-white, they spend their whole life inside the nucleus and are therefore invisible from the outside. Only the larvae are harmful to the grains in the warehouses and feed by eating the kernels of the grains, the larval stage lasts about 21 days. In cold climates, the larvae remain dormant for four to five months. The larva forms a small circular translucent chamber just below the seed coat for the pupal site, where it completes the pupal stage and lasts 8-12 days. The life cycle is completed in about 40-50 days and several generations can be completed in a year (Haines, 1981; Aitken, 1984; Ferguson, 1987; Weismann, 1987; Mound, 1989; Cox & Bell, 1991; Solis, 1999; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

3.2. Pyralidae Family

Pyralid moths are a common moth pest worldwide and feed on a wide variety of dried and stored plant material in a wide variety of environments (Rees, 2004).

Plodia interpunctella: The adults of this pest do not feed, but its larvae enter and seriously damage stored grain and cereal products, foodstuffs, oilseeds and some dried foods and fruits. Adult moths dirty gray, 10-15 mm long, front wings creamy red, reddish brown, rest of wings copper-colored, with some dark gray markings, wingspan 15-20 mm. Females lay about 300-400 eggs singly or in groups on grain or dry food grains, eggs white to off-white, 0.3-0.5 mm long. The fully grown larva is about 12-15 mm long, creamy white, yellowish white, pinkish, with black spots in places. While the larvae are feeding, they completely wrap the surface of the food they feed on with a silky filament. The pupa is 8-11 mm long and dull brown in color, and this stage lasts 4 to 35 days. Adult moths have a short lifespan, they die within 8-10 days. Breeding continues throughout the year (Haines, 1981; Aitken, 1984; Ferguson, 1987; Weismann, 1987; Mound, 1989; Cox & Bell, 1991; Solis, 1999; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

Ephestia kuehniella: It is a cosmopolitan moth seen in many countries with a temperate climate due to its need for warmth. Larvae prefer flour and its products, grain and grain residues, crushed broken grains. The transversely wavy, dark-marked pale gray gray front wings of the adults are white in color and are hidden inside the fore wings when the hind wings are motionless. They form dense nets during their feeding and these nets can cause serious damage to warehouses and to the mills and equipment there. Egg period is 3-4 days, larval period is 38-45 days, pupal period is 8-9 days. Females lay whitish small eggs in flour or crushed grains. The larvae are small, white or whitish-pink, sometimes with a few small black dots on the body. Inside the cocoon woven by mature larvae are dark red, reddish brown pupae. Adults live 8-10 days and their total development time is 50-60 days, and the time taken for a full life cycle is 60-70 days (Haines, 1981; Aitken, 1984; Ferguson, 1987; Weismann, 1987; Mound, 1989; Cox & Bell, 1991; Solis, 1999; Hagstrum et al., 2012; Kumar, 2017; Ahmad et al., 2021).

Pyralis farinalis: These harmful moths are found all over the world and damage flour and bakery products and all kinds of grains. Adults do not feed, greyish brown, with purplish brownish wavy patterns on the fore wings, and a wingspan of 18-30 mm. Adults begin to die immediately after mating, and the incubation period of elliptical eggs laid by females between calves and flour is 8-9 days. Females produce an average of 150-300 eggs in their lifetime. Larvae are 12-15 mm long, dirty grayish, very voracious and weave a dense web. Pupa 5-7 mm long, reddish brown, dark brown. Adults emerge at the end of the 6-8 week pupal period. Adults live 8-10 days. The life cycle is completed in about 8-9 weeks and they can give 3-4 offspring per year (Haines, 1981; Aitken, 1984; Ferguson, 1987; Weismann, 1987; Mound, 1989; Cox & Bell, 1991; Solis, 1999; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

Cadra cautella: Widely found in tropical and subtropical regions, this moth is one of the main pests of grains, dried fruits and oilseeds. Adult moth with a grayish-greyish dirty brown front wingspan 7-16 mm with dark pattern markings. The hind wings are grayish-white with a dirty pattern, and the wingspan is from 16 to 20 mm. Both fore and hind wings have broad rounded tips and vaguely short tip fringes. The female moth lays 100-700 eggs, the eggs are 1 mm long, oval, whitish. Females lay eggs by sticking them into crevices and cracks, the spawning period begins in 4-6 days, the incubation period begins in 4-8 days. Larva 12-20 mm long, head dark, whitish-pink, sometimes marked with black dots, as if the body structure is colored. The larvae make tunnels inside the food grains and this is how their presence is recognized. The larva has five to six stages, in the final stage its color changes to reddish-brown and in this stage, it finds a sheltered place to spin a cocoon. It takes about 8-15 days for the larva to pupate and then develop into an adult moth. Its life cycle ranges from about 25 to 45 days (Haines, 1981; Aitken, 1984; Ferguson, 1987; Weismann, 1987; Mound, 1989; Cox & Bell, 1991; Solis, 1999; Rees, 2004; Hagstrum et al., 2012; Kumar, 2017; Tripathi, 2018; Ahmad et al., 2021).

4. Conclusion

Food safety is the first step towards a healthy future, and for this it is important to reliably protect food, especially against pests. Stored product pests, which pose a serious danger to many stored plant and food products, especially cereals and pulses taken to warehouses after harvest, must be recognized correctly. Correctly diagnosing the major pests that cause serious damage in warehouses is the first step to apply the most accurate and effective control methods against them. It is both easier and more economical to fight with a correctly diagnosed pest. The major pests described in this section are very harmful to stored food products and can cause serious irreversible damage if not controlled. Accurate knowledge of many factors such as the size and appearance of these pests, their movement and distribution in the products, their reproductive rate and lifespan, and their behavior is important in terms of combating them. This section, which was written in order to accurately identify these major pests in warehouses and to know their biology correctly, is an important resource for experts and researchers who will work on this subject.

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CHAPTER IX

STRAWBERRY BREEDING

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1. Introduction

When classified botanically, strawberry, which is included in the berry group, is included in the *Rosaceae* family of the *Rosales* order, the *Rosoideae* subfamily, and the *Fragaria* genus. Strawberry varieties that are widely grown in the world and Turkey are included in the species *Fragaria x ananassa* L. (2n=8x=56) (Hancock, 1999). Since the adaptability of the strawberry is high, it can be grown within wide ecological limits from the equator to Siberia. Strawberry, which can spread under such wide geographical and ecological conditions, besides this characteristic, enables the production of strawberry varieties suitable for every ecology with breeding studies (Yılmaz, 2009).

Strawberry cultivation can be performed in various ecological conditions and the amount of production continues to increase in recent years. Strawberry has become one of the most important products grown in the world and Turkey (Seferoğlu and Kaptan, 2010). Strawberry is popular in the USA, Canada, Japan, and European markets where health and nutrition awareness is high, and it appears as a fruit that has a high economic value in the world market and finds buyers at high prices (Bayram et al., 2013). China ranks first with 3.336.690 tons, followed by the USA with 1.055.963 tons, Egypt with 597.029 tons, Mexico with 557.514 tons, and Turkey with 546.525 tons (Anonymous, 2020). Strawberry production in Turkey in 2021 reached 669.195 tons (Anonymous, 2021).

The most important reasons for the increasing demand for strawberry cultivation are the fact that the amount of strawberry production increases with each passing day, begins to bear fruit from the first year, adapts to different soil and climatic conditions, and yields regular products every year with different cultivation techniques (Demirsoy et al., 2017). Strawberry, which is a perennial, herbaceous, evergreen plant, is a profitable production with a good market advantage since it enters the market when fresh fruit is scarce. Also, the fact that strawberry is very important for health increases its consumption. This encourages strawberry cultivation both in the world and in our country.

Strawberry is used in alcoholic and non-alcoholic beverages, ready-made food industry (jam, confectionery, pastry, fruit juice, canned food) as a raw material, processed or frozen as well as its use with its flavor, vitamin C, mineral substances, enzymes, folic acid in its content. It is a natural antioxidant source rich in acids and phenolic compounds, which makes this plant important for health (Bayram et al., 2013; Sarıdaş et al., 2019). It has been reported that Strawberry fruits have 2 to 7 times more antioxidant capacity than apples, peaches, grapes, tomatoes, oranges, and kiwis (Scalzo et al., 2005; Wang et al., 1996). The antioxidant content of strawberries varies according to the type and variety grown, and for this reason, it is important to consume strawberries with high antioxidant content (Giampieri et al., 2013). In the present day, crossbreeding breeding studies are among the most important and priority issues to develop varieties rich in content (antioxidant), with quality criteria such as yield, size, color, etc. (Sarıdaş et al., 2019). It was shown that 100 grams of strawberries can be a good alternative food against obesity, which is one of the most important health problems of the present day because it provides low energy such as 32 kcal when consumed, and also contains fragrant, aromatic, fat-soluble vitamins such as A and E and carotenoids (Bayram et al., 2013).

One of the most important problems of our country regarding strawberry cultivation is the low yield potential. Yield per plant in strawberry cultivation is affected by variety, climate, soil structure, cultivation style, and cultural practices. Studies have been conducted in recent years to increase efficiency in some universities and research institutions. As a result of these studies, new varieties that are productive and suitable for the conditions of different regions and modern cultivation techniques are used (frigo seedling, fresh seedling, drip irrigation, fertilization, mulching, solarization, etc.), and it has been noted that the yield per unit area increased rather than the increase in the production area. Although some of the characteristics of the domestic strawberry varieties obtained from the breeding studies conducted in some of our institutions are good, they either do not gain a commercial aspect or this process may not be long-term because they do not have similar characteristics to the varieties of foreign origin. In the production of this fruit, the most important producer country is the United States of America, and variety breeding studies are intensively conducted here (Sarıdaş et al., 2019).

2. A General View of Strawberry Breeding Programs in The World

In the middle of the 18th century, the culture strawberry genus *Fragaria* was widespread, generally in the northern hemisphere. Staudt reported that there were 24 species in total, of which 14 were *F. vesca*, 5 were *F. orientalis*, 1 was *F. moschata*, 3 were *F. chiloensis* and *F. virginiana*, and their hybrids were *F. × ananassa* and 1 *F. iturupensis* (Sargent et al., 2009), and in recent studies *F.× bringhurstii* (Rho et al., 2012; Kurt; 2016).

The first systematic classification and extensive information was given on the strawberry plant in the study "L'Historie Naturelledes Fraisiers" published by the French botanist Antonie Nicolas Duchesne in 1768. In our present day, A. N. Duchesne is considered the founder of strawberry systematic (Hancock, 1999; Erdem and **Çekiç**, 2017). According to Darrow (1966), cultivated strawberries began to develop in Brest, France as a result of the accidental crossing of male sterile *F. chiloensis* and female sterile *F. Virginiana* in 1714, and it could not progress in the hands of amateur breeders in 200 years. As a result, the cultivation of the strawberry (*Fragaria × ananassa Duch.*) was introduced in the mid-18th century after *F. chiloensis* (L.) Duch. and *F. virginiana* Duch as a result of the natural hybridization of the species (Hancock et al., 2008). *Fragaria x ananassa* species emerged as a superior species by taking the productivity and endurance characteristics of *F. chiloensis* and the large fruiting characteristics of *F. virginiana* and has become the type of varieties that has gained commercial dimension in our present day (Kurt, 2016).

Strawberry grower Michael Keens selected "Keens" imperial in 1806 and obtained "Keen's Seedling" strawberry variety in 1819, which he selected from Keens "Imperial" (Johnson, 1990). According to Chandler et al. (2012), it was reported that the "Keen's Seedling" strawberry variety was grown at a very important level in England towards the end of the 19th century and used in the breeding of many modern strawberries varieties. Towards the middle of the 19th century, breeding efforts showed significant progress with the transfer of Fragaria x ananassa from Europe to North America. In breeding studies of private individuals, interspecies crosses and wild species were crossed with European genotypes (Chandler et al., 2012; Kurt, 2016). In 1836, a researcher (Charles Hovey) obtained the "Hovey" strawberry variety in North America by crossing between European varieties and natural F. virginiana selections. "Hovey" significantly influenced the American strawberry industry, and in the 1850s, it was brought to California by Dr. Broadus (Johnson, 1990). The cultivars "Downton" and "Elton", which were obtained from the Keen clone of Thomas Andrew Knight, president of the royal horticultural society, were widely used in England for more than 100 years (Johnson, 1990; Erenoğlu, 2019). He named the variety "Wilson" selected from the "Hovey" hybrid by James Wilson in 1851. This variety was productive, firm-fruiting, and durable and made a great contribution to the strawberry industry with its characteristics such as being able to be grown in almost any soil (Anonymous, 2022a). New varieties were bred primarily from hybrids in the second half of the 19th century. Thomas Laxton of the world-famous Laxton Brothers of Bedford introduced the "Royal Sovereign" in 1891 ("Noble" x "King of the Earlies"). The cultivar "Royal Sovereign", with fruitful and bright red fruit, was cultivated until recently in England, British Columbia, and Nova Scotia (Johnson, 1990).

Breeding studies began in the 20th century with more modern and new techniques. During this period, breeding programs spread over a wide area in different countries, especially in Europe and North America (Chandler et al., 2012; Erdem and Çekiç, 2017). Fifty varieties obtained as a result of breeding studies with *F. chiloensis* clones by a researcher named Albert Etter were used in the production of many modern strawberry cultivars at the beginning of the 20th century, between 1903 and 1920 in California (Johnson, 1990; Chandler et al., 2012). Strawberry variety breeding programs have been carried out since 1980 in about 40 countries around the world, most of which belong to official institutions (Attar, 2018). The majority of these cultivars were found in the USA, and 17% were day-neutral. Strawberry breeding in the USA is still performed in three places (California, Florida, and the northern part) (Hancock, 2006; Sarıdaş, 2018). George Darrow made a name for himself with his work on berry fruits in the United States in the 1920s and improved many strawberry varieties. His book "The Strawberry: History, Breeding and Physiology", written in 1966 on strawberry breeding and cultivation, is still a classic work (Galleta, 1993). The cultivars "Blakemore" (1929) and "Fairfax" (1933) were widely cultivated. These cultivars were used in the 1930s extensively in breeding work and became the parents of many cultivars grown all over the USA. Darrow also uncovered other notable cultivars (“Pocahontas”, “Albritton”, “Surecrop”, and “Sunrise”). With the involvement of Donald Scott in the 1950s, the “Midway”, “Redchief”, “Guardian” and “Earlyglow” varieties were introduced. Some of the important cultivars emerging from the breeding program conducted by Darrow, G.F., Waldo, and FJ Lawrence in Corvallis, Oregon were “Narcissa” (1932), “Brightmore” (1942), “Hood” (1965), and “Benton” (1974) (Jhonson, 1990; Galleta, 1993).

Royce Bringhurst and Victor Voth began breeding a very important group of strawberry cultivars at UC Davis after the 1950s. “Tioga” (1964), “Tufts” (1972), “Cruz” (1975), “Pajaro” (1978), “Vista” (1978), and “Fern”, respectively were obtained from the breeding studies conducted by the University of California, Davis, USA along with “Santana” (1982), “Chandler” and “Selva” (1983), “Muir” (1987), “Oso Grande” (1987), “Camarosa”, “Laguna”, “Sunset” (1992), “Pacific”, “Diamente”, “Aromas” (1997), “Ventena”, “Camino” (2001), “Albion” (2004), “Palomar” (2007), “Monterey”, “Portola”, “San Andreas” (2009), and “Majove” (2010) (Hancock, 2006; Anonymous, 2022b; Anonymous, 2022c). Among these cultivars, “Chandler” and “Camarosa” spread all over the world very quickly (Kurt, 2016). Two more strawberry cultivars (“UCD Finn” and “UCD Mojo”) were put into cultivation in California as extremely day-neutral cultivars, especially grown for summer planting in coastal climates south of Santa Maria. These cultivars have been developed to replace “Portola”, which is high-yielding and popular with growers but said to be lacking in flavor (Anonymous, 2022d). “San Andreas” was cultivated at the University of California in 2009 was obtained as a result of the hybridization of “Albion X Cal. 97.86-1” “Portola”, medium day-neutral (Shaw and Larson, 2009a), and “Monterey” obtained by crossing “Albion x Cal. 97.85-6” (Shaw and Larson, 2009b). Again, the “Mojave” variety, which was also bred at the University of California, is a short-day strawberry variety (Shaw and Larson, 2012; Kurt, 2016).

Strawberry breeding studies started in 1948 under the leadership of plant pathologist Albert Brooks with the UF/IFAS program at the University of Florida and the “Florida Ninety” strawberry variety was first introduced in 1952 to the market and became the dominant variety grown in Florida. Then, “Florida Belle” was developed in 1975, and “Dover” in 1979, but they were not successful in terms of fruit quality. A high-yielding and long-season “Sweet Charlie” variety was produced in 1992. The “Festival” variety, which was produced in 2000, has superior fruit quality characteristics such as shape, color, and hardness, as well as its long shelf life and disease resistance, making it preferable to other varieties. Launched in 2008, "Radiance" replaced "Festival" in 2012, known as Florida's leading strawberry variety. "Florida Radiance" is an early, productive, regular-shaped, and large-fruited variety throughout the season (Whitaker et al., 2012). The "Fortuna" strawberry variety was grown outside the United States and expanded internationally (Anonymous, 2022e). Varieties such as "Sweet Charlie", "Festival", and "Fortuna" are early varieties with low cooling demands (Santos et al., 2007).

Strawberry breeding studies are conducted in different countries in Europe. At the East Malling Research Institute, breeding programs have been carried out since 1983 Under the chairmanship of Dr. David Simpson to prolong the harvesting period in strawberries and to obtain varieties that are highly adaptable to different climatic conditions, large fruit, excellent fruit quality, high yielding, less fruit wastage, and disease resistant (Anonymous, 2022f). A total of 43 strawberry varieties have been introduced successfully to the market so far, some of which are "Judibell", "Delia", "Malling Pearl", "Malling Opal", "Sallybriht", "Amelia", "Alice", "Bolero", " Calypso", "Cassandra", "Elegance", "Emily", "Eros", "Fenella", "Flamenco", "Florence", "Irresistible", "Mae", "Pandora", "Pegasus" and "Rosie" such varieties have been registered (Kurt, 2016; Whitehouse et al., 2021; Anonymous, 2022g). The "Winterstar" variety is a short-day plant obtained as a result of the hybridization of "Florida Radiance x Earlibrite". The researchers found that the "Winterstar" strawberry is a suitable short-day variety for single-year growing areas, easy to harvest because of its long flower stalks with its compact and upright structure, and produces hard, conical-shaped fruits throughout the season (Whitaker et al., 2012).

From the breeding programs of private and state institutions in France, the cultivars "Cigaline", "Ciflorette", "Cifrance", "Ciloe", "Cireine", "Cigoulette", "Cirafine", "Cirano" and "Cilady" were registered. Among these, especially "Ciflorette" and "Cirafine" cultivars were remarkable and gained importance (Kıyga, 2009). "Darselect", "Mara des Bois" and "Matis" were other registered cultivars (Erdem, 2018). From the Marionnet SAS breeding program, "Magnum" cultivar with its bright red color, large-medium fruit, tasty and firm fruit, and good yield potential, and "Mariguette" cultivar with an everbearing, very sweet taste and excellent shelf life was introduced to the market from the Marionnet SAS breeding program (Anonymous, 2022 h).

From FNM (Fresas Nuevos Materiales S.A.) breeding program in Spain, which has an important share in strawberry cultivation in the world, the cultivars (“Cisco”, “Coral”, “Pedrone” varieties in 2005 and “Primoris Fnm” in 2009 and “Rabida Fnm” in 2014) have been registered (Refoyo and Arenas, 2017). So far, the Spanish public breeding program has released 10 short-day varieties (“Andana”, “Charisma”, “Marina”, “Medina”, “Amiga”, “Aguedilla”, “Fuentepina”, “Santaclara”, “Fontanilla” (later named “Sarito”) and “Nazaret” varieties (Soria et al., 2008; Ariza et al., 2018). “Nazaret” was the last variety to be jointly introduced by Spanish public and private institutions as an early variety with good fruit yield and an acceptable level of fruit firmness for carrying (Ariza et al., 2018).

The “Red Glory” variety was produced in Scotland by Dr. Lindrea Latham in the ReDeva Limited Breeding Program. This variety of ever bearer has large and conical fruits and one of its most important characteristics is its long shelf life (Anonymous, 2022i).

“Wendy” was bred in AAFC - Nova Scotia breeding program in Canada along with “St Pierre”, “Yamaska” in AAFC Quebec breeding program, and “Nisga’a” in AAFC British Columbia breeding program. The cultivar “St Pierre” is a late-season variety with very large, attractive, and bright fruits. The cultivar “Yamaska” is very late-season, powdery mildew with good eating quality and a good tolerance to Botrytis (Anonymous, 2022h).

Strawberry breeding studies are performed in Italy under the direction of Dr. Walther Faedi. High-yielding “Palatina” (1997), early “Nora” (2001), early, hard and large-fruited “Kilo” and late “Record” cultivars were selected with the project called Frutticoltura (Faedi et al., 2009). Although “Olympia”, “Tea”, “Gemma”, “Asia”, “Alba”, “Syria”, “Roxana”, “Louise” and “Thelma” cultivars were registered by New Fruits S.A.S, “Idea” and “Anitabis” strawberry cultivars were selected from other breeding studies (Anonymous, 2022i).

The CPRO-DLO Strawberry Breeding Program was very successful in the Netherlands and more than 24 new cultivars were obtained, most notably “Elsanta”, “Gorella x Holiday”, and “Gorella” cultivars (van de Lindeloof and Meulenbroek, 1997).

“Kalinda”, “Kiewa”, “Millewa”, “Coogee”, “Mindarie”, “Adina”, “Tallara”, “Wonga”, “Euroka”, “Alinta” and “Lowanna” were released to the market from Agriculture Victoria Knoxfield in Australia, “Kabarla”, “Redlands Joy”, “Maroochy Flame”, “Maroochy Jewel”, “Maroochy Sundew”, “QHI Earliblush”, “QHI Earlibelle” and “QHI Earlimist” from Queensland Horticulture Institute. The breeding goals mentioned here aimed to achieve improved palatable fruit quality, including increased resistance to disease and pests, extended harvest time, resistance to rain damage, increased picking efficiency, and production reliability (Morrison and Herrington, 2002).

"Hakkon", "Nobel", "Saga", "Snorre", "GN06.44.2", "GN08.08.3", and "GN1103" cultivars, which are marketed from Graminor breeding program in Norway, are cultivated all over the world except Finland, Norway, and Sweden. Strawberry breeding objectives are to offer producers varieties that are productive, good in taste, resistant to winter, early maturing, long shelf life, and resistant to transportation conditions and processing. The use of chemical pesticides will be minimized if the new varieties bred are more resistant to diseases and pests, especially fungi, than the varieties we use (Anonymous, 2022 h; Anonymous, 2022j).

"Shenmei 3", "Shenmei 5" in China, strawberry varieties in Israel such as Herut (resistant to anthracnose, suitable for the subtropical climate, 24 g/fruit) and Tamar (very early yield, 27 g/fruit) can be given as the examples in this regard. There are also breeding programs in Japan and Belgium (Paydaş Kargı and Kafkas, 2009; Kurt, 2016).

Strawberry is among the most widespread fruit species in the world because of several reasons such as high genetic diversity, high heterogeneity, and wide adaptability to different environmental conditions (Sarıdaş, 2018). These characteristics of strawberries have great value for breeding studies and enable the production of the present day's cultivated strawberries.

3. Strawberry Breeding in Turkey

It is already known that strawberry cultivation was made in the Black Sea Ereğli region before the 1900s in our country. It is considered that the "Arnavutköy" strawberry brought to Ereğli from Istanbul in the 1920s was later called the "Osmanlı" strawberry. After the "Osmanlı" strawberry was brought to the Ereğli region, its production increased and became popular in the country. However, the production of Osmanlı strawberries decreased after the 1960s gradually and the Osmanlı strawberry was almost in danger of disappearing by the 1980s. The "Association for the Dissemination of Osmanlı Strawberry and Protection of Producers" was established in 1964 and studies were initiated to protect the variety (Yılmaz, 2009; Erdem, 2018).

The Strawberry gene resources of our country consist of local varieties and wild species. Local varieties are often grown/picked for their very intense fragrance and flavor (Ereğli (Zonguldak), Orman (Bolu), Osmanlı (Istanbul), Arnavutköy (Istanbul), Emiralem (Izmir) and Kestel (Bursa) varieties) (Gündüz and Bayazit, 2017). Various studies have been conducted in our country on strawberry breeding until the present day. The reason why native varieties were preferred as parents in these studies is that they are superior to foreign-origin varieties in terms of their aromas. However, a profitable production cannot be made because of reasons such as low yield, soft fruit flesh, and small fruits of our domestic varieties (Erdem and Çekiç, 2017). For this reason, crossbreeding breeding studies are conducted in our country, taking into account the superior characteristics of our domestic varieties such as taste and aroma, and the characteristics of foreign varieties such as yield, fruit size, and earliness (Erenoğlu, 2019).

In Turkey, breeding studies started with crossing studies by Kashka in 1965. Kashka and Paydaş (1986) reported in their hybridization studies in which they used the "Osmanlı" cultivar as the main parent that the aroma and odor of the "Osmanlı" strawberry passed to the new cultivar candidates, but they could not obtain the desired fruit because of its small fruit characteristic (Erdem and Çekiç, 2017).

Konarlı and Akgün (1984) conducted cross-breeding studies in Yalova by using Arnavutköy strawberry as the mother and Aliso and Tioga varieties as the father. As a result of crossbreeding, genotypes Yalova-15, Yalova-104, and Yalova-110 were registered as strawberry cultivars (Konarlı et al., 1984). "Yalova-15" was bred as a result of the hybridization of "Arnavutköy × Tioga" cultivars and "Yalova-104" was bred as a result of the hybridization of "Yalova-13 × Tioga" cultivars and put into production in 1985. It was determined in the adaptation studies that the "Yalova-15" variety was superior in terms of yield, taste, and aroma and was suitable for cultivation in the Marmara Region (Konarlı et al., 1984; Attar, 2018; Erenoğlu, 2019).

In our country, in the other breeding program led by Dr. Burhan Erenoğlu, crosses were made using our native varieties "Osmanlı", and "Yalova-104" and California varieties such as "Tufts", "Cruz" and "Tioga". As a result of the studies that lasted about 15 years on these genotypes, 7 genotypes were determined as variety candidates and "Erenoğlu-77", "Dorukhan-77", "Doruk-77", "Bolverim-77", "Hilal-77", "Eren-77" " and "Ata-77" were registered in 2012. These cultivars are productive and have superior characteristics in terms of taste and aroma (Erenoğlu, 2019; Kıyga, 2009).

Hybridizations were made in the strawberry breeding program in the Department of Horticulture, Faculty of Agriculture, Çukurova University by using one of our native varieties, “Osmanlı”, and some Californian varieties. Positive results were obtained from the cultivar candidates 475/04, 496/2 and 489/A, and 477/2 as a result of two-year crosses. Although positive results were obtained from these genotypes in terms of aroma, it was determined that the hardness of the fruit flesh was not suitable for table consumption and was recommended for use in industry (Ustun and Paydas, 1995). In another crossing study, the “Osmanlı” cultivar was used as the mother and some European and American cultivars were used as the father. The selection was made in line with the results obtained by examining the characteristics such as hardness, fruit size, color appearance, and taste from this hybridization and 14 new types were found to be superior in terms of aroma (Paydaş et al., 1996). As a result of these studies at **Çukurova** University, three cultivars (i.e., “Kashka”, “Sevgi” and “Ebru” in which “Osmanlı” hybrids were used as parents) were registered in 2009 (Erenoğlu, 2019; Kıyga, 2009; Attar, 2018). The variety “Sevgi” is a “504/7 x 216” hybrid. The fruits of this variety, whose plants are vigorous and early, are bright, large, conical in shape, dark red, and aromatic. “Kashka” variety is a “499/1 x Chandler” hybrid. Plants are a medium vigorous and early variety. The fruit of the variety, which has a bright, large, conical, long conical fruit shape, is cardinal red, and its inner color is dark red. The “Ebru” variety is a hybrid of “499/1 x Chandler” and is moderately early. The outer color of the conical, round-shaped fruits is blood red and the inner color is brick red (Kafkas, 2004). The superior taste and aroma characteristics as well as the soft fruitiness characteristic were transferred to the new cultivar candidates because our native varieties were used as the main parent in the study. As a result of the study, it was found that the fruits of the cultivars were not hard enough for preservation and road resistance (Erenoğlu, 2019).

In this context, the project, which is the doctoral thesis of Mehmet Ali SARIDAŞ, performed between 2015-2018 led by Prof. Dr. Sevgi Paydas Kargı, also supported by Tubitak, it was tried to combine the superior taste and aroma characteristics of domestic strawberry varieties with the high yield and fruit firmness values of foreign-origin varieties by using the hybridization breeding method. As a result of the weighted grading of the obtained data, genotypes 33, 36, and 61 came to the forefront with the highest score. The purpose was also to obtain varieties with commercial value by examining the plants obtained as a result of crossing the genotypes that stand out from this project and foreign varieties in terms of certain criteria (Sarıdaş, 2018).

In another study that was conducted in the field of strawberry breeding in our country, Serçe et al. (2008) mapped genes controlling flesh firmness in strawberries. A total of 340 plants obtained from "Camarosa" and "Osmanlı" crosses, which are cultivated most intensively in our country, with high flesh firmness, were characterized for two years in terms of various herbal characteristics.

In their study "Phenotypic Diversity in Strawberry Varieties Obtained from Different Breeding Programs", which included 42 old and new strawberry varieties from breeding programs in the USA, Europe, and Turkey, grown in Hatay, Gunduz et al. (2017) evaluated the products with the phenotypic diagnostic test.

In our country, a very important part of strawberry cultivation is performed on the Mediterranean coastline, and varieties bred at the University of California are generally used in this system. The most intensively cultivated variety in recent years is "Camarosa" which was put into production in 1992. California varieties are generally productive, and their fruit flesh is hard, odorless, and resistant to transportation. Our local varieties (i.e., "Osmanlı", "Ereğli", "Arnavutköy") are superior in taste and aroma; however, their fruit is small and the yield is low (Serçe et al., 2005). Various studies are conducted to transfer the superior characteristics of our domestic varieties to American varieties (Kıyga, 2009).

4. Conclusion

The rapid increase in strawberry cultivation in the world in the last 50 years occurred because its cultivation is very old, its adaptation ability is high, and strawberry cultivation can be performed in every area where agriculture can be done. Strawberry production contributes to the economy in many regions of Turkey, especially in terms of employment and added value to the economy of the country.

The strawberry plant is in the first place among all fruits because it has a high antioxidant capacity and is very tasty as well as its high nutritional value. The increasing consumption of berry fruits in recent years, especially strawberries, has made a positive contribution to a healthy diet. For this reason, studies showing the benefits for consumers are also increasing. Offering consistently high-quality fruit with superior nutritional status would be an ideal way to increase consumer interest and satisfaction in this respect. Another importance of strawberry cultivation is that it can be used frozen and processed in the industry besides fresh consumption. Strawberries may decay easily and are usually sold at a high price right after harvest, especially because they are hand-picked and must be offered for sale immediately.

With the increased strawberry cultivation in the world, breeding studies for the development of new varieties have increased at that rate. In general, the desired character programs are similar to each other in breeding, but the order of priority may vary among breeders. Considering the market demands for each region, the criteria sought in breeding studies primarily yield, size, aroma, resistance to road conditions and duration, hard fruit flesh, resistance to diseases and pests, day-neutral or short-day strawberry variety, ripening times, prolonged flowering period, winter resistance, and compatibility with different soil conditions. Traditional breeding programs focus on increasing crop yield and fruit size, being resistant to diseases and transport, as well as increasing shelf life after the harvest. However, consumers show a high demand for a product with good eating quality and sensory characteristics. There are differences in many parameters (e.g., fruit ripening date, disease resistance, freezing quality, firmness, fruit size, fruit shape, and flavor among strawberry cultivars).

Like other breeding studies, strawberry breeding programs start with genetic and heredity studies and then take place over a long period because they consist of applied breeding studies for the development of varieties. Strawberry breeding studies have been conducted in the world since 1982 and as a result, more than one thousand new varieties were obtained and offered to consumers. With the use of modern breeding methods, breeding studies have gained a new dimension in our present day. The breeding studies conducted in our country are not successful in obtaining strawberry varieties that can compete with the commercial varieties used in the present day. For this reason, there is a need to accelerate breeding studies and conduct new studies aiming at transferring superior characteristics such as the high aroma content of our local varieties to new varieties.

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CHAPTER X

EFFECTS OF PLANTS ON REPRODUCTION IN FARM ANIMALS

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1. Introduction

Animal foods are important in meeting the nutritional needs of people. It has been emphasized that animal foods have important effects on mental development and growth (Bradford, 1999). Meat is a food source that contains protein, iron, vitamin B12 and B complex vitamins, zinc, selenium, and phosphorus (Perumal et al., 2013). Milk and dairy products, which are animal products, are nutritious foods that contain valuable nutrients. It has been reported that whole milk prolongs the feeling of satiety by extending the transit time in the digestive system to a longer interval (Haug et al., 2007). It is known that egg is a beneficial food that contributes to the elimination of nutritional deficiencies in humans (Bourne and Galea, 2006). Livestock makes a significant contribution to the economy of developing countries. As the human population in the world increases, the importance of this sector also increases (Herrero et al., 2013). Livestock farming is developing sustainably due to the growing need around the world. With the increase in the human population, scientific and technological developments in the field of animal husbandry are becoming widespread (Thornton, 2010). The production of farm animals and products is very important to meet the basic needs of the growing human population. Various animal reproduction technologies need to be developed to increase and support high production (Akhtar et al., 2022). It is known that farm animals are necessary for many areas including nutrition, dressing, and various technological developments for the protection and improvement of human health (Kues and Niemann, 2004). Farm animals are also considered as by-products and plants to be converted into food and fertilizer. Thus, it contributes to the cycle of food within the system on the planet (Van Zanten et al., 2019). Some farm animals, called ruminants, contribute to sustainable food production by converting substances that are not consumed by humans into consumables in the form of meat and milk. Increasing reproductive efficiency is possible with genetic improvement and the improvement of fertility (Davis and White, 2020). Approaches related to the production of farm animals and the solution to some problems in this field have become an increasingly dependent field of scientific research and technological developments (Verma et al., 2012). It is known that artificial insemination in farm animals makes a significant contribution to this field (Vishwanath, 2003). It has been emphasized that the quality of the semen used in artificial insemination in animals is important to obtain a successful pregnancy rate (M Morrel and Rodriguez-Martinez, 2009). Improving the sperm quality of male breeding animals in farm animals is important for artificial insemination (Clément et al., 2012). Artificial insemination is thought to be one of the most successful, simple, and economical assisted reproductive techniques in animal husbandry (Vishwanath, 2003). Artificial insemination allows producers to benefit from genetically superior males. It is thought that semen selection and various methods used for semen storage will help to improve the protocols used in artificial insemination and thus increase pregnancy rates (Zuidema et al., 2021). Although there is not enough literature on the use of plants to increase the effects of plants on reproduction in farm animals, it is thought that plants can be used to improve reproductive performance in farm animals due to their antioxidant and antimicrobial properties (Shai et al., 2022).

2. Sperm Storage and Herbal Origin Substances Used

It has been reported that there is a need to improve the storage conditions of semen to increase the efficiency of artificial insemination in animal production (Malecki et al., 2008). Various special semen extenders are used for short and long-term storage of semen in farm animals (De Ambrogi et al., 2006). For the semen to be stored for a short time, the semen is cooled with special cooling methods. Long-term storage is accomplished by freezing the semen. Storage of sperm directly affects temperature, cooling rate, chemical content of diluent, the content of cryoprotectant agent used, reactive oxygen species (ROS), suitability of seminal plasma, hygiene, and storage conditions of spermatozoa. Although there are various methods applied for the storage of semen, the extenders used for cooling and freezing may differ according to the animal species (Barbas and Mascarenhas, 2009). It has been reported that there may be an increase in reactive oxygen species (ROS) during semen storage (Liman et al., 2022). Sperm extenders must have the appropriate pH value and osmolarity specific to semen, and the extender must have a buffering feature. In addition, semen extenders should be able to protect spermatozoa against cellular damage during freezing and thawing (Salamon and Maxwell, 2000). Studies are carried out on the use of substances of vegetable origin as preservatives added to semen extenders. An example of this is soy-lecithin added to the diluent (Murphy et al., 2018; Salmani et al., 2014). Cryopreservation of semen is used to preserve the semen of breeding farm animals. Parameters affecting semen quality after thawing in semen frozen by the cryopreservation method may differ between animals of the same species (Akhtar et al., 2022). Cryopreservation is known as an important biotechnological procedure applied to support reproduction. It allows the use of many different substances for the protection and storage of sperm (Yánez-Ortiz et al., 2021). Plant-based substances are known as natural antioxidant sources for semen storage and protection of semen functions. In addition to being easily available, the antimicrobial properties of some plants have been important in making the plants attractive for storing semen (Ros-Santaella and Pintus, 2021). It has been stated that herbal extracts can be used to reduce the negative effects of the cryopreservation process applied for the long-term storage of semen (Khan et al., 2017). In a study conducted for this purpose, different ratios of green tea extract were added to the bull semen extender and it was observed that it had a positive effect on the motility of spermatozoa, spermatozoa viability, and membrane integrity (Khan et al., 2017). In a study on goat semen quality, it was observed that the addition of polysaccharides of Lycium barbarum and Laminaria japonica plants to the semen extender significantly increased sperm motility, sperm membrane integrity, and acrosome integrity, as well as mitochondrial activity (Ren et al., 2019). Soy-lecithin has been used for the cryopreservation of bull and goat semen (Murphy et al., 2018; Salmani et al., 2014). It was predicted that 1.5% soy-lecithin was found to be successful in the storage of goat semen and could be used instead of egg yolk, which is widely used as an animal product (Salmani et al., 2014). It is thought that Tannin extract, which has herbal antioxidant properties added to animal feeds, contributes to increasing the quality of semen. (Liman et al., 2022).

3. Effects of Herbal Foods on Sperm

It is known that plants are used successfully in the treatment of sexual activity disorders (Jaâ et al., 2015). Various anomalies seen in spermatozoa have been reported to be important causes of infertility. Because the spermatozoa membrane contains polyunsaturated fatty acids, it is very sensitive to reactive oxygen species (ROS). ROS-induced spermatozoa defects may occur. However, it has been stated that there are antioxidant mechanisms that can inhibit the effects of ROS in the body to a certain extent. It is also known that vitamins can be effective against cellular damage (Sheweita et al., 2005). Various antioxidants are available to protect semen against the effects of ROS. Since natural antioxidants are more reliable than synthetic antioxidants, the use of plants containing natural antioxidants is quite common (Zhong and Zhou, 2013). Antioxidant substances in plants contribute to improving semen parameters and increasing semen volume (Inwati et al., 2022). In the evaluation of semen, there is a cost of removing male animals with insufficient spermatozoa density or reduced sexual abilities from the herd. It is also known to cause the loss of animals with high breeding values (Clément et al., 2012). It has been reported that herbal products can be effective through nutrition as well as adding to the semen extender (Ros-Santaella and Pintus, 2021). It is known that it is widely used for the solution of various infertility problems in men, low libido, negativities due to various defects that can be seen in spermatozoa, and problems related to erectile dysfunction with the use of medical plants. *Withania somnifera*, *Astragalus membranaceus*, *Asparagus racemous*, *Andrographis paniculata*, and *Acanthopanax senticosus* plants were found to have positive effects on semen quality (Nantia et al., 2009). In addition, it was emphasized that *Catha edulis* and *Lepidium meyenii* plants positively affect semen quality and spermatozoa density (Clément et al., 2012). The semen that was frozen and thawed by feeding various plant foods that affect semen in buffaloes with low semen quality was evaluated. In the study, it was reported that sperm motility, increased viability, and decreased rate of abnormal spermatozoa were observed (Kumar et al., 2018). It is known that feeding on farm animals improves testicular development and semen quality in young men (Martin et al., 2010). It has been reported that polyunsaturated fatty acids, which are high in plants such as sunflower, safflower, flaxseed, and soybean, are important nutrients that positively affect testicular development and spermatozoa formation process in farm animals. Polyunsaturated fatty acids can also be added to the semen extender and used in the storage of semen to have a protective effect on parameters such as motility and viability in semen (Tran et al., 2017). The negativities in the activity of semen density in poultry may cause problems with the hatching of the offspring. Conditions such as aging and weight gain in male animals in poultry may cause low libido and a decrease in some sperm parameters (Durape, 2007). Phytochemicals are known as non-nutritive preservatives found in plants (Craig, 1997). It has been stated that phytochemicals can be used successfully against fertility-related negativities due to their supportive effect on low libido and semen quality (Durape, 2007). Phytoestrogens, which are phytochemicals, are found at high rates in leguminous plants such as soybean and alfalfa. Phytoestrogens contribute to the increase in animal production by positively affecting animal fertility and growth (Hashem and Soltan., 2016). Drugs used to eliminate infertility in farm animals due to various reasons may cause some side effects to develop. However, it is known that herbal products have fewer side effects and are more reliable in terms of public health (Perumal et al., 2013). Mineral substances are important for the development of the animal's reproductive functions. In mineral deficiency, a decrease in reproductive activities can be observed. Therefore, it has been stated that mineral supplementation is necessary (Ojha et al., 2018). It is known that the addition of selenium to foods has a positive effect on antioxidants and reproduction (Pelye and Mézes, 2013). Deterioration of sperm quality and problems in female reproductive functions in farm animals caused by zearalenone, a mycotoxin that can be seen in cereals, may cause low reproductive efficiency (Minervini and Dell'Aquila, 2008). It has been stated that there are limited studies to evaluate the effect of plants on semen quality in farm animals and more studies are needed on this subject (Inwati et al., 2022).

4. Aphrodisiac Herbs

The word aphrodisiac is defined as substances that trigger sexual desire. Aphrodisiac plants are used to activate sexual stimulation in men (Singh et al., 2012). Aphrodisiac substances can be taken by eating and can be considered in three groups substances that increase libido, substances that increase sexual power, and substances that improve the feeling of sexual pleasure in terms of their mode of action. There are many aphrodisiac plants such as *Tribulus terrestris, Withania somnifera, Eurycoma longifolia, Avena sativa, Ginko biloba, and Psoralea coryifolia* (Malviya et al., 2011).

4.1. Some Commonly Used Aphrodisiac Herbs

Tribulus terrestris, an annual herbaceous plant belonging to the Zygophyllaceae family, finds widespread use in traditional medicine. Tribulus terrestris has sexual aphrodisiac, and antioxidant effects and activities (Shahid et al., 2016). Figure 1 shows the *Tribulus terretris* plant and its leaves. It is known that in medical medicine, it is widely used in pharmacology and biological fields, from central nervous system to parasitic effects, in addition to its antibacterial and aphrodisiac effects (Chhatre et al., 2014). It has been reported that *Tribulus terrestris* extract used in an animal study significantly increased the serum testosterone level (Hussain et al., 2009). It is thought to have an aphrodisiac effect due to its androgens-enhancing feature (Gauthaman et al., 2002). *Tribulus terrestris* has been found to have a positive effect on some semen values and birth parameters in pigs (Mateva et al., 2013).

Figure 1. *Tribulus terrestris* plant and leaves (Chhatre et al., 2014)

It is known that the roots of *Lepidium meyenii* (Maca) have an aphrodisiac effect and are used to eliminate reproductive problems (Gonzales et al., 2003). It grows in the Andes region of Peru. It is known that it has been consumed since ancient times due to its stimulating effect on libido (Tafuri et al., 2021). It is thought that Lepidium meyenii has a positive effect on seminal volume, semen density, and sperm motility (Chen et al., 2021). In a study, it was reported that by adding lepidium meyenii to bull food, there was an effect on improving semen volume and quality in bulls (Clément et al., 2010). Figure 2 shows the parts of the Lepidium meyenii plant.

Figure 2. *Lepidium meyenii* (Chen et al., 2021)

Herbal medicines called ginseng are obtained from the roots of the plant. *Panax ginseng* is widely used. In addition to its antioxidant properties, it has a stimulating effect on physical activity (Kiefer and Pantuso, 2003). Ginseng is believed in Chinese traditional medicine to have an aphrodisiac effect to treat sexual dysfunction and improve sexual arousal. In animal studies, it has been shown to increase libido and improve mating performance (Leung and Wong, 2013). In a study using plants containing *Panax ginseng* in buffaloes, a noticeable increase in semen quality was observed (Kumar et al., 2018). Panax ginseng is in Figure 3.

Figure 3. *Panax ginseng* (Yun, 2001)

5. Conclusion

Antioxidants are used against ROS agents to increase sperm quality. Plants are preferred over synthetic antioxidants because they are natural. In addition to the positive effects of plants on libido and semen volume as an aphrodisiac, their cryopreservative effect is utilized by adding them to semen extenders. Studies on the use of plants and herbal extracts are increasing to improve the quality of semen in farm animals and to improve the storage conditions of semen.

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CHAPTER XI

AN OVERVIEW OF PLANT DEFENSE MECHANISM

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1. Introduction

Since plants are non-active creatures, they are directly affected by the environmental conditions in which they live. Due to these features, they have developed various adaptations to adapt to environmental conditions.

Plants, like other living things, are faced with many threats that negatively affect their development throughout their lives. These threat factors can be biotic, such as disease-causing organisms or herbivores, or abiotic origin, such as extreme climatic conditions and mechanical factors.

Temperature, drought, salinity, pH changes, winds, precipitation, and various living things that come into contact with plants while passing around them, break the plants, cause abrasion with their friction, consume them by eating, and become vulnerable to diseases due to plant injury are abiotic factors that reduce the development of plants. Against these factors, plants try to survive by developing various defense mechanisms.

Plants, which are exposed to different threats and environmental conditions, have various anatomical, morphological, biochemical and genetic arrangements in order to continue their lives and progeny. In this way, they increase their chances of survival by providing homeostasis. In this study, the defense systems of plants against biotic and abiotic factors that threaten their lives were examined. These defense systems can exist in the plant before the stimulus, or they can appear later in response to the effect of any agent. Due to the fact that plants are living things that cannot move, they resist external factors that threaten their lives through these features.

2. Resource Summaries

Plants, which form the first link of the terrestrial food chain, contain very different mechanisms in order to continue their generation and survive. Thanks to the defense they show both before and after the attack, they can hold on to life.

The biotic and abiotic factors they are exposed to cause the plants' defense systems to be activated. Thus, it is ensured that the plants are prepared for the attack and their chances of survival are increased.

Botrytis cinerea Pers.: Fr (Lead mold disease) (Figure 2.1), which complicates the life of plants, causes disease-causing organisms; *Meloidogyne spp.* (Root-knot nematode), *Plutella xylostella* (Cabbage leaf moth) (Figure 2.2), *Helix aspersa* (Garden snail), Trialeurodes vaporariorum (Greenhouse whitefly), *Panonychus ulmi* Koch (European red spider) (Figure 2.3), *Acalitus essigi* (Blackberry mite) (Figure 2.4), and *Sus scrofa L.* (Wild boar) can be given as examples of herbivorous creatures.

Figure 2.1. *Botrytis cinerea* Pers.: Fr (Lead mold disease) on eggplant plant (Source: www.azizozkan.com)

Figure 2.2. *Plutella xylostella* (Cabbage leaf moth) on the cabbage plant (Source:https://www.nhm.ac.uk)

Figure 2.3. *Panonychus ulmi* Koch (European red spider)
(Source:https://www.cropscience.bayer.com)

Figure 2.4. *Acalitus essigi* (Blackberry mite) on
blackberry plant (Source:https://www.fugleognatur.dk)

Higher plants have various defense mechanisms to defend themselves. These defense mechanisms are structurally divided into defense systems that exist before the stimulus and the defense systems that occur after the stimulus (Kilinc and Kutbay, 2019).

2.1. Structural Defense Systems Existing Before The Warning

These types of defense systems are structures that exist in plants throughout their structural development. In other words, they are the formations that do not occur as a result of any stimulus but are present in the natural structure of the plant (Kilinc and Kutbay, 2019).

Since plants are sessile creatures, their protection features are more developed in terms of structure. For this, there are various defense mechanisms in tissues and organs, especially in parts that come into contact with the environment.

2.1.1. Defense Systems in Protective Cover Tissue

The covering tissue is a tissue consisting of chlorophyll-free cells that surround the plant and protect it against external influences and reduce water loss. The covering tissue, which plays an active role in the self-defense of the plant, can be examined in two parts as epidermis and epidermis cell wall.

2.1.1.1. Epidermis

The epidermis layer, which surrounds the plants from the outside, forms the basis of the protective cover tissue. The epidermis is a single layer of cells that covers the roots, stems and leaves of the plant. It consists of living cells that exchange substances with the external environment (Tatlı, 2000; Source: http://www.biyolojiportali.com).

Epidermis cells have little cytoplasm and large vacuoles. Since they do not have chloroplasts, they cannot photosynthesize. Cells are adjacent to each other, there are no spaces between them. In this way, it is easier to protect the plant against mechanical effects (Source: http://www.biyolojiportali.com).

The substances accumulated on the epidermis layer and the hairs and stomata (pores) formed by the differentiation of the epidermis layer are also elements that play a role in the defense of the plant (Tatlı, 2000).

2.1.1.1.1. Wax Layer

It is a non-cellular layer located on the outer part of the epidermis cells. Thanks to the accumulated wax material, a hydrophobic surface is formed and the accumulation of pathogens on the surface is prevented. In addition, secondary toxic substances in the wax layer are also effective in defense (Kilinc and Kutbay, 2019).

2.1.1.1.2. Cuticula Layer

It is the protective layer formed by the accumulation of cutin material on the cellulose micelles of the cell wall (Figure 2.5). By protecting the plant from mechanical effects and pathogen attacks, it ensures that the plant is less affected by adverse conditions. Its thickness changes according to the ambient humidity. The cuticula layer of plants in humid regions is thin, while the cuticula layer of plants in arid regions is thick. In this way, it becomes easier for the plant to protect itself against drought (Tatlı, 2000; Source: http://www.biyolojiportali.com).

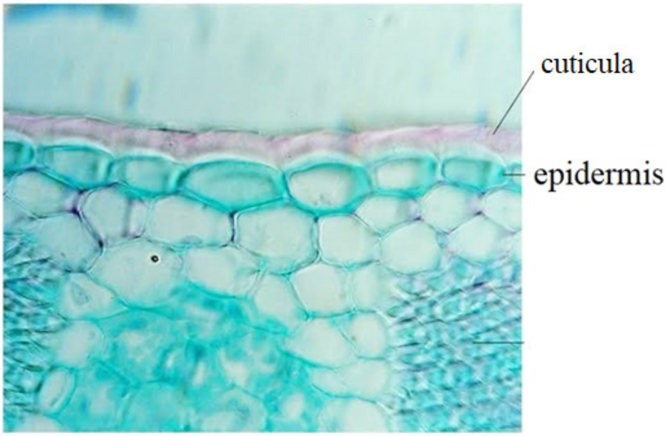

Figure 2.5. The structure of the cuticula in the leaf cross section (Source: https://www.sorianatural.com)

2.1.1.1.3. Feathers (Trichomes)

They are protective tissue elements formed by the differentiation of the epidermis layer. They control water and heat loss by protecting plants against external influences. They are classified according to the number of cells, their structure and function. They differ according to the climatic conditions in which the plant grows (Tatlı, 2000) (Figure 2.6, Figure 2.7 and Figure 2.8).

Figure 2.6: Protective Hairs In Some Plant Species (Source: Büşra ÇİL)

Figure 2.7: An Example Of A Feathery Alpine Plant (Source: Büşra ÇİL)

Figure 2.8: Burning Hair On *Urtica dioica* (Nettle) Plant
(Source: https://www.sorianatural.com; http://yavuzyilmazbiz.blogspot.com)

2.1.1.1.4. Stomata (Pores)

They are the living cells of the plant that are formed by the differentiation of epidermis cells and provide gas exchange. Thanks to the chloroplasts they carry, they are also effective in meeting the nutritional needs of the plant by performing photosynthesis. It is especially found in the green parts of plants such as leaves. Their positions on the leaves differ according to the growing environment of the plant. In arid regions, they are embedded in the leaf to reduce water loss. This type of stoma is called xeromorph stoma (Figure 2.9). The stomata in plants living in moist areas are located far outside the leaf surface and are called hygromorph stomata (Source: http://www.biyolojiportali.com).

Some stomata have a cover formed from the cuticula. This cover makes it difficult for harmful organisms to pass into the inner parts of the plant and ensures the protection of the plant (Kilinc and Kutbay, 2019)

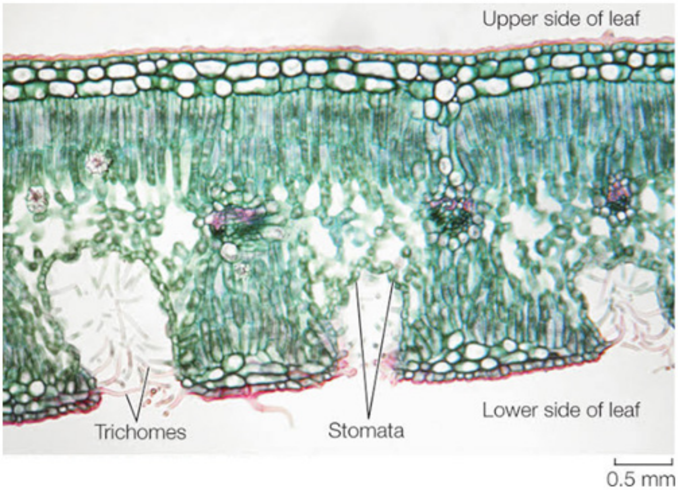

Figure 2.9: Xeromorph Stomata In Arid Plants
(Source: https://www.macmillanhighered.com)

2.1.1.2. Structure of the Epidermis Cell Wall

The thick and durable walls of the epidermis cells act as a barrier against harmful organisms. In addition, silicic acid or lignin substances found in the epidermis cells of some plant species are also very effective in defense. In addition to these substances, suberin also plays an important role in increasing the resistance of plants and preventing their degradation (Kilinc and Kutbay, 2019).

2.1.2. Biochemical Defense Systems Before Contagion

Chemical substances in the structures of plants before any attack are one of the most important weapons of plants. The use of these substances differs according to plant varieties (Kilinc and Kutbay, 2019).

Some plants create a shield for themselves by spreading these biochemicals around them, while others store them in their bodies.

2.1.2.1. Inhibitors Released by Plants to the Environment

Walker and Link (1933), in their study on *Colletotrichum circinans* (Onion Mold) observed in the outer membranes of California onions, determined that the presence of catechol and protocatechinic acid in colored onions gave the plant resistance. They observed that spore growth was inhibited by the removal of these substances from dead scales.

2.1.2.2. Inhibiting Substances in Plant Cells

Plants accumulate some biochemicals in their storage cells in order to protect themselves. While these substances do not harm the plant itself, they can deal fatal blows to pathogens that threaten its existence.

Johnson and Sachael (1952) determined that *Streptomyces scabiens* gained resistance to scap disease caused by potato thanks to the chlorogenic acid found in the tubers.

Yıldız (2019) found that extracts from nettle and black cabbage caused allelopathy by reducing vegetation in sunflower, soybean and corn seeds. Due to the increase in the presence of alkaloids called glucosinolate in its content, germination and seedling development have stopped.

Flavonoids, which have attractive-repellent, fungicidal and allelopathic effects in plants, are harmless to living things and stop plant enemies. In addition, ferulic acid and paracoumaric acid esters protect plants against fungal diseases by inhibiting carbohydrate hydrolases (Kilinc and Kutbay 2019).

2.2. Defense Systems Created After A Warning

These defense systems are formed by the activation of various mechanisms after stimulation in the plant. Plants have developed a response mechanism against abiotic or biotic stimuli. These reactions can sometimes be morphological changes or sometimes metabolites produced.

2.2.1. Structural, Morphological and Molecular Defense Systems Created After Contagion

Although plants take the necessary precautions against attacks, when they are damaged, they try to repair their wounds. This repair differs in the place of damage, the type of pathogen and the characteristic features of the plant. Thus, the damage in the damaged parts is tried to be eliminated without affecting other structures.

In order to provide total defense, plants show differentiation in their tissues, accumulation of chemicals and activation of defense genes.

2.2.1.1. Cork Texture

It is the protective tissue that consists of the cambium of the fungus and covers the outer part of the plant and prevents it from getting too hot. Since the substance suberin accumulates in it does not pass water, it prevents water loss of the plant. There are no spaces between the fungal cells and the cells are dead (Figure 2.10). It is more common in woody plants. In herbaceous plants, it occurs as a result of injury (Tatlı, 2000).

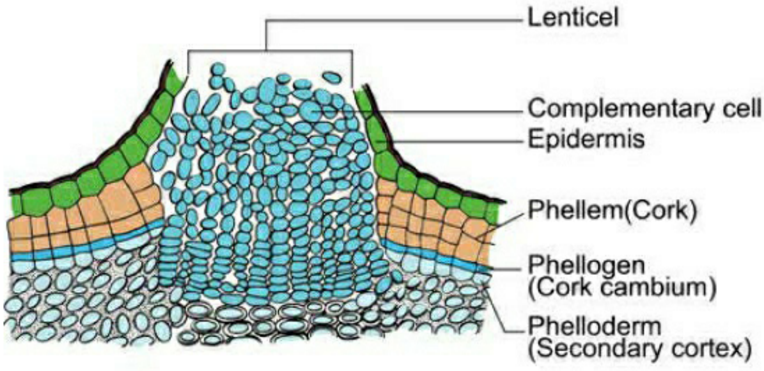

Figure 2.10: Phelloderma and Lenticel Formation
(Source: https://plantlet.org)

In the protective cork tissue, the epidermis cells are replaced by periderm, and the stomata are replaced by lenticels. The periderm layer is divided into three layers, namely phelloderm, phellogen and phellem (Tatlı, 2000).

2.2.1.1.1. Felloderm

It is the collenchymatic cortex parenchyma, which is composed of living cells with chloroplasts and its wall is not cork. It contains cellulose in its walls and there is a space between the cells (Tatlı, 2000).

2.2.1.1.2. Fellogen (Cork Cambium)

It arises from the secondary meristem. It forms cork tissue (phellem) outward and phleloderm inward (Tatlı, 2000).

2.2.1.1.3. Phellem

It consists of fungal cells that protect the plant from external influences. With the wear and tear of the epidermis, the phleem layer occurs (Tatlı, 2000).

2.2.1.2. Abscission Layer

It is the fungal tissue that develops in the area where the leaf attaches to the stem after bacterial, fungal or virus attacks and allows the leaf to separate from the stem. It occurs due to internal and external effects (Kilinc and Kutbay, 2019).

2.2.1.3. Compartmentation

It is the separation process seen in the bark of the roots and trunks of trees in areas damaged by wind, snow, hail, fire, animals and insects. In this way, the worn tissue is separated from the healthy part and the plant is protected (Shigo, 1984).

Compartnebtation is regional and cannot affect attacks that occur outside of the reserved part. In addition, these processes consume a lot of energy. The continuation of the attacks leaves the plant weak and after a while the plant becomes unable to react (Kilinc and Kutbay, 2019).

2.2.1.4. Tylose Establishment

They are protrusions formed in wood pipes (Figure 2.11). These protrusions close the protoplasts of living parenchyma cells and prevent further cell damage. Tylose formation can also be described as a partitioning process (Kilinc and Kutbay, 2019).

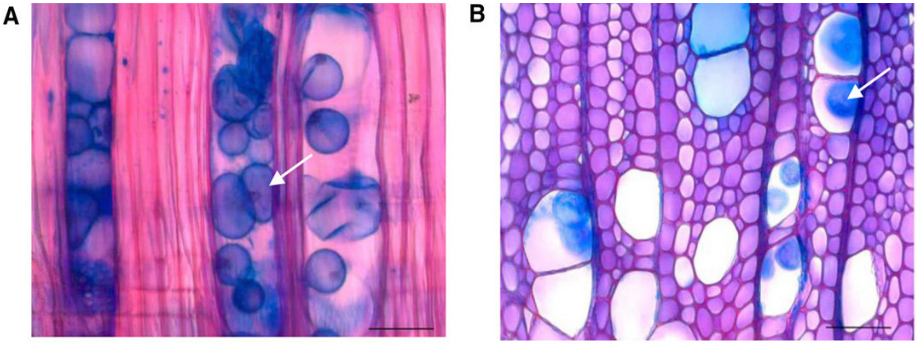

Figure 2.11: Longitudinal (A) and transverse (B) view of tyloses (Source: https://www.researchgate.net)

2.2.1.5. Resin, Balm, Gum and Gum Build-up

The gum or resin accumulated in damaged plant parts provides protection of the plant. Glue is produced in a short time against fungi attacking pershore species and the fungal cells are surrounded by the gum (Kilinc and Kutbay, 2019).

2.2.1.6. Hyphae Formation

The hyphae, which spread into the cell wall and prevent the progression of pathogens inside the cell, are composed of callose, cellulose and other substances. It is also possible that the hyphae are formed from cytoplasmic structures (Kilinc and Kutbay, 2019).

2.2.1.7. Secondary Metabolite Accumulation

Secondary metabolites are chemical substances that plants produce in order to defend themselves. The most important of these substances are alkaloids, saponins, glycosides, phenols, tannins and terpenoids. It is widely used in agriculture, especially since it naturally protects the plant against pathogens (Guncan and Durmusoglu, 2004; Koc and Ustun, 2008).

Ozay, Kilincarslan and Mammadov (2016) stated that secondary metabolites protect the plant against both abiotic stress factors and harmful organisms. They stated that especially nitrogen-containing secondary metabolites of glucosinolates are very effective in chemical defense.

2.2.1.8. Molecular Defense Systems

The inactivity of plants makes them vulnerable to attacks. For this reason, plants have also developed various mechanisms for protection. In addition to the production of secondary metabolites and chemicals after the attack, there is also a defense at the molecular level.

When the plants attacked by the pathogen were examined, the R gene proteins of the host recognized the substances produced by the avr genes of the pathogens. R genes also activated the plant's defense system by activating other genes. It has been seen that Avr genes can thus activate the defense system artificially (Tor, 1996)

In plants infected with different pathogens for the second time, the defense mechanism produces a faster response. In the realization of this situation, hormonal salicylic acid and genes may work in interaction (Şahin, Batı Ayaz, & Ayaz, 2018).

By stimulating the cotton plant (*Verticillium dahliae*) with wilt disease, various transcription factors were activated to produce resistance gene products in the plant. However, an effective defense method against this disease has still not been found (Koral and Turktas, 2017)

2.2.2. Chemical Defense Systems Created After Contagion

They are chemicals that play a role in plant defense by being produced after contamination that are not synthesized in normal situations in plants. In particular, they prevent the occurrence of disease by preventing the spread of the pathogen within the plant.

2.2.2.1. Reactions of Extremely Sensitive Plants

They are sudden deaths that occur in the affected parts of plant cells after infection. Thanks to this reaction, the pathogen that damages the plant is not able to provide the necessary nutrients. Pathogens that cannot develop or multiply lose their lives with this reaction of the plant.

2.2.2.1.1. Hypersensitive Responses (HSR)

Hypersensitive (hypersensitive responses HSR) responses are defensive responses to protect the plant against herbivores and pathogens, which are pathogens. It includes special protection situations such as SAR resistance against viruses, systemic resistance against non-specialized pathogens, and phycoalexin synthesis (PAX) (Kilinc and Kutbay, 2019).

In order for plants to defend themselves against pathogens, the right response is created by the interaction of hormonal signals such as salicylic acid (SA), jasmonic acid (JA) and ethylene (ET) in their defense systems (Yıldız Aktaş and Guven, 2005).

Resistance to the parasite is gained by forming incompatible host-parasite combinations with hypersensitive responses. In other cases, since a normal virus-host association occurs, hypersensitive reactions do not occur (Kilinc and Kutbay, 2019).

Hypersensitive reactions are caused by the oxidation of phenolic substances, reducing and oxidizing events in the cells and disturbing the balance. Sometimes it results in the destruction of cellular structures (Kilinc and Kutbay, 2019).

2.2.2.1.2. Phytoncides

Chemical plant preservatives produced by plants against other organisms. It covers substances that existed before contamination and whose structure has been regulated after contamination. The substances created prevent and terminate insect destruction (Rubin and Artsikhovskaya, 1964).

Kim, Kim, Chung and Moon (2014) investigated the changes in enzymatic blackening observed in freshly cut lettuce leaves by applying phytoncidal essential oil obtained from pine leaves. It was determined that the enzymatic activities of the samples, which were kept in a solution containing phytoncides dissolved in ethanol, increased significantly.

2.2.2.1.2.1. Presence of Phytoalexin

The concept of phytoalexin was first used by Muller and Börger (1941) for the substances produced by the plant to protect against the fungus when a fungal parasite attacked the plant. There are many varieties such as brass, cyclobrass, spirobrass (Figure 2.12) (Source: https://www.researchgate.net).

Phytoalexins are compounds produced not in the whole plant, but only in its invaded cells. In this regard, immunity develops thanks to phytoalexins in the cells infected with fungal infection.

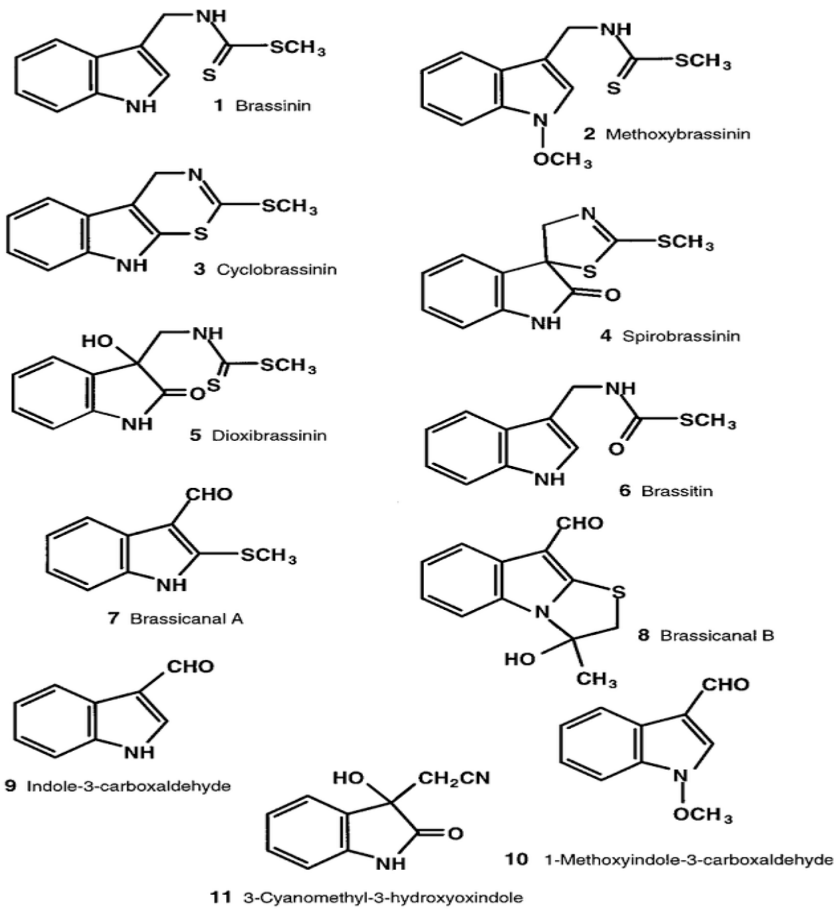

Figure 2.12: Phytoalexins (1-8) and phytoalexin metabolites (9-11) derived from Brassica (Cruciferae) (Source: https://www.researchgate.net)

2.2.2.1.2.2. Other Chemical Defense Products Created After Stress

Plants exposed to various stressors defend themselves by producing various chemicals.

When the above-ground organs of the Carthamus glaucus plant, which was attacked or not, were examined, it was observed that there was an increase in the ratios of quinic acid, tr-caffeic acid, hyperoside, gallic acid, querstin and naringenin compounds used in defense. After the attack, the ratios of vanillin, hesperidin, salicylic acid, 4-OH benzoic acid, campherol, tr-aconitic acid decreased. Tannic acid, another chemical examined in the study, increased only in the attacked plants (Surmus Asan and Ozen, 2015).

It was observed that the total amount of proline increased significantly with the use of plant growth regulator rhizobacteria against gray mold disease (*Botrytis cinerea* Pers.: Fr.), which harms eggplant production. In addition, catalase (CAT) and peroxidase (POX) enzymes used in defense have also increased (Ciftci and Altınok, 2019)

Kokubun and Harbourne, (1994), investigated the content of phytoalexin in the leaves of 130 species of Rosaceae family. They determined that although phytoalexins are mostly produced against fungi, they are also produced against bacteria and viruses. In addition, they found that abiotic stress factors such as UV rays, temperature, injury and inorganic salts cause the production of phytoalexins. They stated that these substances are less common in healthy plant tissues.

Production of phytoalexins occurs only when the plant encounters an infection. Adjusting the organ where the production starts, the correct time and amount affects the plant resistance. Phytoalexins are the most effective agent in fungal infections. Phytoalexins are antibiotics produced at the entrance of injured areas. Their existence has been determined after various diseases. (Kilinc and Kutbay, 2019).

3. Conclusion

Plants are faced with many living and non-living factors throughout their lives. Since they do not have active mobility, they continue their generations and lives by developing various defense systems.

Each plant increases its chance of survival by adapting itself according to the environmental conditions in which it lives. Otherwise, abiotic factors such as temperature, winds, salinity and drought make the life of plants difficult. Apart from these factors, there are also biotic factors such as herbivores, pathogens and nematodes that cause the plant to be stressed. The defense systems developed by plants against these factors differ before and after the stimulus.

The epidermis in the plant, the protective hairs that develop from the epidermis layer, stomata, wax and cuticle layers accumulated on the epidermis provide the protection of the plant before the stimulus. In this way, the plant prepares itself against biotic and abiotic stress factors from the environment.

After the stimulation, the formation of fungal layers in the plant structure in accordance with the environmental conditions in which the plant lives, the formation of the abscission layer, partitioning, the formation of tylose, the formation of substances such as resin and gum are in question. In addition to these, the production of protective enzymes is provided by activating defense genes. Plants that adapt to changing environmental conditions in this way continue to live by protecting their generations.

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