THE CORNERSTONE OF HEALTHY LIVING: GERMINATED GRAINS AND LEGUMES

Assoc. Prof. Dr. Filiz YANGILAR

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Editor in chief: Berkan Balpetek
Cover and Page Design: Duvar Design
Printing : October -2024
Publisher Certificate No: 49837
ISBN: 978-625-6069-82-4

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PREFACE

The biological richness of a country is expressed through its species, genes, and biodiversity within the ecosystem. Dietary habits, influenced by cultural characteristics and evolving developments, rapidly adapt to current consumption trends. Nutrition has played a crucial role in safeguarding human health for centuries and its correlation with various food sensitivities, allergies, and diseases is significant. Scientific research on diverse nutrition styles has necessitated contemporary approaches to nutrition, fostering innovation in alternative nutrition methods, new market creation, diversified food applications, and food preparation techniques. Raw nutrition involves the consumption of natural, raw, and unprocessed foods. In recent years, changes in dietary patterns have led to an increased consumption of germinated grains and sprouts alongside organic and fermented foods. The process of germination triggers critical biochemical processes in plants and seeds leading to the synthesis of compounds like dietary fiber, vitamins minerals, and phenolic substances while altering the composition of carbohydrates, proteins, and fats. Furthermore, sprouting is considered a solution to malnutrition due to its ability inhibit enzymes that hinder nutrient absorption from food items. Sprouted grains legumes are rich sources of nutrients pivotal for environmental sustainability and agricultural productivity. As dietary preferences shift towards healthier options within modern lifestyles there has been an increase in demand for healthier products resulting from consumer awareness which consequently correlates with reduced instances of health issues such as Type-2 diabetes digestive disorders obesity cardiovascular diseases, particularly amongst those following vegan vegetarian diets who rely on grains legumes as essential protein sources.

Filiz YANGILAR / Erzincan, Turkey

CONTENTS

ACKNOWLEDGMENTS

I would like to express my heartfelt gratitude to my father, Necmettin YANGILAR, for providing me with the inspiration and guidance that has always encouraged me to pursue my dreams. I would like to thank my mother, Nevim YANGILAR, whose love and belief in me provide the strength to overcome any obstacle.

1. INTRODUCTION

The rise in chronic diseases such as diabetes, obesity, cardiovascular ailments, digestive system disorders, and colon cancer has led to a greater emphasis on healthy nutrition among consumers. It is widely recognized that the surge in consumption of unhealthy processed foods due to the fast-paced global lifestyle is contributing to numerous health issues. Consequently, dietary fiber has become a primary focus for individuals seeking healthier eating habits, leading to intensified research on its metabolic significance and health benefits (Köten and Atlı, 2021; Salçın and Ercoşkun, 2021). Cereals are annual plants from the Gramineae family which typically have long thin stems and starchy grains such as wheat, rice, corn, sorghum, millet, barley, and rye (Sarwar et al., 2013). Cereals have been a staple food for humans since prehistoric times due to being an affordable source of energy providing food security, particularly for low-income communities. They account for a significant portion of daily energy intake in a balanced diet. Legumes are regarded as an economical and sustainable alternative to meat globally. Pulses - economically significant crops following cereals - cover approximately 15% (270-300 million hectares) of arable land worldwide (Bessada et al., 2019). They serve as an important protein source, especially for populations who cannot consume animal proteins or choose not to do so based on religious or cultural practices. The nutritional value and quality of food proteins are determined by factors such as their essential amino acid composition, digestibility, effect value, and benefits. Legume species are significant plant protein sources globally and are utilized as an important component of the general food supply within programs like the "World Food Program" and other "Food Aid Initiatives" (Sarıoğlu and Velioğlu, 2018). Given the link between diet and health, there is growing interest in enhancing the nutritional profile of various food products, particularly those with high sugar and fat content. It is believed that incorporating functional foods into daily nutrition can enhance the quality of life due to their positive contributions to health development and improvement.

2. ADEQUATE AND BALANCED NUTRITION

The food system comprises the food supply, food environment, consumer behavior, and diet quality (Haddad et al., 2016). A healthy nutrition plan is essential for providing the body with necessary nutrients in sufficient amounts and contributes to physiological, mental, and social well-being (WHO, 1998; Kartal et al., 2019). Consuming a balanced diet is crucial for leading a healthy and high-quality life (Lipman et al., 2016). Modifying diets for healthier nutrition can reduce the environmental impacts of the food system by replacing dense foods like animal products with less environmentally impactful options (Springmann et al., 2016; Tilman and Clark, 2014). A healthy diet entails consuming adequate nutrients based on individual factors such as age, gender, and physical condition (Jenner et al., 2019). Nutrition significantly affects human health as it plays an important role in children's growth and development. Thus, ensuring adequate and balanced nutrition is vital during childhood as it provides essential energy and nutrients for overall health and developmental processes (Taşdemir, 2019). Adequate and balanced nutrition is vital for lifelong health, as it provides the necessary energy and nutrients for growth, development, and overall well-being (Øverby et al., 2023). It involves consuming all nutrients in appropriate amounts and at the right times. Nutrients found in food can be classified into macro and micronutrients. Macronutrients include carbohydrates, proteins, and fats, while micronutrients consist of vitamins and minerals (Baysal, 2009). Inadequate intake of essential nutrients can lead to disruptions in bodily functions and the onset of diseases (Tayar and Korkmaz, 2007). Nutrients play various roles in the body's functioning with direct or indirect relationships to one another. They complement each other in some tasks while aiding each other in others. Consuming all nutrients in amounts that meet the body's needs is crucial for regular and balanced functioning (Çelik, 2006).

Nutrition encompasses a wide range of processes, including digestion, absorption, and transportation of nutrients in the body, as well as anabolism and catabolism, intermediary metabolism processes, and disposal of unabsorbed nutrients and end products (Sato, 2016). It is not simply about satisfying hunger or filling the stomach; rather, it involves consciously taking in the necessary nutrients in appropriate amounts to protect health and enhance quality of life (Öztürk and Tekeli, 2021). Food systems are shaped by a multitude of factors, including geographical conditions, demographic trends, urbanization processes, and the impacts of globalization. Additionally, socio-economic status and income levels, marketing strategies, consumer attitudes, as well as religious beliefs and cultural practices, play significant roles in influencing these systems (Kearney, 2010). These factors shape the way food is produced, distributed, accessed by consumers around the world.

Promoting healthy eating habits is indeed crucial for improving the overall health of a society. Various factors play a role in shaping individuals' eating behaviors, including psychological factors, education status, social and geographical environment, marital status, age, economic status, nutritional knowledge, and access to food (Hakli et al., 2016). Additionally, socio-cultural influences such as traditions, beliefs, and customs impact people's attitudes and behaviors toward nutrition. It's important to recognize that the availability of diverse foods is influenced by geographical and physical conditions. Furthermore, sociocultural factors also influence how often these foods are consumed and the methods used to prepare them (Adak, 2010). By understanding these complex interactions between various factors that shape eating behaviors and dietary choices within a community or society as a whole can help in designing effective interventions to promote healthier eating habits.

The impact of various factors on individuals' nutritional habits is undeniable. Education levels, working conditions, occupations, environment, climate, socio-economic status, family upbringing, and societal development all contribute to shaping these habits. Education about nutrition has been shown to have a positive effect on individuals' eating behaviors (Daşbaşı, 2003). Promoting healthy eating habits and improving nutritional knowledge are crucial in preventing obesity and other health issues such as infectious diseases (Yuen et al., 2018). Given the rise in diseases related to poor nutrition practices, it is imperative to focus on developing nutritional knowledge and promoting healthy eating behaviors within society (Vidgen et al., 2014). By addressing these factors and promoting healthy eating practices through education and awareness programs, we can work towards reducing the prevalence of diseases associated with unhealthy nutrition practices.

Sustainability, as defined by the Brundtland Commission, involves meeting the needs of current and future generations without compromising the ability of future populations or harming the environment (Brundtland, 2018). Sustainable diets are consistent with this concept as they exhibit minimal environmental impacts while promoting food security and nutrition for both current and future generations (FAO). Furthermore, these diets honor biodiversity and ecosystems, are culturally acceptable, economically accessible, nutritionally sufficient, and ensure safety and health for consumers. The carbon footprint is an important tool in evaluating a product's environmental impact throughout its lifecycle. It measures greenhouse gas emissions to mitigate climate change effects (Godlee, 2006; González-García et al., 2018). Greenhouse gases contribute to climate change; focusing on reducing carbon dioxide emissions is critical in addressing this global threat (Afrouzi et al., 2023; Hoegh-Guldberg et al., 2018). Overall, promoting sustainable diets and reducing carbon footprints are crucial for ensuring a healthy environment for current and future populations. It is indeed true that changes in dietary preferences can have a significant impact on the carbon footprint, with potential positive environmental consequences. Transforming current dietary patterns into sustainable and nutritious diets holds promise for addressing both health and environmental concerns (Kovacs et al., 2021). It's important to note that the differences in carbon footprints between animal and plant-based foods, as well as within these food groups, can vary significantly. For example, replacing consumption of meat from ruminants with monogastric animals like chicken has been shown to contribute to reducing the carbon footprint due to lower methane emissions associated with enteric fermentation (Westhoek et al., 2014). Additionally, adopting a vegan diet - which excludes foods of animal origin such as eggs, dairy products, fish, and meat - has been highlighted for its low environmental impacts (Baroni et al., 2007). When comparing dietary patterns, it's essential to consider not only their environmental impact but also their overall nutritional quality and recommended protein intake levels (Van Kernebeek et al., 2014; Esteve-Llorens et al., 2019). This holistic approach ensures that sustainable diets not only benefit the environment but also meet nutritional needs.

Access to adequate nutrition is indeed influenced by social, political, and economic conditions. It's crucial for human health that individuals have access to balanced and sufficient nutrition. The food choices people make not only impact their health but also have environmental, economic, and social effects throughout the supply chain and production process (Esteve-Llorens et al., 2019; Afrouzi et al., 2023). The importance of a balanced diet extends beyond individual health to societal development and living standards. Healthy nutritional practices play a key role in preventing chronic diseases and are fundamental for the social and economic development of societies (Tepper et al., 1997). Moreover, malnutrition and deficiencies in trace elements can contribute to brain dysfunction and neurological disorders such as depression and dementia (Ross, 2018; Melzer et al., 2021; Suárez-López et al., 2023). Macronutrients also play a significant role in brain health and cognitive function (Melzer et al., 2021). Understanding the impact of nutrition on brain health during aging is crucial for developing effective preventive public health approaches to address mental health disorders associated with malnutrition. Overall, these insights highlight the interconnectedness of diet with human health, societal well-being, and mental well-being. It emphasizes the importance of promoting healthy nutritional practices at individual and societal levels.

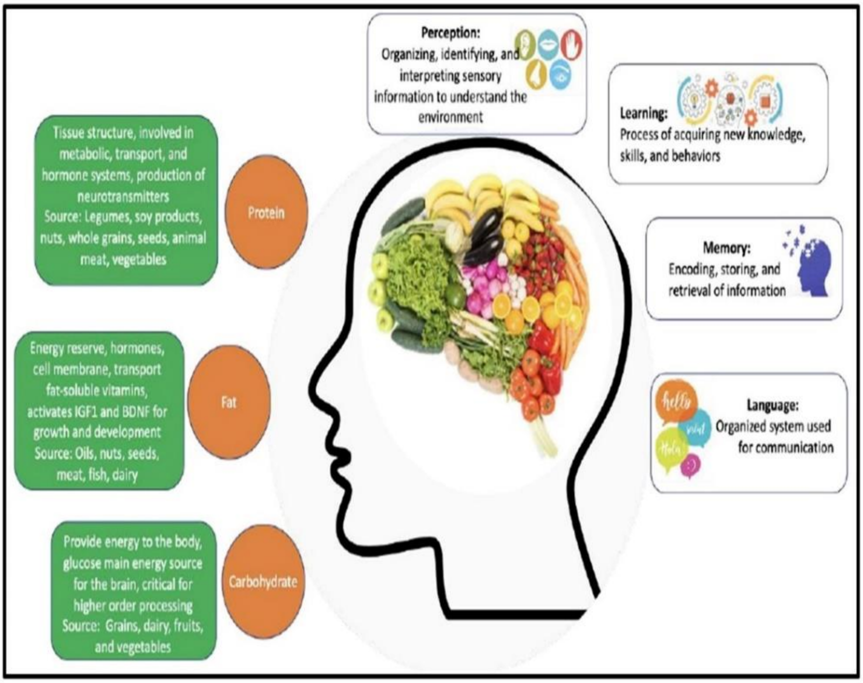


Fig. 1. Effects of macronutrients on brain health and cognitive functions

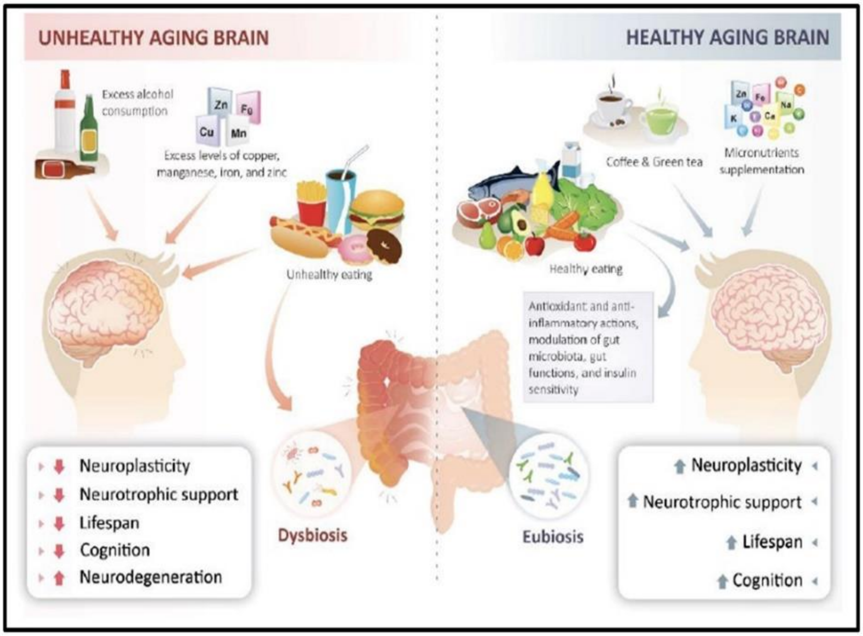


Fig. 2. The effect of nutrition on brain health during aging

There are two significant global nutrition-related issues. The first is health problems from excessive food consumption, while the second is hunger resulting from the inability to access food. Both of these situations have adverse effects on human health. Some regions face fatalities due to food scarcity, while others grapple with deaths due to overeating. Consequently, ensuring adequate and balanced nutrition is essential for the maintenance of overall health. Body image has been a focal point of research for several decades. Recently, there has been a notable increase in the prevalence of negative body image perceptions, surpassing those of positive body image perceptions (Tylka and Wood-Barcalow, 2015). Body image has been extensively researched for its functions, impact on individuals, potential outcomes, and treatment options. Recent studies have revealed that body image and its perception play vital roles in weight management processes and are influenced by social or cultural factors worldwide (Alipour et al., 2015). Body image encompasses an individual's perceptions, feelings, and thoughts about their own body. The societal emphasis on fitness and health in Western culture has often been linked to body dissatisfaction and the development of eating disorders, particularly among women (Toral et al., 2016). Additionally, body image attitudes encompass emotional distress, cognitive aspects, and behavioral avoidance (Pull, 2011). Body image perception is gaining prominence in Western societies. With the widespread use of social communication tools, cultural pressures are on the rise. Among the key factors influencing body image perception are sociodemographic characteristics, nutrition, economy, culture, class status, educational status, and social media usage (Ansari, 2010). An individual's level of education impacts their nutritional attitudes and behaviors. Higher levels of education increase the likelihood of learning healthy nutritional habits and behaviors as well as internalizing these practices and correcting any mistakes (Özenoğlu et al., 2021). Lack of nutritional knowledge leads to the development of poor dietary habits and various health issues. Nutrition education is one of the primary tools for preventing problems stemming from inadequate or imbalanced nutrition. Research indicates that nutrition education effectively enhances nutritional knowledge; furthermore, that higher levels of education correspond to increased levels of nutrition education (Johansson et al., 2009).

3. VEGAN/VEGETARIAN DIET

The term "vegetarian" originates from the Latin word 'vegetus,' which means full of life, healthy, and lively. In Turkish, the word vegetarian is explained as" does not eat meat" by the Turkish Language Association (Yalçınbaş et al., 2022). Vegetarian nutrition is defined as the partial consumption or non-consumption of animal meat and foods obtained from animal sources. It predominantly consists of plant-based foods (Tunçay, 2018). The practices of vegetarianism and veganism have been observed since ancient times and continue to grow. It is estimated that around 22% of the world's population follows a vegetarian diet, with approximately 14% being vegan (Jacimovic, 2022). While vegetarianism is practiced on all continents, India has the highest percentage, with an estimated 30-33% of its population being vegetarians (Pfeiler and Egloff, 2018; Paslakis et al., 2020). The increasing global interest in vegan and vegetarian movements stems from various reasons including concerns about environmental damage caused by industrial animal production, animal rights and ethics, and dislike for meat consumption due to philosophical thoughts or religious beliefs. As more people adopt vegan or vegetarian lifestyles, there has been a rise in experimentation with vegan versions of popular recipes. This movement has also led to increased innovation in gastronomy for vegan products. Famous chefs are creating new recipes catering to vegans while food companies are expanding their product range to include various vegan options (Phillips et al., 2005). Vegan and vegetarian diets have gained popularity due to various reasons such as the understanding of the importance of nutrition for a healthy life, animal welfare, and ecological balance (Akpınar et al., 2019). Adopting a vegan lifestyle is not just about diet; it encompasses an entire lifestyle that individuals should internalize and commit to for the long term. There is limited information regarding the prevalence of vegetarianism among children. However, a study with vegetarian adolescents aged 14-17 reported that female adolescents preferred vegetarianism more than males (Rudloff et al., 2019). In Turkey, there is currently no scientific data available on the rate of vegan and vegetarian populations. A study initiated by the Turkish Vegan and Vegetarians Association in January 2014 aimed to determine this prevalence but has not yet been concluded (Kendilci, 2021).

Carbohydrate consumption indeed tends to be higher in vegans and vegetarians compared to omnivores, as these individuals may rely on carbohydrates to meet their energy needs. It's important for those following a plant-based diet to focus on the quality of their carbohydrate intake, ensuring it comes from sources such as fruits, vegetables, and whole grains rather than refined grains and added sugars. Research suggests that vegans have a higher diet quality than vegetarians and omnivores, which may be attributed to their increased consumption of nutrient-dense plant foods (Parker and Vadiveloo, 2019; Reynolds et al., 2019).

Epidemiological studies have indeed indicated a reduced incidence of specific types of cancer among vegetarians and vegans. Chronic bowel diseases, including Crohn's disease and colorectal cancer, are influenced by a range of factors, such as genetic predispositions, immune responses, metabolic processes, and environmental conditions. Additionally, lifestyle choices and nutritional preferences have been demonstrated to significantly impact the development and progression of these conditions (Conlon and Bird, 2014). This evidence suggests that dietary habits may play a crucial role in either increasing the risk or providing protection against certain chronic diseases.

4. VEGAN DIET

The term "vegan" was coined in 1944 by Donald Watson and his associates to denote a lifestyle devoid of animal products (Turkish Vegan Association, 2024). Vegan nutrition falls within the spectrum of vegetarian diets but adheres to stricter guidelines. It entails complete abstinence from animal-derived foods (including meat, poultry, and seafood), as well as animal products such as eggs, milk, honey, etc., with a focus on consuming solely plant-based items (Gökçen et al., 2019). Veganism is conceptualized as both a philosophy and a lifestyle aimed at minimizing the exploitation and cruelty inflicted upon animals utilized for food, clothing, or other purposes. Furthermore, it promotes the development and adoption of non-animal-based alternatives that benefit humans, animals, and the environment alike (Aymankuy and Topal, 2022). In addition, veganism repudiates speciesism - the belief in human superiority over animals - and opposes any form of animal exploitation or enslavement while promoting ethical alternatives in harmony with nature (Turkish Vegan Association, 2024). The adoption of vegan nutrition is steadily increasing (Sutter and Bender, 2021), particularly among young individuals and women (Craig, 2009). The growing consumer awareness regarding veganism aligns with concerns about health issues sustainability practices environmental sensitivity animal welfare. This has led to heightened interest in the vegan market. Notably human-induced harm to natural environment animals has prompted changes in consumer purchasing decisions and behavioral patterns surrounding this issue (Akkan and Bozyiğit, 2020).

5. VEGAN DIET TYPES

Today, the number of people who follow a vegan diet is quite low. The vegan diet is also classified differently.

5.1. Zen Macrobiotics Diet

It includes grain foods, vegetables, fruits, legumes, and some only consume grain products (Ayyıldız and Ceyhun Sezgi, 2019).

5.2. Rawists

They absolutely do not consume meat, milk and dairy products and eggs. At the same time, stimulants such as coffee, tea, alcohol, and cigarettes are not used. It includes raw foods (Vatan and Türkbaş, 2018).

5.3. Fruitarians/Fruit-fed

Fruits and botanical fruits are consumed. Cucumbers, peppers, tomatoes, etc. are fed. "Everything returns to the soil", they believe in the continuity of the growth cycle (Güler and Çağlayan, 2021).

Vegans have been critical of vegetarianism, as they believe that the consumption of animal products in limited quantities is unsatisfactory (Altaş, 2017). Additionally, vegans reject the use of certain plant-based products. Palm oil, for example, which is derived from the fruit of palm trees and found in many frozen and ready-made foods, is a point of contention. Its widespread use is attributed to its affordability, lack of trans fat, and neutral taste (Akkan and Bozyiğit, 2020).

Comparisons between the gut microbiota profiles of vegans and vegetarians suggest that both groups exhibit a higher abundance of beneficial bacteria than omnivores. Conversely, omnivores demonstrate greater alterations in their gut microbiota composition with an increased presence of potentially harmful microorganisms due to their consumption of animal-based diets characterized by elevated levels of fecal bile acids (Glick-Bauer and Yeh, 2014; Sakkas et al., 2020). Short-chain fatty acids (SCFAs) have demonstrated a range of health benefits, including the improvement of blood lipid profiles, glucose homeostasis, and body composition. Additionally, SCFAs contribute to the strengthening of the mucosal barrier and provide protective effects against various disorders, such as type 2 diabetes mellitus, inflammatory bowel disease, and immune-related diseases (Fig. 3; Hjorth et al., 2019; Singh et al., 2017; Tomova et al., 2019; Sakkas et al., 2020). This figure provides valuable insights into how vegan food components can impact the gut microbiota and associated health markers.

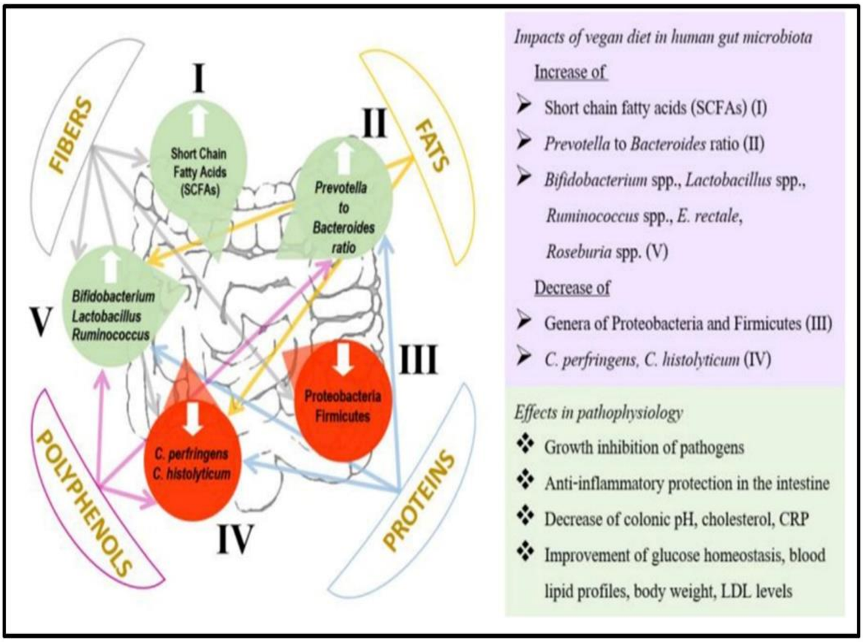


Fig. 3. Effect of vegan diet on human gut microbiota (*Eubacterium rectale*, *Clostridium perfringens* and *Clostridium histolyticum*). LDL: low-density lipoprotein, and CRP: C-reactive protein.

6. VEGETARIAN DIET

Pythagoras is credited as the pioneer of ethical vegetarianism due to his belief that animals were once human and would become so again in the future. His influence led to vegetarian diets being referred to as "Pythagorean diets" until the late 18th century (Altınok, 2022). There is no evidence of complete vegetarianism among people after the advent of agricultural practices in the Paleolithic era. However, it is estimated that many farmers primarily consumed their crops and lived as vegetarians (Hargreaves et al., 2021). Dietary patterns hold significant symbolic and social value, and altering them can have profound effects on social relationships. The transition to vegetarianism can evoke sympathy and support from some while attracting criticism, surprise, or hostility from others due to changes in dietary choices and nutritional beliefs (such as beliefs regarding protein sources) (Beardsworth and Keil, 1992). The Vegetarian Society UK does not consider dietary models including animal meat consumption as truly vegetarian (Vegetarian Society, 2023). It's worth noting that despite common belief, the term "vegetarian" does not derive from "vegetable", but rather originates from the Latin word "vegetus". Vegetus means lively, vibrant, and healthy. In 1842, the Vegetarian Society defined a vegetarian diet as one that does not include meat, fish, or poultry, with the optional consumption of eggs and dairy products (Vegetarian Society, 2024). To address confusion about this definition, the International Vegetarian Union - IVU developed a new definition in 2011 with unanimous agreement from member country unions. According to this definition; vegetarianism is "a diet that is entirely plant-based and in which animal foods such as dairy products, eggs and honey are consumed optionally or not at all" (IVU, 2021). Since 1977, October 1 has been celebrated as "World Vegetarian Day". The Turkish Vegetarian Association was founded on March 3rd, 2012 and later changed its name to the Turkish Vegan and Vegetarian Association (Ayyıldız and Sezgin, 2021). Vegetarianism is defined as a diet centered on plant-based foods rather than animal-based foods. The term 'vegetarian' refers to people whose diet primarily consists of plant-based foods and who exclude animal-based foods (such as red meat, chicken, fish, and eggs) partially or entirely from their diets (Fraser et al., 2009).

A vegetarian diet is indeed centered around plant-based foods such as fruits, vegetables, grains, legumes, and nuts. Research has shown that it typically contains more complex carbohydrates, fiber, antioxidants, and lower levels of saturated fat and cholesterol than non-vegetarian diets (Venderley and Campbell, 2006). It's important to note that a well-planned vegetarian diet can provide adequate nutrition through the inclusion of a variety of vegetables, fruits, whole grains, legumes, nuts, and seeds (Melina et al., 2016). This diet excludes meat foods like beef, poultry, wild game, and seafood in general.

7. TYPES OF VEGETARIAN DIETS

Vegetarian nutrition is considered as partial consumption of animal products or not consuming them at all. It is divided into subgroups according to the type and amount of animal sources consumed. There are polo-vegetarian, ovo-vegetarian, semi-vegetarian, lacto-vegetarian, pesco-vegetarian, lacto-ovo-vegetarian and vegan diets (Seçim et al., 2022).

7.1. Semi-vegetarian

It is defined as a vegetarian diet model where animal-based foods, except red meat, can be consumed. It is a plant-based diet where animal-based foods such as poultry, fish, seafood, milk, eggs, and honey can be consumed in limited quantities. Semi-vegetarianism is seen as the transition stage for omnivores to a vegetarian diet (Mete et al., 2022). Since semi-vegetarianism is a flexible diet, it allows individuals to choose the types and amounts of animal products that suit their preferences and needs, while still emphasizing a plant-based eating approach. This flexibility can make it easier for people to transition to a more plant-based diet and can also ensure the creation of a healthy and sustainable diet in the long term.

7.2. Lacto-vegetarian

Lacto-vegetarianism is defined as a vegetarian diet model in which milk and dairy products are consumed and no other animal source is consumed. In this diet, milk, dairy products, legumes, grains, fruits, and vegetables; foods such as cakes, pastries, pies, pastries, and pastries that do not contain animal food other than milk and dairy products can be consumed (Seçim et al., 2022). Lacto-vegetarian nutrition refers to a diet preferred due to health and environmental reasons within the scope of necessity. It serves the development of good cholesterol due to its effect on heart health and the fat and nutrient balance brought by the nutritional habit. The diet has a positive effect on blood sugar in the balance it creates by including dairy products and the presence of vegetables.

7.3. Ovo-vegetarian

It is a plant-based diet in which no animal-source food other than eggs is consumed. No type of meat, milk, and dairy products are allowed to be consumed (Yıldız and Yılmaz, 2020). Ovo-vegetarians eliminate all forms of meat and animal products from their diet, which encompasses beef, chicken, steak, shrimp, fish, and pork. Additionally, they refrain from consuming any animal milk and dairy products, including cow's milk, goat's milk, cheese, buffalo cheese, ice cream, and butter. This exclusion extends to all products derived from these dairy items, such as cheese pizza, whey protein, cream cheese, sour cream, and numerous baked goods (Barnett, 2016).

7.4. Lacto-ovo-vegetarian

A vegetarian diet model in which no animal meat is consumed, only plant foods and secondary animal products can be consumed. Since they are products obtained without harming animals, milk and dairy products, eggs, and honey are allowed (Shipman, 2021). This diet, classified as one of the vegetarian diet types, is primarily composed of grains, fruits, vegetables, legumes (such as beans, peas, and lentils), seeds, nuts, dairy products, and eggs. It explicitly excludes meat, fish, and poultry, as well as any products containing these animal-derived foods (Hua et al., 2001).

7.5. Pesco-vegetarian (Pescetarianism)

Pesco-vegetarianism is defined as a vegetarian diet model in which no meat other than fish is consumed, and seafood and plant foods can be consumed. However, other studies (Mete et al., 2022; Altınok, 2022) have reported that pesco-vegetarians can consume milk and eggs in addition to fish, seafood, and plant foods. However, since this diet does not include meat, which is a rich source of these nutrients, it is very important to ensure that pesco-vegetarian meals are balanced and provide adequate amounts of other essential nutrients such as iron, calcium, and vitamin B12. This may require careful food selection or supplements (Clarys et al., 2014).

7.6. Polo-vegetarianism

A vegetarian diet model that includes poultry meat in addition to plant foods. Poultry meats such as chicken, turkey, and duck can be consumed, while other animal meats are not consumed (Seçim et al., 2022). Pollotarianism is often adopted for ethical, health, and environmental reasons and is associated with numerous health benefits, such as reduced risk of chronic diseases such as obesity, Type 2 diabetes, and heart disease. In this type of diet, poultry is a good source of high-quality protein and generally contains less fat and calories than red meat (Yalçınbaş et al., 2022).

Vegetarianism is a dietary pattern characterized by the abstention from the consumption of animal products, consisting primarily or entirely of grains, vegetables, fruits, nuts, and seeds. Based on the specific foods included or excluded, vegetarians can be categorized into five main groups: vegans, who consume only plant-based foods; Lacto-vegetarians, who adhere to a plant-based diet except dairy products; ovo-vegetarians, who follow a plant-based diet excluding eggs; lacto-ovo vegetarians, who incorporate both dairy products and eggs alongside plant foods; and pesco-vegetarians, who exclude meat and poultry, dairy, and eggs, but include fish in their diet (Fig. 4; Pahlavani and Azizi-Soleiman, 2023).

Fig. 4. Vegan diet for 5 main groups

8. VEGETARIAN/VEGAN DIET AND HEALTH

The positive effects of vegetarian and vegan diets on health are listed as follows:

- Vegetarian/vegan individuals have lower blood cholesterol levels than non-vegans.
- Cardiovascular diseases and diabetes are less common than omnivorous individuals.
- All cancer cases except breast cancer are significantly lower in vegetarians than in omnivores. Vegans consume more legumes, fruits/vegetables, allium vegetables, fiber and vitamin C than omnivores. These foods protect against cancer, prostate and some stomach disorders.
- Vegetarian diets have more protective effects, especially against colon cancer.
- It is quite meaningful to follow a vegetarian diet during the treatment of obesity.
- It has been determined that vegan nutrition reduces stress and improves mood, especially in women (Gezer and Kabaran, 2013).

The most important problem with the vegan/vegetarian diet is the potential for vitamin B12 and protein deficiency. Vegetarians primarily consume plant-based proteins, and while essential amino acids are found in eggs, soybeans, milk, and dairy products, those following lactoovo, lacto, or ovo vegetarian diets do not typically experience serious health problems related to protein intake. However, vegans may face significant protein deficiency if they do not plan their diet carefully. Therefore, it is recommended that vegans consume soybeans, legumes, and oil seeds as sources of protein. Additionally, it may be necessary for vegans to take supplements such as iron, calcium, zinc omega-3 fatty acids, B12, and vitamin D (Karabudak, 2012; Tunçay, 2018).

Mainly cereals (wheat), rye rice barley quinoa amaranth etc., legumes (chickpeas beans lentils peas etc.), fruits vegetables nuts (walnuts hazelnuts almonds etc.), seeds (chia seeds flax seeds etc.) and vegetable oils olive oil sunflower oil hazelnut oil are consumed in this type of diet (Altınok, 2022).

9. CEREALS IN NUTRITION

Agriculture plays a pivotal role in the economic development of nations, particularly in developing countries. The advancement of agricultural practices is largely contingent upon the effective utilization and dissemination of innovations derived from scientific research among producers. Consequently, the inherent characteristics of agricultural activities and the individuals engaged in these activities significantly influence the capacity of the relevant communities to adopt specific behaviors and innovations. It is, therefore, anticipated that the attributes of the human factor will expedite the development process through the integration of new information and practices. Thus, identifying agricultural innovations, facilitating their adoption, and understanding the factors that influence this adoption are crucial for ensuring that agricultural development proceeds in a desired and effective manner. Information and technology play a pivotal role in advancing agricultural development and enhancing living standards. Therefore, how producers utilize information resources for agricultural production is of paramount importance (Roling, 1988). The foundation of agricultural technology is fundamentally based on information. In a world that is constantly evolving, developing, and facing constraints, a nation that successfully adapts to change and progress is more likely to thrive. The urban concentration resulting from population growth and migration necessitates a greater workforce in agriculture to produce higher-quality products. To enable these individuals to effectively utilize advanced technologies and consciously improve their living conditions, it is essential to provide them with the necessary information. In today’s context, information and information management are regarded as the most valuable assets. Information serves as the principal input for guiding and managing future endeavors. Crucial to accessing and utilizing information effectively is the accurate identification of educational needs (the acquisition of information) and the timely application of the acquired knowledge in suitable contexts (Oğuz, 2010).

Although the brain comprises roughly 2% of total body weight, it is responsible for consuming approximately 20-30% of the daily energy expenditure. The primary fuel for the brain is glucose, which is derived from carbohydrate intake or produced through the process of gluconeogenesis. However, neurodegenerative disorders associated with aging, such as Alzheimer's disease, are characterized by a progressive impairment of brain glucose metabolism (Cunnane et al., 2020; Suárez-López et al., 2023). Globally, wheat contributes to 20% of the total caloric intake from plant-based foods in human nutrition, a figure that rises to 53% within our country. In 2021, global wheat production reached 788 million tons, cultivated across 224 million hectares of land. Our country ranks among the top ten nations in wheat production, yielding 20.5 million tons from an area of 9.8 million hectares (FAO, 2022a). In our nation, grain production is conducted on approximately 16.5 million hectares of the total 23.8 million hectares of cultivated land. In Konya province, grain cultivation occurs on 1.5 million hectares, which represents 79.56% of the 1.87 million hectares of cultivated land in the region (TÜİK, 2023). Wheat, a crop that can be cultivated in various regions across our country, is predominantly produced in the Central Anatolia Region. In 2020, this region led bread wheat production with a significant share of 32% (TÜİK, 2022). It was followed by the Marmara Region, contributing 18%, and the Southeastern Anatolia Region, which accounted for 15%. The Marmara Region is noted for its agricultural product diversity and possesses substantial agroecological potential, characterized by favorable climate conditions, varied vegetation, and fertile soil. The most commonly cultivated products in this region include potatoes, onions, garlic, hazelnuts, olives, pears, grapes, cereals, legumes, and sunflowers (TÜİK, 2021). In 2021, however, grain production in our country experienced a decline compared to the previous year, amounting to approximately 31.9 million tons. The production figures for key grains included 17.7 million tons of wheat (*Triticum aestivum*), around 5.8 million tons of barley (*Hordeum vulgare* L.), 200 thousand tons of rye (*Secale cereale*), 276 thousand tons of oats (*Avena sativa* L.), and approximately 6.8 million tons of grain corn (TÜİK, 2021).

In contemporary society, food security and sustainability have become critical priorities for many nations, with wheat recognized as a strategic commodity due to its significance in human nutrition. The challenges posed by global population growth, coupled with the inadequacy of existing resources to adequately nourish societies, have led to various issues related to food consumption. Current approaches to nutrition, including food preparation, storage, and preservation, enhance accessibility within the food industry and economy by facilitating the transformation of raw materials into innovative products. These methods have gained popularity in both local and export markets by effectively addressing emerging dietary needs. The growing demand for food, driven by advancements in science and technology, has resulted in numerous innovations. A variety of nutrients believed to play a vital role in human nutrition have been identified. This article aims to explore contemporary approaches to nutrition, examine their health impacts, and evaluate the benefits they may offer to human life. One notable example of innovative approaches is the production of unconventional foods that hold potential benefits for humanity. This progress represents a significant advancement in addressing future food challenges. Additionally, it facilitates the treatment of nutritional deficiencies associated with various conditions such as autism, celiac disease, and diabetes by providing essential nutrients. Whole grains and legumes serve as essential sources of complex carbohydrates, fiber, and vitamin E, playing a significant role in the maintenance of healthy body weight, gastrointestinal health, and cardiovascular well-being.

Systemically, the inclusion of these foods can help mitigate primary risk factors linked to dementia, including diabetes, cardiovascular diseases, and obesity, thereby underscoring the importance of whole grains and legumes for overall health (Key and Szabo-Reed, 2023). The growth of the human population, particularly following technological advancements in the post-industrial revolution era, has significantly reduced the necessity for physical labor. Concurrently, there has been an increase in the consumption of white bread and other refined products, correlating with rising incidences of preventable conditions such as diabetes and cardiovascular diseases linked to the over consumption of refined grains. In contrast, whole grain products and legumes are distinguished by their low glycemic index, indicating that they do not induce rapid spikes in blood sugar levels. Examples of such low glycemic index foods include oats, kidney beans, whole grain bread, barley, lentils, and brown rice (Dal, 2012).

Unprocessed whole grains, including wheat, rice, barley, rye, oats, and corn, may not provide an equivalent profile of essential amino acids (EAAs) compared to animal-based proteins. Therefore, it is advisable to combine these grains with other protein sources. For instance, soy and pea proteins can offer beneficial effects on cardiovascular health, energy production, and nervous system functions, owing to their high-quality plant proteins, as well as an array of vitamins (such as folate, niacin, thiamine, and B6), fiber, calcium, zinc, iron, and unsaturated fatty acids (omega-3 and omega-6) (Fan et al., 2022). B vitamins, particularly Vitamin B6, Vitamin B12, and folate, found in whole grains and legumes, may exert positive effects against Alzheimer's Disease (AD) by mitigating oxidative stress and reducing homocysteine levels (Hu et al., 2013; Fernández-Sanz et al., 2019). Some research has indicated that antioxidant compounds present in grains might function as a source of antioxidants, enhancing the human body's defense mechanisms against chronic diseases. Studies have reported that grains, particularly the bran, are rich in phenolic acids and flavonoids. Whole grains contain compounds such as vanillic acid, p-coumaric acid, ferulic acid, and caffeic acid (Zulkadir, 2022). The most widely consumed grains with high nutritional value include wheat (*Triticum* spp.), rice (*Oryza sativa*), and corn (*Zea mays*) (De Bock et al., 2021). The primary storage protein in commonly consumed grains such as wheat, barley, and rye is gluten, which comprises three gliadin and glutenin protein fractions. However, gluten can lead to celiac disease, resulting in digestive disorders in susceptible individuals. In contrast, grains such as corn and rice are gluten-free, which is why individuals with celiac disease often adopt a diet solely based on corn and rice for their grain consumption (Köten et al., 2022).

Cereals are classified under the Gramineae (Poaceae) family and include eight primary genera: *Triticum* (wheat), *Secale* (rye), *Hordeum* (barley), *Avena* (oat), *Oryza* (rice), *Pennisetum* (millet), *Zea* (maize), and *Sorghum* (sorghum). In addition to these true cereals, there are pseudo-cereals, which comprise three genera: *Fagopyrum* (buckwheat) from the Polygonaceae family, *Amaranthus* (amaranth) from the Amaranthaceae family, and *Chenopodium* (quinoa) (Reguera and Haros, 2017).

9.1. Wheat

Wheat is an economically significant product utilized for food, feed, seed, and industrial purposes, serving as the primary food source for approximately 40% of the global population (Jiang et al., 2019; Raza et al., 2019). It is regarded as one of the strategic agricultural commodities. Wheat is thought to have originated approximately 10,000 years ago during the Neolithic Revolution, a significant era characterized by the shift from nomadic hunting and gathering to established agricultural practices. The cultivation of wheat gained popularity due to its versatility, the simplicity of grain storage, and the benefits of milling the grain into flour, which facilitated the creation of a wide range of food products (Curtis, 2002; Shewry, 2018).

As the most produced cereal globally, following corn and rice, wheat is known to host 28 wild wheat species within our country (Özberk et al., 2016). Our nation is recognized as a center of genetic diversity for wild wheat species, particularly *Aegilops* sp. The Middle East, Mediterranean region, and Western Asia are regions where wild wheat species are prevalent; however, our country is distinguished by its rich diversity in terms of the number of species present (Van Slageren, 1994). The widespread production of wheat across the globe can be attributed to several factors, including its adaptability to various cultivation conditions, ease of processing and storage, low production costs, and its nutritional value, which provides an economical source of sustenance. Wheat grains serve as a rich nutrient reservoir, featuring an extensive composition that includes carbohydrates, proteins, minerals, trace elements, various vitamins, fatty acids, and secondary plant metabolites known as color substances and phenols. These diverse nutrients found in wheat are crucial for both human nutrition and various industrial applications (Erekul et al., 2016). Approximately 20% of the protein derived from plant-based foods in human nutrition is sourced from wheat, with this figure rising to 53% in Turkey. The wheat plant is utilized across many food and industrial sectors, particularly in the production of bakery products (Özcan et al., 2016). Wheat is recognized as a natural source of nutritional antioxidants, as it contains phytochemicals such as phenolic compounds, carotenoids, and vitamin E (Yılmaz, 2011). Furthermore, due to the presence of prolamin group storage proteins (gluten), wheat is the most suitable grain for bread-making, particularly with today’s technological advancements. Its neutral aromatic compounds contribute to its status as the most preferred grain globally (Shewry, 2009)

In the geography of our country, wild and related wheat species have evolved first as hulled forms and later as bare-grained cultivars, driven by natural selection, human intervention, and natural hybridization among various species (Atak, 2017). Primitive cultivated forms of wheat, such as Einkorn (*Triticum monococcum*) and Gernik (*Triticum dicoccon*), emerged from mutations and human cultivation of two wild species: Wild Einkorn (*Triticum boeoticum*) and Wild Gernik (*Triticum dicoccoides*). The wild wheat forms include Wild Einkorn (*Triticum boeoticum*), Urartu wheat (*Triticum urartu*), White Wheat (*Aegilops speltoides*), and Tesbih wheat (*Aegilops tauschii*). Wild Gernik (*Triticum dicoccoides*) is considered the ancestor of the primitive Gernik form, while *Triticum durum* serves as the ancestor of modern durum wheat. The ancestors of Spelt Wheat (*Triticum aestivum*) include Spelt Gernik (*Triticum dicoccon*) and Tesbih Wheat (*Aegilops tauschii*), with Spelt Wheat being the progenitor of bread wheat (*Triticum aestivum*) (Atar, 2017; Özberk and Özberk, 2016; Işın, 2018). Wild wheat species, as ancestors of cultivated wheat, offer high genetic diversity and broad adaptability to abiotic stress factors such as drought and salinity (Peleg et al., 2005; Nevo et al., 1993; Shavrukov et al., 2010). These species serve as gene repositories with a wide genetic base, providing crucial resources for addressing future challenges in cultivated plants and for enhancing desirable traits in crops (Özgen et al., 1989). Moreover, it is essential to conduct research and focus on breeding programs aimed at increasing wheat yield potential to meet the rising demand for food and ensure access to safe nutrition in light of the growing global population and climate change. Moreover, the sustainable cultivation of staple crops like wheat, corn, and rice is essential for fulfilling the United Nations Sustainable Development Goals, especially concerning the promotion of sustainable food systems and ensuring nutritional security (Jarvis, 2020).

9.2. Rye

Rye is a member of the *Triticeae tribe* and shares genetic similarities with wheat and barley, being cultivated as a versatile crop for grain production, cover cropping, and forage. Its significance in human civilization is underscored by its agronomic, nutritional, and social contributions (Angioloni et al., 2011). Rye exhibits resilience against cold, drought, diseases, and pests, and it thrives in various soil types due to its robust root system, which enables efficient water utilization. Furthermore, it requires minimal maintenance and is suitable for crop rotation. These properties contribute to its role in protecting and enhancing soil structure (Luthria et al., 2012). Rye (*Secale cereale* L.) is an annual diploid plant (2n=14) that originated in the "Fertile Crescent" region of the Near East. Its primary areas of diversity include Turkey, Lebanon, Iran, Iraq, and Afghanistan. Historical evidence suggests that rye was first cultivated around the Caspian Sea, with cultivation dating back to 3000-4000 BC (Geiger and Miedaner, 2009). Rye grains are the second most significant grains for producing bread, crisp bread, and various bakery products, following wheat (Németh et al., 2021). Interestingly, rye contains the highest levels of dietary fiber and bioactive compounds among cereals. It has been shown to enhance insulin metabolism better than wheat, thus potentially aiding in diabetes prevention (Jonsson et al., 2018). Rye is also recognized as a valuable genetic resource in wheat improvement, attributable to its high tolerance to various biotic and abiotic stresses (Jung and Seo, 2014). With a starch content of 66-73% and pentosans ranging from 4-7%, rye flour possesses significant water-binding capacity (Rosentrater and Evers, 2018). Consumption of rye is crucial for increasing the intake of antioxidants, dietary fiber, bioactive compounds, and phenolic compounds. Analysis of rye grain components reveals a high concentration of bioactive compounds such as phenolic acids, tocopherols, and vitamins in rye bran (Liukkonen et al., 2003; Povilaitis et al., 2015). Rye is particularly notable for its dietary fiber content, comprising 73% insoluble dietary fiber and 27% soluble fiber, which is higher than that found in other grains. The fibers in rye positively influence intestinal activity, metabolism, and the composition of intestinal microbiota (Schlegel, 2013). Both wild and cultivated rye exhibit considerable diversity, with variations in ear color (yellow, red, brown, gray, black), ear density (sparse or dense), and awn length (long or short), along with differences in glume tightness and hairiness. This diversity has led to the belief that cultivated rye originated in Eastern Anatolia, an area particularly rich in rye varieties (Yürür, 1970).

Rye is utilized both directly and indirectly in human nutrition globally and in Turkey (Yanbeyi and Sezer, 2006). In countries like Germany and those in Northern Europe, rye serves as a primary raw material for bread production. Indirectly, it is employed in animal nutrition as silage, green grass, dry grass, and through the grinding of grains, as well as being a raw material in various industrial applications (Yılmaz et al., 1996). In Turkey, rye is valued for its high nutritional content and is used for both bread and animal feed. Recently, its significance has increased as a source of silage, green feed, and dry grass. It is cultivated in various regions as green grass, green manure, and as a protective plant against wind erosion (Anonymous, 2024a). Evaluating the silage potential of rye, whether used alone or in combination with other forage crops, and with or without inoculant additives, is crucial for enhancing the diversity and economic viability of silage feeds. The variety of silage materials is essential for promoting the widespread use of silage feeds in animal husbandry, allowing enterprises to achieve economic benefits. Consequently, ongoing research into the use of different additives in various silages to ensure high-quality and cost-effective feeding practices remains relevant (Keleş and Yazgan, 2005; Uğurlu, 2019).

The growing awareness of conscious eating habits both globally and in Turkey has led to an increase in the use of rye as a raw material for bread production. This upward trend has consequently spurred a surge in research focused on assessing the quality of rye for bread-making. In a notable study conducted in Turkey to evaluate the quality of rye bread, it was found that a mixture comprising 30% rye flour combined with wheat flour yielded the best results in terms of bread quality (Mankan, 2008). As a result, the recommendation is to produce bread using this specific blend of flour, reflecting both the rye's nutritional benefits and the flour mixture's enhanced baking qualities. This book underscores the potential for rye to contribute positively to the baking sector while aligning with the increasing consumer demand for healthier and more diverse bread options.

9.3. Oat

Oats belong to the Avena genus of the wheat family and are classified into three species: hexaploid, tetraploid, and diploid, with hexaploids being the most extensively researched group. The primary members of the hexaploid group include *Avena sativa* L. (white or yellow oat), *Avena byzantina* (red oat), *Avena sterilis* L. (red wild oat), *Avena fatua* L. (wild white oat), and *Avena nuda* L. (naked oat) (Coffman, 1977). The increasing interest in oats is attributed to their composition of soluble dietary fiber, vitamins, minerals, unsaturated fatty acids, and protein, which appeal to both scientific researchers and consumers alike (Sang and Chu, 2017). Oats are notable for having a higher lipid content compared to other cereals, and this lipid fraction significantly influences the energy content and nutritional quality of oats due to the variety of fatty acids they contain (Zhou et al., 1999). Oat grains typically contain 5-9% lipids, with 78-81.5% of these being unsaturated essential fatty acids, a substantial portion of which is linoleic acid. Additionally, oat grains contain free fatty acids, including myristic, palmitic, stearic, oleic, linoleic, and linolenic acids (Lasztity, 1998). While the protein profile of oats differs from that of other cereals, it is predominantly composed of globulin (52%), gluten (19-22%), and albumin (7-11%) (Tanner et al., 2019; Yang et al., 2018). Oat protein is comparable in quality to soy protein and is recognized by the World Health Organization as being equivalent to proteins found in meat, milk, and eggs. The protein content of hulled oats ranges between 12-24% (Lasztity 1999; Mel and Malalgoda, 2022). The health benefits of oats can be attributed to the antioxidant effects of various phenolic compounds, including tocopherols, sterols, phytic acid, flavonoids, and avenanthramides specific to oats, which exhibit anti-inflammatory, hypoallergenic, and anticarcinogenic properties (Dimberg et al., 2005; Bei et al., 2017). Furthermore, oats are abundant in various essential minerals, including iron, calcium, potassium, magnesium, copper, zinc, and selenium. They also provide a wide array of vitamins, such as A, E, B1, B2, B3, B6, B12, and vitamin C (Singh et al., 2013). Furthermore, oats serve as an important raw material in the animal feed industry and are increasingly utilized in human nutrition for products such as bread, biscuits, probiotic drinks, baby food, and oat flakes, attributed to their satiating properties. This rise in usage is due to oats being a good source of protein, fiber, and minerals (Karaman et al., 2020; Peterson et al., 2005).

Oats possess the highest concentrations of both beta-glucan and avenanthramide among cereal grains. Oats are categorized as gluten-free due to their lower gluten content relative to other cereals, making them a safe option for inclusion in the diets of individuals with celiac disease. Despite the growing demand for oats driven by their diverse applications, there is a notable absence of commercially developed varieties tailored to meet consumer needs. This gap highlights the necessity for the development of new oat varieties, particularly for human nutrition (Karaman et al., 2020). Oats are recognized for their functional significance, enhancing the nutritional and sensory properties of the products to which they are added. They are essential in daily diets as a preventive measure against various health issues, including cholesterol management, diabetes, cardiovascular diseases, obesity, and cancer (Yaver, 2014). The fat-replacing capability of oats in various food products, combined with their plant origin, diverse aromas, and high fiber content, underscores their importance in food applications. The health benefits associated with oats are primarily attributed to their total dietary fiber and β-glucan content (Schloermann and Glei, 2017). Oats have garnered attention in both research and commercial sectors due to their elevated β-glucan levels and the presence of antioxidant compounds. Oat protein can be extracted in the form of an oat protein concentrate (OPC) as a protein-rich by-product of traditional β-glucan production. Furthermore, the industrial production of β-glucan facilitates the recovery of this protein-rich by-product, thereby providing a valuable source of grain protein for food applications and enhancing the overall economic viability of the production process (Brückner-Gühmann et al., 2019).

According to data from the Food and Agriculture Organization (FAO), cool climate cereals rank third globally in terms of planting area. In the 2021-2022 period, approximately 25 million tons of oats were produced across roughly 10 million hectares worldwide. A significant portion of this production occurred in the European Union, Russia, Canada, and Australia. Additionally, FAO data indicates that Turkey's oat planting area increased from 99 thousand hectares in 2016 to approximately 110 thousand hectares in 2020. During the same period, oat production rose from 225 thousand tons in 2016 to 265 thousand tons in 2020 (FAO, 2022b). Oats are among the forage crops that can be directly consumed by humans. There are two main varieties of oats: hulled oats, predominantly cultivated in certain regions of China, and large-grained oats, typically grown in Mongolia. Renowned for their high resilience to stress, nutritional benefits, and diverse processing techniques, oats serve as a significant feed source for livestock (Admassu-Yimer et al., 2018; Gangopadhyay et al., 2015; Yan et al., 2020).

9.4. Corn

Corn, a plant known for thousands of years, has become an essential crop that is cultivated extensively around the globe. It accounts for approximately 40% of the world’s food production (Bouis and Welch, 2010). As one of the six major cereals that sustain the global population, corn ranks among the most-produced cereals worldwide due to its versatility, adaptability, and productivity (Cengiz, 2016). Native to the Americas, corn is a warm climate plant that exhibits high adaptability and is cultivated in various regions around the world (Sezer and Yanbeyi, 1997). The introduction of corn to the Ottoman Empire occurred in the 1600s, when it was brought to the Egyptian port via Syria and subsequently distributed in Istanbul. Initially referred to as Egyptian wheat, the nomenclature evolved, and the plant eventually became known as corn. Its widespread acceptance can be attributed to its favorable production characteristics, which include relatively low soil and climate requirements and the capacity to yield hundreds of grains from a single seed (Babaoğlu, 2005; İşler, 2018). Globally, corn varieties are categorized into seven principal groups: dent corn, hard corn, popcorn, sweet corn, husked corn, floury corn, and waxy corn (Kahrıman et al., 2022). Dent corn and hard corn are the most preferred varieties, while popcorn and sweet corn are commonly consumed as snacks. The utilization of corn as a raw material in the food, textile, chemical, and pharmaceutical industries has led to an increased demand for corn, particularly with the growing global population. To meet this rising demand, there is a necessity for high-yielding and high-quality corn varieties (Kahrıman et al., 2013). In many regions, including parts of Africa, South America, North America, Central America, Asia, and Europe, corn is primarily used as a grain product, silage feed, and industrial raw material (Tüfekçi, 2019).

Corn is a plant that can grow from seed to a height of 2.5 to 4.5 meters within a four-month period, producing between 600 and 1,000 grains per cob (Kırtok, 1998). Its high yield and ability to thrive in various environmental conditions make corn a promising solution to global hunger. Due to its significant adaptability, corn is cultivated between latitudes of 58° norths and 40° souths (Kün, 1985). The plant serves multiple industrial applications, including animal feed, ethanol production, cooking oil, and fresh or processed snack products (Öner and Sezer, 2007; Sezer et al., 2009; Yılmaz et al., 2020). In both the world and Turkey, corn plays a crucial role in addressing the feed gap in animal production, serving as silage, green forage, and concentrated feed. Its rapid growth and high yield of both grain and stalk contribute to its importance. Over the past 20-25 years, the cultivation of high-hybrid corn varieties has led to a significant increase in yield in Turkey, with corn silage becoming a primary component of dairy cattle rations over the last two decades (Korkmaz et al., 2019; Kara, 2022).

Approximately 85% of the oil content in corn is located in the embryo, with the remaining oil found in the endosperm and the shell layers. The dry embryo contains 45-50% oil. In recent years, corn oil production has seen an increase, and through modern refining processes, numerous products such as starch, sweeteners, alcohol, oil, and animal feed can be derived from corn for human consumption (Özcan, 2009). Notably, corn flour is gluten-free, with the main storage protein in corn being zein, which constitutes 45-50% of the protein content (Shukla et al., 2001). Research indicates that the average crude protein ratio in corn grain varieties ranges from 7.8% to 9.0%, with an average of 8.2%. Concerning starch, average values for these varieties fall between 64.28% and 65.57%, with an overall average of 65.01%. The fat ratio averages between 3.33% and 4.00%, resulting in an average crude fat content of 3.54% (Kılınç et al., 2018).

Corn grains are also sources of antioxidants, including anthocyanins and ferulic and p-coumaric acid derivatives, which are believed to possess anticarcinogenic properties. The grains are particularly rich in anthocyanins, which offer antioxidant and bioactive benefits (Zulkadir, 2022). For individuals with celiac disease, it is essential to avoid barley, oats, and rye, in addition to wheat. Consequently, patients often prefer corn-based products and corn bread as suitable dietary alternatives. Celiac disease is recognized as one of the most common food intolerances worldwide (Yılmaz and Doğan, 2015).

Corn is recognized as the cereal plant with the highest yield potential under optimal conditions and possesses the largest morphological structure among cereals. In Turkey, grain corn production has experienced a significant increase, rising by 50% over the past five years. Specifically, the area dedicated to grain corn cultivation expanded from 638 thousand hectares in 2019 to 958 thousand hectares in 2023. Despite this increase in cultivated area, the yield per unit area remained unchanged at approximately 940 kg per hectare during the same period. Consequently, the total production volume increased from 6.0 million tons per year to 9.0 million tons per year, correlating directly with the expansion of the cultivation area (TÜİK, 2024).

9.5. Barley

Barley belongs to the Poaceae/Gramineae family and is classified within the *Hordeum* genus. The spike of barley is characterized by the arrangement of its grains around a central axis. Surrounding each grain are structures known as husks, while the thin, fragile, and elongated filaments that extend from the husks are termed awns. Barley is an annual long-day plant capable of adapting to various day lengths. Breeding programs are conducted to enhance quality and yield metrics (Taşçı, 2018). Globally, barley is the fourth most important cereal crop, significant for both food and animal feed industries. However, the detrimental impacts of climate change pose substantial risks to its production capacity, especially in the context of a growing global population (Langridge, 2018; Van Dijk et al., 2021). Barley (*Hordeum vulgare* L.) ranks among the earliest cultivated plants, flourishing in both low- and high-input agricultural systems across a wide range of latitudes, extending from regions near the equator to as far north as 70° North (Newton et al., 2011; Dawson et al., 2015).

Barley grain is composed of roughly 70% starch, 10-20% protein, 5-10% β-glucan, 2-3% free lipids, and 1-2.5% mineral substances (w/w) (Ram et al., 2016). Barley is abundant in phenolic compounds, with barley polyphenols such as ferulic acid, caffeic acid, p-coumaric acid, and vanillic acid playing a significant role. Additionally, the presence of β-glucan, polypeptides, and resistant starch in barley contributes to various health benefits, including anti-obesity effects, prevention of fat accumulation, reduction of blood lipid levels, and the maintenance of a balanced intestinal microflora (Shang et al., 2021). The total fiber content in barley varies from 11% to 34%, with soluble dietary fiber comprising between 3% and 20%. Barley is recognized as a valuable cereal source, particularly regarding its bioactive components and both soluble and insoluble dietary fiber content.

β-glucans, which are the predominant fiber constituents of barley, have been shown to lower plasma cholesterol, enhance lipid metabolism, and reduce glycemic index (Altan et al., 2006; Idehen et al., 2017). Notably, the high concentration of β-glucan in barley is associated with beneficial effects such as reducing blood cholesterol levels, decreasing insulin resistance, preventing colon cancer, and promoting intestinal health (Wang et al., 2007). Furthermore, barley serves as a significant source of phenolic compounds. For instance, it is reported that 60% of the total polyphenolic content in beers is derived from barley (Dvořáková et al., 2008). Folic acid is predominantly localized in the embryo and bran of barley; however, studies indicate that its concentration diminishes during storage (Edelmann et al., 2013).

Global barley production was approximately 159.4 million tons in the 2021 season, but this figure declined to around 145.1 million tons in the 2022 season, reflecting an estimated 9% decrease. This reduction in production is attributed to diminished output from the world's leading barley-producing countries compared to the previous year (USDA, 2022). In Turkey, the area designated for barley cultivation was 30.972 million decares in 2020, which rose by 2.3% to 31.691 million decares in 2021. However, Turkey's barley production faced a significant decline, decreasing by 8.3 million tons in 2020 and by 30.7% in 2021, resulting in a total output of 5.8 million tons. This downturn is believed to be linked to widespread drought conditions throughout the country (TÜİK, 2022).

Barley serves multiple purposes, including as animal feed, in beer production, and for human consumption (Grando and Macpherson, 2005). In the context of human nutrition, barley is incorporated into breakfast cereals, soups, stews, and porridges prepared with water or milk, as well as various bakery products and baby foods. Recent years have seen an increased focus on barley in food production due to its notable nutritional profile, including protein, dietary fiber, non-starch polysaccharides—particularly β-glucan, cellulose, and arabinoxylan—and its rich starch content. Barley flour is utilized in the preparation of bread, semolina, soups, pastries, and even coffee substitutes in certain regions (Altan et al., 2006; Jadhav et al., 1998). In addition to its uses in human food, barley is a vital component of animal nutrition, supporting the dietary needs of livestock such as cattle, sheep, and chickens. The primary applications of barley globally and within Turkey remain its role in beer production and as animal feed (Altan et al., 2006). Barley grains are recognized for their wealth of various minerals, which play essential functions in animal health, thus making them a common ingredient in animal feed formulations (Sönmez and Yılmaz, 2000). It is noted that 95% of the barley produced in Turkey is allocated for animal feed, while the remaining 5% is utilized as raw material for malt production (Sönmez et al., 2017). Given its beneficial health properties, there is an increasing trend in the use of barley in food products such as high-fiber biscuits, cookies, and muffins, contributing to a gradual rise in barley consumption for nutritional purposes (Choi et al., 2011). Furthermore, barley's high-fiber content not only offers health advantages but also provides functional properties in food production, including gelling, texturizing, stabilizing, and emulsifying effects (Şimşekli and Doğan, 2015).

Turkey, recognized as one of the centers of origin for barley, holds significant potential for discovering new alleles that can enhance yield and quality traits in barley breeding programs. The local varieties exhibit a high level of genetic variation, which can be leveraged to improve barley characteristics (Parzies et al., 2000; Jaradat et al., 2004). Barley is notably rich in dietary fiber, making it one of the primary sources for this essential nutrient. Given its health-promoting components, there is a compelling case for increasing the consumption of barley as a human food source. The incorporation of barley into diets can contribute positively to overall health, highlighting the need for greater awareness and utilization of this nutritious grain.

9.6. Rice

Rice is one of the most widely produced cereals globally and serves as a staple food for millions, especially in Asia, including Thailand, where it is a significant source of carbohydrates. In addition to direct consumption, rice can be processed into rice flour and starch, which are then utilized to create a variety of food products such as noodles, baked goods, and extruded items (Chaiwanichsiri et al., 2012). In Turkey, rice is cultivated in nearly every region, although yields vary significantly by location. Paddy rice is an important agricultural crop in Turkey, with production being particularly intense in the Marmara and Black Sea regions (Sürek, 2002). The Marmara region stands out as the foremost area for rice cultivation and production, accounting for 67% of the total cultivation area and 72% of the overall production in the country. The Western Marmara region, comprising provinces such as Edirne, Kırklareli, and Tekirdağ, yields the highest production levels (Ocaklı, 2012). Rice, classified under the grass species *Oryza sativa* (Asian Rice) or *Oryza glaberrima* (African Rice), is an annual monocot that is extensively cultivated for its seeds. It represents the most fundamental food source for a significant portion of the world's population and ranks as the third highest-producing agricultural crop worldwide, following sugar cane and maize. Remarkably, one rice seed can produce over 3,000 grains, making it one of the most high-yielding cereals due to its adaptability to various growing conditions (Padma et al., 2018). Rice can be categorized based on grain shape into short, medium, and long grains. Its composition consists of 76-90% starch, and rice has been noted for having the smallest granule size (3-8 μm) among cereals. Due to its non-allergenic nature and lack of toxic prolamin proteins, rice flour and starch are increasingly used in gluten-free products and baby foods (El Halal et al., 2019). Additionally, rice (*Oryza sativa* L.) is a rich source of phenolic acids, essential nutrients, and phytochemicals. These phenolic acids are primarily located in the bran, existing as hydroxybenzoic acid, p-coumaric acids, hydroxycinnamic acids, and their derivatives (Zhou et al., 2004). Unfortunately, much of the phenolic content is lost when rice is processed, as the bran is typically removed prior to consumption. Phenolic acids can be found in both free and bound forms, with bound phenolic acids being covalently attached to cell wall components, highlighting the importance of retaining the bran in rice products to maximize nutritional benefits.

Rice husk, rice bran, and broken rice are essential by-products of the rice industry that can be considered just as valuable as rice itself, particularly when evaluating their nutritional and medicinal benefits. These by-products are utilized in the food industry for products such as rice milk, rice flour, pudding-like desserts, rice cakes, rice starch, and rice glue (Padma et al., 2018). Commercial rice flour is generally made by wet milling broken rice. On the other hand, rice starch is commonly extracted through an alkaline steeping method that effectively eliminates most proteins and lipids from the starch (Puncha-arnon and Uttapap, 2013).

Rice bran and rice bran oil are important by-products produced during the polishing of white rice (Hata et al., 2008). The layers of rice germ and bran are rich in bioactive compounds such as γ-aminobutyric acid, γ-oryzanol, tocotrienol, phytosterols, and ferulic acid. Additionally, they provide a substantial amount of hypoallergenic protein, lipids, vitamins, minerals, and dietary fibers (Varanyanond et al., 2005). Notably, among the key phenolic compounds present in the dietary fibers of rice are ferulic acid and p-coumaric acid, which can be found in free, soluble conjugate or insoluble bound form (Tian et al., 2004).

Starch from rice can be divided into three fractions based on its digestibility: rapidly digestible starch (RDS); slowly digestible starch (SDS); and resistant starch (RS) (Englyst et al., 1992). High consumption of starchy foods, particularly those rich in RDS, can contribute to obesity due to their high glycemic index (GI) and low dietary fiber content (Hasjim et al., 2010; Panyoo and Emmambux, 2017). Although brown rice is packed with health-promoting components, it is often less acceptable in taste and digestibility compared to white polished rice and requires longer cooking times, primarily due to its higher levels of dietary fiber and phytic acid (Caballero et al., 2003; Cáceres et al., 2017).

Specific bioactive compounds are unique to certain grains; for instance, gamma-oryzanol is found in rice, avenanthramides and saponins in oats, β-glucans in oats and barley, and alkylresorcinols in rye (Collins, 1989). Globally, rice serves as the primary food source for approximately 3.5 billion people, contributing up to 50% of the daily caloric intake for many in Asian populations (Li et al., 2018). The importance of rice is underscored by the fact that over half of the global population depends on it as a staple food, positioning it as the second most widely produced cereal crop in the World (Giri et al., 2022).

Hunger remains one of the most pressing global issues today, especially in under-developed and developing countries, where it continues to lead to tragic loss of life. To address this crisis, rice production must be optimized to meet the demands of an expanding global population. As a strategic crop, increasing rice production worldwide is essential to ensure food security and sustainability. Corn (maize) is another vital cereal crop known for its high yield potential under suitable conditions and is distinguished by the largest morphological structure among cereal plants. In Turkey, grain corn production has seen significant growth, increasing by 50% over the past five years. In 2019, grain corn was cultivated over an area of 638 thousand hectares; this area has steadily increased, reaching 958 thousand hectares by 2023. However, during this same period, the yield per unit area remained unchanged at approximately 940 kg per hectare. Consequently, the total production of grain corn rose from 6.0 million tons per year to 9.0 million tons per year, reflecting the expansion in the cultivation area (TÜİK, 2024). Addressing both rice and corn production is critical in the battle against hunger, contributing to food availability and nutritional security for populations worldwide. Enhanced agricultural practices and sustainable strategies are necessary to further boost yield and ensure a stable food supply for future generations.

9.7. Millet

Millets are gaining recognition for their exceptional resilience to climate change and their rich nutritional benefits. The term "millet" refers to a variety of species from several genera, with the most notable being pearl millet (*Pennisetum glaucum* (L.) R. Br.), finger millet (*Eleusine coracana* (L.) Gaertn), foxtail millet (*Setaria italica* (L.) Beauv), and proso millet (*Panicum miliaceum* L.). Although comprehensive global data on these millet varieties are scarce, it is estimated that the combined cultivated area for finger millet, foxtail millet, and proso millet is under 8 million hectares. In contrast, pearl millet is grown on more than 30 million hectares across 30 countries, including regions in Asia, Africa, the Americas, and Australia (Yadav et al., 2012; Jukanti et al., 2016). This crop has a rich history, having been cultivated in Africa and the Indian subcontinent since prehistoric times (Tarafdar et al., 2014).

Millet is a broad term that describes various small-grain species within the Poaceae family, which have been a nutritional staple for humanity for over 10,000 years (Lu et al., 2005; Lu et al., 2009). One major challenge to increasing millet production is the lack of sufficient economic and technological backing (Macauley and Ramadjita, 2015). Millets possess unique physiological traits compared to other cereal crops, including remarkable drought resistance, the ability to thrive in poor soil, tolerance to high salinity, and resilience to elevated temperatures. These characteristics stem from their deep root systems, which allow them to access moisture and nutrients from lower soil layers (Devi et al., 2014). Among these, pearl millet (*Pennisetum glaucum* (L.) R. Br.) is recognized within the Poaceae family as a cross-pollinating plant, owing to its protogynous flowering structure. It has a diploid chromosome count of seven sets ($2n = 2x = 14$) and a genome size of 1.79 GB (Varshney et al., 2017). This species adapts well to cultivation in low rainfall areas (200-600 mm) with poor soil fertility and high temperatures, making it suitable for regions where other cereals like wheat or maize struggle to grow. In traditional cultivation areas, pearl millet is a primary food source for families in some of the most economically disadvantaged countries and communities. Additionally, it is celebrated for its drought resistance (Nambiar et al., 2011). Pearl millet (*Pennisetum typhoides*) demonstrates resilience in regions with low levels of rainfall, making it a robust candidate for both ongoing and sporadic drought conditions. The grains are processed through time-honored traditional techniques and can be used to create innovative food products. Furthermore, pearl millet provides an affordable and accessible source of starch (Jain and Bal, 1997; Balasubramanian et al., 2014). Globally, pearl millet ranks as the fifth most significant cereal crop, following rice, wheat, maize, and sorghum. It is primarily grown in arid and semi-arid zones of Africa and Southern Asia as a rain-fed crop and is also cultivated intensively as fodder in other areas. The cultivation of pearl millet for grain covers about 26 million hectares in the tropical arid and semi-arid regions of Asia and Africa (Rai et al., 2007; Gloria, 2013).

Finger millet (*Eleusine coracana*) is a nutrient-rich cereal that offers an array of beneficial components, including proteins, carbohydrates, dietary fiber, and essential minerals. Notably, it contains the highest calcium content among all cereals, providing 344 mg per 100 g. In addition to these nutrients, finger millet also possesses phytates, polyphenols, tannins, trypsin inhibitors, and dietary fiber. The seed coating of finger millet is particularly abundant in phytochemicals, which are valuable dietary components (Devi et al., 2014). Epidemiological research has shown that the regular consumption of whole grain cereals, including finger millet, can significantly reduce the risk of cardiovascular diseases, type II diabetes, gastrointestinal cancers, and various other health issues (McKeown, 2002). When compared to conventional wheat-based foods, millet and sorghum present certain health advantages, notably their non-reactivity with celiac disease and other forms of gluten sensitivity (FSA, 2012). With the growing demand for gluten-free foods, finger millet emerges as a desirable option (Noya et al., 2018; Adepehin, 2020). Finger millet is known to contain phytates (0.48%), polyphenols, tannins (0.61%), and trypsin inhibitors, which were once labeled as "anti-nutrients" because of their impact on enzyme function and metal binding. However, these compounds are now acknowledged for their potential health benefits and are considered nutraceuticals (Thompson, 1993; Devi et al., 2014). The nutritional profile of finger millet is notable for its amino acid content, offering higher levels of lysine, methionine, and threonine by 40%, 30%, and 20%, respectively, compared to corn (Osman, 2011). Additionally, it is rich in insoluble fibers (Alyami et al., 2019) and classified as a low-glycemic index (GI) food, owing to its high fiber content. The GI measures how carbohydrate content influences changes in post-prandial blood glucose levels, with low-GI foods being recommended for better glycemic control (Narayanan et al., 2017; Anitha et al., 2021).

Given the rising global incidence of diabetes and obesity, millets are increasingly recognized for their potential to address nutritional insecurity. There is a growing demand for foods that are rich in complex carbohydrates, dietary fibers, and beneficial phytochemicals. Fortifying diets with phenolic acid-rich foods has been shown to confer antimutagenic, antiglycemic, and antioxidative properties, making it possible to develop healthier food options. Finger millet, in particular, can significantly contribute to improved health outcomes due to its exceptional nutritional profile.

9.8. Sorghum

Sorghum can be categorized into sweet, cereal, and fodder species (Almodares et al., 2008). This crop is indigenous to Africa, with archaeological evidence indicating its initial cultivation in northeastern Africa - near the Egyptian-Sudanese border - approximately 5,000 to 8,000 years ago (Akram et al., 2007). Sorghum plants exhibit a high tolerance for water scarcity, allowing them to thrive on soils of relatively low fertility compared to other cereal crops. As a result, sorghum production is typically concentrated in arid climate regions (Widowati and Luna, 2022). Sweet sorghum (*Sorghum bicolor* L.) is particularly noteworthy for bioethanol production, due to its substantial biomass yield, high sugar content, and the absence of competition for food, fodder, and refined sugar applications in various countries (Tansı, 2019). Grain sorghum (GS) serves as a dietary staple for over 500 million individuals across more than 30 countries

(Henley, 2010) and ranks as the fifth most produced cereal globally, providing essential nutrients and bioactive compounds in the human diet.

Sorghum is a rich source of bioactive compounds that provide various health benefits. Research conducted through in vitro and animal studies has shown that phenolic compounds derived from sorghum can lead to positive alterations in factors related to non-communicable diseases, (obesity, dyslipidemia, diabetes, hypertension, cardiovascular diseases, and cancer) (Hassan, 2023). Furthermore, sorghum is rich in essential minerals such as calcium, iron, potassium, magnesium, phosphorus, zinc, as well as B-complex vitamins, fat-soluble vitamins, and vitamin E (de Morais et al., 2014; Motlhaodi et al., 2018). The grain composition of sorghum typically includes approximately 69-72% starch, 9-14% crude protein, 3% crude oil, 2% crude cellulose, and 1.5% crude ash (Kün, 1985). Sorghum storage proteins are primarily classified into three categories: albumins, globulins, and kafirins (a type of prolamin), based on factors such as solubility, structural features, amino acid composition, and molecular weight (Vendemiatti et al., 2008). Kafirins represent around 48-70% of the total protein content in the whole sorghum kernel and can account for as much as 80% of the protein in decorticated kernels. These proteins are hydrophobic and are further subdivided into three types based on their molecular weights: α-kafirin (23-27 kDa), β-kafirin (16, 18, and 20 kDa), and γ-kafirin (28 kDa). Notably, α-kafirins are the most abundant, making up approximately 80% of the overall prolamin content (Espinosa et al., 2016). Furthermore, sorghum proteins are non-allergenic and do not induce autoimmune reactions, making them suitable for individuals with celiac disease (Ofosu et al., 2020; Park et al., 2012). Sorghum serves as an important source of carbohydrates, dietary fiber, essential vitamins, and minerals, as well as a diverse range of phytochemicals, such as tannins, phenolic acids, anthocyanins, phytosterols, and policosanols (Awika and Rooney, 2004). This cereal plays a positive role in the health and nutrition of individuals with lifestyle-related disorders such as celiac disease, diabetes, and obesity (Lemlioğlu-Austin et al., 2012; Pontieri et al., 2013). Among major cereals, sorghum (*Sorghum bicolor* (L.) Moench) stands out due to its diverse phytochemical composition, particularly polyphenols that are beneficial in preventing metabolic syndromes such as type 2 diabetes, obesity, hypertension, and certain cancers (Althwab et al., 2015; Awika et al., 2018). Sorghum grain is acknowledged as a promising source of phenolic compounds (Kang et al., 2016) and is highlighted as a beneficial food choice for the prevention and management of chronic diseases. This is attributed to its rich content of dietary fiber, lipids, phenolic compounds, tannins, and flavonoids, which encompass anthocyanins, flavones, and flavanones (Arbex et al., 2018). The concentration and profile of phenolic compounds in sorghum surpass those present in other cereal grains, including wheat, barley, rice, maize, rye, and oats (Ragaee et al., 2006). Additionally, sorghum varieties that are resilient to both biotic and abiotic stresses demonstrate significantly higher average levels of proanthocyanidins, 3-deoxyanthocyanidins, and flavanols when compared to more susceptible varieties (Dicko et al., 2005). The fact that sorghum grain yields and quality surpass those of other grains utilized as animal feed underscores its significance (Akdeniz et al., 2003). Furthermore, the chemical composition and nutritional value of sorghum grains are influenced by factors such as genotype, climatic conditions, soil characteristics, and fertilization practices (Ebadi et al., 2005).

In numerous countries, climate and energy policies actively promote the utilization and expansion of renewable energy sources. Sustainable agricultural systems are expected to fulfill multiple roles, including the provision of food, feed, and biofuel, while simultaneously enhancing ecosystem services and ensuring economic viability. The significance of energy crops is increasingly recognized in light of the growing food demand driven by population growth. Sorghum, in particular, is noteworthy for its content of secondary metabolites, which include allelochemicals such as sorgoleon and cyanogenic glycosides, specifically dhurrin. These compounds are water-soluble and exhibit selective properties, indicating their potential application in weed management (Weston et al., 1989; Muhammad Shahid et al., 2007; Cheema et al., 2008). Moreover, sorghum demonstrates remarkable adaptability to a diverse range of climatic conditions, exhibiting significantly higher tolerance to elevated temperatures and drought than corn. Given these attributes, our country must leverage the advantages of sorghum cultivation, particularly in arid regions where it can thrive effectively. This strategic approach not only addresses food security but also contributes to the development of sustainable agricultural practices that align with renewable energy initiatives.

10. PSEUDO-CEREALS

Cereals have long been a cornerstone of human nutrition, serving as a vital source of sustenance for centuries. Pseudo-cereals, often referred to as grain-like due to their similar nutritional profiles, belong to the dicotyledonous plant class and are considered nutritionally equivalent to traditional grains. Despite their lower global consumption compared to conventional cereals, pseudo-cereals are gaining recognition as significant dietary components in contemporary nutrition. One of the key advantages of pseudo-cereals is their gluten-free nature, making them an excellent nutritional alternative for individuals with celiac disease. Beyond serving as an important energy source, pseudo-cereals are rich in high-quality protein, dietary fiber, vitamins, minerals, and bioactive compounds, including phytosterols, polyphenols, saponins, squalene, and fagopyritols. Their lack of gluten positions them as healthy substitutes for gluten-containing grains in gluten-free diets, thereby enhancing the nutritional quality of gluten-free products and addressing malnutrition issues in celiac patients (Kupper, 2005; Alvarez-Jubete et al., 2010). When consumed in adequate amounts, pseudo-cereals exhibit beneficial health effects, including anticancer, anticholesterol, antidiabetic, and anti-inflammatory properties (Yaver and Bilgiçli, 2020). Furthermore, proteins derived from pseudo-cereals have been identified as promising candidates for plant-based meat alternatives, owing to their superior quality compared to cereal proteins (Graf et al., 2015). Epidemiological research has pointed out the drawbacks of animal proteins, which tend to be low in antioxidants and may negatively impact gut health by fostering the growth of harmful bacteria such as Bacteroides, *Clostridium perfringens*, Bilophila, Alistipes, and Ruminococcus in the gastrointestinal (GI) tract. Conversely, plant proteins, particularly those derived from pseudo-cereals, are rich in antioxidant compounds and have been found to support gut health by encouraging the proliferation of beneficial bacteria like *Bifidobacterium* and *Lactobacillus*, as well as enhancing the production of short-chain fatty acids (Singh et al., 2017; Usman et al., 2022). In conclusion, the nutritional advantages and health-enhancing properties of pseudo-cereals highlight their potential as a significant addition to the human diet, especially for those seeking gluten-free alternatives and individuals looking to boost their overall health.

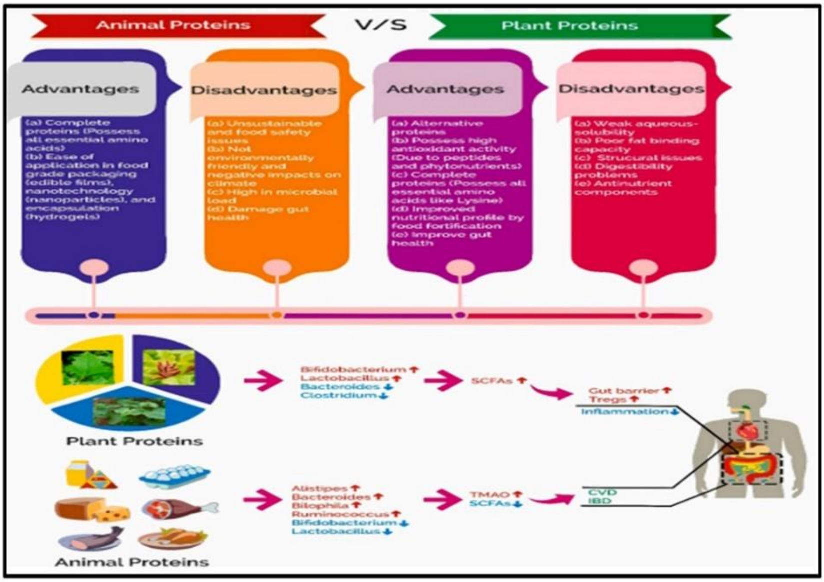


Fig. 5. Differences between plant protein and animal protein. SCFAs: Short-chain fatty acids; CVD: Cardiovascular disease; IBD: Inflammatory bowel disease; TMAO: Trimethylamine N-oxide; Tregs: T regulatory cells.

The nutritional and technological properties of alternative grains, which serve as substitutes for wheat, are currently being explored through various techniques and technologies. Research indicates that these grains can be valuable resources for privileged groups and individuals seeking healthier dietary options (Mezaize et al., 2009). As consumer interest in healthier foods rises, the food industry is responding by producing minimally processed, chemical preservative-free, and nature-identical foods that cater to societal demands (Hancıoğlu and Karapınar, 1998). This shift has led to the development of alternative food processing techniques and the implementation of methods aimed at fortifying or enriching foods nutritionally (Sidhu et al., 2007; Erol, 2010).

The growing interest in pseudo-cereals is particularly relevant for planning alternative products, producing healthy foods, and catering to specialized dietary needs. Pseudo-cereals exhibit an excellent nutritional profile, making them especially suitable for gluten-free food production. They provide a balanced composition of protein, dietary fiber, and unsaturated fatty acids. Additionally, pseudo-cereals are significant energy sources due to their high starch content and are rich in vitamins, minerals, and other bioactive compounds, including saponins, phytosterols, squalene, fagopyritols, and polyphenols. Given their nutritional composition, pseudo-cereals hold considerable potential as foods designed for specific consumer groups, including the elderly, children, high-performance athletes, diabetics, celiac patients, and individuals who are lactose intolerant (Valcárcel-Yamani and Lannes, 2012). Additionally, the diverse range of phenolic compounds and bioactive peptides present in pseudo-cereals like amaranth and buckwheat is believed to diminish the interaction between starch molecules and α-amylases. This reduction in interaction could decrease the bioaccessibility of carbohydrates in the intestine, potentially offering an antidiabetic effect. Fig. 6 depicts the possible mechanisms by which pseudo-cereals may help lower glycemic index (GI) responses (Henrion et al., 2020; Punia Bangar et al., 2022). Overall, the exploration of pseudo-cereals not only highlights their nutritional benefits but also emphasizes their role in addressing contemporary dietary challenges and promoting healthier eating habits.

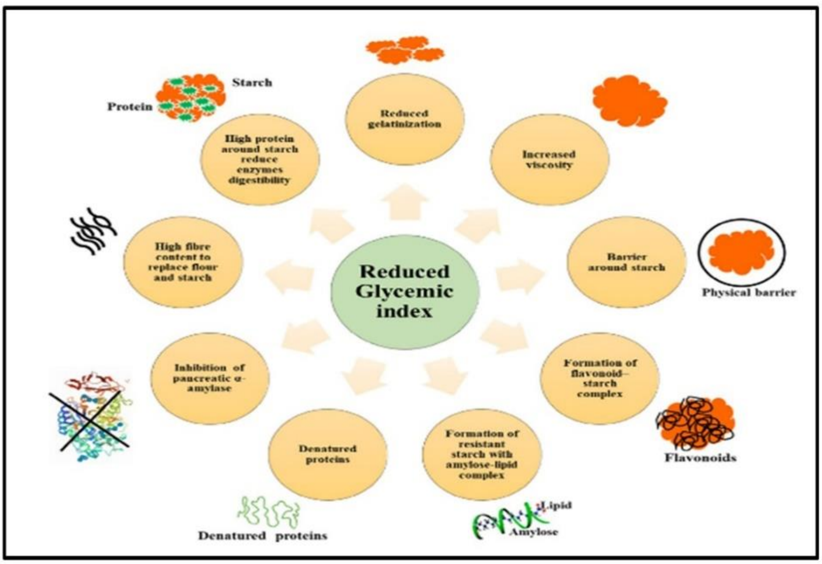


Fig. 6. Mechanism of action of pseudocereals in reducing the glycemic index (GI)

The rapid expansion of the gluten-free products market is driven not only by the increasing prevalence of gluten-related disorders but also by the growing popularity of these products among health-conscious consumers who adopt gluten-free diets as a lifestyle choice (Demirkesen and Özkaya, 2020; Martínez-Villaluenga et al., 2020). Various popular dietarys (Western, omnivore, vegetarian/vegan, Mediterranean, and gluten-free) have been investigated for their impact on modulating intestinal microbiota (Fig. 7). Research indicates that a Western diet, characterized by high animal protein and fat content and low fiber intake, is significantly associated with a decrease in the overall bacterial population, including beneficial species like

Bifidobacterium and *Eubacterium* (Drasar et al., 1973; Reddy et al., 1975; Wu et al., 2011; Singh et al., 2017). In contrast to traditional cereals, pseudo-cereals such as buckwheat, quinoa, and amaranth stand out for their exceptional nutritional profiles. These grains are rich in essential minerals, including magnesium, calcium, zinc, iron, copper, and phosphorus, and they provide substantial amounts of vitamins A, B2, B6, E, C, niacin, and folic acid. Their protein quality and quantity are significantly superior to those of conventional cereals, making them highly suitable for the functional food industry (Valcárcel-Yamani and Lannes, 2012; Moreno et al., 2014; Pirzadah and Malik, 2020). Furthermore, studies have shown that pseudo-cereals, often labeled as cereal-like grains, offer a better nutritional profile, particularly in terms of protein content and lower anti-nutritional factors (Olcay and Demir, 2022). This nutritional advantage positions pseudo-cereals as vital food sources, particularly in low-income countries, where they are frequently consumed as staple foods. Among the most widely produced and consumed pseudo-cereal varieties globally are buckwheat (*Fagopyrum esculentum*), amaranth (*Amaranthus spp.*), and quinoa (*Chenopodium quinoa*) (Thakur and Kumar, 2019). Overall, the interest in gluten-free and pseudo-cereal products reflects a broader trend towards health-conscious eating, highlighting the importance of these grains in contributing to nutritional diversity and addressing dietary needs across different populations.

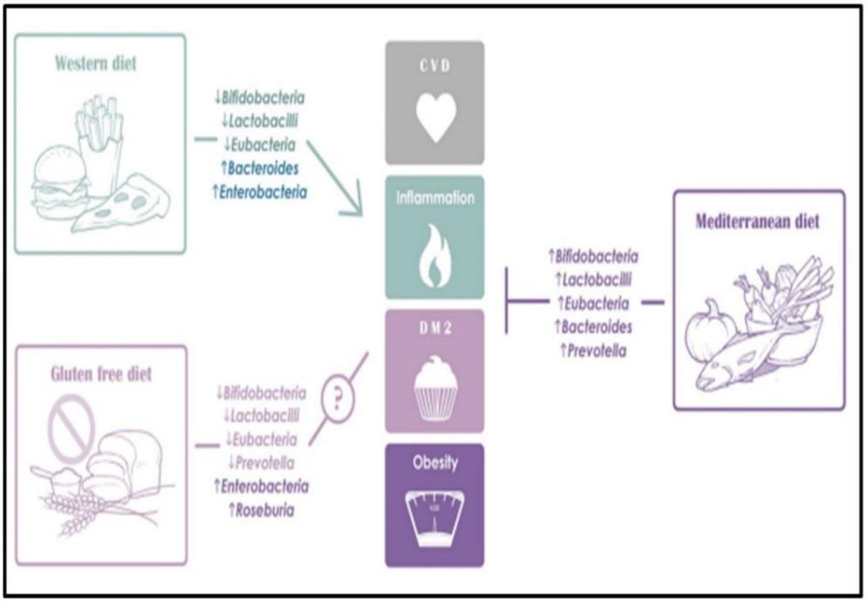


Fig. 7. Mechanism of action of today's popular diets on gut microbiota and cardiometabolic diseases: Cardiovascular Disease (CVD), and Type 2 Diabetes Mellitus (DM2)

Pseudocereals are inherently rich in essential micronutrients, yet they have not been widely integrated into the modern food system due to a variety of factors. These include agricultural challenges (such as efficient production and growth), social issues (including low reputation and lack of awareness), technological barriers (like genetic factors and seed processing), and economic constraints (such as marketing restrictions) (Pirzadah and Malik, 2020). The significance of pseudocereals extends beyond their nutritional value; they hold economic, social, ecological, and functional importance due to their favorable agronomic characteristics. These characteristics include plant height, harvest index, total biomass, number of grains per spike, spike length, thousand seed weight, and grain weight per spike. Additionally, their ecological adaptability to adverse conditions enhances their viability as a food source (Morales et al., 2021). Pseudocereals contain bioactive compounds that can be classified into four main groups: phenolic acids, flavonoids (including flavonols, flavones, isoflavones, flavanones, and anthocyanidins), lignans, and stilbenes (Pang et al., 2018). Notable examples of pseudocereals include quinoa (*Chenopodium quinoa* Willd), buckwheat (*Fagopyrum esculentum* Moench.), amaranth (*Amaranthus spp.*), and chia (*Salvia hispanica* L.), all of which possess seeds that resemble cereal grains and are considered viable alternatives to true cereals (Bekkering and Tian, 2019; Thakur et al., 2021).

Research indicates that the nutritional profiles of pseudocereals, which belong to the dicotyledonous plant class, are comparable to those of traditional cereals in many respects. Furthermore, studies have shown that pseudocereals, often referred to as cereal-like grains, are superior sources of protein and have lower levels of anti-nutritional components (Olcay and Demir, 2022). In low-income countries, pseudocereals are frequently consumed as staple foods due to their high nutritional content. The most widely produced and consumed pseudocereal varieties globally include buckwheat (*Fagopyrum esculentum*), quinoa (*Chenopodium quinoa*), and amaranth (*Amaranthus spp.*) (Thakur and Kumar, 2019). Additionally, images of chia seeds can be found in Table 1 (sourced from Google Images). Overall, the integration of pseudocereals into the food system could provide significant nutritional benefits and contribute to food security, particularly in regions where traditional cereals may be less viable.

Table 1. Pseudocereals with the highest production and consumption worldwide

Name of the pseudocereals	Image of the plant	Image of the seed
Buckwheat (*Fagopyrum esculentum*)		
Quinoa (*Chenopodium quinoa*)		
Amaranthus (*Amaranthus hypochondriacus*)		

Chia (*Salvia hispanica* L.)		

10.1. Buckwheat

Buckwheat, classified as a pseudo-cereal, belongs to the Polygonaceae family and is part of the *Fagopyrum* genus. This species was initially cultivated in China before it was introduced to Europe in the 15th century and later to North America in the 17th century. The primary varieties cultivated globally, including within our country, are common buckwheat (*Fagopyrum esculentum* Moench) and Tatar buckwheat (*Fagopyrum tartaricum* L. Gaertn) (Tömösközi and Lango, 2017). Notably, Tatar buckwheat seeds tend to be smaller than those of common buckwheat (Cai et al., 2016). Both the shape and color of the outer shell of buckwheat varieties may vary depending on specific varietal characteristics and growing conditions (Dizlek et al., 2009). Originating from Asia, buckwheat is an annual plant characterized by a height ranging from 60 to 120 cm. Its red stem produces multiple branches, each terminating in flowers. The leaves are typically oval or triangular in shape and measure between 2 and 8 cm in length. The seeds of buckwheat are triangular, with sharp edges, and exhibit colors ranging from brown and gray to black (Yazgan, 2022; Çaçar et al., 2023). Due to its robust ecological adaptability, buckwheat is cultivated in various regions of the northern hemisphere, including China, Russia, Ukraine, Kazakhstan, Poland, Brazil, the United States, Canada, and France (Hayıt and Gül, 2015).

Despite its classification as a pseudo-cereal, buckwheat is not classified as a true cereal or fruit; it shares certain similarities in usage and chemical composition with true cereals. Although buckwheat seeds possess a starchy endosperm reminiscent of cereal grains, it is fundamentally a member of the Polygonaceae family and specifically the Fagopyrum species. The seeds are notable for their brown hue, irregular form, and four unique triangular faces. Buckwheat is identified as a broad-leaved, herbaceous annual plant, with its kernel classified as a fruit, specifically an achene. The characteristics of the kernel, including its shape, size, and color, can vary significantly among species and varieties (Ahmed et al., 2014).

As a globally cultivated cereal-like plant, buckwheat's value in international trade has been steadily increasing (Yıldız and Yalçın, 2013; Alkay and Kökten, 2020). Within the *Fagopyrum* genus of the Polygonaceae family, the two principal varieties are common buckwheat (*Fagopyrum esculentum* Moench) and Tatar buckwheat (*Fagopyrum tataricum* Gaertn.) (Ekici et al., 2019; Alkay and Kökten, 2020). Buckwheat predominantly flourishes in humid, cool climatic conditions and exhibits a rapid germination period of 3 to 5 days following planting. Its ability to thrive in high-altitude regions can be attributed to its short development period and resilience to low temperatures during the growth phase (Kan, 2014; Korkmaz, 2019). The minimum germination temperature for buckwheat is approximately 7 ^{o}C, with germination being viable at temperatures as high as 40 ^{o}C (Anonymous, 2016; Yavuz et al., 2016). Therefore, the composition of buckwheat may vary based on type, species, and the environmental conditions in which it is cultivated (Ahmed et al., 2014; Ekici et al., 2019). The protein content of mature buckwheat seeds has garnered increased attention for its potential applications in human nutrition, particularly due to its richness in essential amino acids (Kan, 2011; Yavuz et al., 2016).

Research indicates significant variations in the mineral composition of the two cultivated buckwheat species, *Fagopyrum esculentum* and *Fagopyrum tataricum*. Notably, *F. tataricum* contains higher amounts of sulfur, calcium, copper, and molybdenum, while *F. esculentum* is richer in selenium, zinc, iron, cobalt, and nickel (Podolska et al., 2011). The protein content in buckwheat ranges from 11% to 19%, with approximately 55% residing in the embryo, 35% in the endosperm, and the remainder in the hull. In comparison, typical cereal proteins contain 10-20% in the embryo and 80-90% in the endosperm (Wijngaard et al., 2005). The predominant protein types in buckwheat include albumin, glutelin, globulin, and prolamin, with protein composition varying between 85 and 188 mg/g depending on the species (Giménez-Bastida et al., 2015; Kılıç and Elmacı, 2018; Eskici et al., 2019). Buckwheat is also significant in the context of antioxidant compounds. It contains major antioxidant constituents such as rutin, quercetin, and catechin, which are recommended for inclusion in dietary plans aimed at mitigating chronic vascular diseases. Additionally, buckwheat's phytic acid content, an anti-nutritional compound, is noteworthy; phytic acid contains a substantial proportion of the phosphorus present in the grain (Çetiner, 2020). The presence of antioxidant compounds significantly enhances its value, especially in brewing processes, where the inclusion of buckwheat can markedly boost the antioxidant activity of the finished product. Consistently eating buckwheat has been associated with the prevention of various lifestyle-related ailments, such as indigestion, obesity, constipation, high cholesterol, diabetes, and hypertension (Cadenas et al., 2021). Both in vitro and in vivo studies have demonstrated that diets incorporating buckwheat or buckwheat-enriched foods positively influence numerous biological and physiological activities, including hypoglycemic effects, cholesterol reduction, anticancer properties, and anti-inflammatory responses, owing to its high antioxidant capacity (Giménez-Bastida et al., 2015).

In scholarly discussions regarding pseudocereals, buckwheat is frequently cited for its application in gluten-free malts and beers. It has consistently yielded excellent outcomes regarding both productivity and the chemical composition of the final products (Brasil et al., 2020). The functional attributes of buckwheat confer various health benefits, including the reduction of elevated cholesterol and blood pressure, regulation of blood sugar levels, and a diminished risk of cancer. However, the utilization of buckwheat in packaged foods remains quite limited. Recent attention has been drawn to buckwheat due to its high functional properties, which distinguish it from traditional wheat grains. Buckwheat grains are notably rich in vitamins, particularly B vitamins, and are a significant source of nutraceutical compounds (Fabjan et al., 2003). The substantial presence of resistant starch in buckwheat has critical implications for health and nutrition, as it plays a crucial role in enhancing digestibility and regulating blood sugar levels (Wijngaard and Arendt, 2006; Skrabanja et al., 1998).

10.2. Quinoa

Quinoa (*Chenopodium quinoa* Willd.), which originates from South America, holds a significant position within the category of pseudo-cereals. This species is notable for its diversity, exhibiting a variety of colors, including white, red, yellow, and black (Taylor and Parker, 2002). In recent years, quinoa has garnered considerable attention in the context of both human and animal nutrition, leading to extensive research on its properties and benefits (Dağ and Özkan, 2019). Approximately 88% of the world's quinoa production occurs in Bolivia and Peru, with additional cultivation taking place in Argentina, Chile, Ecuador, and Colombia. The shift in consumer preferences towards new and innovative functional foods has been influenced by a multitude of factors, including rising global hunger, environmental degradation, the unfolding climate crisis, increasing food intolerances, and heightened reactions to animal-based foods. Consequently, there has been a rapid increase in demand for plant-based food alternatives (Yeşilkanat, 2019; Diaz et al., 2013). In this context, quinoa has been recognized by the Food and Agriculture Organization of the United Nations (FAO) as a crucial food resource that can support sustainable nutrition in the 21st

century. To promote its cultivation, the FAO declared 2013 the "International Year of Quinoa" (İlkay and Mutlu, 2020). Quinoa has been extensively studied for its nutritional value and compatibility with arid climate conditions, making it a viable food source similar to cereals and legumes (Jacobsen and Stolen, 1993; Sigsgaard et al., 2008; Bertero and Ruiz, 2010; Demir, 2018). Research indicates that quinoa possesses several mechanisms that enhance its resistance to water stress, facilitating its adaptation to arid and semi-arid regions. The yield potential of quinoa under optimal conditions is variable, influenced by factors such as climate, soil quality, planting times, and the specific variety cultivated (Geren et al., 2014).

Nutritionally, quinoa is recognized as a pseudo-cereal that is rich in protein, fat, vitamins, and minerals. While it has a lower carbohydrate content compared to other pseudo-cereals and traditional cereals, the starch content in its dry matter ranges from 55% to 65% (Hernández-Ledesma, 2019). Notably, quinoa typically contains more protein than other cereals, with protein content varying between 8% and 22% (Jancurová et al., 2019; Beyazçiçek and Yılmaz, 2020). Despite lysine being present in lower amounts in many cereals, quinoa is distinguished by its high lysine content, alongside proportionally significant levels of cysteine and methionine. This characteristic renders quinoa an excellent complement to numerous legumes, which tend to be deficient in methionine and cysteine (Doğan and Karwe, 2013; Beyazçiçek and Yılmaz, 2020). Thus, quinoa and its derived products represent an exceptional source of nutrition, particularly when evaluated in terms of protein, fat, carbohydrates, fiber, vitamins, minerals, and phenolic compounds. Furthermore, its gluten-free nature, low glycemic index, and balanced content of essential amino acids and omega fatty acids underscore the nutritional significance of this crop (Vilcacundo and Hernández-Ledesma, 2017).

Quinoa presents considerable benefits for consumers who belong to high-risk groups, including children, the elderly, athletes, individuals with lactose intolerance, women at risk for osteoporosis, and those suffering from conditions such as anemia, diabetes, dyslipidemia, obesity, and celiac disease. This is primarily due to its exceptional nutritional profile, therapeutic features, and gluten-free nature. These characteristics are attributed to the presence of fiber, minerals, vitamins, fatty acids, antioxidants, and notably, phytochemicals in quinoa (Vega-Galvez et al., 2010; Repo-Carrasco-Valencia et al., 2010; Paśko et al., 2010; Bhargava et al., 2006; Navruz-Varli and Sanlier, 2016). The bioactive compounds in quinoa, including phytosterols, saponins, phenolic compounds, phytoecdysteroids, polysaccharides, and betalains, enhance its medicinal properties and confer significant health benefits. These phytochemicals contribute to quinoa's superiority over other grains in promoting human health and wellness (Hernández-Ledesma, 2019; Alamri et al., 2023; Agarwal et al., 2023). The array of health benefits associated with quinoa arises from its rich composition, which not only supports overall nutrition but also aids in the management of specific health conditions. This positions quinoa as a highly advantageous food source in the context of modern dietary needs, particularly for those facing increased nutritional challenges.

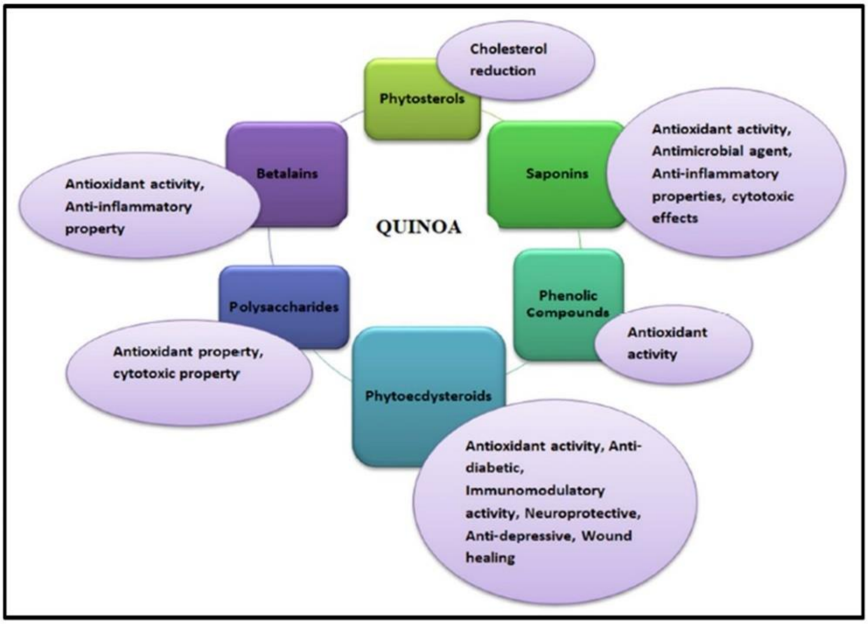


Fig. 8. Functional properties of quinoa

Quinoa, noted for its balanced distribution of essential amino acids, is recognized as being equivalent to the milk protein casein regarding protein quality. Additionally, quinoa is identified as a rich source of lysine, an amino acid that is typically scarce in grains (Demir and Kılınç, 2016). The fat content in quinoa averages between 4% and 10%, which is generally higher than that found in other grains (Ayseli, 2020). The predominant fatty acids present in quinoa include linoleic acid (52%), oleic acid (24%), and palmitic acid (Argan, 2019). A notable attribute of quinoa is its absence of gluten, rendering it a significant food source for individuals diagnosed with celiac disease (Tan and Yöndem, 2013; Geren et al., 2015; Tan et al., 2015; Geren and Kavut, 2020). Moreover, quinoa serves as a superior source of phosphorus when compared to buckwheat, rice, and corn. Despite its notable nutritional advantages, quinoa also contains significant quantities of anti-nutritional components such as saponins and phytic acid, which may limit its bioavailability (Demir and Kılınç, 2016). To enhance the bioavailability and facilitate the industrial utilization of quinoa, methods that do not demand heat treatment, such as soaking and germination, are employed (Huma et al., 2008; Altıkardeş, 2022).

Quinoa seeds, which are consumed similarly to grains and legumes, possess a neutral taste and aroma, making them a viable choice in both global and Turkish culinary practices. The multifunctional uses of quinoa in the kitchen are extensive; it can be ground into flour and blended with wheat and other grain flours to produce bread, pasta, and various baked goods. Germinated quinoa seeds are utilized in salads and cold dishes, while its leaves are consumed as vegetables, akin to spinach. Additionally, quinoa is incorporated into breakfast cereals and baby food due to its rich nutritional profile (Demir and Kılınç, 2016; Kaya and Karaer, 2017). Research indicates that quinoa flour can be utilized at a rate of 20% in bread production and up to 50% in other baked products (Keskin and Evlice, 2015; Kaya, 2018).

Quinoa is well-known among consumers in the United States, Europe, Canada, and Australia. The majority of quinoa exports, about 94%, come from Peru and Bolivia, the top producers. Other significant importers include Brazil, Israel, Japan, New Zealand, Russia, Chile, the UAE, Mexico, South Africa, Argentina, Thailand, India, Malaysia, Uruguay, Ecuador, Venezuela, China, Hong Kong SAR, Costa Rica, Ethiopia, Turkey, Lebanon, Colombia, Singapore, and Panama (Bazile et al., 2013). Owing to its high dry matter yield (800 kg/da), quinoa is also favored as a feed source in cattle breeding (Tan and Yöndem, 2013). Furthermore, quinoa is a resilient plant that exhibits minimal selectivity concerning soil requirements, thriving in sandy-loam soils and demonstrating suitability for arid conditions due to its robust root system (González et al., 2009).

10.3. Amaranth

Amaranth, a plant indigenous to the Americas, is referred to as “kiwicha” in the Peruvian Andes and “huauhtli” by the Mesoamerican populations in Central Mexico. This grain was a staple food among the Aztec, Mayan, and Inca civilizations (Velarde-Salcedo et al., 2019). Notably resilient to arid climate conditions, amaranth is typically regarded as a weed; however, it is also commercially cultivated in regions such as India, China, Southeast Asia, the United States, and Russia (Singh et al., 2011; Kılınççeker and Büyük, 2019). Belonging to the Amaranthaceae family, amaranth encompasses over 50 species. It thrives in bright sunlight and can reach heights of up to 4 meters. The cultivation and harvesting of amaranth, much like other grains, can be performed manually or with machinery. The size of amaranth grains is comparable to that of mustard seeds, and after being dried to the desired moisture level, they can be consumed as whole grains or processed into flour for use in the food industry (Bressani, 2003). Amaranth grains can be roasted, cooked into porridge, or ground into a light-colored flour ideal for various baked goods like biscuits, bread, and cakes. Because they contain little to no gluten, amaranth flours are frequently mixed with wheat flour for making yeast-leavened products (Mlakar et al., 2009). Nutritionally, amaranth consists of approximately 65% carbohydrates and 13-14% protein. Its protein content, characterized by a rich amino acid profile, typically exceeds that of many cereals and is comparable to egg protein (Baykut, 2021). Amaranth species utilized for human consumption exhibit a superior nutritional balance compared to other cereals, legumes, and oilseeds. This nutritional profile has heightened interest in amaranth as a component of a healthier lifestyle, underscoring the role of diet and physical activity (Velarde-Salcedo et al., 2019). It is estimated that there are around 87 species of amaranth, with three commonly cultivated species *Amaranthus hypochondriacus*, *Amaranthus caudatus* and *Amaranthus cruentus* grown in Mexico, Peru, and Guatemala, respectively. These species have been cherished as food sources for generations (Alvarez-Jubete et al., 2009; Caselato-Sousa et al., 2012; Repo-Carrasco-Valencia et al., 2010).

Nutritionally, amaranth exhibits a protein content of 14.19%, significantly higher than wheat's protein content of 9.41%. Additionally, amaranth contains a fat level of 7.49%, which surpasses the 1.33% found in wheat (Weber and Kashyap, 2016). Beyond the peptides produced during digestion, the proteins in amaranth contribute to bioactive components that may possess antioxidant, anti-hypertensive, and anti-thrombotic properties (Moronta et al., 2016). The composition of amaranth grains includes 65% to 75% starch, 4% to 5% dietary fiber, and a sucrose content that is two to three times higher than that in wheat grains, accompanied by non-starch polysaccharide constituents. Among sugars, sucrose is predominant, followed by raffinose, with smaller quantities of inositol, stachyose, and maltose present in amaranth grains (Venskutonis and Kraujalis, 2013). Amaranth grains contain 15.4% to 16% storage protein, which has a balanced amino acid composition when compared to other cereals such as wheat (13.5% to 14.5%), maize (10.6% to 13.8%), barley (10% to 14.9%), and oats (12.4% to 12.9%). In terms of total essential amino acids, amaranth provides approximately 47.6 g per 100 g of protein. Importantly, the prolamin fraction of its protein does not function as a storage protein (Gorinstein et al., 2002; Ogrodowska et al., 2014). Amaranth's fatty acid profile consists of about 76% unsaturated fatty acids. This includes linoleic acid at 25% to 62%, oleic acid at 19% to 35%, palmitic acid at 12% to 25%, stearic acid at 2% to 8.6%, and linolenic acid at 0.3% to 2.2% (Srivastava et al., 2021). Amaranth oil is also a notable source of tocotrienols, which are effective in lowering low-density lipoprotein (LDL) cholesterol, as well as phytosterols that exhibit hypocholesterolemic effects (Bhattarai, 2018; Schmidt et al., 2023). Amaranth is recommended by the FAO/WHO because it contains higher levels of sulfur-containing amino acids, which are typically limited in pulses, resulting in a balanced amino acid profile (Aderibigbe et al., 2022). Moreover, amaranth grains are rich in macro- and microelements. Its macromineral composition is generally equivalent to or less than that of wheat grains, with the exception of magnesium, as amaranth boasts double the magnesium content found in wheat (Tömösközi et al., 2009). Amaranth seeds contain roughly twice the mineral content of other cereals (Chandra et al., 2018). They are rich in iron (72–174 mg/kg), calcium (1300–2850 mg/kg), sodium (160–480 mg/kg), magnesium (2300–3360 mg/kg), and zinc (36.2–40 mg/kg). Additionally, amaranth seeds are a good source of several vitamins, including riboflavin (0.19–0.23 mg/100 g), ascorbic acid (4.5 mg/100 g), niacin (1.17–1.45 mg/100 g), thiamine (0.07–0.1 mg/100 g), vitamin E, and β-carotene (Mlakar et al., 2009; Park et al., 2020).

As health-related lifestyles evolve, there have been innovations in consumption habits, leading to the incorporation of pseudo-cereals into grain-based products aimed at enhancing the rheological properties, nutritional quality, and sensory attributes of foods. Consequently, the food industry is extending beyond traditional methods and raw materials to develop new products that cater to consumer preferences, specifically aligned with the Turkish palate (Demir and Kılınç, 2016). Among the pseudo-cereals that have gained prominence in recent years is amaranth, which served as a central food source for the Aztecs and was historically integral to their religious rituals. Its cultivation faced prohibition after the Spanish conquest, yet it has regained popularity in contemporary diets due to its high protein content. The agricultural appeal of amaranth is attributed to its low water requirement and ability to flourish in less fertile soils (Rezaei et al., 2015). The initial application of amaranth in beer production involved using it as an unmalted cereal, replacing a portion of the malt with this pseudo-cereal. Using amaranth as a substitute has beneficially altered the amino acid and fatty acid profiles of the beer. The specific types and amounts of these acids in the fermented wort play a crucial role in the aromatic compounds created by yeast. Beers brewed with amaranth have shown differences in the profiles of esters and higher alcohols (Bogdan et al., 2020; Salanță et al., 2020).

10.4. Chia seed

Salvia hispanica L., better known as chia, is an annual herbaceous plant that belongs to the Lamiaceae family, commonly referred to as the Mint family. This subtropical summer plant exhibits a relatively lower water requirement than other crop species (Zettel and Hitzmann, 2018). Chia is cultivated across a broad geographical range, from hot to very cold climates, thriving at altitudes up to 2500 meters. However, due to its sensitivity to frost, tropical regions are considered its most suitable growing environments (Muñoz et al. 2013). The genus *Salvia* is the most diverse within the Lamiaceae family, comprising approximately 900 species distributed across various regions, including Southern Africa, Central America, North America, South America, and Southeast Asia (Takano, 2017).

Chia seeds are reported to contain approximately 30% to 35% oil, with both oil and fatty acid content being influenced by factors such as cultivation location, ambient temperature, and the timing of harvest. Specifically, lower altitudes combined with higher ambient temperatures may lead to an increased saturated fatty acid content, while high weather conditions during April and May may result in decreased proportions of polyunsaturated fatty acids (Yurt and Gezer, 2018). Additionally, chia seeds are noted for their superior vitamin and mineral content relative to other grains. Chia seeds are incredibly nutrient-dense. They have six times more calcium, eleven times more phosphorus, and four times more potassium than milk. Additionally, chia seeds boast higher iron content than spinach and contain more calcium, phosphorus, and potassium than wheat, rice, oats, and corn (Muñoz et al. 2013). The primary proteins found in chia seeds are globulin and albumin, which are easily digestible and display high oil and water-holding capacities (Drzewiecki et al., 2003; Sandoval-Oliveros and Paredes-López, 2013; Grancieri et al., 2019). Chia seeds are rich in protein and essential amino acids, providing an excellent source of functional peptides. The composition and health benefits of these proteins and peptides in chia seeds (*S. hispanica* L.) offer significant potential for human health, with various studies examining their functional properties. Chia seeds, which include 20 distinct proteins, are vital to the plant's fundamental metabolic processes (Gómez-Favela et al., 2017). With a fiber content of approximately 40%, chia seeds rank among the top sources of dietary fiber (Reyes-Caudillo et al., 2008). Moreover, they contain about 5% mucilage, a compound with remarkable water-holding properties due to its distinctive structural components-tetrasaccharides with 4-O-methyl-α-D-glucoronopyranosyl residues branching off a main β-D-xylopyranosyl chain (Felisberto et al., 2015). Although chia seeds are characterized by their high mineral content, they are relatively low in vitamins.

They are abundant in magnesium, calcium, manganese, phosphorus, copper, selenium, and iron (da Silva et al., 2017). The seeds also contain significant amounts of B vitamins, such as niacin (883 mg/100 g), folic acid (49 mg/100 g), thiamine (0.62 mg/100 g), and riboflavin (0.17 mg/100 g) (Olivos-Lugo et al., 2010). Chia seeds are especially renowned for their high omega-3 fatty acid content, particularly alpha-linolenic acid (ALA), which makes up about 75% of their total fatty acids, while omega-6 fatty acids account for around 20%. Consuming chia seeds regularly may boost mental health, as studies have indicated that a higher intake of omega-3 compared to omega-6 can lower body inflammation and reduce the risk of various chronic diseases, such as heart disease, cancer, and age-related conditions (Saini and Keum, 2018). Additionally, chia seeds are a rich source of phytochemicals, including chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol, which are thought to offer protective benefits for cardiovascular and liver health, possess anti-aging properties, and have antiseptic effects (Melo et al., 2019; Ullah et al., 2016).

Chia seeds are increasingly recognized worldwide as a superfood, attributed to their impressive nutritional profile (Cassiday, 2017). These seeds are classified as a functional food, known for their multiple health benefits, which contribute to the protection and enhancement of overall health (Marcinek and Krejpcio, 2017). The rising prevalence of obesity has led to the incorporation of chia seeds into various healthy nutrition and diet programs, both domestically and globally. Historically, chia seeds have been utilized not only as a nutritious food source but also in pharmaceutical applications. In contemporary times, chia seeds have experienced a resurgence as a versatile ingredient within the pharmaceutical and cosmetic industries, in addition to their nutritional uses. Research indicates that chia seeds may serve as a functional food in the management of conditions such as diabetes, obesity, and cardiovascular diseases. Furthermore, it has been noted that chia seeds can enhance the satiety index, potentially aiding in appetite control, and may play a role in mitigating inflammation and addressing neurological issues (Doğan, 2019).

11. LEGUMS IN NUTRITION

Legumes are recognized as some of the earliest cultivated "ancient" foods, playing a significant role in human nutrition for millennia (Ahmed and Hasan, 2014). The term “legume” refers to the seeds or fruits of plants in the Leguminoseae or Fabaceae family. It originates from the Latin word “Legumen,” which describes the seeds harvested from pods (Salunke and Kadam, 1989). As a cost-effective and sustainable source of protein and essential nutrients, legumes contribute significantly to both nutritional adequacy and food security for the global population. They also facilitate the establishment of sustainable agricultural production systems that can mitigate adverse environmental impacts. Edible grain legumes are reported to supply approximately 22% of plant-based proteins and 7% of carbohydrates in human diets while providing 38% of proteins and 5% of carbohydrates in animal diets (Adak et al., 2010).

The high protein content of legumes is attributable to the activity of nitrogen-fixing bacteria present in their root systems, which supports the plant's protein synthesis. Despite their high protein levels, most legumes-except for soy-are classified as incomplete protein sources due to their low concentrations of sulfur-containing essential amino acids such as tryptophan, methionine, cystine, and cysteine (Kouris-Blazos and Belski, 2016). Notably, legumes are cholesterol-free and rich in oligosaccharides, essential minerals, dietary fiber, and vitamins. Research indicates that legumes may exert protective effects against cardiovascular diseases and cancer, primarily due to their saponin, phytochemical, and tannin content.

Furthermore, a positive correlation has been established between regular legume consumption and the prevention of certain chronic diseases. Studies suggest that daily intake of legumes can lead to reductions in LDL cholesterol (Ha et al., 2014), total cholesterol (Bazzano et al., 2011), blood pressure, body weight, glycemic index (GI), and insulin resistance (Tor-Roca et al., 2020). Additionally, the consumption of legumes has been associated with a decreased risk of breast cancer, attributed to their flavonol, flavone, and isoflavone compounds (Chen et al., 2014). Moreover, legume intake appears to diminish hunger and acute food intake, thereby contributing to the management of obesity and its related morbidity (Muzquiz et al., 2012; Rebello et al., 2014). The protective benefits of legumes against type 2 diabetes are linked to their high fiber content, low glycemic index, and the presence of bioactive compounds such as isoflavones and lignans (Kalogeropoulos et al., 2010). Additionally, legume consumption has been utilized in the treatment of conditions such as jaundice, toothache, ulcers, and musculoskeletal disorders (Uprety et al., 2010).

In contemporary food industry practices, considerable investment in research and development (R & D) is aimed at creating products that cater to consumer needs and trends. For instance, individuals with lactose intolerance can meet their calcium requirements through calcium-fortified orange juice or herbal beverages (e.g., rice-oat drinks) and soy-based products, such as tofu. These alternatives also serve as viable options for individuals adhering to vegetarian diets. Consequently, legumes-whether consumed as whole grains, flours, or processed into products such as protein concentrates or isolates-are classified as functional foods. Their nutritional profile is enhanced when combined with other food sources, such as cereals, and prepared appropriately, thereby improving their nutritional value and reducing anti-nutritional factors (Day, 2013; Boschin et al., 2014; Babault et al., 2015). It has been observed that peeling legumes can increase their vitamin content, whereas cooking tends to diminish vitamin levels, particularly vitamins B1, B2, and C (Cabrera et al., 2003). Prolonged cooking processes negatively affect vitamin B content, as these water-soluble vitamins are lost in the cooking liquid (Sarıoğlu and Velioğlu, 2018). Research indicates that pressure cooking and autoclaving are the methods that produce the least loss of vitamins during the cooking process (Kopaç Kork, 2009).

Acknowledging the significant role of legumes in human nutrition, the year 2016 was designated as the "International Year of Pulses." Legumes are vital for enhancing food security and alleviating rural poverty through their contributions to sustainable agriculture, crop rotation, and their significance in animal husbandry. These crops hold a substantial position in global agricultural trade, and given their health benefits, various health organizations worldwide advocate for the inclusion of pulses as a fundamental component of a balanced diet to help prevent obesity and manage diseases such as diabetes and cardiovascular conditions (Sarıoğlu and Velioğlu, 2018).

In developing nations, food legumes serve as a crucial source of protein. Globally, food legumes account for approximately 7% of plant-based carbohydrates and 22% of proteins in human diets, as well as providing 5% of carbohydrates and 38% of proteins in animal nutrition. Food legumes represent a cost-effective and efficient means of addressing nutritional deficiencies, with protein content ranging from 18% to 31.6% (Adak et al., 2010). Globally, the legumes that are most commonly consumed include kidney beans, white beans (*Phaseolus vulgaris* L.), broad beans (*Vicia faba* L.), chickpeas (*Cicer arietinum* L.), as well as dry or split peas (*Pisum sativum* L.), mung beans (*Vigna radiata* L.), and black-eyed peas (*Vigna unguiculata* (L.) Walp.). In addition to these, various species of lentils (*Lens culinaris* Medik.) are also popular. Furthermore, there are lesser-known varieties such as lupins (*Lupinus albus* L. and *Lupinus* *mutabilis* Sweet) and bambara beans (*Vigna subterranea* L.) that are cultivated as well (FAO, 2016). In Turkey, the most commonly cultivated food legumes are chickpeas (*Cicer arietinum*), kidney beans (*Phaseolus vulgaris*), and lentils (*Lens culinaris*). Legumes are grown in nearly every region of the country and constitute an essential protein source within Turkish cuisine.

11.1. Bean

The common bean, scientifically known as *Phaseolus vulgaris* L., is among the most important pulses grown and consumed around the world, with an estimated annual yield of roughly 12 million tonnes (Bansal et al., 2019). Often called the dry bean or haricot bean, this self-pollinating species is a crucial legume cultivated globally (Broughton et al., 2003; Singh et al., 2014). It is increasingly recognized as a vital crop in Ethiopia, playing a key role in the daily diet and generating foreign currency earnings for many citizens. The rising market demand for this legume, both for local use and export, has become a significant factor driving the upward trend in its production (Lemu, 2016). Beans are ranked as the leading food legume in terms of cultivation area and overall production globally. They are consumed in various forms, including fresh vegetables and dried beans. The global cultivation area for dry beans encompasses approximately 30 million hectares, with an annual production of around 23 million tonnes (Anlarsal, 2013). Beans exhibit a higher degree of selectivity regarding climatic conditions compared to other legume species. Factors affecting bean cultivation encompass a wide range of physical conditions (such as rainfall, temperature, topography, day length, and soil type), biological factors (including diseases and pests), and socioeconomic elements (Pekşen, 2005). Numerous studies have explored the chemical composition of various bean cultivars, including those originating from Mexico, revealing differences in their content of phenolic compounds, monomeric anthocyanins, polyphenols, and flavonoids (Espinosa-Alonso et al., 2006; Lin et al., 2008; Onyilagha and Islam, 2009; Aquino-Bolaños et al., 2016).

Dry beans are rich in phenolic compounds, which exhibit antioxidant properties, particularly quercetin, anthocyanins, campferol, flavonols, and tannins (Beninger and Hosfield, 2003; Akond et al., 2011). Phenolic compounds are essential for human health primarily due to their antioxidant properties, which are linked to a range of effects including anti-diabetic, anti-obesity, anti-inflammatory, anti-mutagenic, and anti-carcinogenic outcomes (Ganesan and Xu, 2017). Therefore, it is important to consider the diverse compositions among different seed genotypes and the phenotypic variations that arise from different growing conditions when examining the epidemiological relationship between the consumption of common beans and the risk of chronic diseases (Fischer et al., 2013). For healthy individuals and those at risk for metabolic syndrome, incorporating beans into the diet is seen as advantageous, largely due to their ability to reduce total serum cholesterol and LDL cholesterol levels (Anderson and Major, 2002). Furthermore, whole-grain products, which encompass beans and other legumes, are acknowledged for their protective effects, not only in preventing diabetes but also in aiding the management of individuals diagnosed with type-2 diabetes mellitus (Venn and Mann, 2004; Hayat et al., 2014).

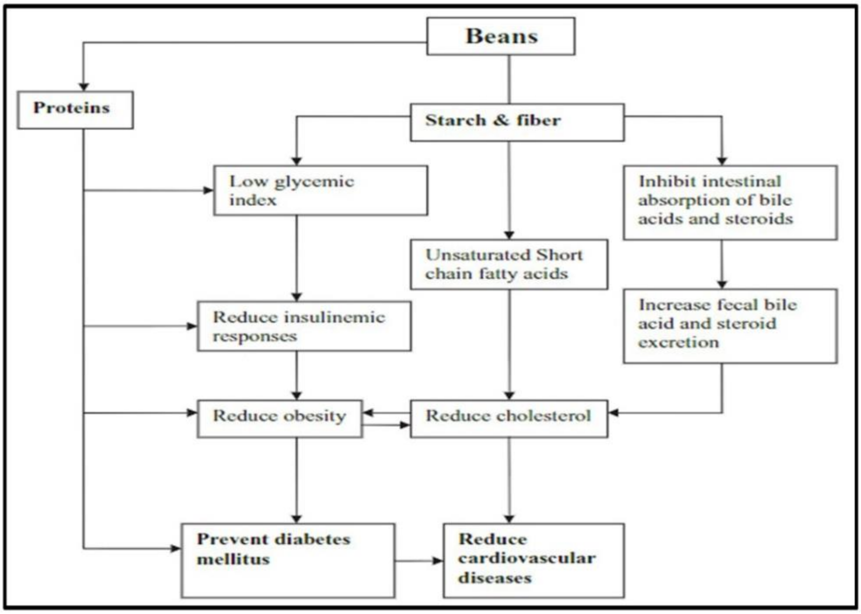


Fig. 9. Mechanisms involved in the reduction of cardiovascular, obesity, and diabetes mellitus through bean consumption

Kidney beans (*Phaseolus vulgaris*) rank among the most important legume crops worldwide and are essential for human dietary intake, largely because of their substantial protein content (20%-25%), complex carbohydrates (50%-60%), along with significant amounts of vitamins, minerals, and polyunsaturated fatty acids (Rehman et al., 2001; Reyes-Moreno and Paredes-Lopez, 1993). In addition to these nutrients, they offer notable levels of folate and dietary fiber (Shi et al., 2007). Serving as a key source of dietary protein, beans significantly enhance human nutrition by complementing other food items, such as wheat and various cereals (Butt and Batool, 2010). Pulse proteins are primarily composed of globulins and albumins, with prolamins and glutelins comprising minor fractions (Adebowale et al., 2007). Globulins make up the primary protein fraction found in beans, representing 50-70%

of the overall protein content. These can be further categorized into 7S and 11S fractions, distinguished by their sedimentation coefficients (Tang and Sun, 2011). Like many other legume proteins, bean proteins boast elevated levels of essential amino acids, especially lysine, which is often lacking in cereal grains. Therefore, pairing beans with cereal proteins creates a nutritionally complementary profile concerning essential amino acids, effectively addressing mutual deficiencies and fostering a balanced diet (Broughton et al., 2003; Iqbal et al., 2006; Slupski, 2010). The dietary fiber content in dry beans differs by variety, generally falling within the range of 15% to 33% (Vasić et al., 2009; Granito et al., 2005). Research indicates that the average soluble dietary fiber accounts for about 3.5%, while insoluble dietary fiber averages around 19% (Kutos et al., 2003). One major reason for the widespread popularity of this crop is its impressive nutritional profile, characterized by high protein, dietary fiber, complex carbohydrates, vitamins, minerals, and phytochemicals that provide protective benefits against numerous diseases (Hayat et al., 2014; Messina, 2014). Studies suggest that consuming common beans decreases the activity of α-amylase; additionally, certain phytochemicals in common beans, including saponins and polyphenols, have been associated with diminished α-glucosidase and lipase activities (Tucci et al., 2010). Moreover, kidney bean starch is recognized for having the highest apparent amylose content and the lowest percentage of long side chains of amylopectin when compared to starches from other legumes. The quality of starchy foods is closely linked to their amylose content, which is crucial for the pasting and gel texture characteristics of starch during cooking (Srichuwong et al., 2005). As a result, the inhibition of digestive enzymes may decrease glucose and lipid absorption, thereby supporting beneficial impacts on obesity management and blood glucose regulation (Figueroa-Pérez et al., 2014).

Turkey and around the world, the bean plant is an essential agricultural crop consumed abundantly due to its outstanding nutritional value. It is marketed fresh, canned, and dried, making it an indispensable food across various households. The bean species cultivated in Turkey are predominantly identified as "*Phaseolus vulgaris* L." and have been diversified and classified by the Turkish Standards Institution (TSE) based on their botanical characteristics. Notable varieties include Selanik, Battal, Tombul, and Şeker (Güvenç and Güngör, 1996).

11.2. Chickpea

Chickpeas, a legume product of Asian origin, belong to the Leguminosae family (Miñarro Vivas, 2013). Recognized as the second most cultivated food grain legume globally after dry beans, chickpeas are classified within the *Cicer genus* of the Papilionoideae (butterfly-flowered) subfamily. Their primary regions of origin are the Mediterranean and certain Indian countries, including

Turkey (Akçin, 1988). Two main types of chickpeas are cultivated worldwide: the pink-flowered Desi variety, known as microsperm, and the white-flowered Kabuli variety, referred to as macrosperm. The Desi types are predominantly grown in Asia and Africa, while the Kabuli types are more common in North America and Europe (Gaur et al., 2016). Chickpeas are nutritionally valuable, containing 18.4% to 29.1% protein, 2.9% to 4.0% ash, 54% to 59% carbohydrates, and 2.1% to 3.2% dietary fiber, along with various minerals, including magnesium, potassium, phosphorus, calcium, and iron (Akibode and Maredia, 2011; Jukanti et al., 2012). The carbohydrates in chickpeas comprise monosaccharides, disaccharides, oligosaccharides, and polysaccharides. The predominant monosaccharides include glucose (0.7%), fructose (0.25%), ribose (0.1%), and galactose (0.05%), while the most abundant disaccharides are sucrose (1-2%) and maltose (0.6%) (Sanchez-Mata et al., 1998; Wood, 2007).

Chickpeas are crucial not only as a source of high-quality carbohydrates and proteins, but also for their content of essential minerals (such as zinc, potassium, magnesium, iron, phosphorus, and calcium) and vitamins, including niacin and thiamine (Kaur et al., 2005). Unlike soybeans and peanuts, chickpeas are devoid of defined allergens, making them suitable protein-rich legume for many individuals (Rincon, 2020). Furthermore, chickpea seeds contain a significant amount of oil, with oil content ranging from 3.8% to 10.2%. The primary fatty acids in chickpeas are oleic, linoleic, and palmitic acids. Mineral content in chickpeas includes manganese, phosphorus, potassium, magnesium, calcium, sulfur, iron, zinc, copper, nickel, and molybdenum. Notably, 100 grams of raw chickpeas contain 140-440 mg of calcium, 190-382 mg of phosphorus, 5.0-23.9 mg of iron, 0-225 μg of β-carotene equivalents, 0.21-1.1 mg of thiamine, 0.12-0.33 mg of riboflavin, and 1.3-2.9 mg of niacin. Studies indicate that boiled and roasted chickpeas retain similar nutrient levels (Wood, 2007; Kopaç Kork, 2009).

Turkey serves as one of the primary centers for chickpea cultivation. The Southeastern region of Turkey is recognized as the homeland of chickpeas, with evidence suggesting that cultivation in this area dates back approximately 7,000 to 7,500 years. Chickpeas are among the earliest domesticated plants. The Eastern Mediterranean region, which encompasses Turkey, is considered a primary gene center (Akçin, 1988). Although various origin areas have been proposed for chickpeas, the southeastern region of Turkey and Syria is often highlighted as the main area of origin (Van der Maesen, 1987). In 2020, global chickpea production reached 15.083.871 tons, with an average yield of 102 kg/da (FAO, 2022b). In Turkey, production amounted to 630.000 tons with an average yield of 123 kg/da during the same year; however, production subsequently decreased by 24.6% to 475,000 tons in 2021 (TÜİK, 2022). Chickpeas are regarded as a healthy vegetarian food source worldwide, particularly in Asia. They provide an economical and protein-rich food option for developing countries with limited access to animal proteins. In addition to their protein content, chickpeas are a good source of carbohydrates and minerals, contributing high fiber content that is essential for a balanced diet (Nikobin et al., 2007; Sastry et al., 2019).

Chickpeas contain a variety of carbohydrates that can be classified into digestible and indigestible categories within human metabolism. Digestible carbohydrates refer to those that can be enzymatically broken down in the small intestine. This category includes monosaccharides such as glucose, fructose, and galactose, along with disaccharides like sucrose and maltose. On the other hand, indigestible carbohydrates encompass oligosaccharides (including raffinose, stachyose, verbascose, and ciceritol), resistant starch, pectin, hemicellulose, and cellulose. These types of carbohydrates cannot be digested in the small intestine (Kaur and Prasad, 2021). Particularly, oligosaccharides from the raffinose family, especially raffinose and stachyose, are known to cause gas production in the intestines and are acknowledged as effective prebiotics. Studies conducted on both animals and in vitro have shown that oligosaccharides, such as inulin, oligofructose, lactulose, and resistant starch, provide health benefits by enhancing the growth of *Bifidobacterium* species (Chen et al., 2018). In Turkey, approximately 62% of the soils used for chickpea cultivation are fine-textured, with 86% exhibiting alkaline reactions, 58% classified as medium to excessively calcareous, and 99% identified as low in organic matter (Güçdemir, 2006). These soil characteristics adversely affect the availability and uptake of essential nutrients for chickpea farming. Given the challenges associated with altering soil structure and lime content in chickpea-growing regions, it is crucial to enhance the physical, chemical, and biological properties of the soil, particularly soil pH, through the application of organic matter. This approach can improve the availability of plant nutrients and their uptake by chickpea plants.

Moreover, chickpeas are frequently processed and consumed in various forms. A notable byproduct of chickpea preparation is aquafaba, the wastewater generated during the boiling of chickpeas. Aquafaba, often referred to as chickpea boiling water, is a functional raw material characterized by its high quality and protein content, and should not be dismissed as waste. In recent years, aquafaba has gained popularity as an ingredient in various food products, including meringue, mayonnaise, cheese, and cakes, due to its unique functional properties such as foaming, gelling, and emulsification.

11.3. Lentil

Lentil (*Lens culinaris* Medik) is a significant pulse crop, with an average annual production of approximately 5 million tonnes, accounting for roughly 15% of global pulse production. The consumption of lentils has been increasing at a pace quicker than that of other pulses, largely due to their rapid cooking qualities (Khazaei et al., 2019). This self-pollinating annual plant is characterized by a diploid chromosome number (14 chromosomes) and is classified under the lens genus within the *Papilionoideae* subfamily of the Leguminosae family. Turkey, along with the Mediterranean and Near East regions, serves as a genetic center for various plant species, including medium and large-grained lentil varieties (Akdağ, 1996). Lentils are noteworthy among legumes due to their extensive global production, trade, and consumer popularity. As one of the oldest crop species, lentils thrive in less-than-ideal growing conditions, requiring an average annual rainfall of 300-400 mm and the capacity to grow in diverse soil types (Asakereh et al., 2010). Canada plays a crucial role in global lentil production, contributing to 50% of the world's lentil supply in 2016, a remarkable achievement given that the country had no lentil production until 1972 (TMMOB, 2018). The historical cultivation of lentils dates back to 8000-5000 BC in regions including modern-day Syria, Iran, Turkey, Greece, and Bulgaria. The genetic origins of lentils extend from the eastern Mediterranean Basin to the higher altitudes of Afghanistan, the Himalayas, and the Hindu Kush Mountains (Vavilov, 1951; Eser, 1970; Kaya, 2010). Lentils play a pivotal role in crop rotation systems, particularly in dry agricultural regions worldwide (Sehgal et al., 2021). As a wild progenitor of *Lens culinaris* subsp., the lentil was cultivated utilizing the Orientalise (Boiss) variant, with its wild ancestors still found in parts of Southeastern Anatolia (Vlachostergios et al., 2018; Özer and Kaya and Karaer, 2018).

Acting as a nitrogen-fixing legume, lentils contribute to the maintenance of biological balance and soil fertility, thus holding significant potential for sustainable agricultural practices (Sellami et al., 2019). Furthermore, lentils are integral to human nutrition and serve as an excellent regulatory crop due to their ecological benefits. Within the global legume production total of 96 million tonnes, lentil production is estimated at around 8 million tonnes (Sırrı, 2020). Variability in lentil cultivars, particularly in Turkey and Syria, corresponds to dietary preferences and consumption patterns, with these countries producing approximately 80-85% of the red lentils typically utilized in soups, while Iran and Morocco account for about 95% of the large-seeded green lentils consumed whole (McNeil et al., 2007; Sarker and Agrawal, 2011). In recent decades, several certified modern red lentil varieties (such as Fırat-87, Şakar, Çağıl, Seyran, and Çiftçi) have been developed and have become predominant in the Southeastern Anatolia Region (Düzgün and Toğay, 2021). In

Turkey, two primary types of lentils are cultivated: red and green. However, there has been a notable decline in cultivation area and production, with red lentil cultivation areas and production decreasing by 23% and 19%, respectively, from 1990 to 2007. Similarly, green lentil cultivation area and production experienced an 88% reduction during the same period. Despite these decreases, climate conditions have influenced yields, resulting in green lentil yields typically falling below 100 kg/da, whereas red lentil yields generally exceed this (Aydoğan, 2008). Additionally, the shell of lentil grains is recognized for its high flavonoid content, while the cotyledons have identified non-flavonoid components (Duenas et al., 2002).

The seed coat of lentils has minimal economic significance, yet it is acknowledged as a promising source of phenolic compounds from a nitrogen-fixing plant. With the increasing recognition of the value of plant phenolic compounds and their diverse biological activities, there are growing opportunities for developing value-added processes that utilize this byproduct from pulse processing (Pathiraja et al., 2023). Lentils are regarded as a nutritious food source, thanks to their abundant composition of proteins, carbohydrates, vitamins, and essential nutrients. They are especially rich in dietary fiber, water-soluble vitamins, crucial minerals, and a variety of phenolic compounds, including tannins (Plaza et al., 2021; Romano et al., 2021; Kaale et al., 2023). Lentils can contain protein levels of up to 26% and are notable for their high concentrations of thiamine and niacin (Abu-shakra, 1981; Akçin, 1988; Şehirali, 1991). The protein composition in lentils consists of four main fractions: approximately 70% globulins (7S and 11S), 16% albumins, 11% glutelins, and 3% prolamins (Boye et al., 2010). These albumins are distinguished by their high solubility in water (Bean and Lookhart, 2001). Moreover, lentil seeds contain unique free amino acids such as alpha-hydroxyornithine, alpha-hydroxyarginine, and homoarginine, which are not typically found in other plant sources (Sulser and Sager, 1974). Lentils are notable for their high levels of prebiotic or low-digestible carbohydrates, which are important for health. They possess resistant starch (75 mg g^{-1}), raffinose-family oligosaccharides (40.7 mg g^{-1}), sugar alcohols (14.2 mg g^{-1}), and fructo-oligosaccharides (0.62 mg g^{-1}), all contributing to their numerous health benefits (Johnson et al., 2013). Moreover, lentils are acknowledged for their potential to lower cholesterol levels, likely due to their significant fiber content, which may be beneficial in managing blood sugar disorders (Varghese et al., 2019). They contain 5% rapidly digestible starch (RDS) and 30% slowly digestible starch (SDS), features that have attracted attention among individuals with diabetes (Singh and Singh, 2014). Additionally, improvements in food processing techniques could enhance the bioaccessibility and bioavailability of the nutrients found in lentils, thereby maximizing their overall health benefits (Li et al., 2023).

11.4. Broad Bean

Broad bean (*Vicia faba* L.), first cultivated in the Middle East, holds the distinction of being the earliest edible legume utilized in human nutrition (Şehirali, 1988). Recognized as one of the oldest legumes, broad beans were cultivated during the early Neolithic period and have been historically grown across extensive regions, from India to the Western Mediterranean, since prehistoric times (Cubero, 1973, 1974). Following peas and chickpeas, broad beans rank as the third most cultivated legume globally. This plant is notably adaptable to diverse ecological conditions and is valued for its high nutritional content, facilitating its use in various culinary applications (Torres et al., 2006). The Near East is considered the center of origin for broad beans, which are currently cultivated in over 70 countries, encompassing an area of approximately 2.2 million hectares and yielding nearly 4 million tonnes annually (Warsame et al., 2018). In Turkey, broad beans rank fourth in terms of cultivation among food grain legumes. As a cool climate plant, broad beans exhibit optimal growth at temperatures between 18-27 ºC. Exposure to temperatures exceeding this range can induce heat stress, adversely affecting plant development and yield (Lavania et al., 2015). The carbohydrate content of broad beans ranges from 42% to 56%, with total fiber comprising approximately 13.8% and protein content averaging 28% (Prabhu and Rajeswari, 2018; Millar et al., 2019). Particularly among legumes, broad beans are renowned for their high protein content, which varies between 24% and 35%, averaging around 29% (Warsame et al., 2018; Tufan and Erdogan, 2017). The total protein content of broad beans is the highest among legumes, following meat and fish, and is influenced by growing conditions and genetic factors. Broad beans are also known for being rich in essential vitamins and minerals, containing significant amounts of vitamins A, B1, B2, B3, B6, B9, C, and K. Due to their substantial iron content, they are frequently recommended for consumption by individuals experiencing anemia. In addition, broad beans provide a variety of micronutrients, including trace elements such as aluminum, boron, cobalt, chromium, copper, lithium, manganese, nickel, lead, strontium, and zinc (Luo and Xie, 2012).

While broad beans boast low fat content and their dietary fibers, minerals, and vitamins offer numerous health benefits, certain components such as gas-forming agents, tannins, enzyme inhibitors, polyphenols, lectins, saponins, and phytic acid may have adverse effects on nutrition (Pekşen et al., 2006; Osman et al., 2014). Research by Chaieb et al. (2011) highlights that broad beans are rich in antioxidants, which can help prevent oxidative damage within the body.

Broad beans (*Vicia faba* L.) are a cost-effective and high-quality source of protein in human nutrition, serving to complement and enhance the grain-based diets of economically disadvantaged populations while also adding variety and flavor to meals for those with greater financial means (Saxena, 1991). With their diverse applications, broad beans are utilized in various sectors including fresh vegetable markets, dried grain products, baby food production from bean flour, the canning industry, and as animal feed (Şehirali, 1988). A notable product is a broad bean meal (fava), created by crushing dried broad bean seeds and combining the resulting flour with several other ingredients (Akçin, 1988). Broad beans possess the remarkable ability to convert atmospheric nitrogen into a bioavailable form through their symbiotic relationship with *Rhizobium* bacteria, making them the most effective nitrogen-fixing legume (Erincik, 2010; Yıldırım and Özaslan-Parlak, 2016). In light of the recent increases in nitrogen fertilizer prices, broad beans have gained significance as an economically advantageous agricultural input. Additionally, broad beans play a crucial role in enhancing bioavailability in both human and animal nutrition, contributing to the fulfillment of daily macro- and micronutrient requirements through their rich protein, fiber, vitamin, and mineral content. Lupin (*Lupinus* sp.) is another legume characterized by high protein and oil content, regarded as an important genus within the legume family due to its ability to thrive in marginal environments where other legumes fail to grow (Baytop, 1994; Tanur Erkoyuncu et al., 2015). Commonly known as Termiye, Gaur bean, and Jewish bean (Hakkı et al., 2007), lupin has gained popularity in recent years owing to its nutritional and health benefits, leading to an increase in the consumption of lupin and products derived from its seeds (Sandoval-Muñíz et al., 2018). With a protein-rich composition of 33-47%, lupin also contains dietary fiber, oil, α-tocopherol, thiamine, riboflavin, vitamin C, and various minerals (Dervas et al., 1999; Mohammed et al., 2017). The protein content of lupin seeds, which ranges from 33% to 47%, exceeds that of most other legumes and approaches the protein concentration found in soy (Dervas et al., 1999). In contrast to other legumes that may have starch content of up to 50%, lupin has a notably low starch concentration, ranging from 0% to 5% (Schuster-Gajzágó, 2004). The oil present in lupin seeds is particularly rich in oleic and linoleic acids, while the seeds also contain significant levels of polyphenols, carotenoids, phytosterols, and tocopherols (Yorgancılar et al., 2020). Furthermore, lupin seeds contain alkaloids such as lupin, angustifolin, lupanin, hydroxylupanin, and glycosides such as lupinyl and vernin. These phytochemicals confer substantial pharmacological value to lupin (Tüzün, 2013).

Lupin seeds are utilized in the production of gluten-free flour, fermented products through bacterial and fungal processes, noodles, and pasta alternatives to meat, egg proteins, and sausages. Additionally, they can be cooked, roasted, ground, and blended with cereal flour in various formulations (Prusinski, 2017). Foods high in lupin content are associated with beneficial effects on diabetes and obesity management due to their low glycemic index (Johnson et al., 2003). Despite the extensive literature detailing the phytochemicals present in lupin and their health-related effects, further intensive clinical studies are necessary to explore aspects such as the bioavailability of these phytochemicals, alterations in metabolism, and the standardization of extracts.

11.5. Cowpea

Cowpea (*Vigna unguiculata* L. Walp) is one of the most significant leguminous plants globally, widely cultivated across Africa, South America, Asia, and the United States (Xiong et al., 2016). Historically, its presence in Europe is noted as "Smilax Kipaia" (garden's Smilax) by Dioscorides, who describes a plant that produces slender, cylindrical fresh pods with ivy-like leaves and kidney-shaped seeds characterized by color variability, aligning closely with cowpea (Kavvadas, 2015). Belonging to the Papilionoideae subfamily of the Leguminosae family, cowpea is a heat and drought-tolerant species. Known colloquially as black-eyed peas, this legume is economically significant due to its low cost and rich nutritional profile, thriving in environments unsuitable for many other legumes (Awika and Duodu, 2017; Uzun, 2017). As a dicotyledonous crop in the order Fabaceae, cowpea is classified under the subfamily Faboideae (Papilionoideae), tribe Phaseoleae, and subtribe Phaseolinae, with the genus Vigna exhibiting a pantropical distribution and notable genetic variability. Besides cowpea, the Vigna genus includes mung bean (*V. radiata*), adzuki bean (*V. angularis*), black gram (*V. mungo*), and bambara groundnut (*V. subterranea*). The subspecies of cowpea, *V. unguiculata*, encompasses four cultic groups: unguiculata, biflora (or cylindrica), sesquipedalis, and textilis (Ng and Maréchal, 1985; Panchta et al., 2021). Over time, cowpea has been disseminated across various regions and has competed with indigenous landraces, leading to the gradual adaptation to diverse climatic and soil conditions, as evidenced by alterations in phenotype and genotype frequencies (Zeven, 1998). Cowpea serves dual purposes: it is utilized as human food and animal feed, representing an essential leguminous crop (Debnath et al., 2018). In recognizing the vital role of food grain legumes, which mirror animal proteins in terms of protein and amino acid profiles and are abundant in vitamins and minerals, there exists the potential to expand cultivation areas and increase yields per unit area, consequently contributing to a balanced diet (Sert, 2011). In Turkey, the primary cultivation regions for cowpeas are confined to the Aegean, Mediterranean, and Southeast Anatolia. It is also grown, albeit in smaller quantities, in western and central Black Sea regions, such as the districts of Sinop, Kastamonu, and the Çarşamba and Tekkeköy areas of Samsun, with farmers marketing their produce directly in local markets (Çulha and Bozoğlu, 2017). Research has highlighted several health benefits associated with cowpea, including anti-inflammatory, anti-diabetic, anti-cancer, anti-hypertensive effects, and a reduction in cardiovascular disease risk (Adjei-Fremah et al., 2019). Components of the cowpea plant, such as leaves and green pods, are utilized for the prevention or treatment of various human ailments, including smallpox, adenitis, burns, and ulcers, in addition to their nutritional contributions. Similarly, cowpea seeds serve to remedy ailments through astringent, antipyretic, and diuretic effects, employing decoctions or soups for issues related to liver and spleen health, intestinal cramps, leucorrhea, menstrual irregularities, and urinary problems (Khare, 2008; Apea-Bah et al., 2017; Jayathilake et al., 2018; Abebe and Alemayehu, 2022). Furthermore, cowpea is recognized for its considerable antioxidant content (Rivas-Vega et al., 2006). Protein content within cowpea pods ranges from 2.0% to 4.3%, while fresh grains contain 4.5% to 5.0%. Mature dried cowpea grains exhibit protein levels that vary between 20.42% and 34.60%, influenced by varietal and environmental factors.

Cowpea (*Vigna unguiculata*), particularly known as black-eyed peas, is an exceptional legume rich in various nutrients, contributing significantly to both human and animal nutrition. The grains of black-eyed peas comprise approximately 50-67% carbohydrates, 1.3% fat, 3.9% cellulose, and 3.6% ash content (Şehirali, 1988). This legume is also abundant in essential proteins, dietary fiber, and vitamins, including thiamine, niacin, riboflavin, pyridoxine, and folate, alongside vital minerals such as phosphorus, iron, potassium, and magnesium (Cavalcante et al., 2016). Notably, the consumption of black-eyed peas has been associated with reduced hypertension risks, attributed to the presence of β-sitosterol (Clark, 1996; Hall, 2004). Furthermore, other legumes like lupin have been recognized for their antioxidant, antimicrobial, anticarcinogenic, and anti-inflammatory properties due to compounds such as γ-conglutin, polyphenols, carotenoids, and alkaloids including angustifolin and lupanin (Lopes et al., 2020; Bengü and Ersan, 2022). Black-eyed peas not only serve as a nutritious vegetable and dry grain for human consumption but also function as a valuable forage crop in livestock nutrition, enhancing soil quality in terms of organic matter and nitrogen levels (Doğan et al., 2011). In many countries of the world, cowpea is a high-quality legume straw, with digestibility and some varieties being more efficient than common alfalfa (Muli and Saha, 2001). These legumes are utilized in animal feeds in various forms, including green or dry forage, silage, and dry grains (Ünlü and Padem, 2004).

To maximize yield per unit area for cowpea varieties, it is critical to develop strains that are better adapted to local ecological conditions, employing appropriate breeding techniques. Adaptation studies are essential for assessing the suitability of different varieties to specific regional environments (Ceylan and Sepetoğlu, 1984). Given their importance, cowpea supports millions in tropical and subtropical regions and has become the focus of breeding initiatives aimed at alleviating poverty in developing countries, particularly in the context of rising global temperatures and increasing water scarcity (Hall, 2012). Despite the wealth of research highlighting the nutritional benefits and positive health effects of cowpea, there are relatively few studies exploring its application as a functional food additive following various processing methods. Cowpea serves as a nutritional complement to low-protein staples, such as cereals and tubers, providing a substantial source of dietary protein for millions in developing nations (Timko and Singh, 2008). Specifically, black-eyed peas, a key member of the legume family, are notable for their high protein content and digestibility. Increasing research efforts on this valuable legume is essential for promoting public health and improving nutrition globally.

11.6. Pea

Pea, a species within the Fabales order of legumes, belongs to the *Pisum* genus of the Fabaceae (butterfly-flowered) family. Characterized by its diploid structure (2n=2x=14), the pea is an annual herbaceous legume capable of self-pollination, with a haploid genome size of 4,300 Mbp (Hofer et al., 1997; Güngör, 2015). This species thrives in cool and temperate climates, making its cultivation prevalent in temperate zones (Togay et al., 2006). Peas display two main phenotypes: smooth and wrinkled. Their seed coats come in a variety of colors, which include cream yellow, chartreuse, light green, green, army green, dark green, brown, and orange-brown (Gao et al., 2022; Santos et al., 2019). The variation in seed coat coloration is closely linked to flavonoid biosynthesis, which can vary due to different cultivars and environmental conditions. Notably, darker seed coat varieties often contain higher concentrations of flavonoids than lighter counterparts (Devi et al., 2019). The varieties of peas with yellow or green cotyledons, commonly known as dry, smooth, or field peas, are the naturally dried seeds of *Pisum sativum* L. These peas are grown globally for consumption by both humans and animals. In 2009, the worldwide production of peas surpassed ten million tons, with major contributions from countries including Canada, the Russian Federation, China, the USA, and India (Dahl et al., 2012). Despite being one of the most widely consumed legumes globally, the consumption of peas remains less widespread in certain regions, including our country, where planting areas and production levels have yet to reach their potential. Peas are predominantly cultivated for their fresh pods or dried grains, with an increasing demand observed in recent years due to the rapid growth of the canned and frozen food industry (Öz and Karasu, 2010). In addition to their nutritional applications, peas function as a valuable forage crop, significantly contributing to soil nitrogen through a symbiotic relationship with Rhizobium bacteria. The nitrogen fixation attributed to peas ranges between 6.4 kg/da and 21.6 kg/da, enhancing soil fertility for subsequent crops (Kün et al., 2005). Among food legumes, peas rank as the most produced globally after chickpeas and beans, occupying the largest planting area after beans and yielding the highest grain output per decare both domestically and internationally (Ceyhan, 2004). Pea seeds are nutrient-dense, comprising approximately 23-25% protein, 50% slowly digestible starch, and 5% soluble sugars, along with fiber, vitamins, and minerals (Bastianelli et al., 1998). The fiber content in peas is primarily composed of 88.2% water-insoluble dietary fiber, which has demonstrated potential as a plant protein source to enhance and diversify the functional properties of food products, owing to its iron, phosphorus, vitamins, and mineral content (Özabravci, 2019). Peas exhibit a high content of starch, fiber, antioxidants, carotenoids, and protein, rendering them a nutritionally superior vegetable. They provide more vitamin C than other legumes and also supply essential minerals, vitamins (A and B), iron, phosphorus, and potassium (Özdemir, 2002). Furthermore, peas are rich in essential amino acids critical for human nutrition, including leucine, lysine, isoleucine, phenylalanine, valine, and threonine (Eser, 1974). Compared to milk proteins, pea proteins demonstrate high digestibility and a rich composition of essential amino acids.

However, extensive research is warranted to investigate the nutraceutical properties and amino acid balance of alternative protein sources (Salles et al., 2021). The biological activities and health benefits associated with peas are significantly attributed to their nutrient composition and bioactive components (Dahl et al., 2012). With a glycemic index (GI) typically lower than 60, peas are classified as medium- or low-GI foods (Yu et al., 2020), contributing to findings that link high-GI diets to an increased risk of cardiovascular diseases (Jenkins et al., 2021). Consequently, the whole pea seed and its derivatives possess substantial potential to partially substitute other high-GI foods. Furthermore, peas are gluten-free (Thakur et al., 2019), making them suitable for individuals with celiac disease. Pea proteins and peptides exhibit various biological functions, including the regulation of metabolic syndrome (Ge et al., 2020).

Peas are extensively utilized in the food industry, available in various forms such as fresh, canned, and frozen (Alan and Geren, 2012). Among legumes, peas are distinguished by their diverse applications and are recognized as significant sources of protein and carbohydrates, playing a crucial role in human nutrition both globally and in Turkey. The dry grains of peas can be directly incorporated into meals, while flour derived from these grains serves as an additive in soups and baby food formulations. Shifts in global population dynamics and dietary habits have prompted a renewed interest in "vegetable proteins" as viable protein sources. By-products generated during the production or processing of plants, such as oilseed cakes (from sunflower, hazelnut, rapeseed, etc.) and legume shells (including pea shells), are notable for their substantial protein content (İsmail et al., 2020; Yıldız and Yemiş, 2024). The increasing focus on evaluating pea shells, an agricultural by-product, for their potential in plant protein production is of paramount importance for enhancing the economic landscape of the country. Due to their excellent yields, availability, and cost-effective production, peas are predominantly employed as a source of commercial proteins (Sun and Arntfield, 2012). Consequently, the development and application of pea protein have garnered significant attention within the food industry. This review paper aims to provide readers with a comprehensive understanding of the potential applications of pea protein across various food systems, while also encouraging further research into the scope of pea protein utilization. Additionally, some commercially available products derived from pea protein are illustrated in Fig. 10 (Ge et al., 2020).

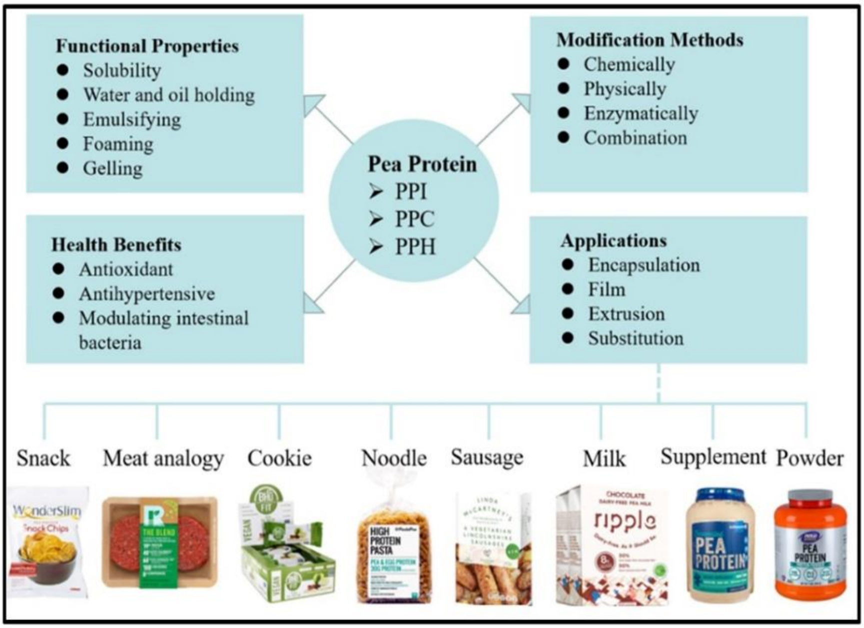


Fig. 10. Pea protein and its application in market products

11.7. Soybean

Soybean, an annual oilseed crop belonging to the legume family, is characterized by its nutritional profile, which includes 38–56% protein, 18-22% oil, 26% carbohydrates, and 18% minerals. Due to these vital nutrients, soybean is recognized as an essential oil and protein source for human health (Arslan et al., 2018; Arıoğlu, 2007). Historically, soybean cultivation originated in Manchuria and China, where it was first grown between the 11th and 17th centuries primarily for food. Subsequently, it was introduced to the Philippines, Japan, India, Thailand, and, by the early 17th century, to Europe, where it was progressively disseminated among farmers (Öner, 2006). Soybean is classified as a short-day plant that thrives in hot and very hot conditions, requiring short-day light conditions to transition from the vegetative to the generative stage. It is well-suited to second-crop cultivation due to its significant light requirements (Board et al., 1996).

The antioxidant properties of phenolic compounds found in soybeans are attributed to their capacity to inhibit chain reactions, terminate free radical chains by donating hydrogen atoms or electrons, and stabilize unpaired electrons in their aromatic structures. The compositional analysis of soybeans reveals approximately 38% protein, 18-24% fat, 20% carbohydrates, 5% minerals, and 1% lecithin (İncekara, 1972). Regarding their amino acid profile, soybeans contain a variety of important amino acids: tryptophan (1%), tyrosine (4%), valine (4%), arginine (8%), alanine (4%), aspartic acid (7%), cysteine (3%), glutamic acid (19%), glycine (4%), histidine (3%), phenylalanine (6%), isoleucine (5%), lysine (8%), leucine (8%), methionine (1%), proline (5%), serine (5%), and threonine (4%). Additionally, soybeans are abundant in dietary fiber, protein, and phytoestrogens, while being low in both saturated fats and lactose. They are also acknowledged as a good source of omega-3 fatty acids and antioxidants (Chen et al., 2012; Rizzo and Baroni, 2018). Research has demonstrated that these compounds possess various health benefits, including anticancer, antiaging, antirenal insufficiency, antiobesity, and anticholesterolemic effects, as well as prevention against gallstone formation, dementia, and hyperlipidemia. It has also been noted that soybeans exhibit diuretic properties, inhibit arteriosclerosis development, and reduce the risk of constipation and cardiovascular diseases (Liu and Udenigwe, 2019; Román et al., 2019). Following the recognition of the benefits associated with soybeans, numerous processing techniques have been employed, including soaking, cooking, frying, peeling, germination, fermentation, various chemical and enzymatic treatments, and extrusion cooking (Osundahunsi et al., 2007; Alonso et al., 2010). While some constituents, such as lectins and trypsin inhibitors, have been deemed harmful, recent studies have highlighted their potential physiological benefits, including diabetes prevention and antitumor activity (Chang et al., 2014; Roy et al., 2018). Given that soybeans contain higher protein concentrations than meat, regular consumption is associated with cholesterol reduction, cardiovascular protection, weight management due to their low-fat content, alleviation of menopausal symptoms, and a decreased risk of cancer, leading to their reputation as a "miracle plant" (Liu, 2004). Due to their high protein value, soybeans are widely employed in the feed industry and have increasingly found applications in the food sector, becoming indispensable raw materials for the industrial sector (Arıoğlu, 2000). Fig. 11 illustrates the production steps of soy products (Liu, 2004; Nilüfer and Boyacıoğlu, 2008). The functional properties of soybeans also make them valuable for enhancing food flavor, supporting dough consistency, serving as emulsifiers, providing whiteness, retaining moisture, improving texture, binding oils, and extending product freshness (Weingarther and Owen, 2009). Through symbiosis with the bacteria *Rhizobium japonicum* in its roots, soybeans contribute 6–10 kg of nitrogen to the soil annually from atmospheric nitrogen (İlisulu, 1973). Following oil extraction, the remaining soybean by-products are utilized as nutrient-rich animal feed (Arıoğlu et al., 1994).

In Asian cultures, soybeans are often referred to by various names such as Wonder Plant, Sacred Plant, God Plant, Breeding Gold, Yellow Jewel, and Boneless Meat of the East. Moreover, in Asia, soybeans are primarily used in the production of traditional foods, including tofu, soy milk, and fermented products, while Western countries predominantly consume refined soy protein (Riaz, 2006). Notably, soy protein demonstrates over 90% digestibility, comparable to the digestibility of proteins found in meat, eggs, and cow's milk (Messina and Messina, 1993).

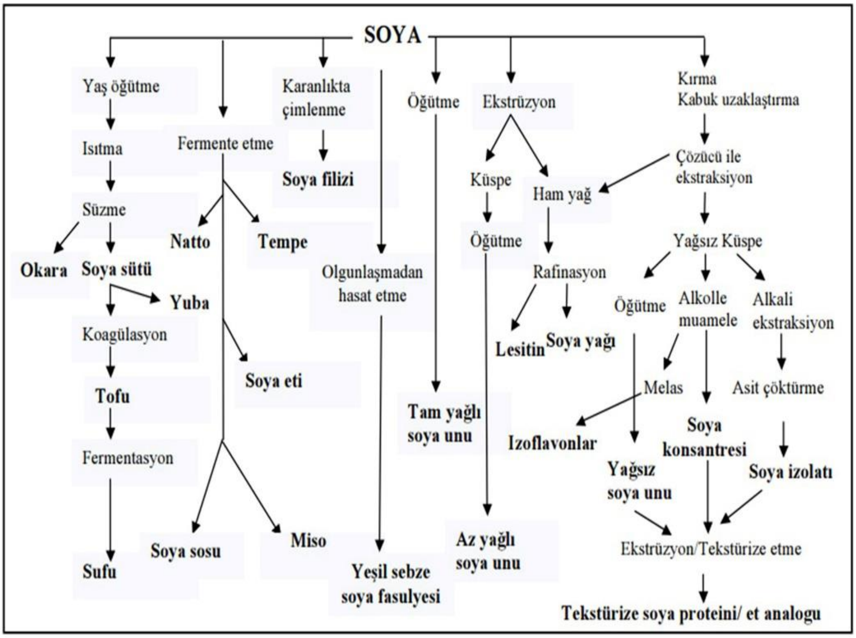


Fig. 11. Processing of soybeans into various products

Soybean contributes to sustainable agriculture through its symbiotic relationship with *Rhizobium japonicum* bacteria in its roots, which enables the plant to fix atmospheric nitrogen. This process not only fulfills the nitrogen requirements of the soybean itself but also enriches the soil with nitrogen and organic matter for subsequent crops. Unlike many other plants, soybeans utilize nitrogen more efficiently, resulting in a nitrogen-rich soil environment after harvest. Additionally, soybeans enhance soil structure, making them an essential component of environmentally friendly agricultural practices. In a world increasingly affected by environmental pollution, the significance of soybeans continues to grow (Öner, 2006; Olgun et al., 2007).

12. RAW FOOD

Since humans first mastered the use of fire for cooking around 700,000 years ago, thermal processing has been utilized to alter and preserve the sensory and nutritional qualities of food. The advantages of thermal processing include the elimination of foodborne pathogens, the breakdown of natural toxins, an increase in shelf life, improved digestibility and nutrient bioavailability, as well as enhancements in taste, texture, flavor, and overall functional properties. Nevertheless, this method of processing can also lead to negative effects, such as the loss of nutrients and the formation of compounds that may adversely impact flavor perception, texture, or color (van Boekel et al., 2010). To avoid these undesirable compounds entirely, consumers would need to adopt a strict raw food diet, consuming only unprocessed food items such as fruits, vegetables, grains, and raw animal products, including eggs, meat, and fish. Such a diet would likely prove inconvenient for most individuals and could lead to nutritional deficiencies; for instance, without adequate consumption of raw animal products, the intake of energy and vitamin B12 may become insufficient, as evidenced by a study conducted in Germany during the 1990s (Koebnick et al., 2005). A healthy diet is characterized by its ability to meet the body's nutritional requirements. Beyond serving as a source of nutrients, food encompasses various dimensions, including cultural, social, emotional, and sensory aspects. It should be varied, balanced, sufficient, accessible, colorful, and safe while also providing enjoyment and contributing to cultural and familial identity. Furthermore, a healthy diet plays a crucial role in preventing disease and promoting overall health (Dutra and Carvalho, 2013). In contemporary discourse, the philosophy of a vibrant and healthy lifestyle aligns with the raw food movement, which asserts that the vitality of food directly impacts health outcomes. This concept emphasizes that diverse foods can fulfill the body's nutritional needs and that similar flavors can be achieved through substitute products. As such, the notion of "live food" refers not to the consumption of living animals (Cousens, 2005; Reid, 2006) but rather to the avoidance of practices that involve consuming animals while alive. Interestingly, the term "live food" can also encompass various culinary traditions that include practices where animals are consumed in living or semi-living states (Liao and Meskin, 2018). Essential components of raw nutrition encompass fresh vegetables and fruits, seeds, nuts, legumes, and unsprouted grains, which can be consumed without thermal treatment (Bavcon Kralji et al., 2017). The main types of foods prevalent in raw nutrition consist of fresh vegetables, fruits, legumes, seeds, and sprouted grains (Karaman and Soylu, 2020). Within the framework of Alternative Food Networks, the raw food movement critiques conventional food systems as offering inferior quality, low essential nutrients, and ethical and ecological irresponsibility, positioning alternative food practices as healthier, ethically sound, and ecologically responsible choices (Guthman, 2007; Honkaken et al., 2006). The raw food movement emerged in Japan in the 1980s when the local government initiated a program aimed at reducing healthcare costs and pharmaceutical expenditures, particularly targeting an aging population. This initiative encouraged practices that could enhance life expectancy among individuals experiencing premature aging (Berry, 2002). Today, raw foods have gained recognition as a prominent trend within the food market. Although multiple definitions exist, the simplest definition, according to Goldberg et al. (2000), identifies a food or ingredient as one that provides health benefits in addition to the traditional nutrients it contains.

Raw nutrition, increasingly favored for promoting a healthy lifestyle, primarily involves the consumption of fruits and vegetables cultivated using animal manure, organic methods, and without exposure to chemical agents. This dietary approach also includes sprouted roots and living foods (Havala, 2002; Cousens, 2003; Craig, 2004; Reid, 2006; Sevinç and Çakmak, 2017). Advocates of raw nutrition assert that this regimen allows for the complete intake of enzymes, vitamins, and minerals found in foods without any loss. Although the principles of raw nutrition have existed for centuries, they have recently resurfaced as a significant trend in contemporary dietary discussions (Cousens, 2005; Reid, 2006; Knowler, 2010; Leitzmann, 2014; Sevinç and Çakmak, 2017). This nutritional model shares similarities with alkaline diets and may provide benefits for individuals suffering from osteoporosis. However, it is important to note that microbiological changes, such as aflatoxin formation, can occur depending on the production, storage, and transportation conditions of fruits and vegetables. Additionally, excessive consumption of green leafy vegetables can lead to the formation of oxalate stones, while frequent intake of hard foods may damage dental health. Moreover, regular consumption of fruit juices can result in enamel erosion (Ayaz, 2018). In raw nutrition, foods are consumed in their raw, uncooked states, or slightly heated (at temperatures below 40°C), and are predominantly unprocessed, organic, or sun-dried. Consequently, raw nutrition is often categorized as a spiritual vegan diet and is frequently associated with the concepts of live food or semi-live food (Howell, 1995; Cousens, 2005; Kyssa, 2009). Common foods included in raw nutrition are beans, chickpeas, rice, oats, barley, rye, lentils, quinoa, and wheat (Okur and Madenci, 2019).

Proponents of raw food diets reject contemporary cooking methods, viewing them as linked to industrialized production paradigms. This perspective posits that standardized food production processes degrade food quality, reducing it to mere commodities that seduce rather than nourish individuals. Within the binary framework of cooked versus raw food, a distinction emerges between "live food" and "dead food." The latter is deemed dangerous due to its association with profit-driven production methods and the use of harmful chemicals. This commodification is opposed for its detrimental effects on human health and environmental sustainability (Thircuir, 2020). Individuals choose a raw diet for various reasons, including perceived health benefits, disease prevention, increased life expectancy, religious beliefs, economic considerations, environmental protection, climate change mitigation, animal welfare, and adherence to ethical guidelines (Aktaş and Algan Özkök, 2018; Okur and Madenci, 2019). Research efforts concerning raw nutrition have focused on identifying suitable foods, optimal consumption practices, and the health outcomes for individuals adhering to this dietary regimen. The literature highlights notable differences related to health outcomes, including the potential for developing cardiovascular diseases or deficiencies in essential vitamins and minerals between raw food consumers and non-consumers. Furthermore, it is suggested that raw food consumption may yield numerous positive health effects, particularly in strengthening the immune system by promoting a more alkaline bodily environment (Çoruhlu, 2013). Today, raw nutrition is recognized as a means to enhance disease resistance, maintain healthy weight, and support digestive health (Howell, 1995; Cohen, 2004; Fry and Klein, 2004; Schenck, 2008; Knowler, 2010). While raw nutrition may be suitable for short-term implementation under medical supervision in adults, the American Dietetic Association advises against its use in infants and children due to the risk of developmental delays (Ayaz, 2018). Long-term adherence to raw nutrition has been associated with detrimental health effects arising from deficiencies in nutrients such as calcium, protein, and vitamin B12, typically obtained from cooked or animal-based foods (Craig and Mangels, 2009). In light of these concerns, scientific investigations, dietary programs, nutrition training, and certification initiatives are underway. This includes the establishment of restaurants offering raw food options, enhancement of menus with raw ingredients, the rise of blog posts documenting culinary experiences, the growth of social media communities, and the globalization of various raw food circles. Critical control points in the preparation of foods for raw consumption, particularly in disinfecting produce, are essential to minimize health risks. Surface decontamination methods for vegetables are commonly implemented, with chemical disinfection techniques being the most widely used approach to reduce microbial contamination and prevent the onset of various foodborne illnesses (Beuchat, 2002; Ayhan and Bilici, 2017).

Raw food diets, a specific subset of vegan diets, are gaining recognition and interest, a trend that health educators should note. Surveys indicate a growing interest in vegetarian dietary patterns, with an increasing number of vegetarians transitioning to veganism (The Vegetarian Resource Group, 2024). A vegan diet excludes not only meat but also dairy products, eggs, and any foods containing byproducts derived from these ingredients (American Dietetic Association, 2003). In recent years, raw food restaurants in California and New York have garnered significant media attention, resulting in numerous articles and features about raw food diets appearing in popular publications and major newspapers (Blake, 2002). These diets are often referred to as uncooked vegan diets, uncooked vegetable diets, or "living foods" diets. While most reports indicate an exclusion of animal products, there are instances where raw food diets may include items such as raw liver. The proportion of raw foods consumed in these diets varies widely, typically ranging from 55% to 95%. Common components of raw food diets include germinated seeds, sprouts, cereals, vegetables, fruits, berries, and nuts (Hänninen et al., 1999; Hänninen et al., 2000). For raw food enthusiasts, there exists a clear distinction between nature and the mechanized, transformed world of contemporary society. The term "artificial" delineates that which is produced by human intervention rather than by natural processes. This perspective establishes a dichotomy between the natural and the artificial, which reflects broader contrasts such as nature versus culture. This normative use of dichotomy assigns a specific value system to these oppositional frameworks (En ligneLarrère and Larrère, 2015).

Despite the emphasis on raw food diets, the foods consumed can undergo significant transformations. It is essential to recognize that the raw food movement emerging in Western countries often develops in contrast to the concepts of elaborated versus unelaborated food. The aspiration to "purify" individuals from cultural influences to restore them to an idealized natural state tends to fall short of realizing a genuine separation from culture. This highlights the complex interplay between dietary choices and cultural identities, suggesting that even raw food diets cannot fully extricate themselves from the influences of modern societal constructs.

13. GERMINATION

Seeds are fundamental to agricultural production, serving as the primary source of biological and genetic diversity, and playing a crucial role in sustainability. A seed, specifically a genuine seed formed from a grain, is a fertilized mature ovule that contains the essential plant structure, a nutrient reservoir comprising the cotyledon and endosperm, as well as a protective seed coat (McDonald and Copeland, 2001; Desai, 2004). Germination is a complex process characterized by a series of metabolic activities, including the degradation of proteins, oxidation of lipids, and conversion of carbohydrates into simple sugars. These processes are vital for providing the energy and fundamental components required for plant development and growth (Urbano et al., 2005). The ability of a seed to produce a new individual is influenced by its quality and germination capacity (Rochalska, 2002). During germination, enzymatic changes occur, and the levels of bioactive compounds within the seed increase. The energy needed for germination is derived from the metabolic activity involving stored carbohydrates, proteins, and fats. Additionally, the synthesis of new compounds, such as gamma-aminobutyric acid (GABA), gamma-oryzanol, and beneficial amino acids, is heightened throughout the germination process (Xu et al., 2020; Kalaycı and Şahin Kaya, 2022).

Germination can be delineated into three distinct phases (Xue et al., 2021; Gunathunga et al., 2024).

1. **Imbibition Phase**: This initial phase involves the absorption of water by the dry seed, leading to swelling and the activation of metabolic processes. During imbibition, the seed takes up water rapidly, which rehydrates the tissues and initiates enzymatic activities necessary for germination.
2. **Activation Phase**: Following imbibition, the activation phase is characterized by the resumption of metabolic activities within the seed. Enzymes are activated, and stored nutrients, such as starches and proteins, begin to break down into simpler compounds. This phase is crucial for providing the energy and building blocks required for the growth of the emerging seedling.
3. **Radicle Emergence Phase**: The last stage of germination is characterized by the emergence of the radicle, which is the embryonic root that emerges from the seed. This event indicates a shift from a dormant state to that of an active seedling. The radicle serves to anchor the plant in the soil and initiates the absorption of water and nutrients, promoting the continued growth and development of the plant.

These phases collectively contribute to the successful transition of a seed into a growing plant, each playing a vital role in the overall germination process. Proper control of germination conditions can significantly improve crop yields and contribute to sustainable agricultural development.

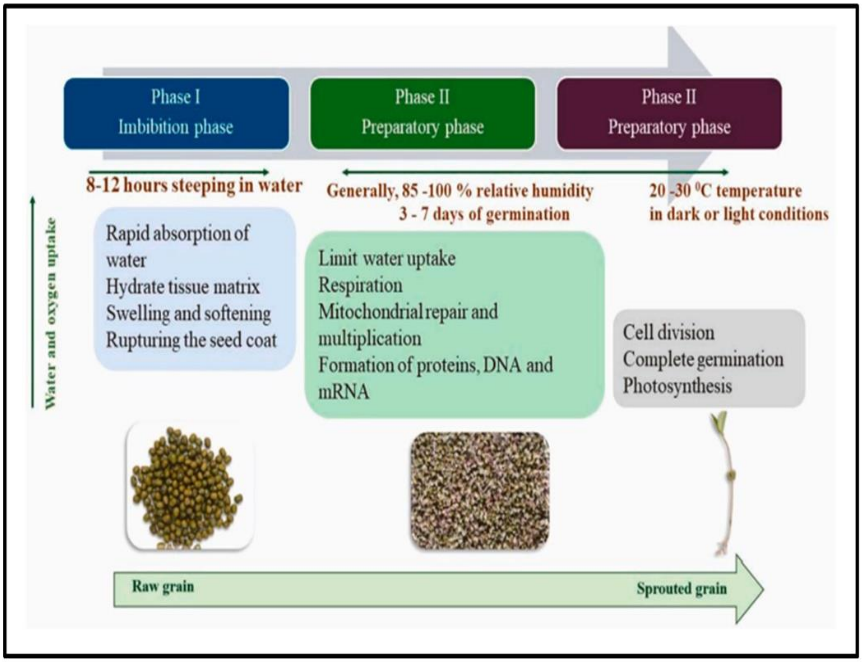


Fig. 12. Typical germination process

Seeds are classified into three main categories based on their storability:

Orthodox Seeds: These seeds can tolerate desiccation and can be stored for long periods under appropriate conditions.

Recalcitrant Seeds: These seeds have a limited tolerance for drying out and cannot be stored for extended periods without losing viability.

Intermediate Seeds: These seeds have characteristics that fall between orthodox and recalcitrant seeds, exhibiting some tolerance to drying but less than orthodox seeds (Roberts, 1973; Ellis et al., 1990).

For optimal storage, dry-stored seeds are kept at conditions near the lowest temperature and moisture content that will not harm the seeds (Schmidt, 2000). The germination process marks the commencement of the plant's life cycle and is closely associated with dormancy. It is regulated by phytohormones, particularly gibberellic acid (GA) and abscisic acid (ABA) (Sakai et al., 2022). Germination can be described as the process where dry seeds absorb water, leading to the breakdown of structures surrounding the embryo through enzymatic reactions, allowing the radicle (the embryonic root) to penetrate these structures as nutrients are transferred to the embryo. Notably, 50-90% of wild plants are reported to produce dormant seeds, which is an important consideration for plant propagation (Kildisheva et al., 2020).

Hormonal effects significantly influence seed germination, sprouting, and overall plant growth and development. Various hormone-like compounds, including cytokinins, auxins, abscisic acid, gibberellins, sterols, and polyamines, have been identified to exhibit biostimulatory activity through biological testing and immunological techniques (Craigie, 2011). A quality seed is characterized by high germination ability and viability, freedom from disease, physical purity, adherence to varietal standards, and optimal moisture content (Desai, 2004). However, traditional chemical and physical treatments that enhance the germination power and growth yield of agricultural seeds can sometimes result in structural damage, genetic dissimilarity, and negative impacts on both life and the environment. Research has been conducted to assess the effects of novel technologies on seed germination and growth rates, with findings indicating that these emerging techniques have several advantages over conventional methods. For example, they can reduce the amount of pesticides used, thereby mitigating their environmental impact, lead to minimal genetic deviations in seeds, and even be effective for seed disinfection during storage prior to sowing (Harris et al., 2001; Joshi et al., 2013). The mechanisms through which these technologies positively and negatively impact seeds, along with the corresponding reasons, are further illustrated in Fig. 13 (Rifna et al., 2019). This highlights the importance of understanding both traditional and novel methods in enhancing agricultural practices while safeguarding environmental integrity.

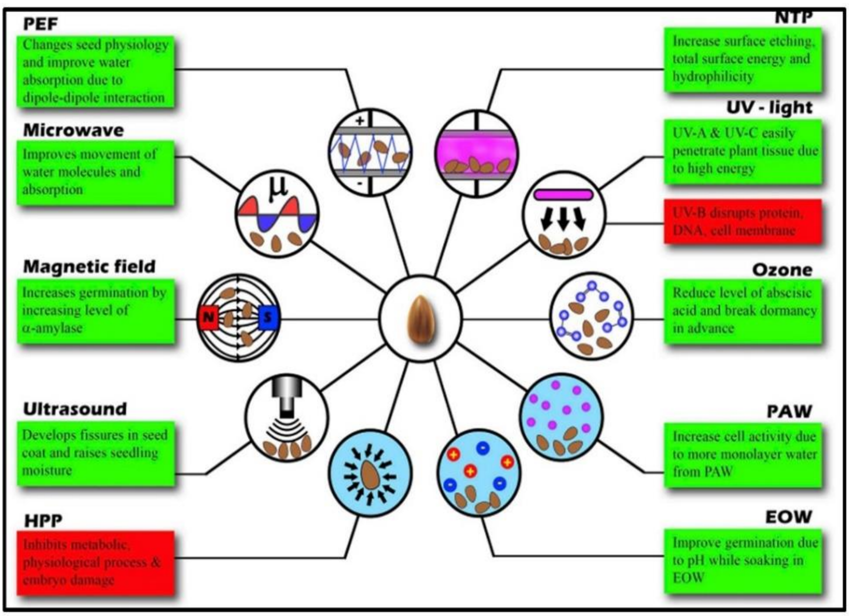


Fig. 13. The causes for profits and limitations of the effect of novel technologies on seed germination and growth characteristics

The evolution of seeds marks a significant transition in the life history of photosynthetic organisms. This evolutionary process involved several key stages; however, the precise sequence of these stages remains uncertain, and it is plausible that multiple steps occurred concurrently. The following stages are proposed in the evolution of seeds (Baskin, 1989; Bareke, 2018):

A. Heterospory: Heterospory is characterized by the formation of two distinct types of haploid spores in separate sporangia: larger, fewer megaspores and smaller, more numerous microspores, which are generated through meiosis in the microsporangium. Each megaspore develops into a female gametophyte that contains only archegonia, while each microspore gives rise to a male gametophyte that has only antheridia.

B. Endospory: Endospory involves the complete development of the female gametophyte within the original spore wall. The ancestral condition, where the spore germinates and develops as an external gametophyte, is known as exospory.

C. Reduction of Megaspore Number: This reduction occurs through two mechanisms. Firstly, there is a decline in the number of megasporocytes (the mother cells of megaspores) that undergo meiosis to produce megaspores. Typically, three out of the four haploid megaspores formed by meiosis abort, resulting in only one functional megaspore.

D. Retention of the Megaspore: This phase is marked by a decrease in the thickness of the megaspore wall, which aids in its retention.

E. Evolution of the Integument: The final phase involves the development of the integument from the base of the megasporangium (often called the nucellus when an integument is present), surrounding it except at the distal end.

The collective practices aimed at enhancing seed germination are referred to as "priming," which can be identified by various terms, including pre-germination, osmotic conditioning, or osmotic seed treatments (Sivritepe, 1999; Demir et al., 2008). Priming induces physiological effects that produce plants more resilient to a range of biotic and abiotic stresses (Jisha et al., 2013). These applications serve to reveal the potential resistance of existing plant varieties. Specifically, seed priming can enhance plant water status, increase chlorophyll content, bolster membrane stability, and improve drought resistance, thereby facilitating germination under both normal and stressful conditions. It also promotes early and uniform germination due to increased synthesis of metabolites associated with this process. Priming applications can be conducted at both seed and seedling stages (Saboor et al., 2019).

Furthermore, priming enhances the expression of antioxidant enzymes (such as peroxidase, superoxide dismutase, ascorbate peroxidase, and catalase) which protect plants from the adverse effects of reactive oxygen species by restoring hormone homeostasis, breaking seed dormancy (Bourioug et al., 2020), and mitigating stress factors (Paparella et al., 2015; Totkanli, 2022). Various methods have been developed to improve seed germination and seedling establishment at low temperatures following priming, including osmopriming, hydropriming, matrix priming, holopriming, biopriming, and priming with plant growth regulators (Aziz, 2018; Farooq et al., 2008).

Osmopriming is a widely used pre-sowing treatment that involves soaking seeds in osmotic solutions with low water potential, which regulates water uptake (Paparella et al., 2015). This method facilitates rapid and uniform germination and seedling emergence, yielding robust seedlings even under stressed conditions (Talebian et al., 2008). Notably, germination is not constrained by seasonal limitations, as it can occur without the need for soil or sunlight. It can be conducted at home using only seeds, water, and a simple germination container (Miyahira et al., 2021). However, the ideal conditions for germination also promote bacterial growth, leading to safety concerns when consuming raw sprouts that are not subjected to cooking processes that could eliminate harmful microorganisms. Consequently, various strategies-both physical (e.g., temperature control), biological (e.g., employing antagonistic microorganisms), and chemical (e.g., disinfectants)-are applied to mitigate the risk of contamination (Ding et al., 2013; Miyahira et al., 2021).

Humidity and temperature are critical determinants for the germination process. In most studies, water is preferred for soaking and germination (Finnie et al., 2019). As seeds absorb water, respiration, protein synthesis, and other biochemical changes initiate (Akgün, 2018). These biochemical changes result in increased levels of free amino acids, proteins, and fiber, as well as enhanced functional properties in the food produced from germinated seeds, while simultaneously reducing carbohydrate, fat content, and glycemic index (Okur and Madenci, 2019; Güneş and Erçetin, 2022).

Bacteria present in the soil can have both stimulatory and inhibitory effects on seed germination. Stimulatory bacteria promote the emergence and development of both weeds and crop plants, while bacteria that inhibit weed germination can serve as biological control agents in field crops. The application of bacteria, fungi, and viruses for weed control in agricultural systems has emerged as a significant area of research in recent years. This microbial approach is advantageous as it has less negative environmental impact compared to chemical herbicides, is generally lower in cost, and exhibits target specificity, making them promising candidates for use as bioherbicides (Harding and Raizada, 2015).

Among the most notable plant groups consumed through germination are legumes, with soybean sprouts being the most widely produced and recognized. Soybeans are particularly rich in phenolic compounds (Kim et al., 2006). Some of the phytoestrogens, isoflavones, vitamins, and minerals present in soybeans have been reported to possess therapeutic effects for cardiovascular diseases, osteoporosis, and various cancers (Lee et al., 2007). Germination enhances the concentrations of lecithin, α-amylase, lipase, and α-galactosidase, along with essential minerals such as calcium (Ca), copper (Cu), manganese (Mn), and zinc (Zn) in soybeans. Additionally, germination leads to a proportional reduction in the levels of lipoxygenase-which negatively impacts the flavor of soy-and trypsin, which diminishes protein digestibility (Plaza et al., 2003; Kumar et al., 2006). Another significant legume, *Lupinus angustifolius* L. (lupin), is highly regarded for its rich protein content, essential amino acids, and important dietary minerals. Research indicates that germination increases the amount of phenolic compounds in lupin, thereby enhancing its antioxidant properties (Duenas et al., 2009).

Germination also induces notable changes in oat components, particularly a significant increase in β-glucan levels - an important functional component - due to heightened activity of the enzyme β-glucanase (Wilhelmson et al., 2001). In several developed countries, wheat is evaluated for its germination characteristics. Wheat sprouts exhibit higher vitamin content, enhanced levels of phenolic compounds, superior protein quality, more aromatic amino acids, and increased polyunsaturated fatty acids compared to ungerminated wheat. Furthermore, germination improves the nutritional profile and functional attributes of wheat by increasing the bioavailability of essential minerals and trace elements (Yang, 2002; Finley et al., 2001). The increase in phytase activity and decrease in phytic acid during wheat germination are additional nutritional benefits (Yang, 2002).

Recently, barley has gained popularity in some developed countries, either as a sprouted food or as an extract for supplements (Simonsohn, 2001). It has been noted that germination leads to a decrease in triglycerides and energy content in the dry matter of barley, while increasing the levels of ash, crude fiber, diglycerides, certain amino acids, and minerals. Although germination of legumes and grains like wheat and barley has been a common practice historically, it has become increasingly popular to germinate alfalfa, broccoli, soybeans, and various other grains to consume as sprouts (Finney, 1993). Broccoli (from the Brassicaceae or Cruciferae family) has emerged as one of the most popular germinated plant products in recent years, attributed to its beneficial functional properties. It is regarded as a healthful food source due to its content of selenium, which possesses antioxidant properties (Finley et al., 2001), and isothiocyanates, which exhibit anticarcinogenic properties (Zhang et al., 2006).

14. GERMINATION IN PSEUDO-CEREALS

Pseudo-cereals are dicotyledonous plants that are not closely related to one another or to monocotyledonous true cereals. This category includes amaranth, quinoa, and buckwheat, with the latter believed to have originated in China and the former two in South America. Additionally, grains such as sorghum, millet, fonio, and teff are also classified as pseudo-cereals (Saturni et al., 2010). These pseudo-cereals are significant energy sources, primarily due to their high starch content, as well as their contributions of vitamins, minerals, and bioactive compounds such as squalene, phytosterols, fagopyritols, saponins, and polyphenols (Valcárcel-Yamani and Lannes, 2012; Gül, 2020). Soaking pseudo-cereal grains for a predetermined duration at room temperature has been shown to decrease the levels of anti-nutritional compounds, including phytic acid, tannins, and saponins. The efficacy of this reduction varies depending on the soaking conditions and duration (Kumar et al., 2022; Arslan and Yalçın, 2023). Germination is one of the most commonly employed pre-treatment methods for pseudo-cereals. The success of germination is influenced by seed type, cultural practices, germination methods, and environmental conditions (Özkaynak, 2011). Traditional methods for germinating cereal seeds include jar, tray, and cover techniques (Kılınçer, 2018; Altıkardeş, 2022).

Buckwheat, as a pseudo-cereal, is noted for its wealth of proteins, vitamins, and minerals. It is particularly rich in significant phenolic compounds such as rutin and quercetin. Research indicates that buckwheat sprouts possess higher nutritional content - specifically in lysine, minerals, crude fiber, phenolics, and vitamin C - compared to their ungerminated seeds (Lintschinger et al., 1997; Hsu et al., 2008; Kim et al., 2004; Kim et al., 2008). Furthermore, germinated buckwheat is remarkably high in flavonols, including anthocyanins, rutin, quercetin, orientin, isoorientin, vitexin, and isovitexin, which are known for their antioxidant, antimutagenic, anticarcinogenic, and antimicrobial properties (Lintschinger et al., 1997). Sprouts, microgreens, and edible flowers are typically consumed raw and are characterized by their diverse phytochemical profiles, which include various phenolic compounds (such as phenolic acids, anthocyanins, chalcones, flavanones, flavones, and flavonols), carotenoids (carotenes and xanthophylls), betalains (betacyanins and betaxanthins), vitamins (ascorbic acid, phylloquinone, and tocopherols), glucosinolates, amino acids, and both macro and micro-minerals. The distinctions between microgreens, sprouts, and vegetables are illustrated in Fig. 14 (Partap et al., 2023).

The current special issue, titled “Sprouts, Microgreens, and Edible Flowers as Novel Functional Foods,” features one critical review and nine original research articles. These contributions examine the effects of preharvest and postharvest factors on the agronomic performance, nutritional value, and functional quality of sprouts and microgreens. The papers included are of high scientific caliber and originate from various esteemed research groups. This issue aims to deepen the understanding of consumers, academics, breeding companies, and farming communities regarding the benefits of these three significant categories of specialty crops. The focus is on producing and designing fresh foods that are healthier (lower in calories and fat) and functional (rich in phytochemicals) (Kyriacou et al., 2016; Aloo et al., 2021; Pires et al., 2021).

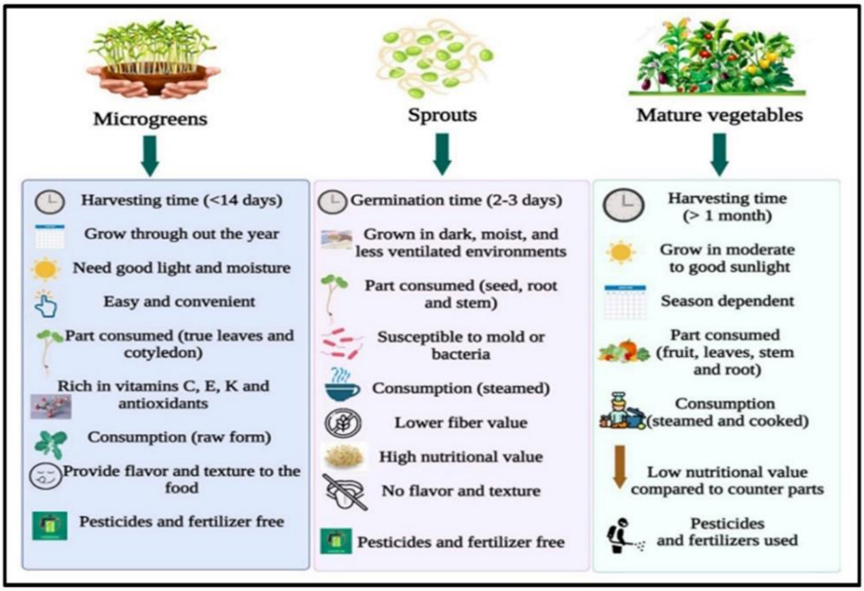


Fig. 14. Some characteristics of microgreens, sprouts and vegetables

In our country, seed sprouts are predominantly available in select markets located in major consumption centers, and their variety is notably limited. Furthermore, scientific research and data pertaining to seed sprouts, which can be regarded as a relatively novel concept within our society, are largely absent (Arın, 1997; Gül and Levent, 2008).

15. MICRO-SPROUTS (MICROGREENS)

In contemporary society, the needs and demands of consumers significantly influence the diversity within the food and beverage sector. Success in this expansive and highly competitive industry relies heavily on dedicated effort and sector-specific expertise. The critical relationship between human nutrition and the environmental sustainability of crop production has become a central focus in addressing the challenges of feeding the world's rapidly growing population. Over the past two decades, there has been a notable increase in interest in fresh, functional, and nutraceutical foods, driven by a societal shift toward healthier dietary practices. Consumers are actively seeking new products that promote health and longevity while also providing gastronomic enjoyment. Micro sprouts, which first gained prominence in the culinary scene of San Francisco and California during the early 1980s, have been cultivated in Southern California since the latter half of the twentieth century. Currently, the popularity of micro sprouts endures in upscale restaurants, where they significantly enhance the creative presentation and concentrated flavors of dishes (Renna et al., 2016). Micro sprouts, also referred to as microgreens, represent a distinct category of specialty crops defined as young, tender greens produced from vegetable, plant, or grain seeds, including those from wild species. The term "sprouts" generally refers to germinated seeds. The development of sprouts involves critical biochemical processes, including the synthesis of various vitamins, minerals, and phenolic compounds, alongside alterations in the composition of proteins, carbohydrates, and fatty acids (Alexander et al., 1984; Yang, 2002). Sprouts are harvested before the germination of diverse plants and seeds, cultivated under controlled environmental conditions (such as appropriate humidity and temperature) before the emergence of leaf structures, and are typically consumed whole along with the seeds (Yetim, 2009; Kılınçer, 2018; Şenlik and Alkan, 2021). Micro sprouts distinguish themselves from conventional sprouts and small-sized fresh-cut leafy vegetables, commonly known as baby leaves. They should not be confused with miniature vegetables produced through specialized cultivation techniques (Di Gioai et al., 2015). Microgreens serve to enhance the appeal and flavor of culinary creations. These young greens are harvested after the germination of various vegetable, plant, or grain seeds, once the first true leaves have formed. Due to their vibrant colors and flavors, microgreens are recognized as "functional foods," attributed to their rich content of bioactive compounds, vitamins, and minerals (Treadwell et al., 2010; Kou et al., 2014; Delian et al., 2015; Marchioni et al., 2021). Unlike microgreens, sprouts are products that do not develop true leaves and are consumed immediately following germination. Microgreens are typically harvested after the germination of seeds and the establishment of the first true leaves (Xiao et al., 2012). Some representative images of micro sprouts derived from cereals and legumes are provided in Table 2 (Anonymous, 2024b). In Turkish literature, microgreens are sometimes referred to as “micro sprouts,” “baby greens,” or “micro vegetables.” These immature greens, which can be cultivated from various seeds including vegetables, cereals, and aromatic plants, are consumed at a stage that is more developed than sprouts but less mature than baby greens. The burgeoning popularity of microgreens is evident globally, and they have begun to capture attention in Turkey as well. The increasing interest in microgreens is attributed to their notable nutritional and sensory qualities, along with their functional food status due to beneficial health effects (Xiao et al., 2012; Sun et al., 2013; Pinto et al., 2015). Additionally, micro sprouts can serve as garnishes or decorative components in innovative recipes and contemporary plate presentations. It is important to ensure that all products used in culinary decoration are food-grade, suitable for human consumption. Available literature suggests that the applications of micro sprouts extend beyond mere decorative purposes; they also contribute to the flavor and aromatic profiles of dishes. Culinary establishments have the option to either procure micro sprouts from suppliers or cultivate them in-house. The versatility of sprouts and microgreens enables them to be grown quickly, easily, and cost-effectively in urban and peri-urban environments where land may be limited. Consumers can produce these crops within or around their residences, independent of seasonal constraints (Ebert, 2015; Renna et al., 2017; Ghoora and Srividya, 2018).

Table 2. Micro-sprout images of some cereals and legumes

Some Microgreenery	Images
Broccoli Microgreens	
Chickpea Microgreen	
Rutabaga Microgreens	
Flax Microgreens	

Buckwheat Microgreens	
Oat Microgreens	
Soybean Microgreens	
Wheat Microgreens	

Barley Microgreens	
Lupin Microgreens	
Bean Microgreens	
Brassicaceae Microgreens	

Sprouted seeds and microgreens represent an innovative category of specialty raw salad crops, particularly esteemed for their health-promoting and disease-preventing attributes (Wojdyło et al., 2020; Sharma et al., 2022). Their production process is both rapid and cost-effective, requiring minimal equipment and supplies. The developmental period ranges from just a few days for sprouts to approximately two weeks for microgreens, indicating significant potential for industrial scalability. This scalability also allows consumers to gain independent access to food items with recognized or suggested nutritional benefits (Renna et al., 2017; Di Gioia et al., 2015). Micro sprouts can be cultivated without soil or any growth medium, relying solely on water or moisture for their development. Among the numerous advantages of producing micro sprouts, key benefits include the ability to achieve large-scale production in a very confined space and the fact that the entire product is edible, eliminating the need for harvesting (Bhaswant et al., 2023). In comparison, microgreens are generally easier and more affordable to grow and maintain than fully matured vegetables. With sufficient sunlight, appropriate growing media, and adequate water, microgreens can be cultivated in plastic trays or any suitable pots within a home environment. The germination period is notably brief, typically spanning only 10 to 12 days before the plants are ready for harvest. Unlike many other vegetables, microgreens can be produced year-round, as illustrated in the production cycle shown in Fig. 15 (Rani et al., 2020).

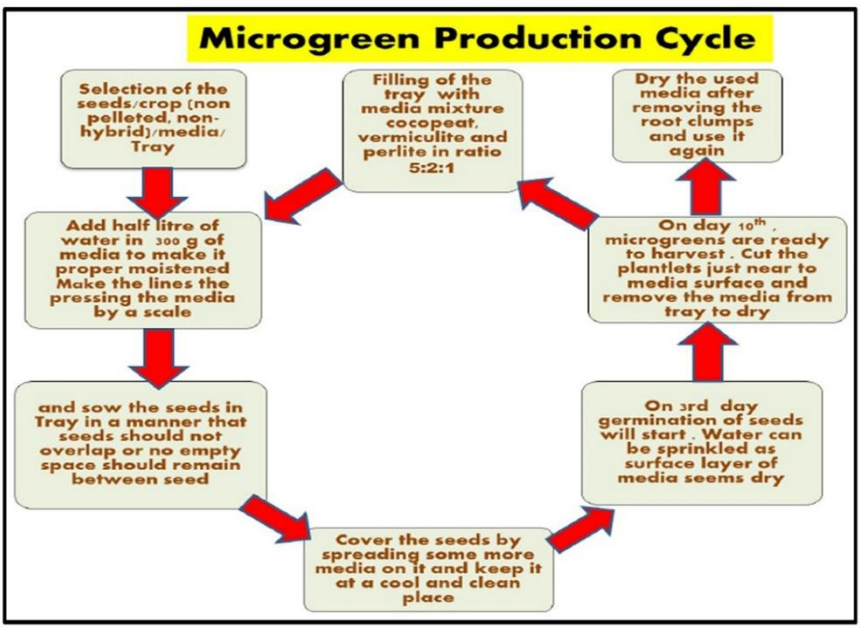


Fig. 15. Microgreens production cycle

The harvesting of microgreens occurs at the soil level, specifically at the hypocotyl's base, once the first true leaves appear. This stage is reached when the cotyledons are completely expanded and swollen, which usually takes about 7 to 21 days following germination. The concept of microgreens originated in San Francisco, California, during the late 1980s and has since garnered significant acclaim as a trendy culinary ingredient in top-tier restaurants and upscale grocery stores worldwide. Their rising popularity can be attributed to their vibrant colors, delicate textures, and unique flavor-enhancing capabilities as a garnish in various dishes, including salads, sandwiches, soups, desserts, and beverages, as well as their enriched phytonutrient content and potential bioactive properties (Kyriacou et al., 2016). What makes microgreens particularly appealing from a gastronomic perspective is the diversity observed in the first leaves that emerge from the seeds. These leaves exhibit a broad spectrum of colors (green, yellow, red, purple), textures (soft, crisp, juicy), and flavors (sweet, neutral, slightly sour, spicy) (Xiao et al., 2012; Pinto et al., 2015). Microgreens are utilized in a multitude of culinary applications, enhancing the color, texture, taste, and aroma of dishes, and serving as edible garnishes for drinks, special dishes, and salads (Treadwell et al., 2010; Xiao et al., 2012; Chandra et al., 2012; Kou et al., 2013; Pinto et al., 2015; Renna et al., 2017; Choe et al., 2018; Riggio et al., 2019). They are also favored as a raw food source among vegans, who prioritize nutrient-dense dietary options. Additionally, microgreens possess a unique growth pattern that allows for cultivation in limited spaces, making them accessible to individuals without the need for professional gardening skills (Riggio et al., 2018). When compared to fully matured vegetables, microgreens contain up to ten times more antioxidant compounds and exhibit intense and concentrated flavors and aromas. Consequently, they serve as a rich nutritional resource for consumers with specific dietary preferences, such as vegetarians and vegans (Ebert et al., 2015). Research studies, both in vitro and in vivo, have highlighted the anti-inflammatory, anti-cancer, anti-bacterial, and anti-hyperglycemic properties of microgreens, affirming their appeal as functional foods that offer substantial health benefits (Zhang et al., 2021). The diverse health-promoting phytonutrients found in microgreens, including antioxidants, vitamins, minerals, and phenolic compounds, are leading to their growing recognition as the next generation of "superfoods" or "functional foods." An overview of the associated health benefits is provided in Fig. 16 (Bhaswant et al., 2023).

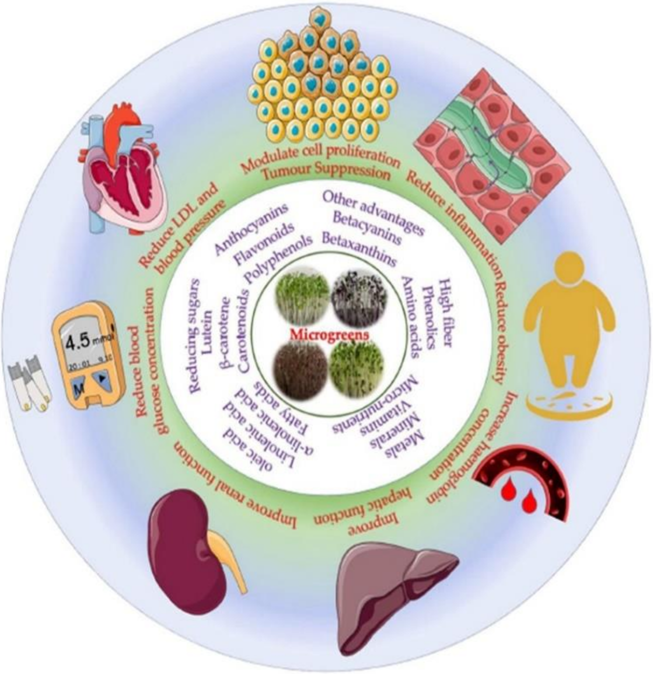


Fig. 16. Overview of health benefits of microgreens

The absence of a consumption culture surrounding micro sprout consumption in Turkey underscores the necessity for comprehensive studies focused on the consumption patterns of sprout-containing foods. Investigating the potential applications of these products as natural additives in various processed foods, alongside their fresh consumption, could present a valuable opportunity to enhance the acceptance and utilization of such products within the Turkish market. By exploring innovative ways to incorporate micro sprouts into processed foods, it may be possible to not only increase their visibility and appeal but also to promote their nutritional benefits to a broader audience. This approach could facilitate the development of new culinary practices and consumer habits, ultimately fostering a culture of micro sprout consumption in Turkey. Further research in this area could provide insights into consumer preferences, potential health benefits, and effective marketing strategies to encourage the integration of micro sprouts into everyday diets.

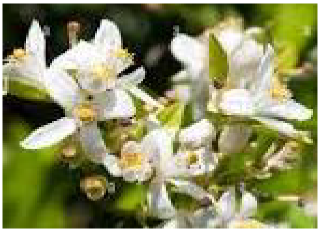
16. EDIBLE FLOWERS

Flowers, celebrated in literature as a natural wonder and symbol of beauty, constitute an integral aspect of human life. Furthermore, many ornamental plant species possess edible characteristics (Chen and Wei, 2017). Among nature's bounties, flowers exhibit growth patterns that align with seasonal characteristics. For centuries, humans have utilized these floral creations for various purposes. Historical texts indicate that seasonal flowers and plants have been employed for health and beauty applications for millennia. Edible flowers have maintained a significant presence in human nutrition since ancient times (Zheng et al., 2019). Across diverse regions, from ancient Greece and Rome to medieval France, as well as throughout Europe, Victorian England, and Asian cultures including China and Japan, the consumption of edible flowers has persisted for thousands of years (Pires et al., 2019). In contemporary culinary practices, fresh flowers, commonly incorporated in summer salads and desserts, are now being utilized in winter months through canning and confectionery techniques. For instance, aromatic rose petals were historically preserved by being spread on paper, thoroughly soaked in rose water, sprinkled with fine granulated sugar, and sun-dried. This method allowed for the storage and utilization of fragrant rose petals throughout the winter season. Traditionally regarded as vegetables, especially for their medicinal properties, edible flowers are undergoing reevaluation by scientists who are examining their nutritional and phytochemical profiles (Benvenuti et al., 2016). While a plethora of edible flowers exists globally, only a fraction has been systematically studied, necessitating comprehensive research to enhance their acceptability as food ingredients while mitigating potential risks (Lu et al., 2016). Commonly utilized edible flowers include chamomile, calendula, mallow, nasturtium, citronella, lemon balm, dandelion, hollyhock, lavender, lilac, borage, violet, rose, and carnation. Additionally, flowers from plants such as chives, thyme, marjoram, mint, sage, rosemary, elderflowers, and various citrus species (orange, lemon, lime, grapefruit, and kumquat) are also considered edible (Fernandes et al., 2018). According to Yıldırım (2022), Table 3 highlights various edible flowers and their culinary applications. The inclusion of edible flowers enhances dish appeal through their vibrant colors, flavors, and other sensory attributes. Additionally, these flowers contain bioactive compounds, such as polyphenols, which can confer beneficial health effects. The presence of phenolic compounds has garnered interest from both consumers and the food industry, given their potential applications as natural additives, new food reserves, and colorants. Consequently, edible flowers enhance dish appeal with their aroma, flavor, visual allure, nutritional benefits, and low-fat content (Pires et al., 2019). Nutraceutical components found in edible flowers remain intact when consumed with minimal processing. In India, local tribal populations have historically utilized edible flowers for both medicinal and nutritional purposes. These seasonal flowers are preserved using traditional methods, including drying and preservation with sugar, honey, and oil (Nicolau and Gostin, 2016). Edible flowers are increasingly recognized as an innovative category of plant-based food. Their sensory qualities, including aesthetic appeal and desirable aroma, alongside their nutraceutical profiles, characterized by phytochemicals and micronutrients, align with consumers' desires for novel flavors and gastronomic innovations—for instance, combining flowers with various foods, such as vegetables, meats, fish, and specialty beers or wines (Benvenuti and Mazzoncini, 2021). In European nations, the predominant application of edible flowers in human nutrition is in the preparation of hot beverages. Consumers enjoy infusions or decoctions not only for their medicinal attributes but also for their sensory qualities (Navarro-González et al., 2016; Ngoitaku et al., 2016). The incorporation of edible flowers significantly influences the color, flavor, and aesthetic of beverages and dishes (Kelley et al., 2001). Additionally, the cultivation of edible flowers meets the demands of urban agriculture, providing locally sourced ready-to-eat foods with reduced transportation impacts while enhancing urban biodiversity, particularly regarding pollinators (Eigenbrod and Gruda, 2015). The phytochemical compositions, unique aromas and textures, and vivid colors of edible flowers play pivotal roles in both the visual and health-related aspects of foods and beverages. Consequently, recent years have witnessed a surge in interest among consumers and culinary experts regarding edible flowers, leading to an escalation in their commercial value (Takahashi et al., 2019). The heightened awareness surrounding edible flowers—pertaining to their chemical compositions, bioactive presence, preservation methods, and biological characteristics—has established them as innovative raw materials for the development of nutraceutical or functional foods (Gostin and Waisundara, 2019).

Table 3. Some Edible Flowers and Their Culinary Uses

Edible Flowers	Edible Flower Image	Use in the Kitchen	References
Dianthus		It is from the Caryophyllaceae family and has many species. The species known as Chinese carnation (*Dianthus chinensis* L.) and Alpine carnation (Dianthus Caryophyllus) are among the edible ones. It attracts the attention of gastronomy chefs due to its vivid colors and spicy taste, and its flowers are used in kitchens. It is consumed raw, served in wine, and the flower petals are crystallized with sugar and usedand in decorating cakes and other foods.	Bayram, 2015; de Morais et al., 2020
Cichorium intybus L.		Its flowers are eaten fresh, its leaves are used raw in salads, cooked or boiled as a vegetable and in soups. There are varieties such as white and red chicory (Chicory) and it is also used as an hors d'oeuvre in serving food. Its roots are dried, ground and consumed as coffee.	Bayram, 2015; Vural, 2017; Pires et al., 2019
Taraxacum officinale		The leaves, roots and flowers are edible. The young flowers taste like honey and can be eaten fresh, but they become bitter when they mature. The flowers can be used in various beverages such as wine and tea, jam, jelly and salads, and the leaves can be eaten raw or cooked (boiled, fried). They are used in meat and vegetable balls and omelets. The youngest, greenest leaves are best for eating raw, while the roots are used as coffee.	Lentini and Venza, 2007; Mlcek and Rop, 2011; Vural, 2017

Viola x wittrockiana		It has a sweet aroma. It is used in the production of sugar dessert, vinegar and various dishes. Violet wine, sherbet, syrup and water are obtained from the purple violet. Its flowers are eaten fresh and provide a colorful and nutritious addition to desserts, soups, drinks, pilafs, salads and are used as a garnish.	Mlcek and Rop, 2011; Bayram, 2015; Vural, 2017; Kumari and Bhargava, 2021
Tropaeolum maju		Its taste, which resembles watercress, is described as bitter, and is therefore considered an appetizer. Its leaves and flowers are consumed raw or dried, and can also be used in the production of cakes, vinegar, liqueurs, teas and confectionery. It is served as a breakfast drink by adding it to cold milk, and it finds a place in kitchens for decoration purposes.	Şahin and Kılıç, 2009; Mlcek and Rop, 2011; Navarro-González et al., 2015; Açıkgöz, 2018; Kumari and Bhargava, 2021
Chrysanthemum		It has a slightly bitter taste. It is used in soups, drinks and consumed as tea. It is used boiled and raw in salads.	Lentini and Venza, 2007; Mlcek and Rop, 2011; Takahashi et al., 2019 Kumari and Bhargava, 2021
Bellis perennis L.		The species known by different names such as May daisy, German chamomile (*Matricaria chamomilla* L.), mini daisy are also among the edible flowers. Although their taste is a bit acidic, the flower petals can be eaten fresh, added to salads and soups, decorated desserts and widely used in tea. It attracts attention with its delicate appearance and is used in liqueur making.	Lentini and Venza, 2007 Singh et al., 2011; Vural, 2017; de Morais et al., 2020

Citrus blossoms		Citrus flowers such as orange, lemon, and tangerine, which can be consumed raw, are usually made into jam. It can be added to salads and lemonade.	Yıldırım, 2022
Allium schoenoprasum L.		The flower has a taste resembling an onion and its petals are separated and eaten, and used in main dishes, salads and sandwiches to add flavor. It is also preferred in presentations and cultivated due to its vibrant color.	Vural, 2017
Cucumis sativus L.		The very delicate flower has a scent and taste reminiscent of cucumber. It can be used in salad and drink recipes, in garnishing cold starters and desserts, and can be consumed raw.	Yıldırım, 2022
Papaveraceae		Its sherbet and jam are consumed at breakfast. It is used in making ice cream.	Şahin and Kılıç, 2009
Plum blossom		White and red plum blossoms have a sour taste and are also called Apple Blossom. They are used in salads and especially in the presentation of cold starters, desserts, cocktails and fruits. They are combined with shellfish and smoked fish.	Yıldırım, 2022
Hibiscus sabdariffa L.		The type known as Roselle is used as a sweetener and coloring agent. It is used in hot and cold drinks, wine, ice cream, chocolate, pudding, cake, dessert, jam and meat sauces.	Lu et al., 2016; Pires et al., 2019 Mulík and Ozuna, 2020

Research has consistently indicated that edible flowers have a low caloric content while being rich in vital nutrients, including minerals, vitamins, amino acids, fiber, carbohydrates, essential oils, and proteins (Rop et al., 2012; Navarro-González et al., 2015; Benvenuti et al., 2016; Grzeszczuk et al., 2018). In the past, edible flowers were commonly used in folk medicine for various health issues. Recent studies have substantiated these traditional benefits by showcasing their rich content of bioactive compounds associated with functional properties (He et al., 2015; Lu et al., 2015; Rop et al., 2012; Wetzel et al., 2010). Ancient civilizations employed edible flowers as medicinal remedies, and contemporary advancements in global research have established a scientific foundation for the medicinal advantages of these floral components. Recognized for their diverse array of nutraceutical and bioactive elements, edible flowers contain significant amounts of antioxidants, flavonoids, anthocyanins, tannins, carotenoids, terpenoids, alkaloids, and phenolic compounds (Bortolini et al., 2022; Pires et al., 2018; Skrajda-Brdak et al., 2020). With the increasing promotion of healthy lifestyles, there is a growing demand for the development of new food products. From a nutritional perspective, pigmented grains are regarded as healthy options due to their fiber content and phenolic antioxidants. Additionally, gluten-free grains are prevalent in the diets of individuals with celiac disease (Mihaylova and Popova, 2018). The visual appeal of food has emerged as a critical attribute, and edible flowers can enhance this aspect, even though they are primarily utilized as garnishing ingredients (Landi et al., 2018). The health-promoting effects of edible flowers are illustrated in Fig. 17 (Kumari and Bhargava, 2021).

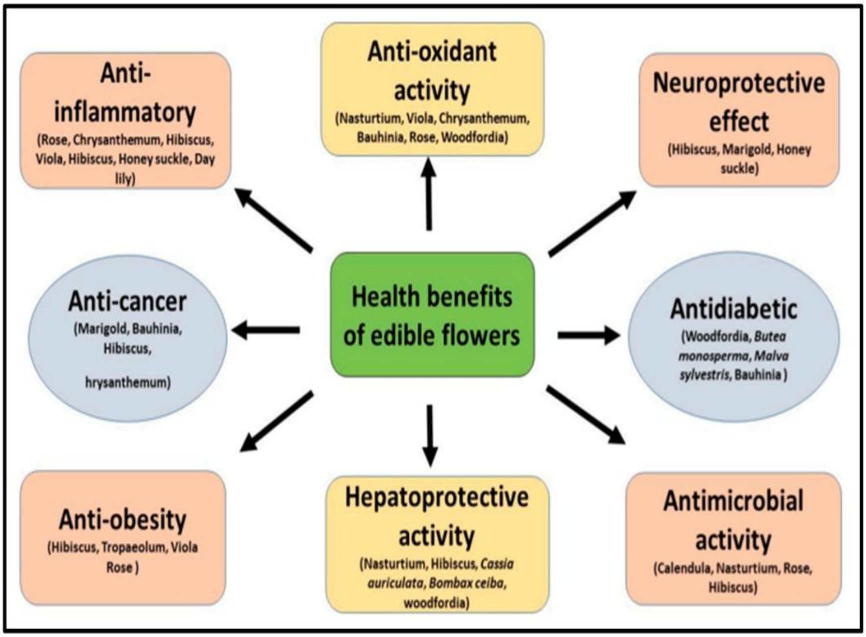


Fig. 17. Health promoting effect of edible flowers

Edible flowers present a nutritious and cost-effective source of essential nutrients, providing a potential solution to address malnutrition issues in developing countries. Within rural communities, the consumption of edible flowers is more prevalent than in urban areas, primarily due to their availability and the lack of awareness among urban populations, which often gravitate towards fast food options such as pizzas and burgers. However, the increasing awareness of health concerns is expected to shift urban consumers' focus toward healthier and more economical alternatives, including edible flowers, in the coming years (Jadhav et al., 2023).

17. DORMANCY

Developing adaptations that facilitate survival during periods of extreme environmental conditions is critical for the perpetuation of a species' lineage. For instance, the survival of individuals, structures, and organs essential for future generations during extremely cold, hot, or dry periods—varying by species—relies heavily on these adaptations. While many animal species evade extreme environmental factors through behaviors such as migration and hibernation, plants achieve similar ends through "dormancy," a state where life functions are minimized. Dormancy is a natural phenomenon occurring across all life forms, effectively halting development (Willis et al., 2014). Seeds that do not germinate within 4 to 6 weeks under optimal conditions are classified as dormant (Chen et al., 2022). Physiological, anatomical, and morphological adaptations within seeds are critical, as they influence the type of dormancy exhibited. In fact, evolutionary processes have led to a gradual increase in the embryo-to-endosperm ratio in seeds, resulting in changes in dormancy type (Finch-Savage and Leubner-Metzger, 2006). Seed dormancy, a significant characteristic in the plant life cycle, plays a vital role in the colonization and establishment success of species. The degree and type of dormancy also regulate seed germination timing, significantly affecting natural selection within populations. By postponing germination through dormancy, seeds can ensure germination occurs at the optimal period in a new location with distinct seasonal characteristics (Willis et al., 2014).

Several factors contribute to dormancy, including the impermeability of the seed coat to water and oxygen, disorders in embryo development such as failure to synthesize storage lipids, the influence of germination inhibitors, and mechanical restrictions posed by the seed testa. To overcome these suppressive factors, various physical, chemical, or physiological treatments are applied to seeds to break dormancy. Common techniques include scarification, abrasion, removal of inhibitors from the environment, application of chemical activators, and use of plant growth hormones. Abrasion is the most prevalent method for breaking dormancy in hard seeds (Bahçeci, 2012). Moreover, when seeds are subjected to high temperatures, which can damage the seed coat, abrasion is frequently employed as an alternative method (Nautiyal et al., 2023). Organisms must develop diverse defensive mechanisms to endure adverse environmental conditions. These mechanisms manifest through various methods across different species. In plants, this adaptation is often expressed through behaviors such as growth cessation and dormancy. Distinct forms of dormancy can be observed in various parts of seed plants. Dormancy, characterized by the inability of seeds to germinate even under optimal conditions (such as temperature, humidity, oxygen, and light), allows seeds to survive and adapt to environmental changes (Boyraz et al., 2019; de Casas et al., 2012; Finch-Savage and Leubner-Metzger, 2006).

While dormancy serves a beneficial role for viable seeds, extended periods of dormancy can lead to low and inconsistent germination rates, as well as diminished seed viability. Understanding the dormancy status and germination characteristics of seeds intended for hybridization studies is crucial for effective seed management (Kildisheva et al., 2020). Many plant species' seeds are unable to germinate, even under optimal conditions, unless they have undergone specific pretreatments. Identifying the underlying causes of this phenomenon, classifying the type of dormancy, and determining appropriate methods for breaking dormancy represent essential initial steps (Buijs et al., 2020; Karakurt et al., 2010).

To facilitate germination and eliminate dormancy, seeds must undergo various pretreatments prior to planting. Common methods include stratification (both cold and hot), soaking, hormone application, chemical abrasion, mechanical abrasion, washing, and dark storage. While some of these treatments can independently break dormancy in the seeds of certain plant species, others may require a combination of treatments to effectively overcome dormancy in different species (Eriş, 1990; Ercişli et al., 1997; Hartmann and Kester, 1959; Karakurt et al., 2010).

18. GERMINATION IN CEREALS AND LEGUMES

The germination of cereal and legume grains is employed to enhance their nutritional and sensory qualities. This process, historically utilized for centuries across various cultures, serves to soften the seed structure, increase nutritional value, including phenolic compounds, antioxidants, and proteins, reduce anti-nutritional factors such as protease inhibitors, non-protein amino acids, lectins, and saponins, and improve flavor. Although germination is an ancient technique, it continues to garner interest due to its potential as an ingredient in diverse products, as well as its ability to enhance food texture. The germination process, characterized by its practicality and low cost, commences with the absorption of water by dormant dry seeds and concludes with the development of the embryonic axis. The end product of germination is referred to as a sprout (Miyahira et al., 2021).

Germination represents an alternative method for making grains suitable for consumption aside from heat treatment. The sprouting process results in the formation of vegetable forms of grains, which can be consumed directly or incorporated into soups, salads, or used in baked goods. Experimental evidence indicates that the sprouts formed during germination are non-toxic in animal studies (Kavas and El, 1991; Bilgiçli, 2002; Vidal-Valverde et al., 2002; Martínez-Villaluenga et al., 2008). The biochemical composition and bioactive properties of germinated grains are influenced by various factors, including grain type, age, germination conditions (such as temperature, pH, light/dark environments, light type and intensity, and humidity), biotic stress, dormancy status, metabolic activation, gene transcription, and embryonic cell wall loosening (Cid-Gallegos et al., 2020). The germination process is implemented to enhance the nutritional value and antioxidant properties of grains. Phytochemical compounds, particularly phenolic acids, increase during germination, making grains more functional for consumers. The rich nutritional content of sprouted grains and legumes, comprising polyphenols, proteins, isothiocyanates, glucosinolates, vitamins, minerals, and antioxidants, confers disease-preventive and healing properties, positioning these sprouts within the functional food category (Reed et al., 2018). Germination is regarded as an efficient and cost-effective means to modify grain structure, augment biological activity via the synthesis of bioactive compounds, and improve nutritional quality (Singh et al., 2017).

The fundamental step in plant development from seed is germination, which entails the emergence of the embryo, enabling it to grow into a plant resembling the parental form under suitable conditions. Germination also marks the onset of cell division, elongation, and the protrusion of the radicle (Yıldız et al., 2007).

Recent research has increasingly concentrated on the germination process to elevate the content of phenolic compounds and enhance the functional properties of grains. Studies extend beyond conventional cereals to include seeds such as sorghum, purple corn, amaranth, chia, and fenugreek. Due to the enhancement of nutritional and phytochemical attributes, the proliferation of germinated seed flours in bakery products has been observed (Singh et al., 2017; Paucar-Menacho et al., 2017; Pająk et al., 2019; Chauhan et al., 2015; Jan et al., 2016). As plants progress through the development stage, the concentrations of certain anti-nutritional compounds (including protease and amylase inhibitors, lectins, and phytates) diminish, while the bioavailability of minerals increases. Activation of metabolic pathways leads to an elevation in bioactive compounds such as phenolic compounds, which exhibit antioxidant, antimicrobial, anticancer, and anti-inflammatory properties (Cid-Gallegos et al., 2020; Gómez-Favela et al., 2017). An increase in dietary fiber content is also noted, with particular emphasis on insoluble fiber potentially offering benefits in the prevention of vascular complications associated with diabetes (Cáceres et al., 2014). Furthermore, germination stimulates amylase activity in grains, facilitating the breakdown of starch and subsequently increasing the concentration of reducing sugars. During this process, grain proteins are also degraded, enhancing the soluble protein content. Post-germination and drying, malt products contain free sugars and amino acids, with germination contributing to an increased protein concentration in grains, attributed to dry weight loss due to respiration (Singh et al., 2015; Hübner and Arendt, 2013).

19. CONCLUSION

Food constitutes a fundamental aspect of consumption, essential for individuals to sustain their lives and enhance their quality of life. Consequently, numerous methods for food acquisition have been developed throughout history, with communities often migrating to discover new food sources; indeed, conflicts have arisen over access to food. The evolution of technology has been significantly influenced by these struggles for sustenance, with technological advancements playing a pivotal role in food production and its subsequent transformation. The rapid increase in the global population has led to environmental challenges, including pollution, depletion of natural resources, atmospheric warming, and climate change. In light of this growing population, the importance of food accessibility becomes increasingly critical. Therefore, it is essential for agricultural production to operate efficiently and for food resources to be utilized effectively. This necessity has spurred consumer interest in natural products, functional foods, and safe dietary supplements as alternatives to pharmaceuticals for health maintenance and the resolution of health issues. Among the emerging trends in healthy nutrition is the concept of veganism, which has gained prominence alongside other dietary models. In recent years, various nutritional trends catering to diverse consumer expectations have emerged, with raw nutrition being particularly popular among those concerned with healthy and natural eating. This trend emphasizes the consumption of foods in their natural state, minimizing exposure to high heat. Within this context, cereals and legumes play a crucial role, as they are integral to the raw nutrition philosophy. Germination not only alters the nutritional, biochemical, and sensory properties of food but also enhances its nutritional quality by reducing anti-nutritional factors. Foods derived from germinated seeds are associated with the activation of endogenous enzymes that positively impact nutritional quality compared to their ungerminated counterparts. Research indicates that germinated edible seeds exhibit a range of bioactivities, including antioxidant, antidiabetic, and anticancer effects, making germination an effective method for enhancing the health benefits of edible seeds. It is anticipated that germinated grains will emerge as foods with significant potential for future health claims and development of new products within the food industry. Recent studies have highlighted the efficacy of certain sprouted edible grains and legumes as valuable dietary supplements, underscoring the importance of their inclusion in functional food formulations as part of health strategies. Further research is warranted to fully elucidate the beneficial effects of sprouting on human health. The objective of this book is to transform existing plant products into innovative forms, creating alternatives for individuals who do not consume animal products and unveiling new product possibilities.

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