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Sustainable gastronomy: Realizing environmental benefits through plant-based proteins and smart packaging innovations

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ABSTRACT

Developing strategic scenarios in the food industry, regarding the limitations of water and food resources, can reduce costs while developing sustainable food and food security. Plant protein production as a safe source can provide proper and sustainable gastronomy. In this process the developing of new packaging systems that have high production capacity and customer attraction, and less consumption, can be desirable in enhancing sustainable gastronomy. In the current research, by examining the current situation of plant-based proteins in the world, the amount of plant-based protein production is presented. Also, we will discuss new innovations in food packaging and examine the role and importance of packaging in achieving sustainable gastronomy. It is expected that the expansion of new technologies and nanomaterials for smart packing system and other surfaces related to food will lead to their development in the future, along with the emergence of new polymeric and antimicrobial materials.

Keywords: Sustainable food, Plant-based proteins, Smart packaging, Food security.
Article type: Review Article.

INTRODUCTION

After the investment of the United Nations Assembly in 2015, the reduction of carbon gases to avoid climate change has become a global issue (McClements *et al.* 2021; Sudarmilah & Maelani 2021; Versino *et al.* 2023). Nowadays, mankind is facing unprecedented challenges caused by climate change and food insecurity in order to supply food for its growing population. In the coming decades, the world needs to significantly increase the production of basic foods to meet this demand *et al*. (Liu *et al.* 2022; Krzywonos & Piwowar Sulej 2022). This puts significant pressure on natural sources like agricultural land, energy and water resources, which are being destroyed due to environmental concerns such as climate condition, loss of biodiversity and changes in vegetation on the ground. Foods of animal origin are the cause of main amino acids and dietary protein for human nutrition. The production of traditional foods of animal origin is less sustainable and in addition to requiring a significant area of land, it causes the emission of greenhouse gases. On the other hand, the constant consumption of a diet based on animal protein is associated with some chronic diseases. A promising solution to solve this problem is

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the use of plant proteins, which are cheaper, more environmental and easy to access (Grosu *et al.* 2021). From an environmental point of view, their sustainable production has found importance and a special place in meeting the growing food needs of mankind. Since animal husbandry brings problems, alternative sources of protein including plant meat and single cell proteins are needed. Protein is an essential part of the diet that helps build muscle, repair tissue, as well as make enzymes and hormones. In fact, it is so important that its name is derived from the Latin word "protos," meaning "first," indicating the importance of this nutrient in the diet (Ishenin *et al.* 2021). Protein is often supplied by meat, but the production of animal protein is harmful to the environment and requires a lot of resources such as chemical fertilizers, fodder, land and water, while producing methane in the process. The most greenhouse gases are generated from the processing of lamb, beef, pork and farmed fish (Gunduz 2023). Efforts include improving feeding practices for better forage digestion, fertilizer management, and diversity of plant and animal species. However, climate issues are urgent and critical, and more radical solutions may be needed to ensure food availability in an environmentally sustainable manner. Therefore, the concept of alternative proteins is proposed as an attempt to replace conventional meat with other protein sources that cause less damage to the environment. Fortunately, there are alternatives as well as certain types of meat that make for a more environmentally friendly lifestyle. Fig. 1 shows some of the most important uses of legume protein in the food industry.

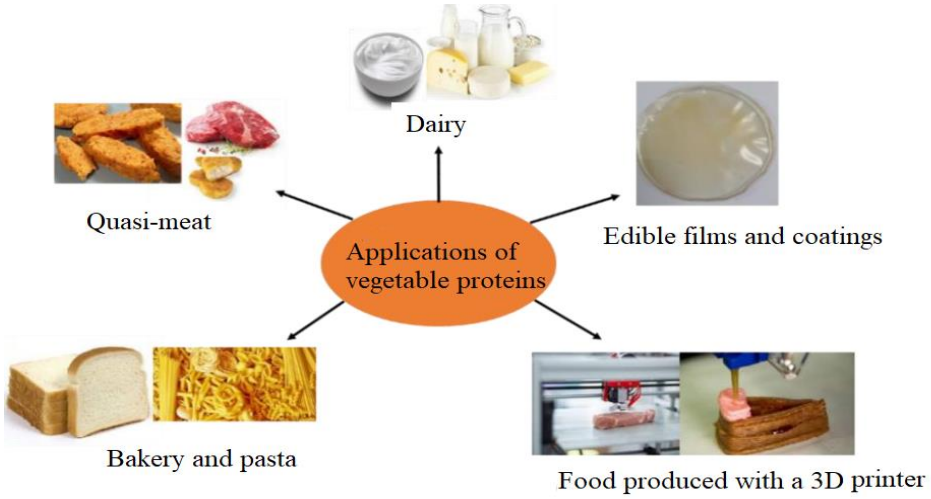

Fig. 1. Legume protein in the production of food products.

Pseudo-meats are composed employing without meat proteins, but they are similar to meat products in terms of texture and appearance. The essential part of the pseudo-meat components are textured plant-based protein, water, polysaccharides, fat, and salt, which contain 50 to 95% protein (Sirenko *et al.* 2023), and protein is the main component of the dry matter. Currently, the main sources of protein used in the formulation of pseudo-meats are soybean, mycoprotein, pea protein, egg, wheat gluten, and albumin. Legume protein is considered as a plant protein for the preparation of pseudo-meats. In recent studies, protein sources such as mung beans, beans, peanuts, and beans have been successfully used to prepare pseudo-meats (Perez Cueto 2020). However, pea protein based structures are softer compared to soybean protein based foods. So, the improvement of protein gel strength through modifications that affect protein hydrogen bonds, or by changing procedure has been studied (Sirenko *et al.* 2023). It is relatively easy to mimic the textural characteristics of minced meat products such as nuggets, burgers and sausages using textured plant-based protein. However, it is an important issue to mimic the textural characteristics of one piece muscles, such as fillet, beef steak, and seafood. The texture of pseudomeats should be similar to regular meat in cooking and chewing (shredding in the eating) to create a sensation similar to animal meat in the mouth. Many plant-based protein materials, such as bean proteins, peanut proteins, hemp proteins, soybean proteins, pea proteins, bean proteins and wheat gluten, were used in texturing by high-moisture extrusion method to make meat-like trends. A combination of pea or soybean proteins with gluten were used to produce a texture similar to chicken meat using cutting methods (Kumari *et al.* 2023).

Packaging industries in food hygiene

Over the years, the food industry has been able to respond to the demand for suitable and diverse food, and the food and beverage packaging industry has played a significant role in paving this way. Inventions such as making

glass bottles, cellophane coating, aluminum foil and plastic containers that happened in the 20th century significantly increased the flexibility of the food industry and made it more practical. Other developments, such as the use of antimicrobial or oxygen absorbent materials in the manufacture of food containers, led to the formation of a new practice in increasing the shelf life of food and protecting it from environmental influences (Hassoun *et al.* 2022). The increase in the industrial processing of food, the high volume of export and import of food products and the shortening of the preparation time of fresh food forces the food product packaging industry to look for newer and more advanced methods of packaging, protecting time and increasing the life of the material food were the main goals of the packaging industry of these products, but now the ease of use and ease of consumption has become equally important. Many new developments in the food packaging industry meet these needs. For a long time, synthetic polymers such as polyethylene terephthalate, polyvinyl chloride and polyethylene have been used as packaging materials, which occupy a market of about 12 million tons per year. The most important problem of synthetic packaging materials is the time-consuming process of their decomposition, which causes environmental pollution. On the other hand, contamination of plastic packaging materials by food or biological materials and migration from the food package are other problems of these materials that reduce food safety and change the taste. These problems have become the basis for the expansion of biodegradable packaging materials such as edible films made of polysaccharides and proteins. There is no doubt that the new approach of the packaging industry is focused on ensuring the health and quality of food along with the ease of use and sustainability of packaging. The process of globalization and the globalization of consumption markets, the mentioned factors are the most important priority for the food packaging industry

MATERIALS AND METHODS

From the point of view of botany, legumes are placed in the order of Fabales and in the family Fabaceae, Papilionaceae or Leguminaceae. As seen in Fig. 2, legumes classified in 5 groups.

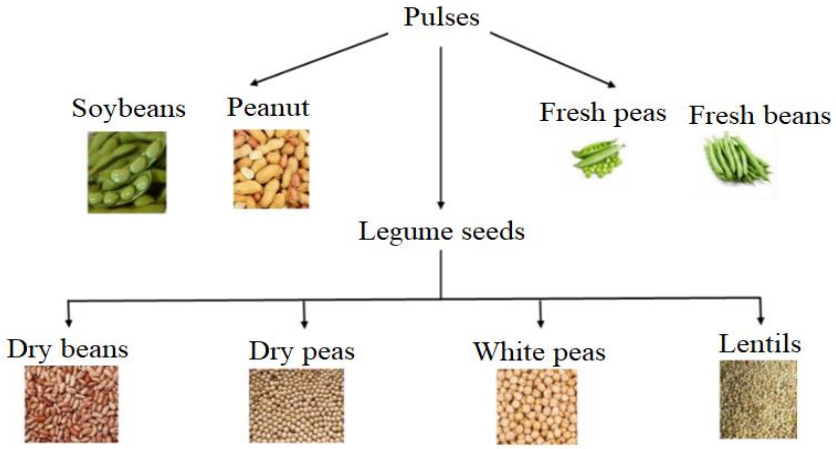

Fig. 2. plant-based proteins classification.

Legumes are one of the most important vegetable sources rich in protein and the second most important food source for humans, after cereals. Legumes include nutritious edible seeds, containing dry beans, white peas, chickpeas, and lentils. In addition to the high amount of protein about 25% (weight/weight) and other nutrients (Hassoun *et al.* 2024). It is estimated to produce 0.98 and 1.79 kg for each kg of peas and beans, respectively, which is significantly lower than 48.99 and 88.23 kg per kilogram for beef and cheese, respectively. Legumes have a significant role in improving soil fertility by having the ability to biologically fix nitrogen. Legumes are planted in rotation with many crops, and thus, by diversifying into grain-based cultivation systems. They have a special place in sustainable agriculture. Legumes grow easily and are very resistant to drought and lack of water due to their deep roots. The advantage of planting and producing legumes is that they reduce water consumption and allocation of agricultural land, minimize damage to the ecosystem, increase the yield of crops in rotation and related crops, and even generate income for small-scale farmers (Mok *et al.* 2020). These plants have low expectations and are suitable for cultivation in low-input farming systems and are effective in preventing soil

erosion as cover plants. The set of these features has placed legumes in a valuable position from agronomic, ecological and environmental aspects.

Plant-based protein extraction

Legumes are constructed of starch granules inside the protein matrix, fibers and fats. Legume protein is extracted by two common methods of dry and wet separation. In both methods, the whole bean is peeled first. In the dry method, compared to the wet method, the protein is less pure, but the dry method requires less energy and operating cost and is a more stable method. In the dry method, the primary structure of the protein and its functional properties are preserved. The wet method is more expensive, more difficult and longer. In addition, it produces a large amount of wastewater and chemicals that have a negative environmental effect.

Table 1. Some functional properties of proteins and their industrial application.

Functional properties	mechanism of action	food substance
Solubility	increasing the hydrophilic properties	Beverages
Viscosity	Hydrodynamic connection to water	Broth, salad dressing and soups
Water binding	Hydrodynamic connection to water	processed meats, cakes and breads
Jellification	3D network formation	Bakery and pasta
Increase elasticity	Establishing hydrophobic disulfide bonds	Processed meats, soups, desserts and sauces
Emulsification	Interfacial absorption, film formation	Whipped food coatings, mousse, nuggets and cakes
foaming	Interfacial absorption, film formation	bakery products
Fat binding	Binding fat and establishing hydrophobic bonds	bakery products Flavoring ingredients

The water holding capacity (WHC_1) and oil holding capacity (OHC_2) of proteins show the amount of water or the amount of oil stored per unit mass, respectively. In general, the WHC and OHC of proteins increase by elevating protein purity. WHC and OHC for legume protein isolate are between 8-7 g/g and 9-7 g/g. The water and oil absorption of chickpea protein isolate is similar to the water and oil absorption of soy protein (Mok *et al.* 2020; Popova *et al.* 2023) and OHC per water. The presence and ability to cook vegetable meats and the synergism of vegetable yogurts are affected. Emulsification activity is used in pseudo-vegetable meats to simulate adipose tissue. Emulsifiers stabilize oil droplets in plant-based emulsified foods such as sauces, plant-based milks, and plant-based creams. Plant-based proteins can stabilize the foam. Foaming features are necessary for foods that have a soft and light texture or cream. The high amount of foam formed and the good stability of the foam in chickpea isolate and concentrate make them suitable as natural soluble proteins in the continuous (aqueous) phases of food (Mihalca *et al.* 2021; Reshitov 2023).

Smart food pack

Intelligent and active food packaging, cause a delaying the environmental factors affecting food, also employs an active dynamic technique to preserve the product. In active packaging, containers contain materials that solve some problems. Oxygen absorbers, if used, absorb the oxygen in the space of the container and in this way prevent the growth of microbes and preserve the taste and quality of the food (Cruz & Boukid 2024). Such as red meat, chicken meat and cheese can be used to prevent the liquid and water accumulation of meat products in the container, condensate on the wall of the container and can limit the oxidation of fats. While active packaging includes effective methods to control oxidation, moisture and microbial growth, smart packaging makes it easy to monitor the quality of the food and labels showing product temperature over time, TTIs, reagents showing product ripeness, biological sensors and RFID tags are all considered components of smart packaging. TTI labels play an essential role in showing product health and freshness. They have it. By using this tool, you can monitor the conditions of food storage and determine the products that are suitable for consumption. This issue is especially important when the food product is exposed to inappropriate conditions such as too hot or too cold storage environment (Taufik *et al.* 2022). In the case of food products that should not be frozen, the TTI label can indicate that the food improperly exposed to below-freezing temperatures. The use of RFID systems, which consists of tags, reader devices, and computer systems, can wirelessly and remotely monitor the condition of food containers. The most important use of this system is to speed up the movement of goods and the possibility of tracking them One of the key trends in the food product packaging industry is "sustainable packaging. The meaning of sustainable packaging is the design of a special mechanism for the production and use of containers in order to

preserve non-renewable resources (Shariati *et al.* 2013). The features of sustainable packaging are listed as follows:

- Ensuring health and safety and benefiting consumers during the consumption period Having efficiency and cost according to market standards;
- The possibility of production, transportation and recycling using renewable energies;
- The possibility of production with clean technologies and the use of the best techniques;
- The possibility of effective recovery and use in all industrial and biological cycles compatible with the environment;
- It is designed in such a way that it uses primary resources and energy in an optimal way.

RESULTS

The benefits of consuming plant-based protein and meat for the environment

Animal husbandry can have dire consequences for ecological systems. But changing the diet is hard. For example, despite decades of advocacy, the percentage of Americans who follow a plant-based diet has hardly changed. In 2018, American meat consumption per capita was about two pounds higher than in US history. Plant-based meats offer a solution to this problem.

Plant-based meat consumes up to 90% less resources. Animal husbandry occupies 90% of all lands, while provide just 20% of human food supply. This inefficiency drives the need for agricultural development, which is the biggest cause of ecosystem damage on land. Plant-based meats offer a promising route to further realizing this increased efficiency.

Plant-based meats emit 30 to 90% less greenhouse gas than regular meats. Worldwide, livestock farming contributes more to greenhouse gas emissions and climate change than the entire transportation sector. Emissions from animal husbandry are produced from three main sources: conversion of forests and grasslands to pasture and cropland, production of animal feed, and animal digestion and decomposition of wastes resulting from these processes. On the other hand, the process of producing plant-based meats has very little greenhouse gas emissions and accounts for only 13-26% of climate impacts. In the same way, agricultural lands that are no longer necessary and needed for livestock feeding can be utilized to reduce climate change through reforestation, soil protection or green energies.

Plant-based meats consume 72-99% less water than regular meats. Animal husbandry accounts for approximately one-third of the water used in global agriculture. Plant-based meat production reduces the primary water requirement in conventional meat production by only requiring products that are consumed in the first stage of agriculture and end up directly in the final product. Although this process accounts for 14-45% of the total water used, the water consumption for the production of conventional animal meats is much higher than for any plant-based meat that has been studied and evaluated to date.

Plant-based meats pollute water and aquatic life 51-91% less than conventional meats. Eutrophication is a major threat to global water quality, and animal husbandry is one of the main sources of its production and increase. Eutrophication is a process in which the whole water or parts of it are gradually enriched with minerals and nutrients, especially nitrogen and phosphorus. This phenomenon creates a huge population of algae, cyanobacteria as well as aquatic plants and, in turn, reduces the dissolved oxygen in the water and thus, affects the underwater life.

Vegetarian meat does not need antibiotics. Plant-based meats do not need antibiotics, which decrease the risk of antifungal resistance that can develop from the use of fungicides on crops, as plant-based proteins meets nutritional needs with a much lower yield than what is needed to feed animals and ultimately produce conventional meats. Achieving sustainable food and nutrition systems is considered as one of the main pillars of achieving sustainable development and ensuring food security. In the chain of food production and consumption, how to preserve the environment and prevent the destruction of natural resources through the development of methods of cultivation, processing, distribution, supply and consumption in a balanced and environmentally friendly way is a question that is in front of experts and workers in the field of food, and nutrition. Given the wide dimensions of the food chain, from the gene of the food-producing cell in the farm to the table and the human cell, the answer to this question will not be so simple. As aforementioned, the use of plant-based proteins as well as the green packaging of food can be two effective factors in the development of sustainable food with environmental criteria. In order

to investigate the impact of various factors on creating a position and value for plant-based protein foods, various factors have been examined and scored by experts in this industry, which is presented in Table 2.

Table 2. Rating of food industry professionals' views regarding the effect of plant-based protein and packaging in improving food safety.

Variables	Mean	SD	Variation factor	rank
Different aromas and flavors in plant-based protein	4.12	1.21	0.32	1
Smart packaging of plant-based protein food products	3.88	1.31	0.35	2
Microbial activity control for plant-based protein food products	3.78	1.30	0.37	3
Detection of any change in plant-based protein (taste, color, smell...)	3.26	1.41	0.39	4

From the point of view of food industry experts, the prioritization of the items shows that the two factors of using the health and taste of food and employing smart packaging to display the health of food with a coefficient of variation of 0.0.32 and 0.35 are in the first and second place, respectively. They also have the highest importance coefficient.

Innovation in smart packaging of food industry

Nanotechnology is an effective and useful tool in the food packaging industry and can play a big role in maintaining food quality. Nanotechnology enables designers to change the structure of packaging elements on a molecular scale and give it desirable characteristics. The purpose of using Nano knowledge is to improve the quality and efficiency of packaging materials, to inform the consumer about tears and small holes and to repair them according to environmental conditions such as: changes in temperature and humidity and thus ensure food safety (Asadipour *et al.* 2005). Nanocomposite (Versino *et al.* 2023) refers to a special category of composites that at least one of their components is on the nano scale. Nanocomposites are a combination of polymer material as a continuous phase and nanoparticles as a dispersed phase. If the dispersed phase used in the composite is nano particles, the composite material will be nano composite. Nanobiocomposites, in addition to having a composition with nano dimensions, also have biological compounds that are biodegradable and in the environment, by means of decomposing organisms, they are converted into their own micro-units, among which biodegradable polymers, we can mention starch and its derivatives as well as bio-polyesters. The use of nanocomposites in the structure of food packaging polymers improves the storage properties of polymers. The high efficiency of nanoparticles and nanotubes has provided the basis for the use of biodegradable polymers in the food packaging industry (Cruz & Boukid 2024). Currently, one of the basic and applied categories of nanotechnology and its features in the development of packaging are the improvement of barriers in plastic materials, the mixing of effective compounds that can provide performance and has features beyond conventional active packaging, in addition, has the measurement and the relevant information signal. Materials in nano food packaging may extend the shelf life of food and improve food safety, alerting consumers to contaminated or spoiled food, preventing food from breaking into packages and even releasing substances. A preservative that is involved in increasing the shelf life of food packaging. Applications of nanotechnology in the food industry can be used to detect bacteria in packaging, produce stronger flavorings with higher color quality, and increase safety by enhancing defensive or barrier properties (Taufik *et al.* 2022).

Sustainable food

The agricultural aspect of a sustainable diet is the starting point of a sustainable food and nutrition system, because it includes the production and process of food, and other aspects of a sustainable diet, such as environmental, cultural, economic, and health, affected by it (Agusmidah & Shalihah 2023). The Green Revolution was strengthened in the 1950s and 1960s, and with the industrialization of agriculture, it led to an increase in production and access to food, however, it resulted in adverse effects such as climate changes, loss of biodiversity, loss of land, soil and fresh water. Agriculture affects both the health dimension and vise versa. Agriculture, by producing sufficient and healthy food, guarantees the health of the body, which in turn increases the efficiency and improves the performance of humans (Cao *et al.* 2020). The level of income and the way of distribution of income at the level of society as two indicators of the economic situation determine the economic access to diet. People with higher income levels can afford more varied and nutritious foods. In addition, countries that have a

higher income level provide people with sufficient and higher quality agricultural products with better investment. On the other hand, the social and food support policies of the countries have an effect on the economic access and availability of food (Mironescu *et al.* 2021). Native foods of developing countries, which as a result disrupts the market of native foods, are mostly healthier choices (Landesz 2023). Another dimension of a sustainable diet that should be considered is the socio-cultural dimension. Food is not only consumed as a nutritional needs remover, but the consumption of food in different societies brings a positive social feeling that is tied to the cultural and religious beliefs of the people of those societies. For instance, the diet which is mainly vegetarian in India has been influenced by the beliefs of Hindus, or the fact that the main strength of Mexicans is from corn originates over centuries of cultivation of this product among the natives. Therefore, paying attention to the social and cultural dimension of food in a sustainable diet is one of the important dimensions of a sustainable diet. Environment and ecosystem also affect what people eat. Ecosystem, which is defined as a complete set of relationships of living organisms in a specific area, includes plants, animals, microorganisms, water, soil, and humans. All these components affect each other in a dynamic structure and the lack of one endangers the stability of the system. What people consume can be effective on water consumption, biodiversity and global warming, and on the other hand, the loss of the environment puts the whole system of a sustainable diet out of balance (Hira & Husnain 2023). Considering such factors and based on the FAO definition, the framework of Fig. 3 for a sustainable diet was compiled. This framework shows the main dimensions, components, factors and process of a sustainable diet. The leaf shape of this figure shows the main components of a sustainable diet according to the definition of FAO in 2010 (Brennan *et al.* 2022). These main components include (1) welfare and health; (2) Biodiversity and environmental issues; (3) Equity, and fair trade; (4) Ecosystem-appropriate, local, and seasonal foods; (5) Cultural heritage and skills; (6) Food needs, food security, and availability; and (7) Packaging system. The main is directly connected to the central pink circle that represents the sustainable diets. Recently, it has been assumed that all components have equal weight in influencing what constitutes a sustainable diet.

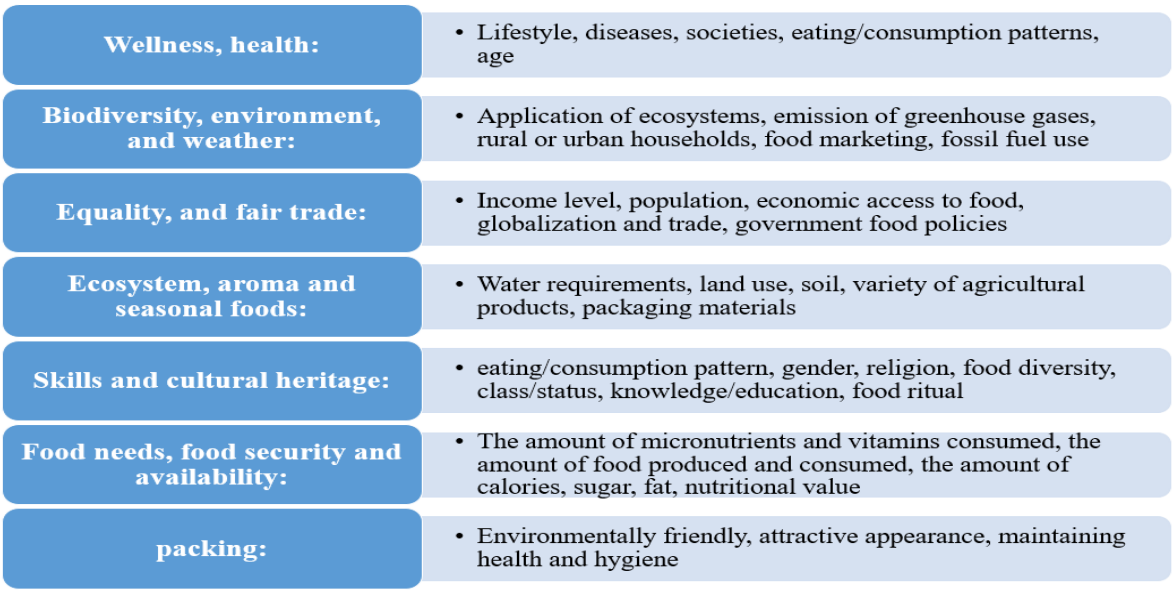

Fig. 3. The conceptual framework of a sustainable diet according to the definition of FAO.

CONCLUSION

It is necessary that the current diet of the world be changed towards a more sustainable one. A sustainable diet can bring environmental and economic sustainability through foods with less biological effects, stress-resistant, as well as supportive of public health and healthy nutrition. From food production to consumption, we should provide food security for the people of the world. In this article, two factors affecting the environment and sustainable food have been investigated. Saving the food chain can be done with plant-based proteins, and by using smart and green packaging, you can take an effective step in sustainable food. Due to their easy access, stable production, suitable nutritional value and their use in a wide range of foods, leguminous proteins are a suitable option to use instead of animal protein. In addition, the proteins in legumes have good functional

properties, so that new food products can be produced using these proteins, and the proteins extracted from different legumes are well responsive to the increasing demand of plant-based protein consumers in the food industry. Therefore, the most important and main strategy to increase the consumption of leguminous protein is to enhance the awareness of consumers about the potential nutritional and healthy of leguminous compounds and their impact in sustainable food production, which can be achieved by using smart packaging of these materials, food to be obtained.

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