



Received for publication, July, 20, 2022  
Accepted, September, 5, 2022

## Review

# The use of mushrooms as source of protein in market products

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## Abstract

To satisfy the needs of a growing population as well as changing dietary habits, the food industry is looking for alternative sources of protein that are sustainable and better for the environment than those of animal origin. Plant protein sources are therefore very promising. However, some of them do not have all the essential amino acids and are therefore considered as low quality protein sources. Nevertheless, mushrooms are plants that generally have a complete profile of essential amino acids. For this reason, edible mushrooms are an interesting protein source for the food industry, which can use them to create high-quality protein-enriched food products. This review will therefore discuss the use of mushrooms as sustainable functional foods and more specifically as an alternative protein source in protein bars.

## Keywords

mushrooms, protein bars, protein content, vegetables

**To cite this article:** HERVOUET LOUISE. The use of mushrooms as source of protein in market products. *Rom Biotechnol Lett.* 2022; 27(4): 3575-3582 DOI: 10.25083/rbl/27.4/3575.3582

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## Introduction

Today, food products with a specific functional property are more and more in demand. It is the case in particular of the products rich in protein which are strongly present on the food market (MALECKI & al).

Indeed, proteins are basic macronutrients in the human diet necessary for the proper functioning of the body and the maintenance of a good nutritional status. (PAUL & al) They have different functions and properties depending on their structure, such as ensuring growth in children, supporting bone and muscle metabolism, contributing to the maintenance of the nervous system or helping to maintain muscle mass and physical performance in old age. It is therefore necessary to include an adequate amount of protein in the diet every day to maintain good health. Protein is found in meat, fish, eggs, dairy products and vegetables (EWY & al).

Because of this great interest in high-protein products, the food industry is developing protein bars. The objective of these bars is to reinforce the nutrient intake. Its consumption is a simple and effective solution to distribute and complete the daily protein intake. They are strongly consumed by athletes to maintain muscle integrity but can also be recommended to avoid deviations during a vegan or vegetarian diet.

Manufacturers are constantly developing new recipes to meet the consumer demands. Indeed, the eating habits have not stopped changing in recent years. For this reason, alternatives are being thought to replace commonly used protein source ingredients to create innovative products that are in line with current trends in healthy, functional, sustainable, ethical and environmentally friendly nutrition. (SPARKMAN & al)

Nowadays, the protein bars that are mostly found on the market contain animal proteins because of their high nutritional value, desirable sensory properties and excellent functional properties. However, for some time now, alternative protein sources such as vegetable proteins started showing interest. They have been increasingly used as an economical alternative to replace animal sources in the face of a rapidly growing world population, but also as functional ingredients for the formulation of food products. (CONZUELO & al).

More specifically, edible mushrooms are among the promising ingredients as a protein source. Thanks to their nutritional value, which is highly appreciated because they are low in fat, calories and carbohydrates but high in fiber and protein, they are very interesting ingredients for the food industry (ZHANG & al. ). Moreover, their proteins have a complete profile in essential amino acids which allows to

meet the nutritional needs of the human being and to consider them as a source of high quality protein (GONZALEZ & al). It is also an economical protein source that can be easily produced on a large scale, unlike other plant and animal protein sources. They are now used to develop varieties of food products enriched with high quality protein. (KAUR & al)

The objective of this review paper is therefore to present mushrooms as a new protein source in protein bars.

## Materials and Methods

This review paper is based on a literature review that investigated recently published research articles and studies that have been made in the past decade regarding plant protein sources used in order to obtain high protein based vegetables products, such as high protein bars. The research was focused on vegetables like mushrooms, broccoli, asparagus, string beans, eggplants which are a rich protein source for the food industry, which can be used to create high-quality protein-enriched food products.

The content analysis of the reviewed articles was focused on the scope of analysis and classifying them into several directions: proteins as basic macronutrients in the human diet necessary for the proper functioning of the body, health effects of vegetarian diets, current trends in healthy, functional, sustainable, ethical and environmentally friendly nutrition, functional ingredients for the formulation of food products, edible mushrooms as the promising ingredients as a protein source and evaluation of functional and nutritional potential of a protein concentrate from mushrooms.

Web of Science, Wiley, Elsevier and Springer databases were electronically searched for articles and the literature search included document types such as: research articles and reviews.

## Discussion

### Proteins as basic macronutrients in the human diet necessary for the proper functioning of the body

Vegetable proteins are very interesting from a health and environmental point of view. The health benefits are related to dietary fiber, vitamins, minerals and phytochemicals in plants. However, it is not possible today to distinguish the health benefits of plant proteins in particular from those of plant foods in general (Ahnen et al., 2019).

Proteins are one of the essential macronutrients for human nutrition and health. Depending on their digestibility, amino acid profile, bioavailability or purity, the nutritional quality changes. To meet human needs, ingesting plant proteins can provide enough essential amino acids. In recent years, plant proteins have gained momentum. Due to the in-

creasing needs of the population, proteins of animal origin will no longer be sufficient and it will be necessary to use plant proteins (Kumar et al., 2022).

One of the essential macronutrients of the human body is protein. They are at the origin of many functions and are made up of 20 amino acids, 9 of which cannot be synthesized by the human body. These 9 amino acids must therefore be ingested through food in order to avoid any deficiency (Ewy et al., 2022). They are found in proteins of animal origin but also in small quantities in vegetable proteins. However, more and more people are following diets based on vegetable proteins. Ewy & al. have shown that the consumption of meat in large quantities leads to a high intake of saturated fats and a low intake of fiber.

In Europe, protein-rich foods and food products with specific functional properties are increasingly present on the food market. Malecki & al. show that proteins are increasingly popular ingredients and are attracting more and more attention from the consumer. This is why conventional sources are seeing alternative sources coming in.

### **Vegan or vegetarian diet**

Vegetarian diets are known to improve the health state of the people. Parker & al. qualitatively compared quality of vegetarian and non-vegetarian diets. They showed that vegetarians generally met the nutritional recommendations better than non-vegetarians. Mariotti & al. state that protein-rich foods such as legumes and seeds are sufficient to obtain a complete protein intake in adults following a vegetarian diet. Rogerson 2017 stated that the vegan diet is becoming more and more accepted in the fitness and sports domain.

### **Health effects of vegetarian diets**

Plant-based diets are recommended because of the health benefits, sustainability and ethical aspect. The consumption of meat rich in saturated fats is said to lead to cardiovascular disease and certain types of cancer. However, plant-based diets reduce the risk of chronic diseases, diabetes, obesity. In addition, they have a lesser impact on the environment: reducing land use, greenhouse gas emissions, water consumption. Plant-based diets therefore help reduce chronic diseases while reducing the impact on the environment and cruelty to animals (Lynch et al., 2018; Jenkins et al., 2019).

Plant-based diets are known to improve health but also to improve the performance of various types of exercises due to the high level of carbohydrates and the high concentration of antioxidants and phytochemicals. However, some plants have anti-nutritional factors. It is therefore necessary to carefully plan plant-based diets to ensure good health (Shaw et al., 2022).

The origin of the dietary proteins we consume determines the degree of insulin sensitivity. In diabetes, it is therefore recommended to reduce meat consumption and increase vegetable proteins to improve insulin sensitivity. Indeed, animal proteins activate the secretion of glucagon and increase insulin resistance while vegetable proteins increase insulin sensitivity (Adeva-Andany et al., 2022). In renal disease, a high-protein diet showed accelerated renal deterioration and a low-protein diet showed protein malnutrition. For this reason, vegetarian diets are a good alternative to stop the progression of kidney disease while maintaining proper nutrition (Bernstein et al., 2007). Bernstein et al., 2007 conducted a review in order to compare the effects of plant and animal proteins on renal function. It has been shown that the effects of animal and vegetable proteins are different but not well understood.

A review made by Herpich et al., 2022 summarizes the results of people following a plant-based diet and presents the limitations of this diet. Studies showed that mortality rates were lower than when the diet was regularly fed with meat. Plant-based diets are shown to be healthier. People show an improved metabolic and inflammatory profile and a lower incidence of cardiovascular disease. However, this type of diet leads to deficiencies and in particular to a lower protein intake. This type of diet is therefore not appropriate for people over 65 years of age who need more protein (Herpich et al., 2022).

Craig & al. state that a properly planned vegetarian diet is nutritionally adequate. In addition, a vegetarian diet can promote health and reduce the risk of chronic disease because of the low intake of saturated fat and cholesterol and the high intake of fiber. Nutrients that are often low in the vegetarian diet are vitamin B, vitamin D, calcium, iron and zinc. Vegetarians often have lower body mass index, total cholesterol and blood pressure than non-vegetarians.

Kahleova et al., 2017 carried out a study regarding cardiovascular diseases, which are a very important health problem today. Vegetarian and vegan diets are an effective prevention strategy to avoid these diseases thanks to the better intake of nutrients. These diets reduce the risk of type 2 diabetes by 50% and coronary heart disease by 40%. Plant-based diets are therefore good for the health of the consumer if they are well planned. They also allow the reversal of atherosclerosis and the reduction of lipids in the blood.

A lot of research on the health effects of plant-based diets is underway. However, it is difficult to assess the effects of nutritional factors on bone. However, plant-based diets can alter the balance of macro- and micro-nutrients as well as alter the inflammatory and immune response. According to various studies, there is no difference in bone health between

vegetarians and non-vegetarians, provided that vitamin D and calcium intake is sufficient. Furthermore, theoretical results have shown that the plant-based diet can reduce the risk of osteoporosis by mechanisms that are not well understood today (Hsu, 2020).

Plant-based diets allow the development of innovative preventive strategies against obesity, eating disorders and associated comorbidities. However, no conclusion can be drawn on the cerebral effects and on cognitive functions because this subject remains unexplored (Medawar et al., 2019).

### **Current trends in healthy, functional, sustainable, ethical and environmentally friendly nutrition**

Vegetables proteins are a possible alternative to animal proteins because they are abundant, inexpensive, sustainable, low in allergens and accepted by consumers. Goldstein & al. showed that the techno-functional properties of legumes varied from one legume to another and could allow to replace animal proteins in food. Today, alternative protein sources are already a global trend in the food industry. Alternative protein sources allow the development of new products in the consumer market (Otero et al., 2022).

Susman et al., 2022 carried out a study in which gluten-free rice cookies from buckwheat and sorghum flour and enriched with pea protein powder were made and their physicochemical and sensory proprieties were analyzed. The results showed that samples that had 20% and 30% of buckwheat or sorghum flour had better sensory attributes compared to the control samples. Also, the protein content was higher because of the above mentioned raw materials added.

### **Functional ingredients for the formulation of food products**

Today, legumes are more and more used in the food industry to replace cereals. Thanks to their functional characteristics, legume flours can be used to make healthier snacks by replacing cereal flours. However, it is necessary to find the most appropriate combination of flours so as not to modify the qualitative and sensory properties of the snacks (Tas & Shah, 2021).

Mushrooms have long been used for food purposes. They are sources of compounds that could be used to improve human health. Indeed, mushrooms possess for example ergothioneine. This is an antioxidant molecule that boosts human health and can preserve food. This favors the use of mushrooms as functional foods (Martinez-Medina et al., 2021).

Vadnerker et al., 2022 studied the characterization of an exopolysaccharide (ESP) produced by *Ganoderma* sp for its antioxidant and antitumor activity. The analysis performed in this study were TLC, HPLC, NMR and FTIR and the re-

sults showed that the EPS produced by the *Ganoderma* sp positively affects tumor cell growth reduction.

### **Edible mushrooms as the promising ingredients as a protein source**

Mushrooms have always been interesting foods because of their rich composition in nutritive and bioactive compounds. Lopez-Hortas & al. discuss the use of edible mushrooms in food and especially in novel foods.

The recent developments and prospect in the high-valued utilization of edible fungi are discussed and summarized by Zhang, et al. The objective of this review is to improve the understanding of health-promoting properties of edible fungi, and provide reference for the industrial production of edible fungi-based health products. Edible fungi are large fungi with high added value that can be utilized as resources; they are rich in high-quality protein, carbohydrate, various vitamins, mineral elements and other nutrients, and are characterized by high protein, low sugar, low fat and low cholesterol. In addition, edible fungi contain a variety of bioactive substances, such as polysaccharides, dietary fiber, steroids, polyphenols; most of these compounds have antioxidant, anti-tumor and other physiological functions (Zhang et al., 2021).

Trujillo et al., 2021 carried out a study in which they studied the antioxidant capacity and protein content of edible mushrooms on the longevity of the fruit fly (*Anastrepha ludens*).

For thousands of years mushrooms have been used as food or medicine. Mushrooms are good sources of protein. They have no cholesterol and a low fat content. Some mushroom proteins have specific interesting biological activities such as pectins, fungal immunomodulatory proteins, ribosome inactivating proteins or ribonucleases. Some proteins have become natural anti-tumor, anti-viral or anti-microbial agents (Xu et al., 2011).

Spim et al., 2021 carried out a research article which presents the attributes of mushrooms, their relevance for the food industry and the possible development of innovative protein-rich products from mushrooms. In recent years, mushrooms have become interesting functional plants. Thanks to their nutritional composition, notably their low fat content and their high fiber and protein content, as well as their natural source of food molecules such as ergosterol, polyphenols, mannitol, trehalose. These are interesting ingredients for the food industry. They have already been used in formulations of meat and starch based products but not for alternative products without meat for example. Their functional performances must be explored (Spim et al., 2021).

Kaur & al. recognize mushrooms as an excellent source of protein but also of minerals, unsaturated fatty acids, poly-

saccharides and other secondary metabolites. Mushrooms differ from other plant and animal protein sources because their amino acid profile is complete. This complete profile makes mushrooms a good quality protein source that meets the nutritional needs of humans. In addition, mushrooms protect against certain chronic diseases. For example, thanks to their low calorie, carbohydrate, fat and sodium content, they can be used to treat cardiovascular and kidney diseases. In addition, they can be used to treat neurological diseases such as Parkinson's or Alzheimer's or certain cancers. Edible mushrooms are used today in the food industry to improve the functional properties of certain protein-enriched food products.

### Evaluation of functional and nutritional potential of a protein concentrate from *Pleurotus ostreatus* mushrooms

Mushrooms have antibacterial activity and are a good immune system enhancer. Also it was discovered that the consumption of mushrooms could lower the cholesterol levels; Additionally, they are important sources of bioactive compounds (Valverde et al., 2015).

Torres-Martínez et. al., 2022 stated in a research article that edible mushrooms as an important source of nutritional and bioactive compounds. The results of research show that *Pleurotus* spp. are an important source of proteins and amino acids, carbohydrates, minerals, and vitamins. In this review, the findings of macronutrients, bioactive compounds, antioxidant activity, and antimicrobials against foodborne pathogens of some *Pleurotus* spp., as well as their potential use as an ingredient in the meat industry are discussed. The presence of some bioactive components, such as polysaccharides ( $\alpha$ -glucans,  $\beta$ -glucans, and so on), proteins/enzymes and peptides (eryngin, pleurostrin, and others) phenolic acids (p-coumaric, chlorogenic, cinnamic, ferulic, gallic, protocatechuic, and others) and flavonoids (chrysin, naringenin, myricetin, quercetin, rutin, or the like) has been demonstrated. The use of *Pleurotus* spp. in some meat and meat products (patties, sausages, paste, and suchlike) as a novel ingredient in order to improve their chemical composition and functional health promoting properties, as well as to increase their physicochemical and sensory attributes, was evidenced by several works.

González et al. ., 2021 carried out a study on edible mushrooms. They are an interesting alternative source of protein to conventional sources of protein. The purpose of this article is to characterize and evaluate the nutritional and functional properties of a *Pleurotus ostreatus* mushroom flour protein concentrate. The results showed that the total phenolic content decreased increasing protein digestibility.

To cope with rapid population growth, it is necessary to develop strategies to meet the needs of the population. As far as proteins are concerned, they are mainly provided by proteins of animal origin. For this reason, researchers are interested in alternative, low-cost, under-exploited sources: plant proteins. However, not all plant proteins are considered to be of high quality because they do not contain all the essential amino acids. Mushrooms are one of those foods of vegetable sources that have a complete profile of essential amino acids. They can therefore meet the nutritional needs of humans. Moreover, by processing, it is possible to obtain high quality protein-enriched products from mushrooms. Gonzalez & al. show that mushrooms are sustainable functional foods that can be used in the food industry.

### Technology and challenges

The current status of legislation, standard setting, and regulatory acceptance of meat alternatives were reviewed by Zhang et. al., 2022. Considerable progress has been made towards the development and production of meat alternatives, including cultured meat, plant-based meat alternatives, microbial protein, edible fungi, microalgae, and insect protein. Meat production has long suffered from practical problems, such as high resource consumption, pollution, animal antibiotic residues and zoonotic diseases. The meat-based diet has been criticized for a high carbon footprint not only for inefficient production processes, but also for potential nutritional unbalance. Considerable progress has been made towards the development and production of meat alternatives, including cultured meat, plant-based meat alternatives, microbial protein, edible fungi, microalgae, and insect protein.

One of the current challenges is the reduction of meat consumption and the development of new sustainable and healthy meat products. Mushrooms are a promising source of bioactive compounds to solve this problem (Gupta et al., 2018). Pérez-Montes & al. show that different species of mushrooms allow the improvement of protein and fiber contents in meat products. Moreover, they show that mushrooms can replace salt, phosphates, proteins and fats in the formulation stage of meat products due to their high fiber content, texture and easily digestible proteins.

Vegetable proteins have major advantages compared to animal proteins: a sustainable origin, an economical low cost, health benefits. Plant proteins have inferior functions that make them less soluble in water, sensitive to environmental stress, pH, temperature and salt. Vegetable proteins are poorly digestible because they are surrounded by hemicellulose or lignin or other polysaccharides. It is possible to modify plant proteins to improve their applications and make them more accessible. It is possible to modify them by

improving their flavor, nutrition or techno-functional attributes to improve their application in plant-based food products (Nasrabadi et al., 2021).

The development of plant-based protein products in place of animal-based proteins must be equally nutritious. However, the quality and protein content in plants varies according to the source. Conzuelo & al. have created a model in order to create food products of plant origin that can be used for long term consumption. Moreover, it is still possible to improve the device in the future. A great potential for expansion is possible for example to model menus or even whole diets.

Known for their low lipid but high protein composition as well as their vitamin and mineral content, *Lentinula edodes* (shiitake mushrooms) are the second most cultivated edible mushrooms in the world. Spim et al., 2021 carried out a research study in which were created and evaluated four food bars (two sweet and two savory) containing this mushroom. To create the bars, the binding ingredients were heated and then the dry ingredients were added. Each bar was developed and then underwent a sensory analysis of texture, aroma, taste, appearance and purchase intention. In addition, an evaluation of the moisture content, lipids, carbohydrates, proteins, chemical elements composition was performed. After analysis of the results, the sweet bars presented very good results. They are an easy alternative to add functional ingredients beneficial to health thanks to their stability, good acceptance and low production cost.

Erjavec & al. consider fungi as a promising source of new bioactive proteins for use in biotechnology, medicine and agriculture. Indeed, mushrooms contain proteins with unique characteristics such as lectins or protease inhibitors. These proteins can be the solution to several current problems: resistance to microbial drugs, low crop yields, and the demand for renewable energy. Mushrooms are therefore a valuable source with great potential.

Xu & al. discuss the potential of these proteins in biomedicine and their future prospects. Many species of mushrooms are excellent sources of protein because of their low fat and cholesterol content. Among these proteins, some are biologically interesting due to their action. We can mention lectins, fungal immunomodulatory proteins, ribosome inactivating proteins, ribonucleases, laccases and other proteins. These proteins have thus become natural antitumor, antiviral, antimicrobial, antioxidant and immunomodulatory agents.

Motta & al. show through experiments the effects of these proteins on human immune cells. The fungal compounds induce biochemical changes in macrophages, dendritic cells, T cells and NK cells. Further studies are needed, but mushroom compounds could be useful for human health.

## Conclusions

The use of mushrooms as a protein source in food products is proving to be very interesting. From an environmental, ethical, health and sustainable point of view, proteins from edible mushrooms seem to be a good alternative of sustainable functional ingredient. Indeed, they allow replacement of proteins of animal origin which nowadays do not seem sustainable. Moreover, thanks to their attractive nutritional properties and their specific functional properties, mushrooms are the plants of major interest for their proteins with a complete amino acid profile. They are increasingly used in the food industry to replace mainly proteins of animal origin. They are found in particular in food products enriched with proteins such as protein bars. In a few years, proteins from edible mushrooms will probably be more present on the market. More generally, plant proteins will certainly take over from animal proteins in order to satisfy the overall needs of the growing population and achieve sustainability in terms of protein demand.

## Conflict of Interest

The author has no conflict of interest to declare.

## References

1. Adeva-Andany, M. M., Fernández-Fernández, C., Carneiro-Freire, N., Vila-Altesor, M., & Ameneiros-Rodríguez, E. (2022). The differential effect of animal versus vegetable dietary protein on the clinical manifestations of diabetic kidney disease in humans. *Clinical Nutrition ESPEN*.
2. Ahnen, R. T., Jonnalagadda, S. S., & Slavín, J. L. (2019). Role of plant protein in nutrition, wellness, and health. *Nutrition reviews*, 77(11), 735-747.
3. Bernstein, A. M., Treyzon, L., & Li, Z. (2007). Are high-protein, vegetable-based diets safe for kidney function? A review of the literature. *Journal of the American Dietetic Association*, 107(4), 644-650.
4. Conzuelo, Z. R., Robyr, R., & Kopf-Bolanz, K. A. (2022). Optimization of Protein Quality of Plant-Based Foods Through Digitalized Product Development. *Frontiers in Nutrition*, 9.
5. Craig, W. J. (2010). Nutrition concerns and health effects of vegetarian diets. *Nutrition in Clinical Practice*, 25(6), 613-620.
6. Erjavec, J., Kos, J., Ravnikar, M., Dreo, T., & Sabotič, J. (2012). Proteins of higher fungi—from forest to application. *Trends in biotechnology*, 30(5), 259-273.
7. Ewy, M. W., Patel, A., Abdelmagid, M. G., Mohamed Elfadil, O., Bonnes, S. L., Salonen, B. R., . . . & Mun-

- di, M. S. (2022). Plant-Based Diet: Is It as Good as an Animal-Based Diet When It Comes to Protein?. *Current nutrition reports*, 1-10.
8. Goldstein, N., & Reifen, R. (2022). The potential of legume-derived proteins in the food industry. *Grain & Oil Science and Technology*.
9. González, A., Cruz, M., Losoya, C., Nobre, C., Loredó, A., Rodríguez, R., . . . & Belmares, R. (2020). Edible mushrooms as a novel protein source for functional foods. *Food & function*, 11(9), 7400-7414.
10. González, A., Nobre, C., Simões, L. S., Cruz, M., Loredó, A., Rodríguez-Jasso, R. M., . . . & Belmares, R. (2021). Evaluation of functional and nutritional potential of a protein concentrate from *Pleurotus ostreatus* mushroom. *Food Chemistry*, 346, 128884.
11. Gupta, S., Summuna, B., Gupta, M., & Annepu, S. K. (2018). Edible mushrooms: cultivation, bioactive molecules, and health benefits. *Bioactive molecules in food*, 1, 1-33.
12. Herpich, C., Müller-Werdan, U., & Norman, K. (2022). Role of plant-based diets in promoting health and longevity. *Maturitas*.
13. Hsu, E. (2020). Plant-based diets and bone health: sorting through the evidence. *Current Opinion in Endocrinology, Diabetes and Obesity*, 27(4), 248-252.
14. Jenkins, W., Jenkins, A., Jenkins, A., & Brydson, C. (2019). *The portfolio diet for cardiovascular disease risk reduction: an evidence based approach to lower cholesterol through plant food consumption*. Academic Press.
15. Kahleova, H., Levin, S., & Barnard, N. (2017). Cardio-metabolic benefits of Plant-based diets. *Nutrients*, 9 (8), 848.
16. Kaur, J., Singh, J., Bhaduriya, V., Gogna, S., Jarial, S., Rasane, P., & Sharma, K. (2022). Edible mushrooms: A source of quality protein. In *Wild Mushrooms* (pp. 169-192). CRC Press.
17. Kumar, M., Tomar, M., Punia, S., Dhakane-Lad, J., Dhupal, S., Changan, S., . . . & Kennedy, J. F. (2022). Plant-based proteins and their multifaceted industrial applications. *LWT*, 154, 112620.
18. López-Hortas, L., Flórez-Fernández, N., Torres, M. D., & Domínguez, H. (2022). Update on potential of edible mushrooms: high-value compounds, extraction strategies and bioactive properties. *International Journal of Food Science & Technology*, 57(3), 1378-1385.
19. Lynch, H., Johnston, C., & Wharton, C. (2018). Plant-based diets: Considerations for environmental impact, protein quality, and exercise performance. *Nutrients*, 10(12), 1841.
20. Małecki, J., Muszyński, S., & Sołowiej, B. G. (2021). Proteins in food systems—Bionanomaterials, conventional and unconventional sources, functional properties, and development opportunities. *Polymers*, 13(15), 2506.
21. Mariotti, F., & Gardner, C. D. (2019). Dietary protein and amino acids in vegetarian diets—A review. *Nutrients*, 11(11), 2661.
22. Medawar, E., Huhn, S., Villringer, A., & Veronica Witte, A. (2019). The effects of plant-based diets on the body and the brain: a systematic review. *Translational psychiatry*, 9(1), 1-17.
23. Motta, F., Gershwin, M. E., & Selmi, C. (2021). Mushrooms and immunity. *Journal of autoimmunity*, 117, 102576.
24. Nasrabadi, M. N., Doost, A. S., & Mezzenga, R. (2021). Modification approaches of plant-based proteins to improve their techno-functionality and use in food products. *Food Hydrocolloids*, 118, 106789.
25. Otero, D. M., Mendes, G. D. R. L., da Silva Lucas, A. J., Christ-Ribeiro, A., & Ribeiro, C. D. F. (2022). Exploring alternative protein sources: evidence from patents and articles focusing on food markets. *Food Chemistry*, 133486.
26. Parker, H. W., & Vadeloo, M. K. (2019). Diet quality of vegetarian diets compared with nonvegetarian diets: a systematic review. *Nutrition reviews*, 77(3), 144-160.
27. Paul, G. L. (2009). The rationale for consuming protein blends in sports nutrition. *Journal of the American College of Nutrition*, 28(sup4), 464S-472S.
28. Pérez-Montes, A., Rangel-Vargas, E., Lorenzo, J. M., Romero, L., & Santos, E. M. (2021). Edible mushrooms as a novel trend in the development of healthier meat products. *Current Opinion in Food Science*, 37, 118-124.
29. Rogerson, D. (2017). Vegan diets: practical advice for athletes and exercisers. *Journal of the International Society of Sports Nutrition*, 14(1), 36.
30. Shaw, K. A., Zello, G. A., Rodgers, C. D., Warkentin, T. D., Baerwald, A. R., & Chilibeck, P. D. (2022). Benefits of a plant-based diet and considerations for the athlete. *European Journal of Applied Physiology*, 1-16.
31. Sparkman, K., & Joyner, H. S. (2019). Impact of formulation on high-protein bar rheological and wear behaviors. *Journal of texture studies*, 50(6), 445-455.
32. Spim, S. R. V., Pistila, A. M. H., Pickler, T. B., Silva, M. T., & Grotto, D. (2021). Effects of Shiitake Culinary-Medicinal Mushroom, *Lentinus edodes* (Agaricomycetes), Bars on Lipid and Antioxidant Profiles in Individuals with Borderline High Cholesterol: A Double-Blind Randomized Clinical Trial. *International Journal of Medicinal Mushrooms*, 23(7).

33. Susman, I. E., Multescu, M., Stamatie, G., Culetu, A., Popa, M. E. (2022). Buckwheat vs. Sorghum flour in gluten-free rice cookies enhanced with pea protein powder. *Scientific Bulletin. Series F. Biotechnologies*, Vol. XXVI, No. 1, 104 – 107.
34. Tas, A. A., & Shah, A. U. (2021). The replacement of cereals by legumes in extruded snack foods: Science, technology and challenges. *Trends in Food Science & Technology*, 116, 701-711.
35. Torres-Martínez, B. D. M., Vargas-Sánchez, R. D., Torrescano-Urrutia, G. R., Esqueda, M., Rodríguez-Carpena, J. G., Fernández-López, J., . . . & Sánchez-Escalante, A. (2022). Pleurotus Genus as a Potential Ingredient for Meat Products. *Foods*, 11(6), 779.
36. Trujillo, K. G., Sánchez, J. E., Guillén, K., de la Rosa, A. P. B., & Liedo, P. (2021). Edible Mushroom Protein Content and Antioxidant Capacity Increase the Longevity of *Anastrepha ludens* Fruit Flies. *International Journal of Medicinal Mushrooms*, 23(6).
37. Vadnerker, P. S., Vyas, T. K., Kapadia C. K. (2022). Characterization of exopolysaccharide produced by *Ganoderma* sp TP and its immunomodulatory properties, *Rom Biotechnol Lett.* 2022.,
38. Valverde, M. E., Hernández-Pérez, T., & Paredes-López, O. (2015). Edible mushrooms: improving human health and promoting quality life. *International journal of microbiology*, 2015.
39. Xu, X., Yan, H., Chen, J., & Zhang, X. (2011). Bioactive proteins from mushrooms. *Biotechnology advances*, 29(6), 667-674.
40. Zhang, C., Guan, X., Yu, S., Zhou, J., & Chen, J. (2022). Production of meat alternatives using live cells, cultures and plant proteins. *Current Opinion in Food Science*, 43, 43-52.
41. Zhang, Y., Wang, D., Chen, Y., Liu, T., Zhang, S., Fan, H., . . . & Li, Y. (2021). Healthy function and high valued utilization of edible fungi. *Food Science and Human Wellness*, 10(4), 408-420.