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PHYTO PROTEINS: THE BASICS

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Abstract

Proteins have a critical role as an essential macronutrient in human health and nutrition. Their significance in terms of nutrition varies considerably based on factors such as digestibility, composition of amino acids, how easily they can be absorbed by the body, processing methods, and purity. To ensure the supply of necessary amino acids for human well-being, it is ideal to incorporate a variety of plant-based proteins from a nutritional perspective. In recent times, there has been a notable surge in interest surrounding the utilization of plant-based proteins, primarily due to their versatility in various applications, both consumable and non-consumable, and their environmentally friendly characteristics. As the global population continues to expand, plant proteins are gaining significance as a viable substitute for animal-derived proteins when the latter fail to meet the growing demands. The food and processing industries are particularly intrigued by the physical and chemical properties, structural attributes, amino acid composition, and functional qualities exhibited by plant proteins. This article provides a comprehensive overview of the diverse applications of plant proteins. These include their use as dietary supplements to enhance human nutrition, as coatings for fruits and vegetables, as emulsifiers in a wide array of food products, as sources of bioactive peptides in nutraceutical and pharmaceutical items, as hydrogels for drug delivery systems, and even in non-edible applications such as wood adhesives. Furthermore, the article delves into the distinctive biological properties of proteins derived from various plant sources, including peanuts, soybeans, kidney beans, rice, quinoa, sunflowers, cottonseed, camelina, maize, and others. It emphasizes the varied contributions of these proteins to human well-being and nourishment.

Introduction

Protein malnutrition arises from an insufficient or imbalanced intake of dietary proteins, leading to negative effects on bodily functions, metabolism, structure, and medical outcomes. While it is rare in developed nations, protein malnutrition remains the primary cause of childhood mortality and morbidity globally. Traditionally, land plants have played a vital role in sustaining human nutrition by providing nutrients and energy. Plant-based proteins are more abundant and cost-effective than animal proteins; however, their direct utilization is currently limited. Instead, plant proteins are primarily used as animal feed, which is then converted into meat, eggs, and milk. Unfortunately, this conversion process is highly inefficient, with a conversion rate of only 3%. Consequently, this inefficiency places a significant burden on the environment due to the excessive use of resources in animal protein production. If humans were to consume the same amount of plant-based proteins directly, the land required for cultivating food crops would be less than 10% of the current land needed to grow crops for animal feed and produce an equivalent amount of animal proteins. Additionally, the production of animal proteins necessitates nearly 100 times more water compared to producing an equivalent quantity of plant-based proteins.

The food industry is faced with a significant challenge in ensuring nutrition and food security, as the global population continues to grow at a rapid pace. The world's population is growing at an alarming rate, and this, along with significant sociodemographic changes, will create immense challenges in meeting the global demand for healthy food. Furthermore, the increasing requirement for protein, which is a direct consequence of population growth, is predominantly influenced by socioeconomic factors like urbanization, higher incomes, and aging societies. Recognizing the importance of protein in promoting healthy aging and a well-balanced diet is crucial. Dietary patterns, especially in middle- and low-income nations, have undergone significant changes due to economic progress and urbanization. Furthermore, there is growing recognition among nutrition specialists about the adverse health effects linked to the intake of meat.The World Cancer Research Fund (WCRF) and the World Health Organization (WHO) both promote the adoption of a plant-based eating pattern as a solution to address these issues.

Protein Composition and Properties from Various Plant Sources

The importance of protein quality goes beyond its quantity when it comes to maintaining good health. A key factor in determining protein quality is the presence of essential amino acids that can be easily digested and utilized for protein synthesis in the body. The composition of amino acids primarily determines the quality of a protein. Various plant sources offer proteins with different profiles of amino acids, each having unique characteristics and health benefits. Proteins derived from grains, seeds, legumes, nuts, pulses, and vegetables often lack specific essential amino acids such as lysine, cysteine, methionine, and threonine. While soy proteins are sometimes considered "complete" proteins, their overall content of essential amino acids is relatively lower (around 85% less than that found in milk). Typically, the primary distinction in essential amino acid content between plant and animal proteins lies in the amount of lysine, except for soybeans (which have low levels of sulphur amino acids) and maize (which is low in tryptophan). Consequently, nutrition experts recommend including a combination of legumes or soy (which lack sulphur-containing amino acids) with grains (which lack lysine) in the diet to fulfill the body's amino acid requirements. In terms of digestibility, protein fractions from wheat gluten, peanuts, wheat flours/breads, and soy protein isolates are more easily digested (at rates of 94-99%) compared to kidney beans and lentils.

Nutritional Value of Proteins and the Needs of Humans for Each

Protein, an essential macronutrient, plays a crucial role as the fundamental component of tissues in both humans and animals. Proteins play a vital role in the body by performing diverse functions that are crucial for overall well-being. These include the production of enzymes for metabolic processes, supporting growth and maintenance, acting as signals and hormones, aiding in pH regulation and the immune system, and serving as storage units and carriers for molecules.The nutritional importance of protein is determined by its distinct composition of amino acids and how the body utilizes each amino acid after it is absorbed, digested, and subjected to minimal obligatory oxidation rates. The metabolic rate of a particular protein is determined by the proportion of amino acids it contains. At first, the rate of amino acid oxidation is relatively low until the amount consumed surpasses the necessary quantity for protein synthesis. Subsequently, the oxidation process accelerates rapidly. The availability of amino acids can fluctuate depending on various factors such as processing techniques, protein origins, and interactions with other elements found in the food composition.

The fundamental concept of the essentiality of amino acids forms the basis for all methods used to evaluate protein quality. Amino acids play a crucial role in providing nitrogen for the synthesis of proteins and other important biomolecules. These amino acids can be categorized into three groups based on their rate of protein synthesis in vivo:

(a) Valine, Tryptophan, Threonine, Phenylalanine, Methionine, Lysine, Leucine, Isoleucine, and Histidine amino acids are crucial and need to be acquired from the diet as they are essential.

(b) Tyrosine, cysteine, and arginine are amino acids that are usually produced by the body. However, there are circumstances or particular life stages in which they can become necessary even though the body can usually synthesize them.

(c) The body has the ability to produce certain amino acids known as non-essential amino acids. These include serine, proline, glycine, glutamic acid, glutamine, aspartic acid, asparagine, and alanine. Non-essential amino acids differ from essential amino acids in that they can be produced by the body and do not require consumption from dietary sources.

The evaluation of a protein's nutritional value is influenced by the proportions and levels of the specific amino acids present in the protein.

Increasing the essential amino acid content is a way to enhance the quality or biological value of a protein. The arrangement of amino acids within the protein also plays a significant role in this regard. For physically inactive healthy adults, the recommended dietary allowance (RDA) for protein is 0.8 grams per kilogram of body weight (BW) per day. However, to promote muscle protein growth and improve physical strength during intense workouts, it is recommended to consume higher amounts of protein. The RDAs for low, moderate, and high levels of physical activity are 1.0, 1.3, and 1.6 grams of protein per kilogram of BW per day, respectively. It is generally considered safe for healthy adults to consume up to 2 grams of protein per kilogram of BW per day for an extended period. However, it is important for well-informed individuals to avoid exceeding the upper tolerable limit of 3.5 grams per kilogram of BW per day. Consuming excessive amounts of protein, especially exceeding 2 grams per kilogram of BW per day for adults, can have negative effects on the vascular, digestive, and renal systems.

Comparison between Plant and Animal Protein Quality

Assessing the nutritional value of proteins entails examining several factors, including the composition of essential amino acids, the digestibility of the protein, and additional parameters like the protein digestibility-corrected amino acid score (PDCAAS), biological value (BV), and net protein utilization (NPU). The PDCAAS assesses how effectively a protein meets the body's amino acid needs, while BV indicates the percentage of absorbed amino acids from a food source that contribute to protein synthesis in the body. In contrast, NPU compares the quantity of amino acids converted into proteins to the amount of amino acids provided.

Animal-derived proteins are known to have better digestibility and show superior performance in terms of NPU, BV, and PDCAAS when compared to unprocessed plant proteins. The lower PDCAAS of plant proteins can be attributed to factors like reduced digestibility and the absence of specific essential amino acids. Furthermore, animal proteins are easier to digest compared to plant-based proteins due to inherent structural differences. Plant-based proteins tend to have higher levels of β-sheet structures and lower levels of α-helixes, making them more resistant to enzymatic digestion. The higher fibre content in plant proteins also contributes to their reduced digestibility. Additionally, plant proteins may contain a larger amount of antinutritional factors that further hinder their digestibility. These factors are often found in the protein bodies present in the cotyledon and legume hull fractions. Nevertheless, by utilizing various processing methods, it is possible to reduce the quantities of these antinutritive components. As a result, the digestibility of plant proteins can be improved. It is essential to comprehend these nutritional factors in order to develop alternative protein products and formulate effective strategies for product development.

Different types of animal proteins are commonly employed in the food industry to improve the stability and thickness of various food substances. For instance, milk-derived proteins like casein and whey are frequently used to stabilize and thicken different food compositions. Egg white proteins are employed to heat and create foam in food items, whereas muscle proteins (such as stromal, sarcoplasmic, and myofibrillar proteins) play a role in forming gels and enhancing color. In addition to animal proteins, plant-based substitutes like soy and pea proteins provide advantageous functional characteristics such as emulsification, fat assimilation, gelation, and moisture preservation.Cereal grains contain gluten, which possesses viscoelastic and cohesive characteristics, enabling the formation of fibrous protein networks. Additionally, canola oil and rapeseed proteins exhibit advantageous attributes for foaming, emulsification, and gel formation.

As Supplements in Food Products

Proteins have a vital role in the human diet by providing additional nutrients to enhance the nutritional value of meals. They serve as dietary supplements, serving multiple functions such as maintaining strong bones, promoting muscle growth in older individuals, managing weight, and fulfilling additional nutrient needs. Acting as bioactive compounds, proteins are essential for a healthy immune system and cardiovascular health, protecting the body against diseases. Plant proteins offer well-established advantages, encompassing the reduction of cholesterol levels, maintenance of bone health, enhancement of muscle mass in older individuals, and fulfilment of protein needs for athletes. As a result, protein supplements are vital for individuals across all age brackets. Scientists have extensively investigated different plant sources to harness their potential as protein supplements. The sources encompass a variety of plant-based foods, comprising legumes like chickpeas, cowpeas, soybeans, peas, and lupins; cereals like wheat, rice, sorghum, minor millets, maize, and barley; pseudocereals such as amaranth, buckwheat, and quinoa; seeds including sunflower, pumpkin, sesame, and flaxseed; and a range of dried fruits.

Lupin, a type of leguminous seed, contains approximately 32.2% protein, similar to soybeans. It has a relatively low oil content of 5.95%. Due to its beneficial chemical composition and widespread availability in different countries, lupin has gained popularity as a protein supplement for both humans and animals. Individuals who are allergic to protein formulas based on cow milk often depend on protein supplements derived from soybeans. Defatted soy flour, with minimal amounts of fats, saturated fats, sugars, sodium, and calories, offers a valuable protein source for human nutrition. This flour contains essential amino acids and is devoid of cholesterol. Various research studies have indicated that incorporating plant-based proteins into one's diet, particularly those derived from soybeans, can lead to decreased serum cholesterol levels.

As Edible Coating or Films

The increasing demand from consumers for food products that promote sustainability and health, combined with a growing recognition of the adverse environmental impact associated with non-biodegradable materials utilized in food packaging, has stimulated the advancement of edible packaging materials derived from plant-based proteins. The characteristics of these proteins are shaped by the unique makeup and proportions of amino acids present in the polymer.Natural biopolymers such as proteins, which are environmentally sustainable and biodegradable, offer a feasible solution for coating and packaging food. Edible coatings and films, which are thin layers created from edible materials, are utilized for food packaging purposes. These movies effectively hinder the movement of moisture, oxygen, and solutes, while also preserving the flavor and texture of the food. Edible films are often made using globular proteins, which dissolve in water and are commonly found in solutions containing salts, acids, and bases. To make these proteins suitable for film formation, they can be modified and denatured through processes involving heat, solvents, acids, or bases. The positioning of polar amino acids along the polymer sequence plays a pivotal role in establishing vital connections. The interplay between the polymer chains dictates the durability and gas, liquid, and vapor permeability of the edible film coating. Films that possess a higher quantity of interactions demonstrate improved resilience and reduced permeability to gases, liquids, and vapors.Consequently, these coatings, derived from proteins, act as highly effective barriers against oxygen, even in environments with low humidity levels. Currently, there is a growing interest in utilizing dairy and plant proteins to create packaging that can be consumed along with the food it contains. Recent developments in the realm of edible coatings for food have embraced the use of various proteins such as soy protein, corn zein, and wheat gluten. Corn zein, distinguished by its elevated levels of nonpolar amino acids, exhibits a hydrophobic characteristic that renders it well-suited for the production of consumable films.The presence of numerous disulphide and hydrogen bonds in zein significantly contributes to its exceptional ability to form films and prevent moisture penetration. Likewise, wheat gluten, a globular protein with hydrophobic attributes, demonstrates impressive film-forming capabilities owing to its elasticity and ability to stick together.

A method known as wet processing was utilized to create edible packaging by utilizing yellow pea protein and whey protein isolates. The resulting film was examined using FTIR analysis in order to evaluate its hydrophobic and hydrophilic properties.The study results indicated that protein films derived from concentrated yellow pea protein displayed minimal hydrophilic properties on their surfaces. This variation in surface characteristics was attributed to multiple factors, such as the purity, type, and amino acid composition of the protein samples. Films created from yellow pea protein isolates showed low permeability to UV light, while those made from whey protein isolates permitted maximum transmission. The films derived from yellow pea protein isolates exhibited noteworthy thermal and mechanical properties.

An original study focused on the development of edible films enriched with antioxidants by combining mung bean protein and pomegranate peel powder. These films demonstrated an increase in the levels of total phenolic compounds and displayed enhanced capacity to counteract oxidation and bacteria. The improved ability to combat harmful bacteria such as Listeria monocytogenes and Escherichia coli, which belong to different bacterial categories (gram-positive and gram-negative, respectively), can be attributed to specific phenolic compounds. These compounds, including punicalagin, catechins, gallic acid, and ellagic acid, are derived from pomegranate peels. Moreover, pomegranate peels showcase enhanced antioxidant properties.

Conclusion and Future Perspectives

Plant-based proteins find diverse applications in various industries, such as food supplements, edible food coatings or films, bioactive peptides, stabilizers, emulsifiers, hydrogels, and adhesives. To enhance the durability of coated products, protein-based edible food coatings can incorporate natural or artificial antioxidants, plant extracts, oleoresins, and essential oils. This integration aims to protect against discoloration, degradation, and oxidative rancidity. The intricate interactions within food emulsions pose challenges when predicting their stability and physicochemical properties. By conducting studies on the interplay between emulsifiers and biopolymers, we can enhance our comprehension of emulsion stability and shelf life. Additionally, we can advance protein-based emulsifiers by manipulating proteins' rheological properties, surface tension, and electrical properties at the interface, thereby broadening their applicability in the food industry. However, there is currently a lack of molecular-level investigation into the health benefits associated with plant-based proteins. Therefore, further research is necessary to understand their potential in promoting overall well-being.It is important to generate scientific hypotheses that can guide the targeted release of plant-based proteins, taking into account their specific physical and chemical properties. Exploring alternative protein sources that contain the necessary amino acids for producing biologically active peptides (BAPs) and understanding how these peptides interact with cells is crucial, as they show promise as potential drugs. Additionally, further investigation is required to ensure the safety of protein hydrolysates and BAPs and to identify any potential negative effects. In the present age of nanofabrication, there is a need to reduce the size of protein-based hydrogels while preserving their exceptional mechanical properties, durability, and compatibility with the food and pharmaceutical sectors. Additionally, by incorporating other gels, whether they are synthetic or biopolymer-based, which exhibit shear-thinning behaviour and optimal strength, it becomes possible to alter the structure and mechanical characteristics of hydrogels. This approach of integration also enables the creation of responsive hydrogels capable of controlled release of bioactive substances. Furthermore, plant-derived proteins offer unique characteristics that make them a preferable alternative to detrimental chemical adhesives. While considerable research is currently being conducted in the fields of protein-based hydrogels, bio-based adhesive products (BAPs), edible packaging materials, food stabilizers, adhesives, and health supplements, the development of novel methods to produce these substances with tailored attributes has the potential to expand their versatile uses in diverse industries.

There are two primary methods for examining plant-based proteins: protein fortification and complementation. Complementation entails combining food items that are deficient in specific essential amino acids with other products that contain those amino acids in limited quantities. Numerous plant sources such as chickpeas, cowpeas, soybeans, peas, lupins, wheat, rice, sorghum, minor millets, maize, barley, amaranth, buckwheat, quinoa, sunflower, pumpkin, sesame, and flaxseed have been utilized to extract protein of high quality. This extracted protein can then be used to augment the nutritional value of food.

Furthermore, there exists the possibility to personalize the sensory and functional characteristics of plant-based protein isolates, flours, and concentrates by employing specific extraction and processing methods. These proteins, sourced from plants, assume a vital function in stabilizing, emulsifying, structuring, and modifying the texture of vegan and vegetarian food items, contingent upon their distinctive attributes. The technological and sensory properties of these proteins can be modified via diverse approaches, such as physical manipulation, heat treatments, fermentation, and enzymatic processes. Given the escalating global demand for plant protein within the food industry, the protein content found in pseudocereals, grain legumes, seeds, and other crops harbors immense potential.However, current crop production tends to focus on a limited range of species. To address the protein deficit and promote more sustainable farming practices, integrating legume crops into agriculture presents a viable solution.

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