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Vegetable Proteins: Nutritional Value, Sustainability, and Future Perspectives

Nazir Ahmed, Anwar Ali, Sakhawat Riaz, Arslan Ahmad and Muhammad Aqib

Abstract

The growing world population demands more production of proteins for healthy growth and prevention of protein-energy malnutrition. The animal proteins are not sufficient to meet the requirement of daily proteins intake. Furthermore, due to limited resources of animal number, land, water, environmental impact, the demand for vegetable proteins and sustainability have been increasing tremendously. This chapter will outline the demand scenarios of vegetable proteins, nutritional aspects, and technological challenges in product development and consumer acceptance. It will summarize the potential of vegetable proteins related to health and existing diseases. The consumption of vegetable proteins, development of product, economic, sustainability, and food safety aspects will be summarized.

Keywords: vegetable protein, malnutrition, sustainability, techno-nutrition functionality, bioavailability

1. Introduction

Protein is a necessary nutrient, but not all protein-rich foods are equally represented, and you may no longer require as much as you believe. Protein, together with carbs and fat, is one of the three essential crucial components. Protein is made from more than 20 amino acids that assist create and repair muscle fiber, so that it is known as the “building blocks” of your body. Adults should consume at least 0.8 g of protein per kg of body weight each day or little over 7 g every 20 lb of body weight. In 2005, it was projected that 20% of children under the age of five in the lowlands were overweight [1]. Even though southern Asia has the biggest number of children (74 million), East Africa and South East Asia have the highest stunting rate [1]. When nations with a stunting frequency of at least 20% were included, approximately 36 mainly consisted of 90% of all retarded young children [1].

According to various reports from Germany, the U.N, and French during the previous century, acute malnutrition was more prevalent among the hospitalized pediatric patients in Germany, the United Kingdom, the United States, and France [2–4]. Pawellek and colleagues discovered that 24% of children in a German major government hospital were underweight (90th percentile weight for height), with 17.9% mild malnutrition, 4.4% moderate malnutrition, and 1% severe, using Waterlow’s criteria. Undernutrition was found in 40% of patients with

chondrogenesis, 34% of patients with infection, and 33.3% of patients with cystic fibrosis, 28.6% of patients with heart disease, 27.3% of patients with cancer treatment, and 23.6% of patients with gastrointestinal disorders [3]. Protein is necessary for proper growth and the avoidance of malnutrition.

The population of the world is predicted to double by 2063, from around 6.5 billion currently to 13 billion. Because proteins are the only one of three macronutrients in our diet (the others being carbohydrates and fats), ensuring that adequate protein is available to feed the world's population is crucial. Proteins are made up of a variety of amino acid residues that are required for tissue growth, repair, and replenishment. Protein costs are rising as a result of societal shifts such as rising wages, increasing population, and living standards, where the value of proteins in healthy aging is well recognized [5, 6], as well as a growing recognition of the needs of protein in a healthy diet. Economic urban development is generating significant population dynamics nutritional status, particularly in moderate and high countries, with developing countries accounting for the majority of global increases in demand for animal-based meals [5].

2. Vegetable protein

Vegetables are not only the most energy effective in the green house, but they are also a major source of energy, nutrients, elements, protein, omega-3 fatty acids, and widely accessible energy for global agricultural production. Over 3000 plant species have been utilized for food by humans over history, with at least 50 species being farmed for business reasons. Nevertheless, approximately 20 different vegetable crops support the majority of the world's population. Vegetables produce two-thirds of all dietary protein on the planet. **Table 1** shows that cereal crops, especially, provide a significant amount of protein to the global protein supply. The data are derived from FAO and Agro state sites [7].

Table 2 illustrates the amounts of necessary amino acids in various dietary sources, with the most restricting amino acids in protein sources meals shown in bold. The necessary protein lysine is significantly lower in vegetable-food protein classes than in animal nutrition, as can be shown. Children can thrive as well as recover from acute malnutrition if carefully prepared meals based exclusively on vegetable food sources are supplied. As a consequence, vegetable meals can supply the critical components needed for optimal health and function in the correct ratios and combinations. Protein sources meal combinations have the potential to be nutrient dense. Despite the soybean's reduced sulfur content, soya, peanut and sesame flour, and cereal grains, for instance, are mostly poor in lysine. This

	Protein (g)	Protein (%)	Energy (Kcal)	Energy (%)
Total plant	46.1	65	2277	84
Cereals	33.7	47	1385	51
Pulses, nuts	6.0	8	109	4
Starchy roots	2.0	3	141	5
Other vegetables	2.5	4	46	2
Fruits	0.8	1	65	2
Total animal	25.0	35	433	16
Total	71.1	100	2710	100

Table 1.

Worldwide relative importance of various food groups and per capita intake.

Food source	Threonine	Tryptophan	Lysine	Sulfur amino acids
mg/g protein				
Legumes	38 ± 3	12 ± 4	64 ± 10	25 ± 3
Cereals	32 ± 4	12 ± 2	31 ± 10	37 ± 5
Nuts, seeds	36 ± 3	17 ± 3	45 ± 14	46 ± 17
Fruits	29 ± 7	11 ± 2	45 ± 12	27 ± 6
Animal foods	44 ± 6	12 ± 6	85 ± 9	38 ± 7

Table 2.
 The presence of the amino acid content of different food protein source.

suggests that oil-seed proteins, especially soy proteins, might be used efficiently for most cereal grains to enhance protein properties. Data from the FAO and the US Department of Agriculture are included in **Table 2** [8].

3. Protein requirement

This is entirely dependent on the individual's age, exercise level, weight, medical history, and desired outcomes. People who are sedentary have distinct needs, adults have different requirements, and athletes possess different needs. Assessments of protein requirements, as according to FAO/WHOIUNU [9], refer to metabolic activities that last for a long duration. Though protein and amino acid requirements are usually expressed as daily rates, this is not always the case, and this does not mean that they must be ingested every day. To preserve muscle mass and function, as well as to fight osteoporosis, the aged require a larger protein consumption than younger people [10, 11]. Although current guidelines recommend a protein consumption of 0.8 grams per kilogram body weight per day (g/kg/d) [12], it has been shown that fit and healthy seniors need a protein intake of 1.2 g/kg/d to avoid age-related weight gain and function [13, 14]. There is presently no evidence on the usual protein consumption of healthy and active older adults, including any potential differences between males and females, to our knowledge. **Figure 1** shows how protein requirements differ depending on the individual [15].

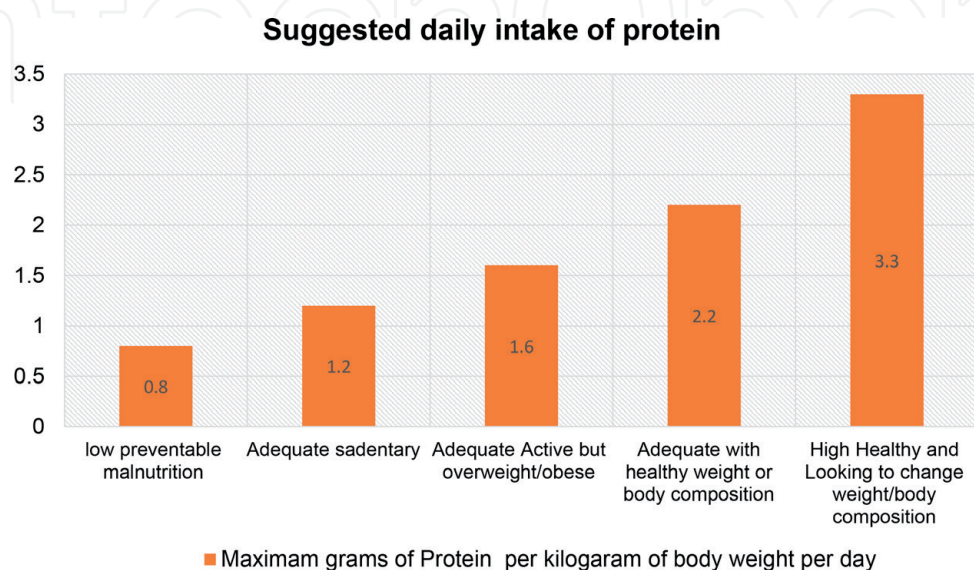


Figure 1.
 Protein intake requirements on a daily basis.

Because our bodies are unable to manufacture critical amino acids, we must obtain them from food. Some amino acids found in proteins could not be used by our bodies. **Figure 2** shows many forms of amino acids [15].

When a person consumes vegetable-based protein, their nutritional needs are higher than when they consume animal protein. **Figure 3** depicts the protein requirements for the plant. Vegetable-based proteins that include essential amino acids and branched-chain amino acids include soy, pea, and rice. These are complete proteins that are hypoallergenic and gluten free. Proteins are essential components of human diets because they aid in the maintenance of muscle mass, the regulation of immune responses, the healing of cells, and the enhancement of communication. Proteins are important components in functional meals because of their helpful activities in terms of delivering different proteins in the human diet, such as stiffening and meshing capability, emulsion, fizzing, water retention, and body fat [16, 17].

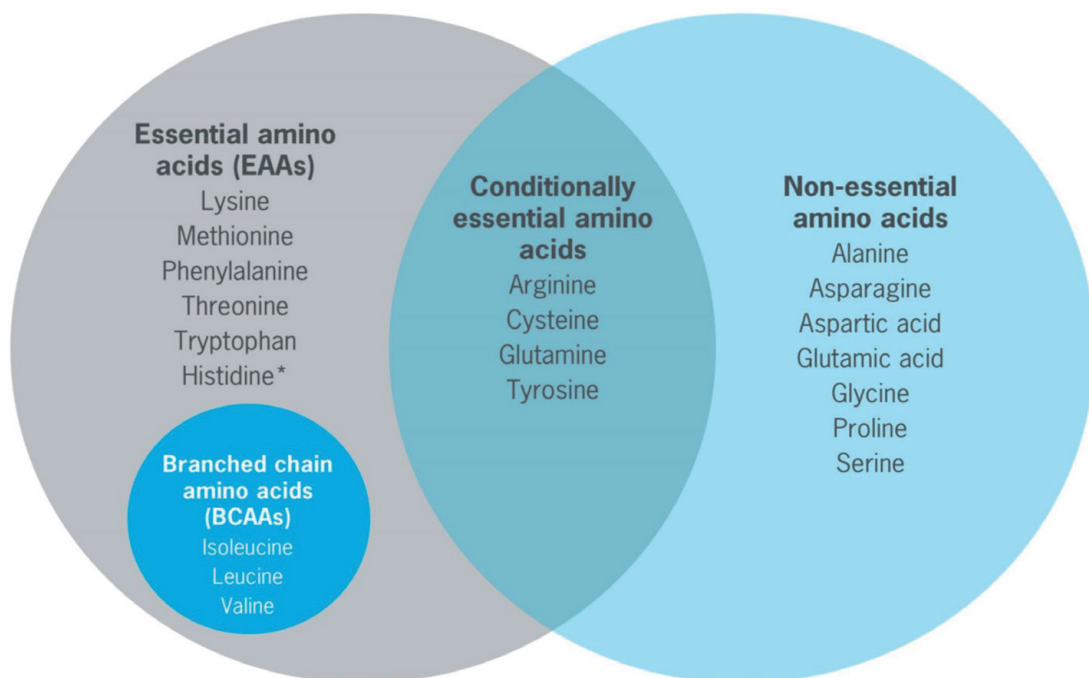


Figure 2.
Types of amino acids with their importance.

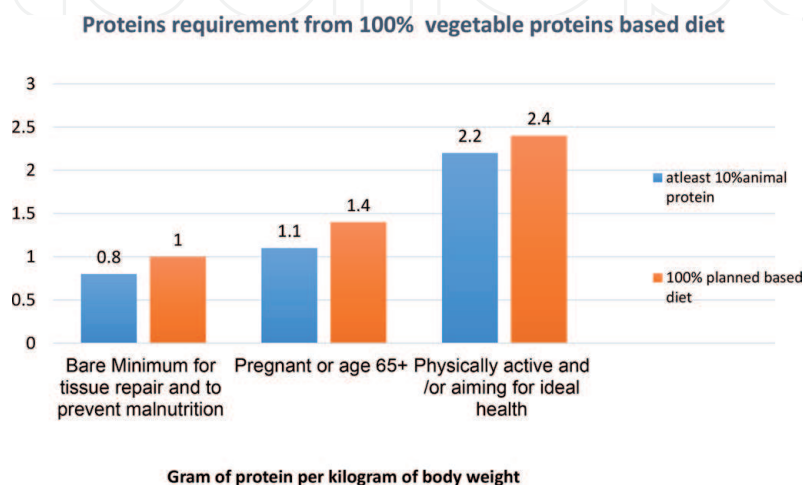


Figure 3.
The protein requirements including essential amino acids and branched-chain amino acids.

4. Vegetable proteins and their quality

Figure 4 shows a wide range of vegetable-based proteins derived from several sources. These can be extracted from low-cost and ecological sources such as agricultural wastes and crop and oil industry by-products, which can help to achieve food security [16].

Because of the varied metabolic requirements of certain tissues, rats, and humans have varying amino acid requirements. The fact that the protein-energy ratio of animal proteins (or a combination of proteins) does not reach its maximum value but rises when methionine is added supports the notion that rodents have a higher sulfur amino acid need than humans. The consumption of a protein in people can be measured by monitoring the fecal matter and urine nitrogen (N) losses; it is predicated on the nitrate adjustment study premise. These studies indicated that some vegetable proteins, particularly beans and wheat, are underappreciated. Wheat's net protein utilization was calculated to be 41% when compared to egg protein. In humans, data show that most vegetable sources of protein have true digestibility in the 80–90% range, with references having lower digestibility (e.g., “rice, cereal”: 75% and “rice, polished”: 88%) and others having higher digestibility (e.g., “wheat, refined”: 96%, “soy protein isolate”: 95%). When protein percentage is purer, vegetable protein is much more digestible. Instead of looking at total nitrogen levels, per specific amino acid's digestion should be studied, as this has been suggested for many years. Because some protein acids personal digestion fluctuates or is lower than that of others for several reasons, average digestion is an insufficient proxy with each protein bioavailability.

The digestibility of various dietary proteins was found to be between 89 and 95 % in investigations using advanced techniques. The findings were 89 %–92 % for soy protein isolate, pea protein flour or isolate, wheat flour, and lupine flour, which were close to those reported for eggs (91%) and meat (90–94 %), but somewhat lower than those published for milk protein isolate (95 %). When absorbed at a level that fulfills the entire protein needs (e.g., 0.66 g/kg weight), a dietary protein with an amino acid score offers precisely the exact quantities of proteins that satisfy metabolic requirements and at a ratio in which no amino acid limits utilization of others. Lysine in grains and sulfur amino acids in beans typically emerge as restricted AAS stands for Amino acid score of vegetable protein. A closer analysis of the literature discloses that lysine rates are reduced or near zero in cereals such as sorghum,

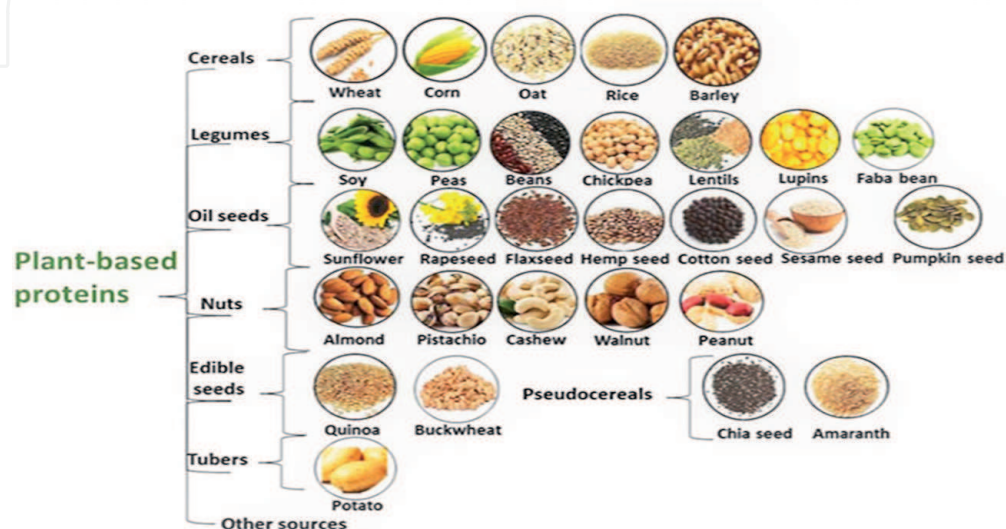


Figure 4.
Major plant-based protein sources.

wheat, triticale (47, 49, and 62%), and rice (80%), and also low in few more both these sources (walnuts and almonds: 60%). In contrast, it is high or extremely high in other sources, notably legumes (e.g., pea: 168 %; fava bean: 152 %; soybean: 134 %) and animal proteins (milk: 168 %; beef: 193 %; egg: 160 %) [18].

5. Challenges for vegetable protein utilization

Vegetable proteins can also be used to generate bioactive peptides. Most vegetable-based proteins, however, are insoluble in water due to their poor wet-tability, intricacy, and vulnerability to pH, osmotic pressure, and temperature, limiting their application. Flaxseed, soy, and pea proteins are examples of vegetable proteins with varied percentages. The presence of antinutrients with in form of individual plant residuals is a disadvantage of vegetable proteins. These compounds are produced by vegetables and have biological functions such as protecting vegetables from bugs, infections, fungi, and other organisms. Some of these changes can also assist to mitigate the negative effects of antinutrients [19]. **Figure 5** shows plant protein utilization issues and challenges. To overcome challenges of vegetable-based proteins to date, modifications tactics have been used to circumvent these difficulties. Protein modification is the process of changing a protein's chemical composition or a few chemical units using particular procedures to enhance its techno-functionality and bioactivity. The advantages and disadvantages of each of the physical techniques of protein change used yet for vegetable proteins will be examined separately. Plant-based protein utilization and challenges are shown in **Figure 5**.

6. Modification of vegetable proteins to improve digestibility and quality

Heat is among the most common methods for significantly modifying the structure and sensory attributes of vegetable proteins. Protein unwinding is aided by a low-temperature environment, resulting in an intermediary molten globule

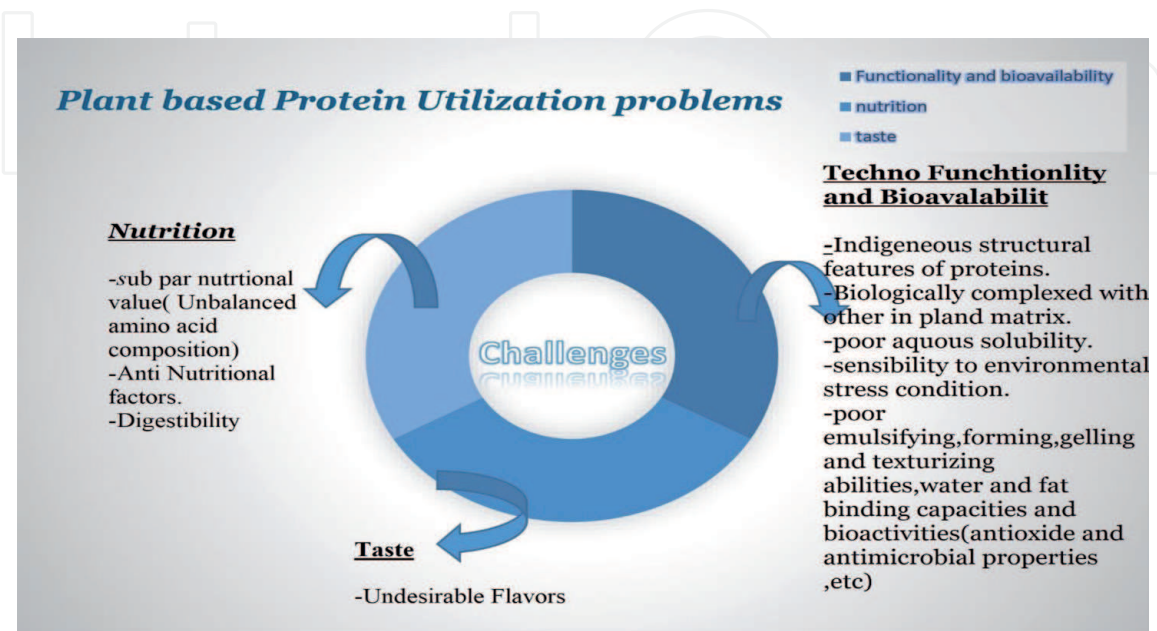


Figure 5.
Plant-based protein utilization issue and challenges.

state with improved functioning. Extreme heat stability, on the other hand, causes permanent changes in protein structures, resulting in hydrolysis and aggregating *via* various bonds such as disulfide, hydrophobic, and electrostatic, resulting in a loss of functional characteristics [18]. Vegetable proteins have been shown to be an effective technique of decreasing or eliminating anti-nutritional compounds using heat [19]. In chickpeas and soybeans, heat treatment has been used to inactivate trypsin inhibitors, and the combination of heating and met bisulfite as a reductant eliminated the trypsin inhibition up to 99.4%. Trypsin inhibitors are among the anti-nutritional factors limiting its use of lentils because they help prevent the action of pancreatic trypsin and chymotrypsin in the gut, causing a range of issues such as complicated digestive processes, poor protein intake, pancreatic expansion, stunted growth, and muscle loss [19]. Heat treatment of vegetable proteins can also enhance their digestion and nutritional properties. The digestibility is increased to 87.55% and the availability of essential amino acids is increased by heating the albumin protein isolate at 100°C for 30 min [20]. Ohmic heating can cause unfolding, denaturation, and the creation of uniform-sized protein aggregates with different techno-functional characteristics by delivering rapid and uniform heating as well as electrical effects. As a consequence, standard heating methods could be replaced with this electro-heating technology that has minimal negative impacts on protein quality and amino acid concentration [21].

Microwave frequency is less than chemical bond rate [22], and the approach can change the protein without disrupting its core structure, making it attractive as a classification scheme before further physical methods. The microwave approach has also been used to regulate the immune system of vegetable proteins. A significant drop (24.7%) is found in soya mutagenicity by microwave heating at 600 W for 10 min [23]. The activity of chemicals released by dipolar and ionic movement in the existence of an RF field impacts protein function. Radiofrequency (RF) like the microwave is premised on heat production and impacts protein function *via* the action of free radicals generated by dipolar and ionic flexibility in the presence of an RF field. Both RF and microwave heating technologies can solve the issues of low-heating rate impacts that are popular heating techniques due to their heat production [22]. RF heating was discovered to have significant effects on the structure of soy protein by breaking disulfide linkages and increasing surface hydrophobicity [24]. High hydrostatic pressure (HPP) is a non-thermal technique that uses hydrostatic pressure varies from 100 to 800 MPa for a few seconds [25]. HHP treatment influenced the denaturation, aggregation, and interactions of a variety of vegetable proteins. HHP treatment frequently promotes muscle hydrophobicity and lowers solubility, resulting in aggregation, thanks to its capability to expose hidden sulfhydryl groups following unwinding and inhibition [26]. HHP was also investigated as a means of increasing the nutritional value of vegetable proteins. When contrasted to other treatments such as enhanced ultrasonic, microwaving, and elevated homogenization, for example, H. HHP was shown as being the most efficient in lowering the allergen concentration of soy isolate for use in newborn formula [23]. Sonication is a one-of-a-kind, ground-breaking, and lengthy strategy associated with high electrical impulses (>16 kHz) that are imperceptible to the human ear [27]. Sonication has been proposed as an approach for decreasing antinutrients and increasing plant protein digestion in the literature [23]. The inhibitory activity of soy protein was reduced by 18.9% using high-intensity ultrasound [28]. According to the researchers, ultrasonic technique (25 kHz, 400 W, 1–16 min) decreased soymilk protein ace inhibitory activity by 52% while boosting digestion [29]. The combined components contribute to vigorous agitation and severe mechanical forces induced by a huge rotating screw moving at peak pressures (1.5–30.0 MPa) and heats (90–200 C) [30]. Extrusion could enable the molecules of vegetable

Vegetable proteins	Animal proteins
Adjustable for CKD patients	Non-adjustable
Lower cholesterol	Higher in cholesterol
Reduced blood pressure	Increase blood pressure
Lower the obesity	Increase risk of obesity

Table 3.

The utilization of vegetable and animal proteins in disease status.

protein to unfurl, denaturant, and realign, enhancing their techno-functionality while also giving them a meat-like texture. As a result, these contoured vegetable proteins could be used in place of meat in recipes [31].

It is the fourth form of matter could be generated at a wide range of temperatures and tensions *via* a combination of heat, physical, radioactive, and electromagnetic sources of energy. Malnourishment is described as just a structural mismatch in between availability of food and fuel as well as the body's requirement for any of them to ensure growth, repair, and certain activities, as per the World Health Organization [32]. Other dietary deficits often occur with protein-energy malnutrition. Malnourishment has also been linked to a reduction in the number of cells, connections, dendritic arborizations, and myelinations, each of which leads to a shrinking of the mind. Brain growth is retarded and the cerebral cortex gets reduced. Protein-energy malnutrition has been linked to impairments in a global function, brain function, and cognition, with newborns and babies, is now the most vulnerable, considering the newborn brain's adaptability [33]. As hunger advances, development is slowed, resulting in stunted, and some other organs are affected, including hairs, epidermis, fingernails, mucosa, as well as other organs. Because poor nutrition, specifically vitamins and minerals inadequacies are widespread in malnutrition individuals, most of them will show symptoms of them. Malnourishment, micronutrient deficiency, kwashiorkor, and miasmatic kwashiorkor can all be aided by sufficient protein with correct modification. Decreased thoracic lean muscle, a lower metabolic activity, and electrolyte imbalances can all lead to a reduction in respiratory rate, affecting the ventilator's capacity to act to hypoxia. The utilization of vegetable and animal proteins in disease status is presented in

Table 3.

7. Vegetable protein sustainability

The expected increase in the world population to 9 billion people (United Nations Population Department, 2000, 2050—medium version) defines the growth plan. As a result, not only does the quantity of food necessary change, and so will the food groups required, as well as their major contributors to nutrition. Predicted protein consumption seems to be of key significance, with forecasts that global demand for animal protein will quadruple by 2050 [34], raising concerns about food management and sustainable development. This is partial because it is widely acknowledged that animal meals emit more greenhouse gasses than vegetables, which are affected by temperature. The fact that rapid growth for animal protein is likely to rise land stress due to the requirement to generate more animal feed adds to the problem. As a result, the clearance of land, lakes, and natural grassland to farming land would rise, negatively impacting greenhouse gasses emissions, diversity, and other essential natural ecosystems [35]. Excess supply of proteins is fueled by social and economic developments including such rising incomes, increase in

urbanization, and population growth, in which the importance of proteins to health and longevity is commonly understood [5, 6], as well as awareness of the function of protein in a balanced diet. Economic growth and urbanization are causing large shifts in demographic nutritional status in middle to low nations especially in developing nations accounting for such bulk of worldwide increases in costs for animal-based meals [6]. Protein isolate synthesis, on the other hand, has a smaller impact on the environment but is a long-term alternative since it consumes less fuel, produces less pollution, requires less land, and uses less water. Animals are not efficient kilo converters of the proteins they ingest; thus, manufacturers should provide vegetables to animals to make animal proteins. It is the typical switching frequency of veggie to animal protein is 10 to 1, which indicates that 10 pounds of feed protein is required to create 1 pound of animal protein. Foods high fiber and low in fat are common in vegetable-based diets. A high-fiber, low-fat diet has been demonstrated in multiple trials to reduce the risk of certain malignancies, including colon, breast, and prostate cancers.

Our ever-increasing world population necessitates the availability of low-cost protein. As per world population projections, we will have to deliver protein to nearly nine billion by 2050. Accessibility to low-cost protein sources is critical for sustaining the growing world population while reducing environmental harm. Vegetable proteins have obvious health advantages. Vegetable proteins have been shown to reduce our risk of cardiovascular disease. Incorporating soy protein into your diet may also aid in the prevention of heart disease. Packaged beef should be designated as a “human carcinogen,” according to a research published by the International Agency for Research on Cancer. Meat, on the other side, has been deemed “possibly carcinogenic to humans.” While the exact evidence is inconclusive, iron absorption is assumed to play a key role in N-nitroso-compound processing, the formation of lipid oxidation, and a probable cytotoxic impact. The demand for agricultural production would likely be higher to population growth and the moral imperative to provide enough, healthy, and inexpensive food for everyone. By 2050, simply supplying 2900 kcal mean food production with 50% of the proteins coming from animal protein will roughly treble grain consumption. Furthermore, economic expansion, coupled with someone who can afford its desire for an excess of animal goods and poor eat conversion, may drive up prices even more. The purposeful decrease of animal protein intake as well as the replacement of animal proteins with protein sources could be used as a temporary fix to lessen the social change caused by the existing agricultural system. The worldwide market for protein foods is expected to be different combinations of that of the United States. The industry for protein isolate components is growing due to a number of factors. Food producers are reacting to the rising costs for meat-restricted, protein foods among the wellness Boomer Generation and other consumers. Animal food prices are high and variable, placing pressure on global food makers to come up with new ways to reduce expenses.

Our world’s expanding population necessitates the availability of low-cost protein. As per population projections, by 2050, we would be supplying protein to roughly 9 billion individuals. The availability of low-cost protein sources is critical for feeding the world’s growing population while reducing environmental stress. Vegetables are popular on the market right now. As per market research firm Frost & Sullivan, the U.S. protein-ingredients market alone is expected to produce about \$4.5 billion in sales in 2008 (43.3% vegetable proteins and 56.7% animal proteins) and is expected to increase at an annual growth rate of nearly 5%. Barriers are there in shifting from animals to vegetable protein. The transition from animal to vegetable meals is not without its challenges, or at least four have been identified [36]. Change is difficult because social factors oppose it beef has a high social position

and that it is the average human's wish to consume high up food given the correct financial circumstances. Lobby groups inside the meat manufacturing chain are significant, and economic concerns against reform are considerable. The advanced technologies required to generate innovative protein sources foods are lacking. Because the animal protein supply chain has been designed for using all by-products for generations, eliminating meat on a broad scale might just have a significant impact on linked production systems, perhaps canceling out most of the putative environmental benefits.

8. Conclusion

Vegetable proteins are more long-lasting and sufficient to meet the demands of a rapidly growing population. Vegetable proteins are more adaptable and can be altered in response to health issues than animal proteins. In this chapter, we focused on vegetable protein because the consumption of protein is increasing as the world's population expands. The population of the globe is anticipated to double by 2063, from 6.5 to 13 billion people. Rapid urbanization and rising protein consumption have exacerbated the problem, leading to an increase in malnutrition among children. As a result, we must meet our protein requirements in order to develop healthy and combat malnutrition. We will underline that everyone's protein requirements, as well as the demands for vegetable and animal proteins, are unique. Animal protein sources are not sustainable as the world's population expands; thus, we cannot meet our protein demands only from them. In this chapter, we reviewed how vegetable protein sources are more stable and sufficient for meeting our protein requirements. Vegetable diets produce more greenhouse emissions than animal meals because they are affected by temperature. The fact that rapid development of animal protein production is expected to create land stress due to the requirement to produce more animal feed exacerbates the problem. As a response, land, lakes, and natural grassland conversion to farming land would rise, posing a threat to greenhouse gas emissions, biodiversity, and other essential natural ecosystems. Vegetable proteins are promoted as more sustainable, disease-adjustable, and cost-effective than animal proteins. We made the switch from animal- to vegetable-based protein. There are various challenges to overcome when it comes to employing vegetable proteins. As a result, we looked at numerous methods for using vegetable protein and its derivatives to meet amino acid deficiencies, including heating, ohmic heating, microwave, radiofrequency, and extrusion, among others.

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Conflict of interest

There is no conflict of interest as declared by all authors.

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Author details

Nazir Ahmed^{1*}, Anwar Ali², Sakhawat Riaz³, Arslan Ahmad^{1,3}
and Muhammad Aqib³

1 Department of Nutritional Science, Government College University Faisalabad,
Pakistan

2 Department of Epidemiology and Health Statistics, Xiangya School of Public
Health, Central South University, China

3 Department of Home Economics, Government College University Faisalabad,
Pakistan

*Address all correspondence to: drnazirahmad@gcuf.edu.pk

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