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Soy

Green Protein for Health and Sustainability

1. **Rosalin Laishram**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi
Email: rosalin.laishram96@gmail.com
2. **Minakshi Dutta**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi
3. **Arpitha S R**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi
4. **Nagesh C R**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi
5. **Vinutha T,**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi
6. **Anil Dahuja**
Division of Biochemistry, ICAR-Indian Agricultural Research Institute, New Delhi

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Introduction

Protein malnutrition, stemming from inadequate dietary protein intake, has profound implications over growth, development and health aspects. Its prevalence in low and middle-income nations is underlined by recent data from the World Health Organization (WHO), which reports 462 million individuals as underweight and identifies malnutrition as the cause of 45% of death among children under the age of five. Furthermore, the aftereffects of protein malnutrition extends beyond childhood, impacting adults as well, with long-lasting implications. Despite the historical importance of land plants in providing abundant and affordable protein, their direct utilization remains limited. Plant-based proteins, sourced from whole grains, legumes, and nuts, are primarily used as animal feed to produce meat, eggs, and milk. However, the conversion of plant-based proteins to animal proteins is inefficient, with approximately only 3% of plant proteins transformed into animal proteins. Furthermore, Animal protein production places significant strain on the environment due to its inefficiency, leading to excessive land and water usage compared to plant-based protein production. If plant-based proteins were directly consumed by humans instead of being used to feed animals for meat production, less than 10% of the land area would be required to produce the same amount of food crops. Furthermore, animal protein production consumes nearly 100 times more water than producing an equivalent quantity of plant-based proteins (Qin, P. *et al.,* 2022). Additionally, prolonged and elevated consumption of red meat is correlated with a heightened risk of chronic diseases, including a 58% increased likelihood of hyper LDL cholesterolemia and a subsequent contribution to atherosclerosis. This rise in LDL levels is attributed to the presence of L-carnitine in red meat, which has the potential to impact cardiovascular disease risk through the activation of mTORC1 (mammalian target of rapamycin) and the suppression of PPAR-α (Peroxisome proliferator-activated receptor), thereby disrupting lipid homeostasis within the body (Bacha, U *et al.,* 2013) .Recognizing these challenges, there has been a notable global trend shifted from animal to plant-based proteins. This transition shift is driven by concerted efforts to diminish adverse environmental impacts, ensure sustainability and meet the nutritional needs of growing populations. The partial replacement of animal-based proteins with plant-based alternatives in diets stands out as a key initiative in achieving these goals. Diversifying protein sources, including tapping into underutilized soybean protein, holds great promise in facilitating this transition towards a more sustainable, balanced dietary landscape and but also provides a brand-new choice for vegetarians.

Composition and Characteristics of Soy Protein Ingredients

Soybean, a protein-rich legume extensively cultivated in Asia and globally consumed, accounts for around 40-41% of their composition, along with lipids and fibre. The protein compositions varies depending on the wild and cultivated habitats in which they are grown. Soy protein contains two of the four protein groups: globulins and water-soluble albumins (salt soluble). Globulin is the main protein found in soybeans. The majority of the protein content in soybean is made up of the key storage proteins, glycinin and β-conglycinin. Glycinin is distinguished from β-conglycinin by having larger concentrations of sulfur-containing amino acids, such as cysteine and methionine. The remaining proteins play critical roles in the seed's defence systems and nutrient mobilisation. The soy proteins can be fractionated into 2S, 7S, 11S, and 15S by ultracentrifugation (Sui *et al.,* 2021). The primary proteins identified in various components of soybeans include Kunitz trypsin inhibitor (KTI) and Bowman-Birk trypsin inhibitor in the 2S portion, β-conglycinin and α-amylase in the 7S segment, as well as glycinin present in the 11S part. Glycinin may also be found within the 15S section. Soybeans contain several anti-nutritional factors such as protease inhibitors, lectins, goitrogens, cyanogens, anti-vitamin factors, phytic acid, saponins, and estrogens that can impact soy protein utilization. Various food processing techniques like fermentation have been demonstrated to decrease ANFs in soybeans with a noticeable reduction observed in trypsin inhibitor content. Additionally, a research study indicates that reducing levels of anti-nutritional factors in soybean protein isolate by genetically eliminating KTI did not result in a decrease in protein content (Madibana, M. J. *et al.,* 2022). This suggests that breeding soybeans without KTI while maintaining protein levels is achievable. Soy protein is also comparable to milk and whey protein in terms of protein quality because it closely matches the amino acid composition and achieves a Protein Digestibility-Corrected Amino Acid Score (PDCAAS) of 1.00 which signify its capability to serve as a complete protein source for meeting essential amino acid requirements for human growth and development. Soy protein, while lower in leucine compared to whey, contains almost three times as much arginine and 2-3 times more glutamine. It also has double the glycine content. Glutamine serves as a main energy source for rapidly growing cells like those in the immune system and gastrointestinal tract, and plays a role in producing arginine, ornithine, and various other compounds. Glycine is essential for collagen synthesis and accounts for about one-third of the amino acids in collagen. Soy protein's richness in lysine, despite its deficiency in sulphur-containing amino acids, limits its nutritional value. Techniques such as breeding and genetic engineering aim to increase methionine-rich proteins, addressing this limitation. Complementing with other cereal proteins can also compensate for the lack of amino acid content. With its high protein content (~90%) and rich in essential amino acids, soy protein is considered as a crucial raw material for producing soy-based infant formula, enhancing the nutritional value of foods, particularly for vegans and individuals allergic to milk proteins. Glycinin is favoured for achieving balanced amino acid profiles in food production. Additionally, research emphasizes the growing demand for plant-based proteins such as those derived from soybeans due to their nutritional value and functional properties, which contributes to the expansion of global plant-based protein market. These findings collectively highlight how significant and versatile soybean proteins are across various food applications.

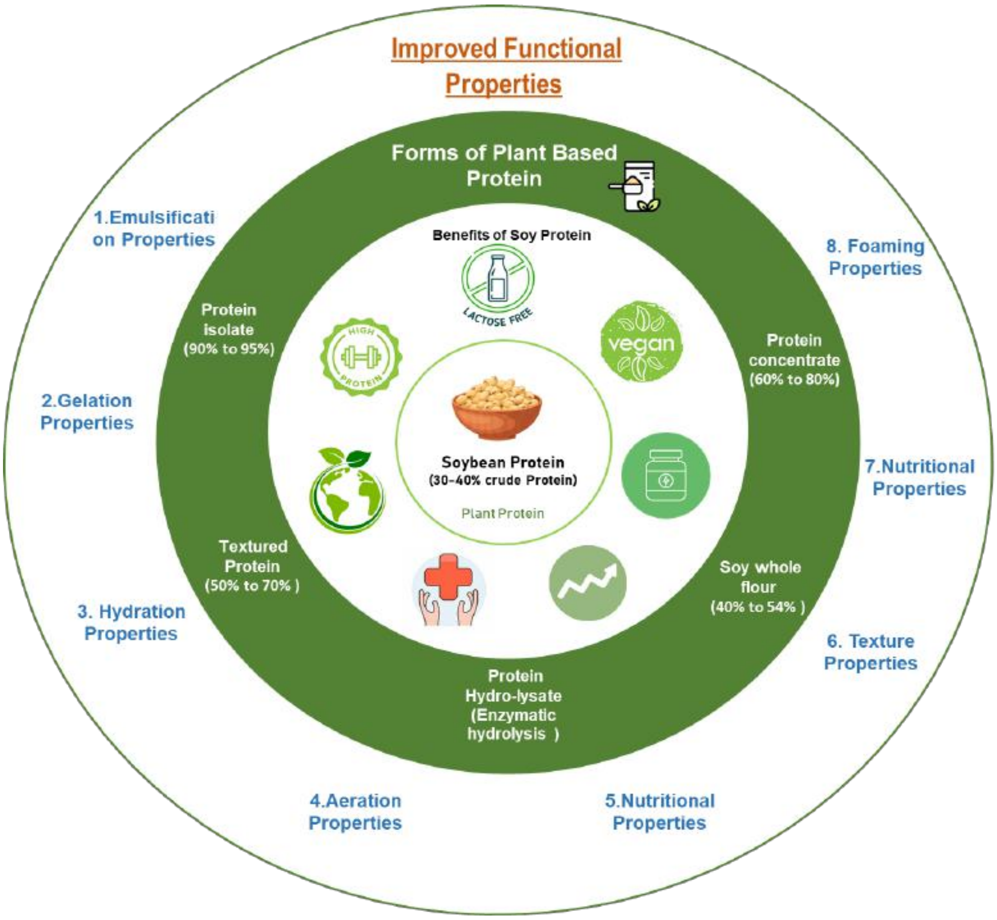

Figure 1: Soy protein, its different forms and improved functional properties

Forms of Soybean Proteins

Currently, soy proteins in their various forms are primarily used for their functional effects rather than their nutritional properties. However, there is a growing trend among companies to utilize soy proteins as the main source of protein in food products and leverage their functional properties for successful product development. Following oil removal from the soybean, what remains is known as defatted flakes. There are five distinct forms of soy protein products that serve as protein supplements or sources with content ranging from 50% to over 90%: soy flours/grits, soy protein concentrates, and soy protein isolates. **(Figure 1)**

1. **Soy protein concentrates (SPC):** Soybean protein concentrates are more refined, containing 70% or higher protein on a moisture-free basis. These are produced from defatted flakes or flour through one of three methods that involve the removal of oligosaccharides, some ash content, and minor components. The first method utilizes aqueous alcohol wash to dissolve sugars and other compounds, leaving insoluble proteins and polysaccharides. In the second procedure, acid leach at around

pH 4.5 removes sugars while unifying both proteins and polysaccharides in insolubility before neutralization and drying. The third technique involves using moist heat to denature proteins followed by a water wash for sugar and minor component removal. They offer consistent protein levels but vary in physical properties, providing reduced flavour compared to flours and grits.

2. **Soy protein isolates (SPI):** Soybean isolates, the most purified forms of soybean proteins containing 90% or more protein, are produced by eliminating water-insoluble polysaccharides and other low-molecular-weight components. Defatted flakes or flours undergo extraction with an alkaline water solution at a pH range of 7 to 8.5, followed by separation of insoluble residue and clarified extract treatment adjusted to about pH 4.5 for protein precipitation. The precipitated proteins are then separated through centrifugation or filtration, washed, and dried to obtain isoelectric protein with over 95% purity. Isoelectric protein may contain ash up to 2-5% and minor constituents up to 3-4%. They offer a concentrated protein source with bland flavour, high lysine content, and improved product quality.
3. **Soy whole flours (SF):** The least processed types of proteins include flours and grits, which differ in fat content, particle sizes, textures, and levels of processing heat treatment. Flours are produced by grinding soybean flakes to a fineness of 100 mesh (0.157 mm-sieve pore size) or finer, while grits are coarser than 100 mesh. The protein contents in these materials range from 40% to 54%, depending on the fat content. Protein, carbohydrates, and ash with residual lipids as well as minor components such as saponins and isoflavones that contribute to the unique flavours found in raw soybean flour and grits. Approximately half of the flour carbohydrates consist of oligosaccharides (such as sucrose, stachyose, and raffinose), while the other half is made up of polysaccharides insoluble in water or alcohols.
4. **Texturized Soy protein (TSP):** It is generally refer to defatted soy flours or concentrates that have been mechanically processed using extruders to achieve a texture resembling meat when rehydrated and cooked. Coarse defatted soy particles (flakes and grits) as well as shaped soy protein isolates (referred to at times as structuring proteins to distinguish them from extruded products) are also creatively employed for adding texture and enhancing the appeal of food products. Additional advantages of extrusion cooking include denaturation of the proteins, deactivation of trypsin inhibitors, management of bitter flavors, and the uniform binding of ingredients which may encompass colors, chemicals, and other additives and impacting appearance or textural quality

Soy protein hydrolysate (SPH): Soybean protein hydrolysate is a product obtained through the enzymatic hydrolysis of soy protein, resulting in peptides with various functional and antioxidant properties. Different enzymes like Alcalase and Flavourzyme have been utilized to hydrolyze soy protein, leading to increased levels of essential amino acids and improved antioxidant activities. The hydrolysis process enhances solubility, emulsifying activity, and foaming capacity of soy protein, making it suitable for various food applications. Studies have shown that the degree of hydrolysis, enzyme type, and reaction conditions significantly impact the properties of soy protein hydrolysates, influencing their potential as functional food components or antioxidant additives. Overall, soybean protein hydrolysates exhibit promising nutritional benefits and functional characteristics, making them valuable ingredients in the food and pharmaceutical industries.

Importance of Soy based Plant protein in Human Health

1. **Cardiovascular Health:** Soy-based protein intake has been associated with improved cardiovascular health, including reductions in total cholesterol, Low density lipoprotein (LDL or bad cholesterol), and triglyceride levels by 9.3%, 12.9%, and 10.5% respectively, along with increases in High density lipoprotein (HDL or good cholesterol) up to 2.4%. Research indicates that soy protein holds potential for reducing the risk of coronary heart disease, with a daily intake of 20 to 50g possibly resulting in a risk reduction of 20% to 30%.
2. **Bone Health:** Studies suggest that soy protein intake may support bone health, potentially reducing bone resorption turnover rates and increasing bone mineral density, especially beneficial during menopause-induced bone loss.
3. **Antidiabetic Properties:** Soy protein and its derived peptides, such as dipeptidyl peptidase IV (DPP-IV), α-amylase, and α-glucosidase, show promise in modulating postprandial glycemic response, indicating potential benefits for managing diabetes.
4. **Antihypertensive Effects:** Fermented soy protein isolates with *Lactobacillus rhamnosus* have demonstrated significant angiotensin-converting enzyme (ACE) inhibitory activity, suggesting potential antihypertensive effects.
5. **Renal Antioxidant Status:** Soy protein, along with its main isoflavone genistein, may improve renal antioxidant status, potentially offering protection against oxidative stress-related conditions like nephrotic syndrome.

Functional Properties of Soy protein and its application in food products

Soy protein products are mainly used for their functional properties, which are essential in traditional food production processes and help with process management and the development of convenient food items, excluding certain applications like infant formulas, dietary wafers, breakfast cereals, and specialized dietary products in **Table 1**.

Table 1: Functional and edible applications of soy protein products

Sl. No.	Types of Soy Protein	Functional properties	Food products
1		**Emulsification**	
	F, C, I	Formation	Frankfurters, bologna, sausages, bread, cakes, soups
	F, C, I	Stabilization	Whipped toppings, frozen desserts, frankfurters, bologna, sausages, soups, Mayonnaise, sauce, yoghurt and some beverages, baby food formula
2		**Fat absorption**	
	H, F, C, I	Promotion	Frankfurters, bologna, sausages, meat patties
	H, F, C	Prevention	Doughnuts, pancakes
3.		**Water absorption**	
	H, F, C	Uptake	Breads, cakes
	H, F, C	Retention	Macaroni, confections, breads, cakes
4.		**Texture**	
	F, C, I	Viscosity	Soups, gravies
	I, H	Gelation	Simulated ground meats

	F	Chip and chunk formation	Simulated meats
	F, I	Uptake	Breads, cakes
	I	Shred formation	Simulated meats
	F, C, I	Fibre formation	Simulated meats
	F, C	Dough formation	Baked goods
	I	Film formation	Frankfurters, bologna
	C, I	Adhesion	Sausages, lunch meats, meat patties, meat loaves and rolls, boned hams
	F, I	Cohesion	Dehydrated meats, baked goods, macaroni, simulated meats
	I	Elasticity	Baked goods, simulated meats
	H, I, C	Foaming Capacity	Beer, coffee-milk mixes, meringue, cakes, chocolate mousse, tiramisu, meringue and bread
5.		**Colour control**	
	F	Bleaching	Breads
	I	Browning	Breads, pancakes, waffles
6.	I	**Aeration**	Whipped toppings, chiffon mixes, confections
7.	H	**Fat Replacer**	Reduced fat ice cream

*F, C, H and I represent flours, concentrates, hydrolysate and isolates, respectively (Adapted from reference Singh, P *et al.,* 2008).

Conclusion

In conclusion, soy protein emerges as a nutritious and sustainable dietary solution with profound implications for human health and environmental sustainability. Its high protein content, combined with essential nutrients and functional properties, makes it an ideal choice for addressing global protein malnutrition. By harnessing the potential of soy protein, we can not only improve the nutritional quality of diets but also mitigate environmental pressures associated with animal protein production. Incorporating soy-based plant protein into our diets offers a pathway to healthier lives and a more sustainable future for generations to come.

Reference

1. Ashaolu, T. J. (2020). Applications of soy protein hydrolysates in the emerging functional foods: A review. International Journal of Food Science & Technology, 55(2), 421-428.
2. Bacha, U., Nasir, M., ASIF, M., Akbar, N., ANJUM, A., Muhammad, J.& Rashid, A. (2013). L-carnitine of red meat consumption contributes less in heart diseases progression as compared to low expressed PPARα leading to activation of mTOR1C. *International Journal of Advanced Research*, *1*(7), 169-174.
3. Blum, S. C., Heaton, S. N., Bowman, B. M., Miller, S. C., & Hegsted, M. (2003). Dietary soy protein maintains some indices of bone mineral density and bone formation in aged ovariectomized rats. *The Journal of nutrition*, *133*(5), 1244-1249.
4. Chen, W., Liang, G., Li, X., He, Z., Zeng, M., Gao, D., & Chen, J. (2019). Impact of soy proteins, hydrolysates and monoglycerides at the oil/water interface in emulsions on interfacial properties and emulsion stability. *Colloids and Surfaces B: Biointerfaces*, *177*, 550-558.

5. Madibana, M. J., Fouché, C. H., Davids, J. J., Mthembu, S. T., Motubatse, M. H., Poni, Z. & Nemakhavhani, R. L. (2022). *Lactobacillus acidophilus* and *Lactobacillus cereus*-containing products do reduce soybean antinutritional factors. *Agricultural Science & Technology (1313-8820)*, *14*(3).
6. Qin, P., Wang, T., & Luo, Y. (2022). A review on plant-based proteins from soybean: Health benefits and soy product development. *Journal of Agriculture and Food Research*, *7*, 100265.
7. Singh, P., Kumar, R., Sabapathy, S. N., & Bawa, A. S. (2008). Functional and edible uses of soy protein products. Comprehensive reviews in food science and food safety, 7(1), 14-28.
8. Sui X, Zhang T, Jiang L. Soy protein: Molecular structure revisited and recent advances in processing technologies. Annual Review of Food Science and Technology. 2021 Mar 25; 12:119-147.