

# Health Benefits of Sunflower Seed Byproducts- Sunflower Seed Protein and its Hydrolysates

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**Abstract:** In recent years, sunflower seed protein (SSP) and its hydrolysates have garnered significant attention in food science and nutrition research due to their plant origin, rich nutritional ingredients and potential health benefits. SSP is not only rich in a variety of essential amino acids, especially lysine, but also has the advantage of sustainable development as a hypoallergenic and environmentally friendly protein source. Hydrolysates derived from SSP, produced via enzymatic or acid-base hydrolysis, yield bioactive peptides with enhanced bioavailability and physiological functionalities in the human body. In addition, the application of SSP and its hydrolysate in the food industry cannot be ignored. It exhibits exceptional emulsifying and gelling properties, making it a preferred material for multifunctional food additives. This review aims to systematically summarize and analyze the nutritional value, functional characteristics and potential health-promoting effects of SSP and its hydrolysates, providing a scientific foundation for its subsequent development and utilization.

**Keywords:** Sunflower Seed Protein; Sunflower Seed Protein Hydrolysates; Bioactive Peptides; Functional Foods; Antioxidant Activity; Sustainable Protein Sources.

## 1. Introduction

Protein is the basic component for the construction of human tissues and is composed of amino acids in sequence, forming the foundation of life. [1]. A protein usually contains 20 different amino acids (AAs), which are linked to each other by peptide bonds to form the diversity of proteins. These amino acids (AAs) are indispensable components of organisms, providing organisms with nitrogen, hydrocarbon skeletons, and sulfur, and these elements cannot be replaced by other nutrients [2]. During digestion, dietary proteins are broken down into absorbable units (e.g., free AAs, dipeptides), which are critical for synthesizing proteins, enzymes, and low-molecular-weight compounds such as glutathione, nitric oxide, and neurotransmitters, which play a key role in maintaining physiological functions [1, 2]. Consequently, adequate intake of high-quality protein is vital for maintaining physiological functions across all age groups [2, 3].

The global protein market, valued at \$38 billion in 2019, is projected to grow at a compound annual growth rate (CAGR) of 9.1% through 2027 [6]. This surge is driven by increasing consumer awareness of protein's health benefits and the environmental challenges associated with animal-derived protein production [4]. As the global population is expected to reach approximately 9.7 billion in 2050, the demand to produce protein-rich foods will further increase [8]. However, the increase in food protein production, especially high-quality animal protein, may pose a challenge to environmental sustainability [4]. Although animal protein is superior to plant protein in terms of digestibility, net utilization, biological value and protein digestibility-corrected amino acid score (PDCAAS) [5], the negative impact of animal agriculture on the environment cannot be ignored, including deforestation, greenhouse gas emissions, water consumption, land use and biodiversity loss [7]. It takes 6 kg of plant protein to produce 1 kg of high-quality animal

protein [4]. Additional drivers include ethical concerns, allergenicity (e.g., soy, dairy), and the rising prevalence of vegan and vegetarian diets [4,5]. Therefore, there is growing interest in developing sustainable plant-based alternatives to replace animal-derived food sources in the human diet [7].

Sunflower seeds (*Helianthus annuus* L.) are an annual plant belonging to the Asteraceae family, native to North America or Peru, and introduced to Europe by the Spanish in the 16th century [9]. As an oilseed crop, sunflower seeds are considered one of the top five annual oilseed crops in the world, along with soybeans, rapeseed, cottonseed and peanuts [10]. Its by-product, sunflower seed cake/meal, is rich in protein and has become a potential sustainable source of plant protein [9]. Global sunflower seed meal production is estimated to be 21 million tons, and its chemical composition varies depending on the degree of shelling and oil extraction method [7]. In sunflower seed meal, the protein content of mechanically extracted sunflower seeds is about 40%, the protein content of oil extracted using organic solvents is about 50%, and the protein content of defatted meal prepared from hulled seeds can reach 53% to 66% [10]. In addition, the hydrolysates of sunflower seed protein, due to the production of its bioactive peptides, show higher bioavailability and absorption efficiency, and has significant effects on health functions. Although research on SSP and its hydrolysates has increased in recent years, their potential has not been fully realized due to the lack of detailed information on their nutritional and health benefits. This review aims to systematically summarize and analyze the nutritional value, functional properties, and potential effects on human health of SSP and its hydrolysates, in order to promote their wider use.

## 2. Basic Characteristics and Nutritional Value of SSP

The proteins in sunflower seeds are mainly divided into

two categories: globulins and albumins, which account for 46% to 80% and 19% to 35% of the total protein in sunflower seeds, respectively. Globulins (Sunflower globulins - helianthinin) are high molecular weight storage proteins with a molecular weight between 300 and 350 kDa; while albumins (Sunflower albumins - SFAs) are the second largest protein storage component.

According to Table 1, sunflower protein contains all essential amino acids, but is relatively low in lysine (2.9 g/100g protein vs. FAO's 5.5 g/100g standard), likely due to the predominance of lysine-deficient globulins [13]. Except for lysine, the amino acid composition of SSP meets the standards of the World Health Organization/FAO/UN and shows the characteristics of being rich in sulfur-containing amino acids (methionine and cysteine) [14]. These sulfur-containing amino acids are often limiting factors in other plant protein sources, such as legumes. In addition to the amino acid composition, the nutritional value of a protein also depends on its digestibility, meaning the ability of the protein to be hydrolyzed by proteases and the amino acids to be absorbed in the gastrointestinal tract. Studies have shown that the protein digestibility of hexane-defatted sunflower meal or whole dehulled seeds can reach 89.7% to 91.5% after 8 hours of pepsin treatment and 16 hours of trypsin treatment. The digestibility of sunflower seed protein isolate, calculated as the ratio of soluble nitrogen to initial nitrogen in the sample, is much higher than that of initial sunflower meal (83.13%), ranging from 90.66% to 95.32%. The digestibility SSP is affected by its purity, with higher purity resulting in higher digestibility. The effects of other compounds in sunflower seed need to be considered [13]. Sunflower seeds contain relatively high levels of phenolic compounds, especially chlorogenic acid (CGA), whose cross-linking with protein may lead to darkening of the color of the final protein product, altered functional properties, and decreased bioavailability. This interaction may reduce the solubility of protein, thus affecting its application in the food industry [10]. Nevertheless, compared with other plant protein sources, the content of anti-nutritional factors in sunflower seeds is low [12]. Salgado, Drago et al. found that sunflower seed protein concentrate still showed a high digestibility even in the presence of anti-nutritional factors such as phenolic compounds [15]. In addition, by adopting appropriate processing technology or a combination of technologies, the adverse effects of these factors on plant protein sources can be reduced or eliminated, thereby improving their nutritional value [11].

**Table 1.** Essential amino acid content (g/100g of protein) [16]

Amino acid content	FAO standard	Sunflower protein isolates
Lysine	5.5	2.9
Threonine	4.0	3.7
Methionine	3.5	2.0
Valine	5.0	4.5
Isoleucine	4.0	3.8
Leucine	7.5	6.9
Phenylalanine	3.0	5.6

It is worth mentioning that chlorogenic acid (mainly 5-O-caffeoylquinic acid) itself has a variety of biological activities, including antioxidant, anti-inflammatory, antibacterial and

antiviral effects. Population epidemiological surveys and intervention studies as well as animal experiments have shown that chlorogenic acid plays an important role in regulating glucose and lipid metabolism, improving insulin resistance, reducing the risk of type 2 diabetes and cardiovascular disease, and protecting organs such as nerves, liver, lungs, eyes and joints from oxidative and inflammatory damage [17]. Therefore, chlorogenic acid can be used as a functional ingredient to significantly improve the overall utilization value of sunflower protein by-products.

### 3. Generation and Properties of Hydrolyzate/Peptides of SSP

The hydrolysis of Sunflower Seed Protein (SSP) entails the conversion of high molecular weight proteins present in sunflower seeds into low molecular weight peptide chains and amino acids. This process is primarily achieved through enzyme catalysis or acid-base treatment, with the core objective of breaking the peptide bonds within protein molecules to release peptides and amino acids. Commonly utilized enzymes include animal-derived trypsin, plant-derived papain, and a variety of microbial proteases [20]. The application of hydrolysis technology aims to improve the digestibility of protein, improve its flavor characteristics, and enhance its functionality. The solubility of SSP in acidic (pH 2.0) and alkaline (pH 9.0) conditions is significantly higher than that in neutral conditions (pH 5.0-7.0). By rationally selecting enzymatic conditions, the solubility and functionality of SSP can be more effectively improved. Sophie Beaubier, Sara Albe-Slabi, and their colleagues found that enzymatic hydrolysates exhibited remarkable performance in terms of emulsification ability and emulsification stability. Notably, the hydrolysate treated with Prolyve enzyme had an emulsification ability of approximately 60%, which was significantly higher than that of untreated sunflower seed protein. In addition, sunflower seed protein hydrolysate also demonstrated excellent foaming ability and stability [19]. Protein hydrolysis can also markedly improve the nutritional value of sunflower seed powder [21]. The peptides produced by the hydrolysis process are smaller and have better nutritional properties. In vitro proteolysis is a pre-digestion process of protein, which can promote protein absorption. There is evidence that some short peptides are absorbed faster in the digestive tract than free amino acids [18]. In summary, sunflower seed protein hydrolysate/peptide produced by hydrolysis technology has higher solubility, better emulsification, foaming and stability, while improving its nutritional properties and bioavailability.

## 4. Potential Health Benefits of Sunflower Seed Protein and Its Hydrolysates

### 4.1. Antioxidant Effect

The antioxidant potential of sunflower seed protein hydrolysates has been supported by extensive scientific research. Studies have shown that the bioactive peptides produced by sunflower seed protein hydrolysis can activate the Keap1/Nrf2 signaling pathway, enhance the activity of antioxidant enzymes, effectively reduce oxidative stress, and protect cells from free radical damage [22]. In addition, sunflower seed protein hydrolysates showed significant

antioxidant activity under a variety of enzymatic hydrolysis conditions. For example, the peptide fragment obtained by trypsin hydrolysis for 60 minutes had the highest antioxidant activity, which could significantly scavenge free radicals and delay the aging process [19]. Further studies have also found that sunflower seed protein hydrolysates can effectively scavenge 1,1-diphenyl-2-trinitrophenylhydrazine free radicals (DPPH), hydroxyl free radicals, superoxide anion free radicals, etc. These properties make it a potential source of natural antioxidants [23].

#### 4.2. Anti-inflammatory Effect

SSP and its hydrolysates exhibit significant anti-inflammatory effects through multiple mechanisms. First, by activating the Keap1/Nrf2 signaling pathway, antioxidant defense is enhanced, thereby reducing the inflammatory response caused by oxidative stress [24]. Secondly, the sunflower seed protein-derived peptides produced by hydrolysis can inhibit the activation of the NFκB signaling pathway, which is a key regulator in the inflammatory response. In addition, these hydrolysates can also enhance the differentiation of dendritic cells, regulate immune responses, and thus alleviate health problems caused by chronic inflammation. Dendritic cells are important immune cells that can activate adaptive immune responses. [21]. These studies provide important support for the application of SSP in the development of functional foods, especially in improving health and preventing chronic inflammatory-related diseases.

#### 4.3. Antidepressant Effect

SSP also shows potential application value in the prevention and treatment of depression. SSP is rich in aromatic amino acids such as tryptophan, phenylalanine and tyrosine, which are closely related to the synthesis of neurotransmitters. Studies have shown that sunflower seed protein can improve the symptoms of depression induced by chronic unpredictable mild stress (CUMS) and increase the levels of monoamine neurotransmitters (such as 5-hydroxytryptamine, dopamine, and norepinephrine) in the brain. At the same time, sunflower seed protein also has an antioxidant effect, which can increase the activity of antioxidant enzymes (such as superoxide dismutase, glutathione peroxidase, and catalase) in depressed mice and reduce oxidative stress damage [25]. These results provide theoretical support for the potential application of SSP in antidepressant.

#### 4.4. Antibacterial Effect

Sunflower seed protein hydrolysates also show significant antibacterial effects. Studies have found that sunflower seed protein hydrolysates under different enzymatic conditions can inhibit a variety of foodborne pathogens, especially the products hydrolyzed using a mixture of Alcalase and Flavourzyme enzymes, which show strong antibacterial activity [20]. These hydrolysates are not only rich in essential amino acids, but also have antibacterial effects. They can be used as natural antibacterial agents and are widely used in the field of food safety.

### 5. Application of SSP and its Hydrolysate

SSP and its hydrolysate have shown wide application potential in the food industry due to their rich nutritional value

and unique functionality. The following are some possible application directions of sunflower protein and its hydrolysate in food:

#### 5.1. Development of Plant-Based Snacks and High-Protein Foods

Studies have shown that sunflower seed protein isolates and concentrates can significantly increase the crude protein content of energy bars while maintaining low allergy and high digestibility. Through response surface methodology optimization, the study determined the ratio of adding 9% sunflower seed protein concentrate and 6% sunflower protein isolate to energy bars. This ratio can significantly increase the protein content without affecting the sensory properties, providing a scientific basis for the development of high-protein, low-allergy plant-based healthy snacks [26].

#### 5.2. Potential in Baked Goods

The application of SSP and its hydrolysate in baked products is gradually gaining attention. They can not only serve as a substitute for wheat flour, but also significantly improve the nutritional value of bread and other baked goods. Specifically, the addition of sunflower seed protein isolate (SMPI) to bread can increase the protein and amino acid content of bread and improve the amino acid composition, but it is necessary to balance the nutritional enhancement and sensory quality to avoid excessive addition affecting the sensory properties of bread [27]. The addition of defatted sunflower seed flour (DSSF) can increase the protein and ash content of muffins while reducing the carbohydrate content, but it may change the structure and sensory properties of muffins. Therefore, it is necessary to further optimize the addition level and formulation of DSSF to improve its application in baked products and consumer acceptance [28]. In addition, as an ingredient of gluten-free bread, sunflower seed cake can not only improve the nutritional value of bread, especially in terms of protein, fat, crude fiber, polyphenols and soluble sugars, but also improve the texture characteristics of bread and enhance its market appeal [29]. In summary, SSP and its hydrolysates have broad application prospects in baked products and can provide consumers with healthier and more nutritious baking options.

#### 5.3. Functional Food Ingredient

As a plant protein rich in essential amino acids, SSP shows great potential for application in the production of healthy foods and nutritional supplements. SSP and its hydrolysates are rich in peptides with antioxidant and other bioactive properties, further enhancing their value as functional food ingredients. These properties make them promising for application in the food industry, especially in the development of foods with health benefits [30].

#### 5.4. As a Nitrogen Source for Industrial Applications

SSP and its enzymatic hydrolysates have been found to be able to serve as a nitrogen source and play a role in the biosynthesis of vitamins B2 and B12. By replacing traditional meat peptones, SSP and its hydrolysates provide a low-cost and renewable nitrogen source for the fermentation process of *Bacillus Pasteurii*. This does not only help to reduce the production cost of vitamins B2 and B12, but also improves the sustainability of the process. The bioavailability of sunflower seed protein was improved after enzymatic

hydrolysis, which significantly accelerated the growth of bacteria, demonstrating its potential for industrial applications [31].

## 5.5. Potential for Prevention of Cardiovascular Diseases

The application of angiotensin I converting enzyme inhibitory peptides (ACEI peptides) extracted from sunflower seed protein hydrolysates after liposome encapsulation provides new ideas for the treatment of cardiovascular diseases and the development of functional foods. Studies have shown that by optimizing the preparation conditions of liposomes, the encapsulation efficiency of ACEI peptides can be significantly improved and their sustained release *in vivo* can be ensured, thereby enhancing their efficacy in cardiovascular health [32].

In summary, SSP and its hydrolysates are widely used in the food industry, covering a wide range of fields from healthy snacks, baked goods to functional foods and nutritional supplements. These studies provide solid theoretical support for the use of SSP in improving the nutritional value of food, improving health, and promoting sustainable development.

## 6. Summary

As a high-quality plant protein source, SSP and its hydrolysate have shown extensive research and application value in the fields of food science and nutrition. These products are not only rich in essential amino acids, especially lysine, but also hypoallergenic and environmentally friendly, which is in line with the current trend of sustainable development. Through enzymatic hydrolysis or acid hydrolysis, SSP can be converted into bioactive peptides, which have higher bioavailability and absorption efficiency, and show significant physiological functions in anti-oxidation, anti-inflammatory, anti-depressant, and antibacterial aspects.

Future research should focus on further exploring the health effects of SSP and its hydrolysate, optimizing the extraction and hydrolysis process to improve the yield and quality of bioactive peptides, and developing new application areas to further explore the health benefits and industrial potential of SSP. At the same time, research should focus on how to reduce or eliminate the negative effects of anti-nutritional factors through processing technology, so as to enhance the nutritional value and market competitiveness of SSP. In view of the growing global demand for plant protein, the research and application of SSP and its hydrolysate are expected to play a greater role in many fields such as nutritional supplements, functional food development and food industry.

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