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A Review on Soy Protein Concentrate: A Source of Protein Enrichment for Food Applications.

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Abstract
Soybean is naturally a dynamic source of protein, defatted meal remaining after extraction of oil is also excellent source of protein. Soy protein concentrate (SPC) can be prepared from defatted meal by various methods, mingling of isoelectric PH and alkaline precipitation followed by centrifugation is the traditional method used for extraction and formation of Soy Protein concentrate (SPC). Soy protein concentrate can be used in various food applications. It can be used for enrichment of proteins in many sectors of food products.

Keywords: Defatted Meal, Extraction, Soy Protein Concentrate (SPC),

Introduction

Soybean is rich sources of proteins and defatted meal obtained after extraction of oils from seed can be processed to produce protein rich foods, such foods can help to solve the problem deficiency of proteins in our population. Like infant, children's and pregnant mothers. It have been known for centuries for good nutritional properties. Unfortunately, during processing, from 5 to 25% of this production is wasted, generating by-products that can still be a rich source of useful compounds, such as proteins and micronutrients, which can still be used in food and formulations. The current era of speed and drastically advanced lifestyle Food intake has become one of the major work being neglected and least preferred. This situation resulted in huge cases of Protein deficiency. Protein Energy Undernutrition/Malnutrition: Primarily caused by deficiency of Protein, Energy and micronutrients.

Production and availability

Brazil in recent years been the highest producer of soybean and is expected to grow at 0.8% p.a. over the next decade progressive than the United States, the second highest producer, at 0.6% due to double cropping with maize. The production of soybean is projected to grow vigorously elsewhere in Latin America, with Argentina and Paraguay producing 51 Mt and 12 Mt by 2032. In china, soybean production is await to resume growth after slow down over the past decade due to partly to reduce policy support for the cultivation of cereals. Soybean production is also await to grow in India, Russian Federation, Ukraine, and Canada.
(OECD/FAO 2023, "OECD/FAO Agriculture outlook")

Soybean: Composition

Soybeans (Glycine max) are a species of legume that yields a valuable amount of oil that has a healthy fatty acid profile and high-quality protein that is replete in all the essential amino acids required for sustaining human nourishment (Young, 1994). Soybeans have anti-hypertensive, anti-cholesterol, and antioxidant activities, and seems to prevent not allowing many types of cancer (Wu *et al.,* 1998; Messina, 1995). Soybean contains 36 - 40% protein, 18-20% oil, 13-17% soluble carbohydrates like sucrose, stachyose, 13-17% insoluble carbohydrates Dietary fibres, 8 to 10% moisture,/ash/and others. Soybeans are also good sources of calcium, iron, zinc, phosphate, magnesium and vitamin B. Soybean have high capacity as a very nutritive and high protein food. It can supply much needed protein to human diet, because it contains above 40 percent protein of superior quality and all the essential amino acids particularly glycin, tryptophan and lysine, similar to

cow's milk and animal proteins. Soybean is excellent source of good quality protein and compares well with other protein foods. Soybean oil is rich in polyunsaturated fatty acids and contains no cholesterol (Garcia *et al.,* 1997).

Health benefits of Soybean

Soybean is good source of important nutrients and also the flexible foodstuffs. It possesses good quality protein which is comparable to other protein foods and is suitable for all ages, infants to the elderly. Moreover, soy protein is acceptable in almost all diets due to no cholesterol and absence of lactose. The improved processing methods of soy ingredients caused greater functionality and blander flavor. The new emphasis on soy protein has got more use in breakfast to increase protein quality and quantity for a wide variety of textural, functional, and nutritional values.

Attempts to improve soy flavors by inactivating the enzymes. They found that heat treating whole beans and grinding them allows the beans to hold good flavor for up to two years of storage. A downside to heating the LOX is that it leads to some insolubilization of the soy proteins, loss of functionality of protein and the introduction of a toasted or cooked flavor. Hexanal is mainly responsible for the "greeny" flavor of soy because of its low flavor threshold (less than 1ppm.). Lipoxygenase is also a catalyst for cooxidation of pigments such as carotenoids and chlorophyll by free radical mechanisms that require the presence of polyunsaturated fatty acids. This is a reason that the enzyme-active full fat soy flour is used in bleaching wheat flour. It helps release bound lipids which improves dough rheology and increases the loaf volume of bread. Due to the off flavors caused by this enzyme it is only used up to 0.5% in wheat flour since the most important cause of the off flavors caused by soy is the effect of lipoxygenase on linoleic and linolenic acids. Mustakas *et al.,* (1969). Kakade *et al.,* (1971) carried out to determine the effect of acid treatments on protein quality of soy flour. During their research, Lecithinated and nonlecithinated soy flours with and without acid treatment were fed to young rats as the only source of protein. They found that rats receiving lecithinated soy flour which had been treated with acid grew better than those fed untreated soy flour. Upgradation was not observed with non lecithinated soy flour treated with acid. On the basis of obtained results, they reported that beneficial effect of the acid treatment of soy flour, appears to involve the lecithin component of the soy flour which they used in their studies.

Grains of cereals and legumes remain the major sources of calories and proteins for a large proportion of the world population. In terms of quantity, cereals occupy the first place as sources of calories and proteins and grain legumes are the next. About 80% of the proteins consumed by the humans in the developing countries are supplied by plants. Protein calorie-malnutrition (PCM) is believed to be the primary nutritional problem in most developing countries of the world. Legumes are rich sources of protein and the essential amino acid, lysine, but are usually deficient in sulphur containing amino acids, methionine and cystine. On the other hand, cereal-grain contains lower amounts of proteins which are deficient in lysine but have adequate amounts of sulphur amino acids. It is often, therefore, emphasized that legume-grain proteins are the natural supplement to cereal-grain protein introducing an overall essential amino acid balance. Also, there is a growing recognition that legumes and their products are good sources of vitamins and minerals. Although, grain legumes contain various anti-nutritional factors which impair their nutritional quality, these factors may be removed by processing. U. Singh and B. Singh (1975)

Compared with sodium caseinate and commercial soy protein concentrate (Promocaf) as protein sources in milk replacers, supplying 0.75 of the protein in 20%-protein replacers. The protein efficiency ratio of experimental soy products determined with rats correlated 0.68 with in vitro protein digestibility, 0.60 with soluble nitrogen, and 0.59 with trypsin inhibitor activity. Coblentz *et al.,* (1976). Eka *et al.,* (1978) studied nutritive value of paps and porridges prepared using millet, guinea corn and maize was assessed by chemical analysis before and after supplementation with soya bean milk or flour. Millet porridge mixed with soya bean milk had the most quantity of protein and essential amino acids. The nutrient situation of the mixed paps and porridges was similar with commercial weaning food. The value of the soya bean paps and porridges as weaning foods for Nigerian children is discussed.

V. A. Jideani (1979) explained that, soybean is crushed into oil and defatted meal. The meal is usually used as an animal feed; a smaller percentage is further processed into food ingredients including soy flour, concentrates, and isolates and textured protein. These are soy protein products used as food ingredients because of their multiple functional properties. Functional properties are the intrinsic physicochemical parameters which affect the behaviour of a food ingredient in food systems during processing, manufacturing, and storage Functional properties are important in determining the quality (nutritional, sensory, physicochemical and organoleptic properties) of the final product as well as facilitating processing such as improved machinability of cookie dough or slicing of processed meats.

Soy protein is highly digestible (92–100%) and contains all the essential amino acids except methionine which is relatively low but good source of lysine. He also described that soybean-protein products also contain a high concentration of

isoflavones, up to 1 g/kg. Setchell *et al.,* (1987). Kullaya and Yao-Wen (2007) studied that, the soy protein fortalice from sweet potato on paste products. Pasta made from 100 g/100 g alkaline-treated sweet potato flour (ASPF) had the less cooking loss (9.9 g/100 g) with the more firmness (1.8 N). Cooking loss enhanced as dose of DSF and SPC enhanced (from 9.9 to 16.6 g/100 g). Inclusion of DSF and SPC enhanced the lightness ("L*" value) from 40.6 to 48.7, and depress the redness ("a*" value) from 21.6 to 15.2. Interchange of DSF and SPC reduces firmness from 1.8 to 0.4 N, cohesiveness from 0.6 to 0.5 and springiness from 1.2 to 1.1 mm. Pasta prepared from 100% ASPF had more t β-carotene content (9.0 mg/100 g). The β-carotene contents drpressed from 7.9 to 2.7 mg/100 g as the levels of DSF and SPC enhanced.
Development and evaluation of composite flour for missi roti / chapati were carried out to develop the nutritious flours from various food commodities like whole wheat flour, chickpea, soybean and methi leaves powder to prepare excellent quality parameters of chapaties. Four types of bends were acceptable. They were made from wheat flour, chickpea, full fat soy flour and methi powder in different ratio viz; 'A' wheat flour: chickpea flour (80:20). 'B' wheat flour: fullfat soy flour (90:10) 'C' wheat flour: chickpea flour: soy flour (80:10:10) and 'D' wheat flour: chickpea flour: soy flour: methi leaves powder (75: 10: 10: 05). The proximate composition of blends used for preparation of various products contained higher amount of protein and other nutrients. They contained proteins (11.8 to 15.37%), fat (1.53 to 3.45%), fibre (1.24 to 2.05%), ash (2.08 to 2.70%) and carbohydrates (65.99 to 74.2%). These results showed that soy flour / chickpea flour alone or in combination, both increased the amount of protein significantly. Calcium, phosphorus and iron were enhancing on fortification of chickpea, soy flour and methi powder. Iron content increased in methi fortified mixture. All these combined flours were found to have better organoleptic properties of products as control. All these combined flours could be well stored in polyethylene bags or tin boxes for the tenure of 3 months without any quality depression. The fortification of 5% methi powder enhancing the nutritional quality of flour particularly in minerals (calcium and iron) and fibres Kadam ML *et al.,* (2012).

Oil Extraction and concentrate production

There are two ways to extract the oil out of soy: mechanical expelling and solvent extraction. Hexane extraction is the most common industry practice. However, this method requires a lot of capital investment and it can be prone to explosions. Mechanical expelling followed dry extrusion is a more cost-effective way to extract oil and it is safer than hexane extraction. It is also chemical free and requires low capital investment and low operation costs (Riaz 2001).Full-fat and defatted soy flours shows basic forms of soy protein that can be prepared by simple, easy and cheap processes, and neatly processed soy flours have good nutritional value as given in biological feeding tests with humans and small animals. Novel easy processing methods for full-fat soy flours, in addition to an extrusion process for use in urban communities and a simple manual process for use in villages where skilled labor ,machines and steam power are not present, have been developed. Severe heat treatment during processing depressed the availability of amino acids, repair oxidative stability, depress vitamin content and made poor flavor parameters in the product. Lipoxygenase inactivation before the toasting treatment is vital to obtain a stable, high fat product. Better flavor in soy flours can be attend to make them consumable to the consumer in a wide range of processed foods (Mustakas *et al.,* 1969).

Renu Singh *et al.,* (2022). Explained, Oilseed cakes remaining after the oil extraction for various uses are mainly used as cattle feed, compost amendment, or plant conditioner. These oilseed cakes are full in protein, nitrogenous compounds, and minerals. Other than its conventional usage, research have been conducted to use these protein rich resources for human intake. Considering the excessively raising population and increasing food prices, these protein rich sources can be a great food commodity and used to extract protein. The quality and functional properties of extracted oilseed cake proteins not only add-on the existing protein sources for the human consumption but also solve the issue of oilseed cakes discarding with the surplus income to the oilseed crop cultivar's and processers. Production of proteins for human consumption from oil seed cakes may also decrease the carbon and water footprints while producing animal protein. The present review will give emphases on analysing the oilseed cake as a protein source, characterization, extraction techniques, and exploration in food products. Umar garba and Sawinder kaur (2014) guided, Protein isolates and concentrates are purified form of protein carrying the higher amount of protein with high digestibility. Nowadays it's the major source of low cost proteins especially for athletes, bodybuilders, vegetarians, and has gained wide uses in various beverages and dairy industries, and infant foods due to its non-identical functional properties. It is widely processed from deoiled cake of legumes such as peanuts, cowpeas, soybeans, etc and animal origin like fish and milk by a mingling of isoelectric and alkaline precipitation using H2SO4 and NaOH, followed by centrifugation to obtain the pure isolates which

can more be dried to powdered form of about 90% protein. The problem of anti-nutritional factors in legumes can be successfully decreased by these processing methods**.**

The study aimed to develop soy protein concentrate (SPC) from soybean. SPC was produced using different concentration of acetic and citric acid (40, 50 and 60%), purpose of developing the concentrate and residue was to get value add products rich in protein and fiber. The experimental work was also carried out to determine the chemical compositions of whole soybean seed, defatted soybean, SPC and soy protein residue (SPR) by proximate analysis i.e. moisture, ash, fat, fiber and protein contents. Citric acid and acetic acid being edible acids were used to get highest protein content of soy protein protein content of 87.49% was obtained from SPC with 60% citric concentrate and to see the maximum yield as well. High protein content of 87.49% was obtained from SPC with 60% citric acid concentration and high fiber content of 13.36% was obtained from SPR with 50% citric acid concentration. While in case of acetic acid, high protein content of 69.81%, and high fiber content of 10.50% were obtained with 60% and 40% acetic acid. The protein content obtained from SPC was significantly higher than from SPR. Unlike the protein content, high fiber was found only in SPR in both the acids used. (Shumaila usman *et al.,* 2017)

Application in Food Products:

Growing malnutrition and health issue in India can be well handled with supplementary diet incorporating soy proteins as soy proteins are superb quality proteins offering many health benefits. Health care profession across the globe examined the quality of soy protein same to that of other high-quality protein such as egg and milk. Soy protein helps to solve cancer, lowers cholesterol level, combat osteoporosis and handle menopause. Existence of bioactive components arginine and isoflavones is accountable for the health benefit of soy Protein. From food fortification point of view, soy protein isolate is superb among all the sources of soy proteins. Biscuits are the best food vehicle for soy Protein isolate fortification. Parate V.R. *et al.,(*2018)

The global development of livestock production systems, accelerated by the growing demand for animal products, has greatly contributed to land-use change, greenhouse gas emissions, and pollution of the local environment. Further, excessive consumption of animal products has been linked with cardiovascular diseases, digestive system diseases, diabetes, and cancer. On the other hand, snacks, pasta, and bread available on the market are made from wheat, fat, salt, and sugar, which contribute to the risk of cardiovascular diseases. To counter these issues, a range of plant protein-based food products have been developed using different processing techniques, such as extrusion**.** Given the easy scale enhancement, cheap costing of extrusion technology, many health profits of soy proteins, this review concentrates on the extrusion of soy protein and the utilization of soy protein-based extrudates in the processing of nutritious, and sustainable meat analogs, snacks, pasta products, and breakfast cereals. This review elaborate the enrichment of soy protein to formulate hyper caloric foods through extrusion technology. It also talks about physical and chemical differences of soy proteins/soy protein blends during low and high moisture extrusion. Hydrogen bonds, disulfide bonds, and hydrophobic reactions affect the characteristics of the extrudates. Adding soy protein to snacks, pasta, breakfast cereals, and meat analogs interferes their nutritional value, physicochemical properties, and sensory characteristics. The use of soy proteins in the production of low-calorie food could be an excellent opportunity for the future development of the soybean processing industry.(Yuyang H *et al.,*2024)

Protein is a main structural component in many foods. Soybeans are a plant-based protein that is used in food. Soy concentrate is generally have high values in nutrients, particularly protein, with an essential amino acid profile that is immense in plant products and closely similar to animal protein. In enhancing the parameters of processed soybean products, such as physical modification, namely the preheated process. The preheated process is a physical modification that needs heating the product at a particular temperature and time, with the aim of attaining the protein denaturation point for boosting the functional parameters of protein contents. Greater public interest in healthy diets may lead to add to the processing of protein-enriched foods, one of which is biscuits. The aim of this study was to analyse the effect of modified preheated soybean concentrate powder in the physical characteristic of high protein biscuits (11 - 15%). Texture characteristics, macrostructure, and sensory quality of biscuits were studied. In this study, soy protein was preheated for 20 minutes at a temperature of 80°C. The results showed that preheated treatment impart a depression in texture quality compared to control biscuits, also it shows a decrease in porosity of biscuits, compared to control. The preheated treatment that attain the denaturation point simulate enhancing the physical parameters of biscuit, one of which is not give an excessive textural effect in the formulation of high-protein food. The best-preheated treatment was found in an 11% soy biscuit with a great texture. Analysis of microstructural test results expalined that the porous biscuits were found in 11%

preheated soy biscuits. According to the comparison sensory, triangle test, the panellists cannot defined a pair of control and 11% soy biscuit.(Huda *et al.,*2023)

The objective of this work was to search the effect of soy flour and whey protein concentrate (WPC) addition on the extent of Maillard reaction and caramelization during cookie baking. Wheat flour from a rotary moulded cookie recipe was substituted by full fat soy flour and whey protein concentrate. A main complex structure was used and second order models were employed to make replies surfaces for losing of already present lysine and for colour enrichment. Diffuse reflectance estimation of cookies was used to get the k/s coefficients of the Kubelkae Munk equation where k is the absorption coefficient and s is the scattering coefficient at 450, 557 and 680 nm. Luminance, ruling wavelength and excitation purity was also calculated. The fortification of WPC produced an main enhancement in available lysine loss, k/s values and excitation purity, and a depression in luminance and dominant wavelength. These results shows that the putting of WPC favours the formation of cookie color may be because of its high lactose composition. On other hand, the increase of water content produces a late of Maillard reaction and caramelization. Soy flour had not majorly affect the present lysine and its effect on color characteristics was much low significant than that of WPC.(Santiago P *et al.,*2012)

Replacement of flour with soy protein isolate in bread processing enhance the protein Content and nutritional value of baked product as it has more lysine than wheat flour. However, changes in the bread recipe may hasten the pH and amino acid content of the baked products, and product evaluation is necessary to estimate if the product is a non-time/temperature control for safety food. This study evaluates the consequences of replacement high-gluten flour with 2–8% soy protein isolate on bread quality and on the shelf life of the bread utilizing the microbiological challenge test. The results shows that enhancing soy protein isolate replacement reduces the volume and specific volume of bread. Six percent soy protein isolate-fortified bread also had a poorer taste, and, therefore, the average replacement amount is 4%. Based on the yeast and mold growth during the storage period, the 4% soy protein isolate-enriched bread has a use by date of four days, also the 2% soy protein isolate-fortified bread has a shelf life of five days. The microbiological challenge test results explained that the replacement of flour with soy protein isolate is favourable to Staphylococcus aureus growth within the bread. To summarize, the optimal soy protein isolate replacement in bread is 4%, which offers a four-day shelf life at room temperature. (Yu H.C. *et al.,*2023)

The market of gluten-free food products has been growing agressively in recent years, also, it is needed to conduct research on the impact of various compounds to increase the quality of these products. The present study is designed at look into the impact of incorporating whey protein concentrate (WPC) and soy protein isolate (SPI) at three levels (0%, 5%, and 10%) and xanthan gum (XG) (0%, 0.15%, and 0.3%) on the textural and rheological characteristics of gluten-free batter and cake based on rice flour. The results showed that enhancing the levels of XG, WPC, and SPI increase the apparent viscosity of the batter samples. The effect of WPC on the apparent viscosity was more marked than that of SPI, as the major value (21.9 Pa·s) was comparable to the sample that contains 10% WPC and 0.3% XG. The depressed tangent values of the batter samples, analysed at a frequency of 1 Hz, ranged from 0.531 to 0.8 for varying grades of WPC/XG and from 0.466 to 0.699 for SPI/XG, showing a gel-like behaviour of the batter samples. The sample contain 10% SPI and 0.3% XG show the strongest gel with higher storage modulus (982.112 Pa) and loss modulus (458.039 Pa) contrast to other samples. Enhancing the grade of XG, WPC, and SPI arise in higher specific volume, porosity, firmness, and springiness of the samples compared to the control sample ($P < 0\ 05$). The enrichment of WPC, SPI, and XG enhance the overall acceptance of the cake samples, with the samples contain WPC/XG blend being the most suitable. In the end, the cake sample containing 10% WPC with 0.3% XG taken as optimal sample. This recipe not only can increase the parameters of gluten-free cake but also meets parts of the nutritional fulfilment of consumers, specifically those with celiac disease. (Parastoo G *et al.,*2023)

Conclusion

Soybean is in its composition naturally contains many health promoting characteristics, also there are so many health benefits by consuming soybean. Oil extraction from soybean produces by product i.e. defatted meal and it is abundant in the protein content so by using different methods of extraction we can get Soy Protein Concentrate (SPC) and as Soy protein concentrate (SPC) is abundant source of protein it can be used in variety of food applications to full fill the protein demand of the population.

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