

REVIEW PAPER

Soybean Production and Utilization in India: A Path Towards Functional Nutrition

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Paper No.: 338

Received: 11-09-2025

Revised: 28-11-2025

Accepted: 06-12-2025

ABSTRACT

Purpose: Pulses, part of the Legume family, are staple foods worldwide. Soybean, a major leguminous crop, is unique with its economic value. Soy is a functional food rich in bioactive compounds, especially Isoflavones. Despite its benefits, vegetable soybean is not widely recognized in India due to lack of awareness and compatible genotypes. **Findings and values:** India accounts for 2.99 percent of global soybean production. In India primary cultivators of soybeans are Madhya Pradesh, Maharashtra, and Rajasthan, contributing over 95% of the country's soybean land. Consumers increasingly demand health-conscious food products with low sugar, high protein, and dietary fiber. Soybean products, with superior vegetable varieties, offer unique flavors, textures, and high amino acid content, making them a valuable source of nutritious food. Functional and nutritional content should be maximized by processing methods. This investigation examines soybean production, use, processing, and market in India. Soybeans are processed into various food products like roasted nuts, milk, flour, and oil. Soy milk, a popular food product, accounted for 60.1% of global soy food sales in 2020. **Conclusion:** There are many improvements in technologies for processing and product development. But the Farmers and brokers sell raw soybeans, rather than processed forms. The development of the soy market in India depends on addressing consumer preferences, the supply chain, and health benefits.

Keywords: Consumer, Demand, Functional, Processing, Production

The Latin word “puls or pultis,” which indicates thick slurry, is from which the term “pulse” originates. Pulses are part of the Legume family, which has been a staple of traditional foods worldwide for thousands of years. While legumes include such like soybeans, peanuts, fresh peas, etc., pulses are foods like dry peas, lentils, chickpeas, and dry beans, etc. However, not all legumes are pulses, every pulse is a legumes¹. Soybean is a major leguminous crop around the world for its economic value and variety of products (Sharma *et al.* 2014). Compared to grain soybean, which has seeds that range from 10 to 25 g dry

weight per 100 seeds, vegetable soybean, also known as “edamame,” is a higher-value, unique variety of soybean. There are two main markets for vegetable soybean around the world: local consumption as a fresh vegetable, or export of frozen fresh pods or beans to Japan, to USA and Europe in recent times (Keatinge *et al.* 2011). And also the Soybean is grouped

How to cite this article: Neelaveni, K. and Angeline Esther Preethi, S. (2025). Soybean Production and Utilization in India: A Path Towards Functional Nutrition. *Int. J. Food Ferment. Technol.*, 15(02): 491-500.

Source of Support: None; **Conflict of Interest:** None 

under many categories which include legumes, oil-seeds, vegetables, or even fuel sources, based on its uses. Soybeans are one of the remarkable plants that consists most of the amino acids in their protein to known it as “complete” proteins, comparable with meats, milk products, and eggs (Karuga, 2018). Despite all of these benefits, vegetable soybean is still not widely recognized in India, either for domestic consumption or in agricultural practices. It is brought on by both a lack of awareness and the unavailability of a compatible genotype (Poornima *et al.* 2014). In view of this, the present investigation examines the market for and production of soybeans as well as their use, processing, and research and innovation in Indian agriculture and consumption.

Soybean in Indian Farming and Economy

The agricultural sector supplies raw materials to numerous agro-industries and ensures food security for the entire population. Within the category of field crops, oil seeds rank second in importance for determining the agricultural economy, just ahead of cereals. One of the world’s top producers of oil seeds, India plays a significant role in the country’s agricultural economy (Rani & Singh, 2022). Based on the primary crop production value, the major producers of soybeans worldwide are Brazil, the United States, Argentina, China, and India, listed in

descending order of production (FAOSTAT, 2022). According to a survey carried over the past five years, India accounts for 2.99 percent of global soybean production and nearly 98.83 percent of all soybean production in South Asia. With regard to the global consumption ratio, India represents 3.13 percent.

India holds fifth in Soybean production (10 Mt) in the world. It is mainly cultivated in Madhya Pradesh, Maharashtra and Rajasthan. These states contribute more than 95 per cent of the area under cultivation and production of soybean in the country (Jha *et al.* 2012). The major Soybean varieties produced and in the use are JS 93-05, JS 95-60, JS 335, JS 80-21, NRC 2, NRC 37, Punjab 1, Kalitur for its high seed longevity. And there are about 30 varieties are in seed chain at present in India (<https://iisrindore.icar.gov.in/varieties.html>). Known as the “Soybean State” of India, Madhya Pradesh occupies over 55% of the nation’s total land used for soybean growing (Maish *et al.* 2022).

The remarkable 5352% growth rate suggests a major spike in demand or price. This could be due to increased use in food products, animal feed (<https://fas.usda.gov/regions/india>). The most significant seed legume in the world, soybeans provide 25% of the world’s edible oil, over two thirds of the protein concentrate used in animal feed, and are an

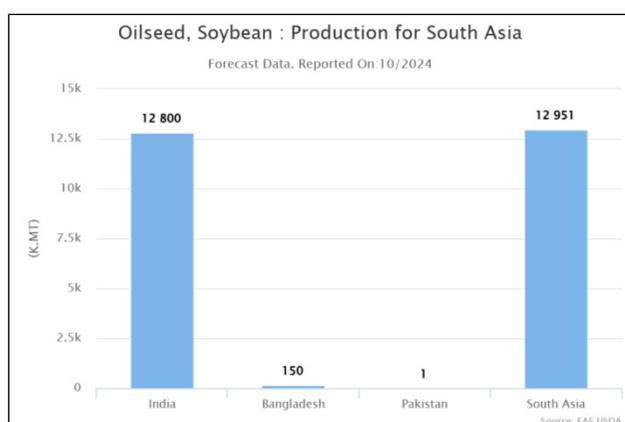


Fig. 1: Soybean production in South Asia

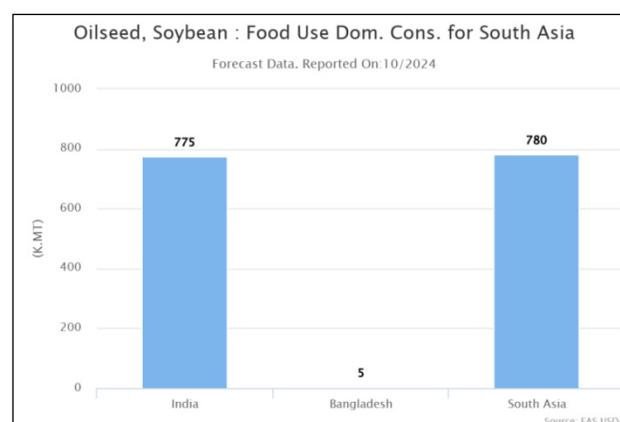


Fig. 2: Domestic consumption of Soybean in South Asia

Source: United States Department of Agriculture, Foreign Agricultural Service (<https://apps.fas.usda.gov/psdonline/app/index.html#/app/statsByCommodity>).

Table 1: 2023 Soybean Productions by State

Sl. No.	States	Kharif 2023 (in Million Metric Tons)		
		Sowing Area	Expected Yield	Estd Production
1	Rajasthan	10.945	925	10.126
2	Madhya Pradesh	52.05	1008	52.47
3	Maharashtra	45.64	1028	46.917
4	Andhra Pradesh	—	NAN	—
5	Chhattisgarh	0.354	879	0.311
6	Gujarat	2.663	934	2.487
7	Karnataka	4.077	950	3.873
8	Others	1.02	870	0.887
9	Telangana	1.798	932	1.676
Grand Total		118.547	1002	118.747

Source: <https://sopa.org/statistics/soybean-production-by-state/>

essential component of fish and poultry formulas (ICAR VISION, 2023). Based to a literature review investigation, Indians should consume high-quality soybean protein on a daily basis to help reduce the nation's chronic energy-protein malnutrition. Both the public and commercial sectors in India ought to react promptly to promote the nation's consumption of soybeans (Agarwal *et al.* 2013).

Based on the previously mentioned data, it is evident that soybeans are essential to the global economy, the Indian market, and northern agriculture.

Nutritional Insights of Soybean

Considering the affordable price as well as worldwide availability, legumes have the ability to become an important form of nutritious protein in a person's diet (Semba *et al.* 2021). Based on the dry weight of mature raw seeds, the soybeans have about 35–40% protein, 20–% lipids, 9–% dietary fiber, and 8–5% moisture content (Qin *et al.* 2022). The fatty acids linoleic, oleic, palmitic, and linolenic comprise 54, 24, 12, and 8% of soybean oil, respectively. Consuming soybeans may be beneficial because of their high unsaturation (unsaturated fatty acids >85% of total fatty acids) and tendency to reduce blood cholesterol (Lokuruka, 2010).

Compared to cereals, soybeans are a greater source of B-vitamins, although they are lower in vitamin C

and B 12. The trace amounts (mg/kg) of α -, β -, γ -, and δ -tocopherol (naturally occurring antioxidant) are present in soybean oil. Moreover, minerals make up about 5% of soybeans. It has a comparatively high K, P, Ca, Mg, and Fe content (Dixit, 2011).

The protein derived from soybean can be divided into two groups as water-soluble proteins and salt solution-soluble proteins (Sui *et al.* 2021)). After fermentation, the overall amino acid concentrations improved with a single exception of arginine. The fermenting microbe in the samples may have hydrolyzed the storage proteins into peptides and amino acids, which is how the quantities of amino acids have increased (Ojokoh & Yimin, 2011). The High Hydrostatic Pressure (HHP) processing technique helps to improve protein solubility and to deactivate trypsin inhibitors and lipoxygenase (Munekata *et al.* 2020).

Considering all these numerous nutritional benefits, it is recognized as an excellent pulse or legume for human nutrition.

Unlocking the Unique Properties of Soybean

Beyond providing nutrients, food can help in the prevention and treatment of certain diseases through the dietary intake (Kim, 2021). Soy is an excellent option for a functional food considering that it contains a variety of bioactive chemicals, iron,

Table 2: Nutrients present in Soybean per 100 g

	Soybean (brown)	Soybean (white)	Amino Acid content	Soybean (brown)	Soybean (white)
Energy (k.cal)	381.45	377.39			
Protein (g)	35.58	37.80	Palmitic acid (mg)	2381	2338
Fat (g)	19.82	21.55	Stearic acid (mg)	566	523
Carbohydrate (g)	12.79	10.16	Arachidic acid (mg)	47.10	43.30
Dietary fibre (g)	21.55	22.63	Behenic acid (mg)	67.89	65.49
Thiamine (B1) (mg)	0.59	0.61	Lignoceric acid (mg)	29.84	30.95
Riboflavin (B2) (mg)	0.24	0.23	Palmitoleic acid (mg)	22.79	25.35
Niacin (B3) (mg)	2.12	2.28	Oleic acid (mg)	4499	4723
Pantothenic acid (B5) (mg)	1.97	1.97	Eicosenoic acid (mg)	35.99	68.10
Total B6 (mg)	0.43	0.45	Linoleic acid (mg)	9969	9754
Biotin (B7) (mg)	0.73	0.77	α -Linoleic acid (mg)	1310	1318
Total Folates (B9) (μ g)	297	288	Total saturated fatty acids (mg)	3092	3002
Calcium (mg)	239	195	Total MUFA (mg)	4558	4817
Iron (mg)	8.29	8.22	Total PUFA (mg)	11279	11071
Magnesium (mg)	259	189			
Phosphorous (mg)	483	494			
Potassium (mg)	1613	1634			
Sodium (mg)	2.07	2.83			
Zinc (mg)	4.01	3.47			

Source: Longvah *et al.* 2017.

calcium, zinc, B vitamins, fiber, unsaturated fatty acids, and other nutrients. This is in addition to Isoflavones and soy protein (Rizzo & Baroni, 2018). Soybeans contain a functional compound known as bioactive Isoflavones. Isoflavones are a group of phyto-estrogens which have similar structures to the estrogens (Shirabe *et al.* 2021). Good source of soy Isoflavones in the diet could be an important, cost-effective, and suitable early prevention technique for breast cancer risk among women (Rajaram *et al.* 2023). As acceptable alternatives for high-quality proteins, Soybeans are now gradually taking on the role of milk and other animal protein sources, which are expensive and challenging for consumers to come by. Lactose is not contained in soy. Therefore, soy milk is suitable for those who are lactose intolerant (Kalaiselvan *et al.* 2010). There are many alternatives for lactose free diet, and soy milk is one of the best choice among all that.

According to the findings in a clinical investigation, people with prostate cancer might experience minimal negative effects related to their intestinal, urinary tract, and sexual effects when soy isoflavones are taken in addition to radiation therapy (Ahmad *et al.* 2010). Another study conducted in China found that consuming more soy could minimize the risk of breast cancer (Wei *et al.* 2020).

Vegetable soybeans' fermented soymilk shown to be an effective dietary matrix for probiotic bacterial delivery (Battistini *et al.* 2018). So this could help in improving the gut health. The blood lipoprotein profile, dietary fat quality, and fiber intake all improved when animal protein was substituted with plant protein sources. Alternatives to the existing, primarily animal-based diet that are healthier and more sustainable could be found in flexitarian diets (Päivärinta *et al.* 2020).

A study by Jannah, A. R., *et al.* (2020) found that the treatment attempts to decrease the causes of fracture caused by osteoporosis and enhance bone mineral density (BMD) by combining hydroxyapatite nanoparticles with isoflavones (Jannah *et al.* 2020).

Bio-active Compounds in processing

A study investigates the impact of soybean processing on isoflavone content in soy beverage and tofu preparation. The recovery of isoflavones was 54 and 36%, respectively. However, a significant percentage of isoflavones was lost in water used to soak raw soybeans, okara, and whey. The study suggests that appropriate techniques should be developed to recover and utilize functional constituents from soybean by-products, while optimizing processing techniques to ensure the final products contain the starting material's nutrient and nutraceutical content (Jackson *et al.* 2002). An investigation revealed that when soybeans are processed at a higher temperature, the amount of isoflavones is reduced. There is typically little loss when the processed water is discarded. On the other hand, shorter germination period change composition whereas longer germination period increase isoflavone content in the processing of soybean milk (Chiarello *et al.* 2006).

A study was aimed to evaluate how the black soybean's minerals (Fe, Zn, Mn, and Cu), as well as its bioactive components, were affected by soaking, germination, natural fermentation, and roasting. The findings showed that during the stages of germination, fermentation, and roasting, there was a considerable increase in the phenolic contents as well as a rise in the protein contents. Processed grains showed a considerable increase in antioxidant activity throughout germination, fermentation, and roasting. Phytic acid and tannin concentrations, two anti-nutritional chemicals, dramatically dropped following processing procedures. Following the germination, fermentation, and roasting procedures, tannin concentrations and phytic acid levels declined (Chauhan *et al.* 2022).

The soymilk samples prepared by W-BBF (wet method-boiling before filtration) presented higher

values for total flavonoid content and ferric-reducing antioxidant power assay and have higher values of phenolic acids. In general, it was discovered that the soymilk sample's higher phenolic levels and antioxidant activity were caused by the wet technique (Yu *et al.* 2021).

According to a study, soy milk fermented with *Lactobacillus acidophilus* and *Lactobacillus casei* has greater potential than non-fermented soy milk because of its superior physicochemical and compositional results, as well as its higher antioxidant activity as measured by DPPH, ABTS, and FRAP. The fermented soy milk's rheology revealed a high viscosity, the sensory assessment indicated greater acceptability, and the levels of bioactive components (genistein and daidzein) were also higher. Thus, it can be concluded that fermented soy milk can be used as a functional diet supplement to help prevent diseases linked to it (Ahsan *et al.* 2020).

So it was found that when the soybean is processed under low temperatures, the retention of non-nutrient bio active compounds were high and hence the soy food manufacturers should consider this to meet the maximum nutrient retention.

Research and product development in soybean

Consumers are getting progressively more concerned about their health, and they expect food products that provide health benefits like low sugar, low calorie, high protein, and dietary fiber (Amin *et al.* 2016). Soybean and its products may serve a significant part in supplying nutritious foods that meet the needs of consumer (Dukariya *et al.* 2020). According to a study which evaluated the characteristics of soybeans, superior vegetable varieties of soybeans generally possess exceptional umami and sweet tastes as well as soft textures. Their chemical composition is characterized by a high concentration of soluble sugar and a high quantity of umami and sweet amino acids. It was determined that SX6 exhibited significant sweet and umami flavor, positive sensory qualities, and was a rich source of amino acids (Guo *et al.* 2022). In terms of physiology, the vegetable soybean varieties resemble grain soybeans, but in

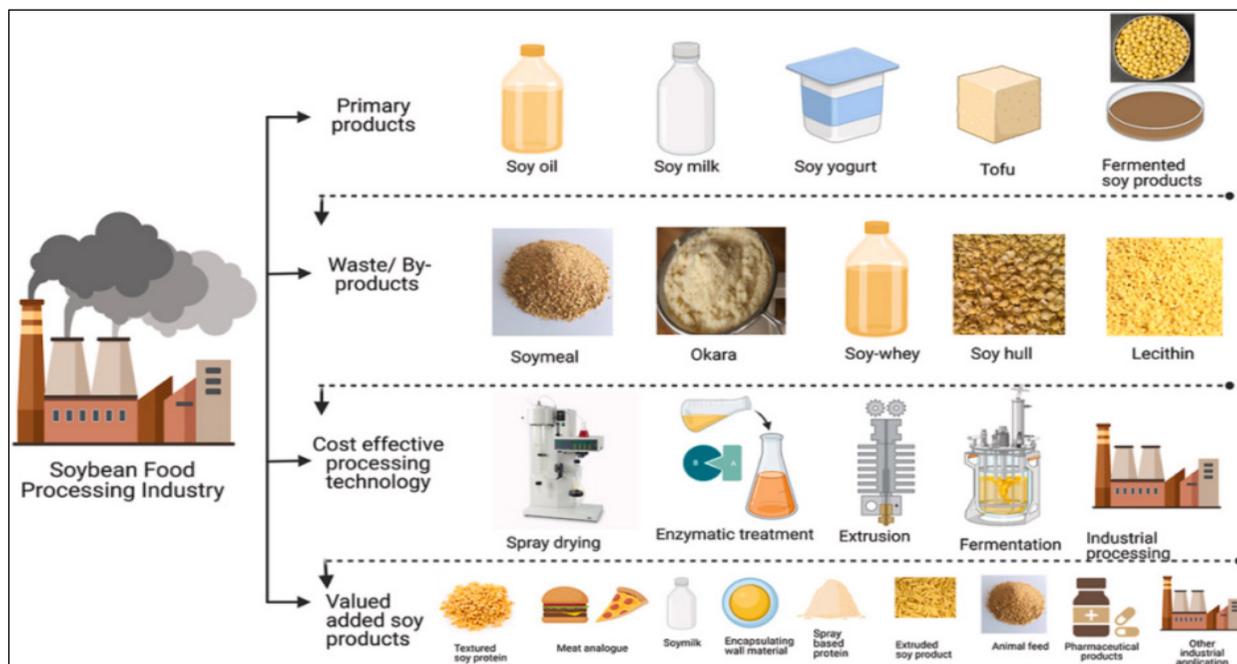
the R6 stage, they are sweeter and tastier. Vegetable morphological, physiological, and organoleptic testing revealed that the genotypes AGS447 and AGS 406 were superior to the remaining genotypes (Poornima *et al.* 2014).

The processed products of soybeans available in the market are: roasted soy nuts, full-fat soy flour, low-fat soy flour, defatted flour/ flakes, soy concentrates, soy protein isolates, soy germ, soy Isoflavones (extracted), soybean oil, dry beans, fresh beans for consumption (Riaz, 2006).

For the purpose of flavor, digestibility, and the bioavailability of nutrients and bioactive, soybeans are processed into a variety of food products. The primary processing procedures comprise steaming, cooking, roasting, and microbial fermentation, which breaks down protease inhibitors and cleaves the glycoside bond and extend the shelf life (Zaheer & Humayoun Akhtar, 2017). There are several infant formulas made of soy available in many countries worldwide, with North America holding the largest market (Maryniak *et al.* 2022).

In terms of processing, Soybeans are classified, cleaned, dried at a humidity level of nearly 10%, and then split to extract the shell. In order to make fiber additions for bread, cereals, snacks, and animal feed, Soybean shells are processed. The beans are husked and then rolled into fatty flakes that can be processed into whole grain flour for human use or utilized as animal feed. By breaking up the seed's oil cells, crushing facilitates better oil extraction. The next stage is to extract the raw oil, which is processed to make pastry fat, frying oil, and margarine (Colletti *et al.* 2020).

Extrusion-expelling, super critical fluid extraction of oil, extruded soy-based snack foods, expander technology, membrane technology, texturized soy proteins, coagulation and fermentation of soy proteins, chilling and freezing, electromagnetic waves, high pressure pasteurization and cooking, ohmic heating, retort, and aseptic packaging are some of the areas that currently involve investigation and advancement in soy food processing technologies (Tiwari, 2017). A study revealed that, the soy flour made from sprouts had the highest concentration of aromatic amino



Source: Singh & Krishnaswamy, 2022)

Fig. 3: Soy processing and by products

acids (phenylalanine and tyrosine), while the highest concentration of branched amino acids (leucine, lysine, and threonine) was found in silken tofu (Kumar *et al.* 2016). Wheat flour is the main player of any bakery products which is deficient in lysine. In other hands soybean is richer in lysine which is suitable to fortify wheat in bakery products (Mishra & Chandra, 2012). Newly formulated composite breads in which soy-flour was incorporated as substitute for wheat flour were found to be nutritionally superior (have higher protein, fat and crude fibre content) when compared to whole wheat bread. The substantial fiber content of the composite breads would make them suitable as functional foods (Ndife *et al.* 2011). There is a growing market for gluten-free products because pasta made with wheat often contains gluten which may produce gluten allergy. Rice based pasta varieties strengthened with soy were developed. The finest sensory qualities are found in rice flour that has been 15% enhanced with soy flour (Bolarinwa & Oyesiji, 2021).

Currently, soy sauce is highly used as a food product rather than employed as a food preservative. In reality, as an outcome of the development of advanced technologies in the production processes of Soy sauce, the flavor quality and consistency have significantly increased (Diez-Simon *et al.* 2020).

The most popular type of soy food product is liquid soymilk, which accounted for 60.1% of all soy food sales worldwide in 2020, according to Global Data. This excludes the large amount of soymilk offered in traditional marketplaces. The two biggest categories, tofu (sometimes referred to as "Other portions") and soymilk, brought in a total of \$45.9 million in 2020, accounting for more than 85% of sales of soy products in India (2021 Global Soyfoods Market Overview). A study found that when compared to soymilk prepared using the dry method, the wet approach showed a higher quantity of bioactive polyphenols and antioxidant activity. In this wet process, soybeans were soaked in distilled water (1:9 w/w) at 20 °C for 16 hours, after which they were ground, filtered, and then boiled. This is the traditional Chinese method to make soy milk (Yu *et al.* 2021).

According to a study on plant-based meat, the main reconstructing method for producing meat-like fibers from plant proteins is thermo-extrusion. The main components are polysaccharides, gluten, and proteins from soy and peas. The texture and flavor can be altered with vegetable oil blends and spices; color can be added with pigments; and nutritional value and shelf life can be increased with the addition of vitamins, minerals, antioxidants, and antimicrobials (Sha & Xiong, 2020).

Even though there have been all the processing techniques and product varieties were available, the consumption rate may be low in India especially in the southern parts.

FUTURE RECOMMENDATIONS

Currently, farmers and brokers sell the majority of their produce as raw soybean. In turn, solvents transform soy into goods like oil, which are then sold on both the domestic and foreign markets. On a very small scale, certain organizations, like GCC, turn soy into soy powder, which they then sell in the local markets under their brand name (Reddy, 2020). There are so many technology based food products on Soybean and the training also provided in the ICAR-Indian Institute of Soybean Research, Indore (Dupare, 2023). Consumers prioritize doctor's suggestions, product attributes like taste and aroma, availability of products, and price when purchasing gluten-free foods (Masih & Sharma, 2016).

The area we need to focus should be on consumer preferences over the variety of products. For the success of soy market in India, it is crucial to address both the health sector and the supply chain. The awareness among consumers about the nutritional importance and health benefits of consuming soy and soy-based food products in their regular meal.

Furthermore, additional research on consumer purchasing behavior regarding soybeans and their products has to be done. And the product should reach the customers and should fulfill their expectations or demands. This might support the effort made by the sector to create new products

or enhance existing ones, thereby boosting both innovation and demand from consumers. By doing this, the local soybean market may be expanded instead of to being exported, and the country's food and nutritional security can also be enhanced.

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