

Valorization of Soybean (*Glycine max* (L.) Merr.) Processing By-Products: Pharmacological Properties and Clinical Significance: A Comprehensive Review

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ABSTRACT

The number of soy-based goods accessible has expanded in recent years due to a shift towards less environmentally conscious agriculture, increasing understanding of the health advantages of ingesting soy-based meals, and an understanding of milk-related concerns. The Pacific area is home to China, South America, and the United States, the world's top producers. Alongside this huge manufacturing, a number of related by-products, including a material called okara, accumulate. The Okara variety is a kind of paste that is high in vitamins, small amounts of fat (10%), protein (25%), and fiber (50%). When used properly, it would have positive economic effects and lessen the possibility of environmental pollution. However, the product's high level of moisture (70–80%) causes it to deteriorate quickly, making it challenging to handle and costly to dry using traditional methods. Therefore, the purpose of this work is to design a generic strategy for okara harvesting and valorization by carefully examining the literature already available on the topic. Vegetable soybeans are regarded as an alimentary crop or a nutraceutical since they are high in phytochemicals that are good for humans. People all over the world are interested in soybeans as a "functional food" that lowers the risk of a number of dangerous conditions, including osteoporosis, atherosclerosis, and several cancers, including breast, uterine, and prostate cancer.

Keywords- Milk-related, Environmental pollution, Functional food, Vegetable soybeans, Alimentary crop, Nutraceutical.

I. INTRODUCTION

1.1. Use of By-Products in the Food Sector

A significant quantity of resources is needed for the ever-growing food production, and raw materials have not yet been fully utilized. Trash is produced as a result, adding to the trash produced by eating leftovers [1]. The predicted 60% increase in food production that the world's population would require by 2050 can be met by reducing the disposal of food and using resource wisely. Because food waste uses a lot of energy and resources and produces greenhouse gas emissions, it also contributes considerably to environmental problems [2]. Within the food supply chains in the most developed nations, there are notable food losses, such as 39 percent throughout the manufacturing process and a remarkable

42% by consumers [3]. In an effort to reduce the negative effects of food production on the environment and the economy, numerous by-products of the different stages of food manufacturing have been examined, and researchers have tried out novel methods for recovering useful components. Additionally, the transformation of numerous main metabolites might produce additional resources.

1.2 Soybeans: Characteristics, Processing and Use

Nowadays, the one of the oldest and most significant food crops in the world is soybeans (SBs). Seven of the biggest producers are currently located in both South and North America on the opposite side of the Pacific, despite the fact that they were first planted in Asia thousands of years ago. [4]. Even though soy foods have a long history, it has just been demonstrated in the

last fifteen years that they can help prevent and treat a number of chronic illnesses [5]. Because of their superior chemical and structural qualities and great nutritional value, SBs are now well recognized as a plentiful source of proteins. Furthermore, SBs and SB derivatives are abundant in phytochemicals, which are small non-nutrient components with possible health advantages. Physiologically active peptides and protein fragments, including protease inhibitors, are found in this class of compounds.

1.3. Okara: between Production and Consumption

The availability of soy products has increased because to a shift towards environmentally friendly food production, increased awareness of the nutritional benefits of consuming SB food, and knowledge of milk-related allergies. One of those goods is soymilk, whose production and consumption have grown in the majority of nations while the okara by-product continues to build up. There aren't many recent data on soymilk production. Production of soymilk was estimated to be at one million tonnes in 1983 [6], however, it has significantly expanded in the last few decades. In the western region of Europe, North America, and Japan alone, SB beverage manufacturing exceeded one million tonnes in 2006 [7]. While enhanced and coloured soy beverages are created at a seed-to-water ratio that can go up to 1:20, traditional soymilk is made at a ratio of 1:5. However, using a seed-to-water ratio of 1:7 and assuming which 1.2 tonnes of SB are created per kilogramme of SB during soybean milk production, it is predicted that around seventeen thousand kilogrammes of okara could be generated from 1 million tonnes of dairy-type soymilk (protein composition 3.5%) [8]. Although they are based on fundamental soymilk production, tofu along with additional soybean-derived goods are not taken into account in this estimate. Thus, it makes sense to estimate that several million pieces of okara are generated annually

II. COMPOSITION OF OKARA, A BY-PRODUCT OF SOYMILK PRODUCTION

A by-product of SB processing, soybean curd residue (SCR) is sometimes referred to as an okara (Japan), biji (Korean), or douzha (Chinese). Roughly 1.1–1.2 kg protein okara are produced for every kilogramme of SB used to make soymilk or tofu [9]. Broken cotyledon cells as well as the SB coating are its primary constituents. SCR is now handled as waste and either landfilled or used as fertiliser or feed. The majority of material is burned, producing carbon dioxide, especially in Japan [10]. The Okara plant is made up of approximately eight percent water, 3.5 or 4.0% proteins, and the majority of the persistent SB parts. Okara additionally features water-soluble ingredients due to its high moisture content. The type of SB utilised, the amount of sunshine and other

surroundings, and the processing procedures employed during soymilk production are the key determinants of its precise composition. As a result, the water-soluble fraction's properties could change based on the source material [11]. Okara has about 10% fat, 55% crude fibre, and 30% protein when it is dry.

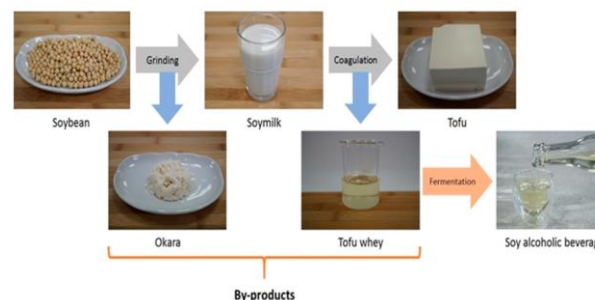


Figure 1:- Soya by product Production [12]

2.1 Dietary Fibre

Although the okra has a substantial moisture content (around 70–80%), the majority of the water is associated with the nutritional fiber, giving it a pasty feel akin to wet sawdust. The majority of the total amount of dry matter (40–60%) is made up of fibre, primarily insoluble fibre (cellulose and hemicellulose) [13]. that can be fermented by microorganisms in the large intestine but cannot be broken down in the small one. In contrast, only 4–5% of mobile carbohydrate (such as arabinose, simple galactic fructose, sucrose, raffinose, and stachyose) is present, and the primary factor preventing effective fermentable microbial development is the absence of fermentable carbohydrates. Specifically, it includes 1.4% refines and stachyose, which might induce swelling and flatulence in certain people. The monomers Galacturonic acid, fructose, arabinose glucose, xylose, fucose, and a tiny quantity of both rhamnose and mannose comprise the majority of the polysaccharide part of the cell wall [14]. Okras is a possible source of texturising additives due to its impact on the material's ability to retain water and swell. In order to ensure that okara has soothing and anti-cancer advantages for the digestive tract, Mateos-Aparicio et al. subjected okara to significant hydrostatic pressure (HHP), which increased the concentration of soluble dietary fibre by more than eight times.

2.2 Protein Component

About 15.2 - thirty-three percent of the okara (dry matter) is composed of proteins. Globulin 7S and the two proteins Globulin 11S are the primary proteins [15]. The okara protein isolates have low water solubility but they include all the five essential amino acids and have an antibody efficiency score that is even greater than that of tofu and soymilk (2.71 vs. 2.11). Additionally, it has been discovered that the protein portion of SCR may withstand full digestion by the stomach enzymes pancreatin (which primarily consists of trypsin, amyllopsin, and steapsin) and pepsin. These

digestible peptides' tiny molecular fraction (less than 1 kDa) exhibits strong antioxidant activity and is more effective at inhibiting the angiotensin-converting enzyme, most likely as a result of its considerable aqueous amino acid content [16]. Even though they can be rendered inactive with the right heat treatment, inhibiting trypsin can make up 5.2 and 14 percent of the protein present. Linoleic (54.1% among all lipid acids), oleic acid (20.4%), the acid palmitic (12.3%), linolenic acid (8.8%), and stearic acid (4.7%) [17]. During SB grinding, the liver's lip and hydrophilic lyase react with saturated fatty acids, primarily linoleic acid, producing aromatic chemicals like alcohols and hexyl and nonyl aldehydes. The scents of raw soymilk are represented by these low-detection-threshold smells. The Chinese method of manufacturing soymilk, which grinds the SBs before boiling the filtrate, generates an okara in a more environmentally friendly way because these enzymes are typically denatured at temp

2.3 Lipid Fraction

Additionally, from 8.3 and 10.9 percent (dry matter) of CR is made up of lipids eratures below 80 °C [18].

2.4. Isoflavones

Many legumes produce isoflavones, and SB is one significant source. It has been demonstrated by Wang and Murphy that okara contains more aglycons than soymilk. The isoflavone content of SCR typically ranges from 12% to 40% of the beans' initial isoflavone content. Depending on the type of SB, this results in isoflavone levels in the pulp ranging from 0.02 percent to 0.2 percent (dry weight) [19]. Because of their position as phytoestrogens, isoflavones have been extensively studied in the literature due to their significant activity over menopausal syndrome diseases, osteoporosis, and hormone-derived malignancies [20]. Aglycones (15.4%), glucosides, malonyl-glucosides (28.9%), and acetyl-glucosides are the four different types of isoflavones found in Bs, which can be separated into three major classes (daidzein, genistein, and glycitein). Although the processing procedures used to produce soymilk and leftovers may alter the initial isoflavonic composition, okara may still contain one of the twelve isoflavones. Polyphenols that resemble flavones in structure are called isoflavones [One of the biggest classes of polyphenols, flavonoids, includes both these compounds and ester SB variety, cultivation, processing, and storage conditions all affect the total level of isoflavone and its various forms in SBs and their derivatives. The two main types in SBs are β -glucosides and malonyl-glucosides. However, during processing, neither enzymatic conversion or stress from heat can convert these components into acetyl glucosides and aglycones. The dehydration of malonyl-glucose to acetyl-glucosides and ester hydrolysis of neither acetyl nor malonyl-glucosides generating β -glucosides are the most frequent chemical changes in isoflavones. even more aglycones are produced as a result of these glucosidic bond

breakage and these compounds have higher digestibility in humans. A common ingredient used for the synthesis of isoflavone is soy molasses, an by-product of the manufacturing of soy protein concentrate. It includes isoflavones in a somewhat more concentrated form because it is an alcohol-based extract of soy flakes. However, while recovering the compounds from side items, such as okara, calls for less valued resources, several patented procedures use SBs or SB dinner as a starting material.

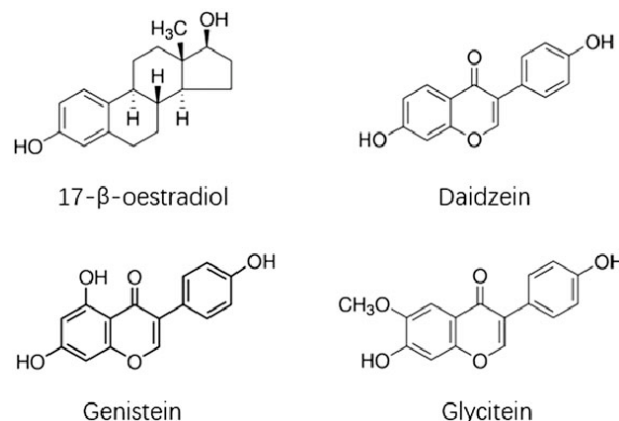


Figure 2 :- Chemical structure of Isoflavones [21]

2.5 Nutritional and Anti-Nutritional Element

Many different types of legume seeds, including SBs, peas, lentils, and lupins, include a class of non-volatile amphiphilic compounds called soyasaponins, the primary food sources of these substances are products made from soy [22]. These occur primarily in SB cotyledon cells, which are then processed and discharged into the okara. They have immunostimulating, antiviral, liver-protective, and chemopreventive qualities, according to a 2003 study by Gurfinkel and Rao [23]. Minerals, lignans, carbonates (the latter two falling under the umbrella of phytoestrogens), that are inhibiting agents of enzymes involved in the breakdown and biosynthesis of oestrogens, such as aromatase 17- β -hydroxysteroid reductase, sulfatase, and sulfotransferase, phytosterols, and phytates (which chelate calcium and iron in the intestine). Okara's usage in animal feed is restricted by anti-nutritional components such as phytates, saponins, and trypsin inhibitors [24]. By producing a final fermentation product with better nutrition and digestibility, fermentative bacteria can utilise these and other elements, including allergenic substances (which include glycine and β -conglycinine). Additionally, the plant contains a number of minerals that might enhance the well-being of humans, including potassium, calcium, and iron. For instance, potassium lowers systolic heart rate, iron boosts immunity and antioxidant, and magnesium lessens hypertension issues and helps avoid consequences from diabetes. While calcium prevents fractures and osteoarthritis in adulthood and old iron

deficiency has been linked to fatigue as well as a greater chance of cardiovascular/thromboembolic events

III. BOTANICAL DESCRIPTION

Glycine max (L.) Merr., or the soybean, is a perennial herbaceous crop that is a member of the Fabaceae family. It reaches a height of roughly 30 to 100 cm and grows either erect or semi-erect. The plant has many lateral roots with nodules of root filled with bacteria known as *Rhizobium* for nitrogen fixation, and it has a substantial tap root system. At maturity, the thickly pubescent, cylindrical, branched stem turns woody. The leaflets are oblong to elliptic, whole, hairy, and have reticulate venation at the tips. The leaves are trifoliate, alternating, and have long petioles. The flower head is an upright raceme or cluster that produces tiny, bisexual, white, pale yellow, or dark purple papilionaceous flowers. Every flower has five petals arranged in a typical pattern and a gamosepalous calyx. wings, keel, an upper, one-celled ovary with marginal placentation, and ten diadelphous stamens (9+1). The fruit has between two and four seeds and is a woolly legume (pod). Seeds range in colour from yellow to brown, black, or green, are spherical to oval, and are not endospermic. Soybeans are an important component of oils from vegetables and protein, and they are mostly self-pollinating [25].

3.1 Taxonomical Classification

Minimum *Glycine* (L.) According to taxonomy, Merr. belongs to the Class Dicotyledonae, Division Angiospermae, and Kingdom Plantae. It is a member of the Subfamily Papilionoideae of the order Fabaceae. (Leguminosae) and the Order Fabales. The plant, also referred to as soybean, belongs to the genus *Glycine* with the species *Max* [26].

Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta (Angiosperms)
Class	Magnoliopsida (Dicotyledons)
Order	Fabales
Family	Fabaceae (Leguminosae)
Subfamily	Papilionoideae (Faboideae)
Genus	<i>Glycine</i>
Speceis	<i>Glycine max</i> (L.) Merr.

3.2 Morphological Classification

Glycine max, or soybean, is an annual, upright or semi-erect herb based on its morphology. Numerous lateral roots with nitrogen-fixing nodules are part of the plant's well-developed tap root system. At maturity, the thickly pubescent, cylindrical, branched stem hardens. The leaflets are oblong to elliptic, hairy, and have complete margins with reticulate veins. The leaves are

trifoliate, alternating, and have long petioles. Racemes or clusters of tiny, bisexual, petals-like flowering arranged in white, pale yellow, or dark purple make up the axillary inflorescence. A bearded legume pod with two to four seeds is the fruit. The seeds range in colour from yellow to brown, black, or green, are spherical to oval, and are not endospermic [27].

Character	Description
Habit	Annual, erect, bushy herb
Root	Tap root system with lateral branches; root nodules present (<i>Rhizobium</i>)
Stem	Erect, branched, hairy, cylindrical
Leaves	Trifoliate, alternate, ovate leaflets, petiolate
Inflorescence	Axillary raceme
Flowers	Small, bisexual, papilionaceous; white to purple
Calyx	5 sepals, gamosepalous
Corolla	5 petals (standard, wings, keel)
Androecium	10 stamens, diadelphous (9+1)
Gynoecium	Monocarpellary, superior ovary
Fruit	Legume (pod), hairy

3.3 Geographical Description

Glycine max, or soybean, originated in East Asia, especially China, where it was cultivated thousands of years ago, according to its regional distribution. Soybeans originated in this region and then expanded to various regions of the world, including Asia, Africa, and the North American continent. It is currently widely grown in temperate, tropical, and subtropical parts of the world. United States of America, Argentina and Brazil, China, and India are major producers of soybeans. The crop thrives in areas with mild temperatures, well-drained fertile soil, and moderate rainfall [28].

IV. PRODUCTION AND USE OF OKARA

The soymilk-okara separation process is mostly responsible for the moisture content. Wet okara is difficult to use because of its high level of moisture, which causes it to disintegrate quickly. Every component is essential to the manufacturing of so ymilk. Whole soaking SBs are boiled, pulverised, and sifted in the Japanese process of manufacture. The Chinese approach includes grinding raw SBs, extracting them with water, filtering them, and then heating them [29]. The literature describes two primary methods for using okara in meals. In the first, the entire SCR is incorporated into final goods. The second method involves separating a number of its elements and using them as ingredients. Its fresh leftovers must frequently be dried before okara may be used as a full ingredient in food products. Okara's high

propensity to agglomerate, which causes spewing occurring, and the drying process's low energy efficiency make it a challenging material to dry [30]. It can be employed to enhance a product's consistency when it is dry. Producers are considering adding even less wet water to food goods than they did in the past. Whatever if SBs have undergone heated prior to grinding, its direct absorption into feeds or food is restricted by its lack of enzyme inhibitors [31]. Its application for developing low-fat hamburgers with beef and lowering the fat content of a coconut-derived baked has been reported by Additionally, freshwater goods The polysaccharide portion has gotten increased attention when it comes to the utilisation of SCR substances. Numerous writers have thoroughly defined its compounds, as detailed in Section 2.1. While recent literature has documented extensive characterisation and composition previous research on the protein fraction of okara has concentrated on techniques for separation and modification that can make it useful as a component Furthermore, the ability to retrieve of protein in SCR and the creation of a protein concentration through membrane separation .According to a study on protease hydrolysis-based peptide synthesis, the resulting peptides exhibited antioxidant action Finally, okara's capacity to supply natural antioxidants has been investigated. Polyphenols and oligosaccharides, highly valuable elements with reactive and prebiotic qualities, have been extracted using methanol, acetone, and water.

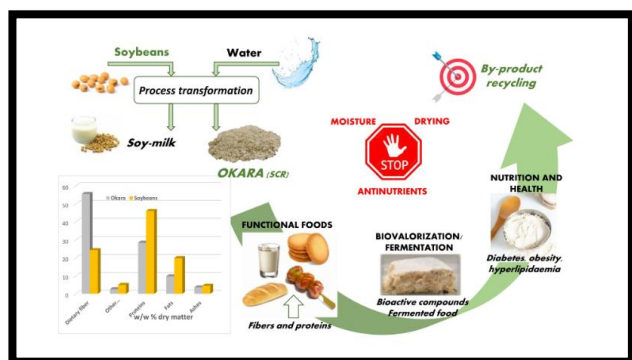


Figure 3:- Sustainable By-product Recycling of Soybean Okara [32]

V. APPLICATION OF OKRA IN FUNCTIONAL FOODS

The food industry has been quite interested in SB's chemical and nutritional properties over the years, especially its high protein content, fat content which is full of unsaturated fats (like linoleic acids), and high isoflavones concentration. In particular, the emphasis has been on incorporating compounds produced from soy into a range of goods in order to give them advantageous qualities for the body. We refer to these as "functional foods" For instance, one among the primary

products in Western cultures is water-soluble SB extract, often known as soy drink or soymilk, which has been utilised as a significant substitute for those who are lactose intolerant or allergic to cow's milk proteins [33].

5.1 Manufacturing of Food for Human Intake

In Japan and China, okara has long been used as food, both raw and processed, to more easily supply a balanced diet of protein and fibre. Due to its solvent-binding qualities, SCR is a perfect low-cost additive to boost meat product yields [34]. At an ideal concentration of 5%, it has also been demonstrated to prolong the shelf life of cacao cookies and inhibit syneresis in the cheese dumpling mixture during freezes and defrosting. However, because of its insipid flavour, it can be employed at comparatively high concentrations without negatively impacting the flavour and texture attributes of meat and baked goods. To boost the amount of fibre and protein in cuisine, okara can partially substitute wheat flour, SB flour, and other ingredients. Its value in the manufacturing of bread, breakfast puff baked goods, pasta, candies, beverages, sausages, and nutritional flour has been demonstrated by several research. The use of enzymes (pentosanase, lipase, and glucose oxidase) greatly improves the quality of bread made with okara. It has also been discovered that increasing the powder substitution between 4% to 8% improves quality After being treated with 1 percent sodium hydroxide (NaOH) for one hour and 1% Ph at 60 °C for two hours, bread containing 5% clean SB pulp fibre looked and felt very much like regular bread. Additionally, okara can partially substitute the wheat flour used to make cakes and cookies. The processed product lacked the characteristic sweet taste, which is suggestive of broad beans, and instead had a firm consistency and a pleasing flavour A high-quality product was obtained by fried at 160 to 165 °C for 3.5 minutes after extrusion using 54% starch, 8% SCR incorporated into a mixture of sweet potatoes residue (6:4 :1), 31% water, and 7% other ingredients [35]. Last but not least, Yu suggested using 100 g of okara, 500 g of potatoes, 150 g of wheat flour, and 20 g of concentrated milk as raw materials. These ingredients, when fermented with yeast for one hour at 28 °C, dried for one to two hours, and then fried for one minute at 180 °C, produced a dish based on okara fibre.

5.2 An Analysis of Paste Manufacturing

Once dried, even SCR is a great substitute for adding to culinary items like pâté, food fortification, or process adjuvants [36]. The potential utilisation of the okara as a food enrichment is being examined economically. The procedure of making soymilk uses 1 kg for SB and ten cups of water, yielding a total of 1.2 grams of okara flour. As a result, the okara produced by the method represents a tenth of the material that was previously utilised and is typically thrown away without producing any revenue. According to an estimate of the overall cost of transforming SBs to make soymilk, 227.7 US dollars per tonne of beginnings is wasted when okara is produced. A uniform blend of vegetables is called

vegetable paste, to which different scents are added to enhance its sensory qualities.

They prepared and analysed Carrots and mayonnaise were boiled away to create a homogenous mass, to which SB pulp, spices, and lemon juice were then added in the proper amounts to produce a product that has good acceptability and nutritious qualities. With an energy-efficient consumption (89.65% kcal/100 g) and lipid concentration (5.6%), the vegetable paste formulation enhanced with 33.9 percent okara (F1) has high levels of protein (3.1%), - carotene (0.411 milligrams per mL), dietary fibre (5.8%), and isoflavone. (0.15 milligrams per kilogram of fresh matter) and has shown high sensory acceptability. In summary, using okara to make a vegetable batter is an intriguing and practical way to boost a product's nutritional content and precisely utilise the waste produced during the soymilk production process.

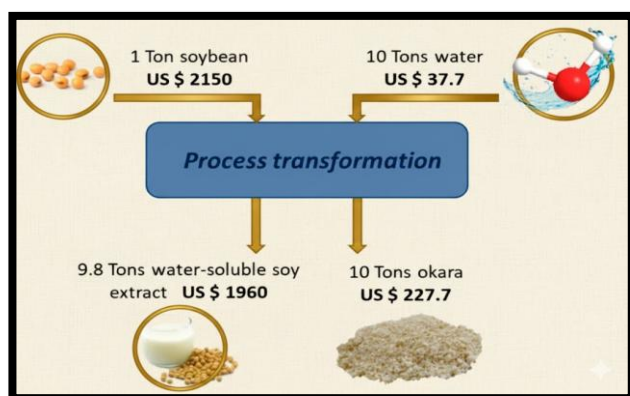


Figure 4:- Costs (US \$/Ton) of the production processes of water-soluble SB extract (soymilk) and okara [37]

5.3 Recovery and Improvement of Fiber

Because dietary fibre lowers the risk of coronary heart disease and cancer, the market for it is very competitive [38]. SCR is a great raw material for recovering dietary fibre because of its high fibre happy, affordability, and large production volumes. The production and distribution of Okara fibre fibre has been the subject of numerous published studies. The following procedures were used in one of these investigations to prepare dietary fibre from wet okara: porphyry drying, soaking in an alkaline solution, hydrolysis by enzymatic means, bleaching, ethanol precipitation, and drying. Alkaline soaking was conducted with 4 % sodium hydroxide at temperatures of 80 degrees Celsius for 80 minutes. Trypsin was hydrolysed enzymatically for 30 minutes in order to extract the protein. Whitening was done for 60 minutes at 50 °C using 3% H₂O₂. Following processing, 41% insoluble material, 15% dissolving fibre, 6% lipids, 1% protein, 2% ash, and 8% moisture made up the okara fibre. 10.08 g H₂O/g of product was the water-retention

capacity, while 18.66 mL H₂O/g of product was the hydration capacity.

5.4 Uses in the Nutrition of Animals

Due to the high moisture content of many food by-products, silage—a forage storage method that involves neutralising the plant mass via anaerobic microbes in an attempt to keep other microorganisms to colonising it and destroying its nutritional value—is frequently used to store them with the objective to avoid the high price of electricity of drying. To create low moisture total blend ration (TMR) silage, it is common practice in Japan to combine wet waste materials with dry feed. Therefore, adding okara and shellfish from peanuts to the silage mix can work in concert to produce the ideal dry matter and palatable carbs for silage fermentation. After eight weeks, it has been discovered that hay that has an okara/peanut wastes ratio of 78:22 improves the effectiveness of both hay fermentation and vitro ruminal fermentation modelling while lowering fibre amount and lignification [39].

Microbial molecules, which are synthesised via solid state fermentation, can also be produced using SCR. The mould breaks down the okara fibre during fermentation, producing low molecular weight polysaccharides that yeasts use to synthesise proteins. Furthermore, fermentation can break down or diminish some of the anti-nutritional components of okara, including trypsin inhibitors, saponin, and lectin. The crude protein level of okara rose by 43.1% in comparison to the original after three days of solid fermentation by a mixture of bacterial culture employing *Saccharomyces cerevisiae*, *Aspergillus oryzae*, and *Aspergillus niger* yeasts [40]. Additionally, it has been discovered that, after three days of fermentation at 32 °C, the crude protein content doubled when utilising okara as well wheat starch (ratio 8:2) as a substrate and *Aspergillus niger*, *Trichoderma*, or *viride*, *Saccharomyces cerevisiae*, and the *Candida* species utilis (ratio one to one to three) as a mixed crop.

VI. FERMENTATION-BASED BIOVALORIZATION

Okara is a potentially helpful fuel for microbial fermentation since it is high in proteins, carbs, and other nutrients. The health benefits and processing qualities of okara can be improved by fermentation, which can lower the amount of raw fibre and increase the amount of soluble fibre, amino acids and proteins, and isoflavones. It can also break down phytic acid, which is a phosphorus deposit in seeds that is insoluble to humans and can chelate other nutrients; in ruminants, however, it is lysed by the bacterial community. Therefore, the creation of food goods and functional substances depends heavily on fungi, bacteria, and yeasts [41].

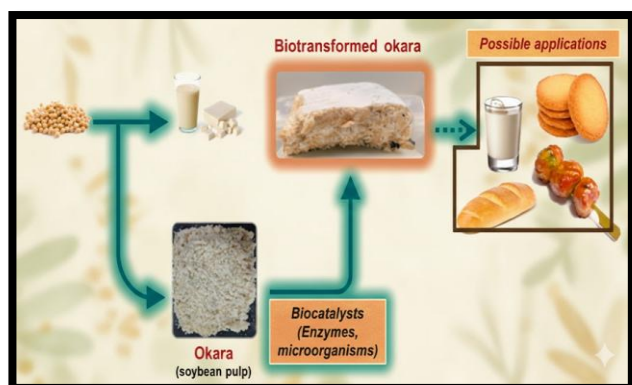


Figure 5:- The procedure's progression from SB to bio transformed okara, including possible uses in food products, is shown in this flowchart [42]

6.1 Fungal fermentation

Because SB pulp offers a physical surface for fungal adherence and growth, it is appropriate for fungal fermentation. Endoglucanase, esoglucanase, and β -glucosidase are among the cellulolytic enzymes released by filamentous fungi that break down lignin-containing biomass and improve digestibility [43].

6.1.1 Manufacturing of Bioactive Substances

The removal of bioactive compounds from okara has been investigated by fungal fermentation. *Aspergillus* HK-388, a strain discovered in soil samples in the Japanese city of Osaka, was used by Fujita, Funako, and Hayashi to ferment okara [44]. 8-hydroxydaidzein was the bioactive substance that was identified in the methanolic extracts. The ability of 8-hydroxydaidzein to inhibit tyrosinase and aldose reductase suggests that it may find use in medicine and cosmetics. The research team assumed that it was a byproduct associated with the biotransformation of zinc and daidzein, which are both present in the base material, because it was not found in unfermented okara. The extract was fermented with the red-purple mould *Monascus purpureus* in IFRPD 4046 in a different study in order to produce monacolin K, a low-lipid drug that has received approval in Europe. About 2.5 times less monacolin K was produced with 192 mg/kg of okara than with rice as the substrate. Therefore, a supplement containing carbohydrates might be required to enhance the synthesis of monacolin K from SCR. Additionally, it has been demonstrated that, in comparison to hot water extraction, ultrasonic-assisted extraction increases the amount produced of fungal polysaccharides. Okara fibres may be broken down by fungal growth to yield extremely light oligosaccharides while also releasing antioxidant peptides through proteins. The extract's bioactive okara components and fungal polysaccharides may work in concert as a result.

6.1.2 Manufacturing of Fungi-Fermented Food

Fungi can ferment SCR to create food that can be eaten directly. Meitauza is an indigenous dish made mostly in the Chinese province of Hubei. It is made with

fermented okara. To achieve natural fermentation, steamed okara is often formed into blocks, cooled, and covered via rice straws for 8–14 days at a temperature lower than 20 °C. Two microorganisms that have been isolated from meitauza are *Actis elegans* and *Zymomonas mobilis*. Pure plants of these microorganisms were inoculated to generate meitauza in a work by . Crude protein and moisture content decreased in the finished product, and the degradation of dietary fibre from okara and a notable rise in free amino acid levels. The result of these compositional adjustments is a smooth, rubbery texture and a delicate, pleasing flavour. The classic Indonesian dish tempeh, which is often made from whole SBs fermenting by *Rhizopus oligosporus*, can also be made with okara. A research study conducted through employed okara-tempeh as a dog snack. After a week, there were notable increases in the levels of *Bacillus* and *Bifidobacterium* as well as short-chain fatty acid concentrations. *Aspergillus oryzae* is commonly used in Asia to ferment SBs as the initial step in the production of various SB-based spices. Koji is SB biomass that has undergone mould fermentation. Okara-koji, which was made by substituting okara with SBs, was then dried and put to cupcakes and biscuits. With substitutions of up to 10% in biscuits and 5% in cakes, the final baked goods' consistency and palatability remained unaffected. During storage, this pastry also displayed less starch retrogradation and lipid oxidation. The expected lifespan of high-fat baked goods was then increased by using dried okara-koji in place of flour [45].

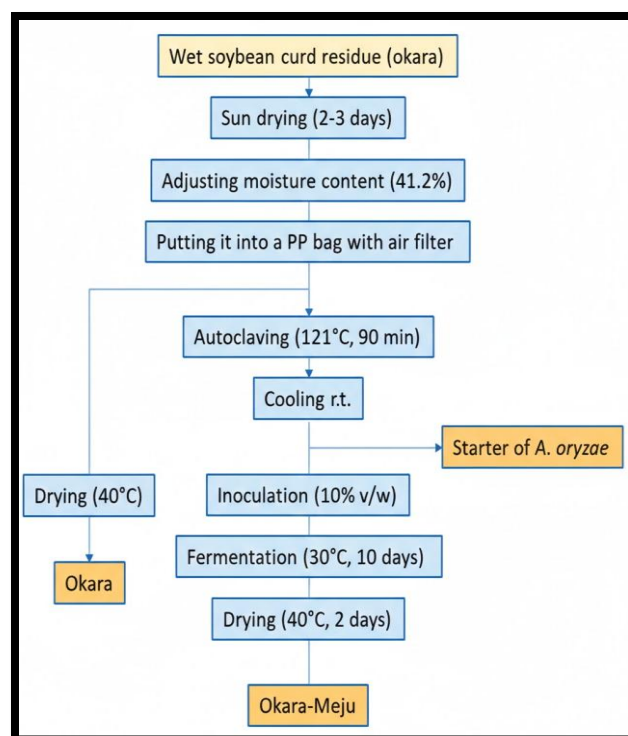


Figure 6:- Procedure for the preparation of fermented SCR (okara-meju) [46]

VII. PHARMACOLOGICAL ACTIVITIES

7.1. Antioxidant Activity

The abundance of bioactive substances found in Glycine max (soybean), including these compounds (genistein) and daidzein), and phenolic compounds, tocopherol (vitamin E), and flavonoids, is largely responsible for the plant's antioxidant activity. By neutralising oxygen species that are reactive (ROS) and avoiding oxidative damage to biological substances like phospholipids, proteins, and DNA, these components function as powerful free radical scavengers. By boosting the activity of chemicals such glutathione peroxidase, catalase, and superoxide dismutase (SOD), soybean extracts have been demonstrated to improve endogenous antioxidant defence mechanisms. Isoflavones can also lessen inflammation brought on by oxidative stress and prevent lipid peroxidation. This antioxidant potential highlights the therapeutic significance of soybeans in preserving general health by playing a major role in avoiding a number of chronic diseases, such as diabetes, cancer, cardiovascular problems, and neurological ailments [47,48].

7.2. Cardio protective Activity

The high concentration of soy protein, isoflavones, (genistein and daidzein), a phytosterols, and unsaturated fatty acids in Glycine max (soybean) is primarily responsible for its cardioprotective properties. These elements help to improve the overall lipid composition by lowering triglycerides and LDL cholesterol (low-density lipoprotein) while encouraging an increase in HDL (high density lipoprotein) cholesterol. Additionally, isoflavones have anti-inflammatory and antioxidant properties that preserve vascular endothelium and stop oxidative damage associated with the onset of atherosclerosis. Furthermore, it has been observed that soybean peptides block the angiotensin-converting enzyme (ACE), which causes vasodilation and blood pressure management. Therefore, a lower risk of cardiovascular disorders, such as elevated blood pressure, coronary artery and stroke, is linked to regular consumption of soybeans or their derivatives [49,50].

7.3. Anticancer Activity

The bioactive components of Glycine max (soybean), especially isoflavones like genistein and daidzein, as well as saponins, protease inhibitor and phytosterols, are largely responsible for the plant's anticancer properties. These substances reduce tumour

cell proliferation, induce apoptosis (programmed cell mortality), and restrict angiogenesis, which is necessary for tumour growth and spread, among other mechanisms that prevent the development of cancer. It has been demonstrated that genistein in particular modulates important cellular signalling pathways, including cell cycle regulation and tyrosine kinase, which stops the growth of cancerous cells. Furthermore, by lowering oxidative DNA damage, soybean isoflavones' anti-inflammatory and antioxidant qualities help prevent cancer. such as prostate and breast cancer, emphasising its possible function as a dietary chemopreventive agent [51,52].

7.4. Neuroprotective Activity

The rich presence of these compounds (genistein and daidzein), lecithin, and antioxidants chemicals in Glycine max (soybean) is primarily responsible for its neuroprotective action. These substances are essential for shielding brain cells from oxidative damage and neurodegeneration. These bioactive components support the preservation of neuronal integrity by scavenging reactive oxygen forms (ROS) and lowering lipid-mediated peroxidation in brain tissues. Additionally, isoflavones have estrogen-like activity, which allows them to interact with brain oestrogen receptors. This is advantageous for preserving memory and thinking and neuronal survival, especially in postmenopausal and ageing settings. Additionally, it has been observed that soybean components inhibit neuroinflammatory pathways, enhance synaptic plasticity, and alter neurotransmitter levels [53,54].

7.5. Anti-urolithiasis Activity

The bioactive components of Glycine max (soybean), including saponins, phytates that potassium, magnesium, and phenolic compounds, are responsible for the plant's anti-urolithiasis (anti-kidney stone) properties. These ingredients aid in avoiding the development and aggregation of urinary calculi. By preventing nucleation and crystal development, soybean extracts have been shown to lessen calcium oxalate crystallisation, the most prevalent kind of kidney stone. Furthermore, phytates have the ability to chelate calcium ions, reducing their availability for the production of stones. Additionally, soybeans have a moderate diuretic effect that encourages more urine production and helps the urinary tract flush away tiny crystals. Renal tissues are further shielded from oxidative damage caused by crystal deposition by its antioxidant qualities [55,56].

VIII. CLINICAL SIGNIFICANCE

S. No.	Study Design	Population	Dose & Duration	Key Outcomes	Conclusion	References
1	Open-label, multicentric clinical trial	190 postmenopausal women	35 mg/day isoflavones for 4 months	↓ Hot flushes in 80.82% patients; improvement in	Soy isoflavones effective for menopausal symptom relief	57

				menopausal symptoms		
2	Randomized, double-blind, placebo-controlled trial	80 postmenopausal women	100 mg/day isoflavones	Significant reduction in climacteric symptoms (hot flushes)	Supports estrogen-like benefits of soybean	58
3	Randomized controlled trial	40 postmenopausal women	37.3 mg/day for 10 weeks	↓ Bone resorption markers	Isoflavones help prevent osteoporosis	59
4	Double-blind randomized trial	202 postmenopausal women	99 mg/day for 12 months	No overall improvement in endothelial function; subgroup benefit	Mixed evidence for cardioprotection	60
5	Randomized, placebo-controlled trial	46 patients with fatty liver	100 mg/day for 12 weeks	Improved metabolic parameters and liver condition	Soy isoflavones beneficial in metabolic disorders	61
6	Randomized placebo-controlled trial	202 elderly women	Isoflavone-rich soy protein for 1 year	Slight improvement in quality of life (not statistically significant)	Limited but supportive benefits	62-63

IX. CONCLUSION

In order to encourage the appreciation of these by-products, this review looks at the makeup of dried standard SCR its condition, functions, applications, limiting factors, and current cautions. Due to the rising production of soymilk, tofu, and their derivatives worldwide, the disposal of okara remains an unresolved issue. While many research have been conducted on this subject, very few offer a way to profitably use SCR. Additionally, it is challenging to gather a large amount of okara for quick, central processing before it deteriorates because the majority of tofu along with soymilk factories are tiny and widely scattered. Therefore, the creation of appropriate dryers is a basic requirement for the full utilisation of this material. While SCR is applicable in a variety of situations, adopting suitable techniques for its application is also crucial. An intriguing option for its utilisation is to dry and crush it into powder, then combine it with wheat meal or other substances to create composite flours for the dietary requirements of individuals with particular needs (such diabetes and obesity) or functional foods. Additionally, okara's nutritional value, flavour, and processing qualities can be enhanced by chemical and enzymes treatment, fermentation, ejection, high pressure, and micronization, which will increase the food's overall acceptability. Future long-term randomised clinical trials are required to validate the health benefits of functional

foods and nutraceutical components from SCR. To comprehend the processes of activity of polyphenols, isoflavones, or bioactivated peptides extracted from SCR, pharmacodynamic investigations would additionally be helpful. In this sense, standardised protocols and more effective extraction techniques will ensure high-quality products for industrial preparations of food and nutraceuticals. In conclusion, despite significant advancements in recent years, future difficulties include the creation of tools for the appropriate recycling of SCR and methods for its appropriate application. Converting waste materials' byproducts into new, high-value products is an increasingly pressing problem, according to "circular economy" ideas.

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