Journal of Food Legumes
38(2): 187-198, 2025
DOI: 10.53550/jfl.v38.i2.259

Review Paper

Unlocking the potential of soymilk industry waste (Okara): A comprehensive review on valorization and food applications

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***Received**: January 9, 2025*
***Accepted**: February 14, 2025*

ABSTRACT

Okara, the residue generated during soymilk and tofu production, is a nutrient-dense byproduct often underutilized in industrial and domestic settings. Its composition includes approximately 50–60% moisture, 20–30% dietary fiber, 15–25% protein, 10–12% lipids and various bioactive compounds like isoflavones. Okara offers significant nutritional benefits, including antioxidant, anti-inflammatory, and cholesterol-lowering properties. However, its utilization is limited due to high moisture content, perishability, and coarse texture. Various methods are being developed to improve okara's functional and sensory properties. Drying techniques, including freeze-drying, vacuum drying, and spray drying, enhance its shelf life and usability. This review delves into the valorization of okara, emphasizing its potential in sustainable food applications. Okara's incorporation into bakery products, gluten-free items, dairy alternatives, and functional foods highlights its versatility and economic value. By addressing these challenges, okara can be transformed into an eco-friendly, cost-effective ingredient, aligning with global sustainability goals and reducing food waste. Future research directions aim to optimize processing methods, expand applications, and foster consumer acceptance, positioning Okara as a valuable contributor to the circular economy.

***Key words**:* Soybean, Soymilk Residue, Okara, Valorization.

INTRODUCTION

Soybean belongs to the *Leguminiaceae* (bean family) and is an important legume and oil crop. In 2022, global soybean production was estimated at 348.86 mt, covering 133.79 million hectares. India ranked fourth in soybean cultivation area (12.14 m ha, 9.07% of the global total) and fifth in production (12.99 mt). Major soybean-growing states include Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Gujarat, and Telangana. For 2023-24, the Government of India's second advance estimates project soybean production at 125.62 lakh tonnes, a decline from 149.85 lakh tonnes in 2022-23. Maharashtra leads production with 52.69 lakh tonnes, followed by Madhya Pradesh (51.29 lakh tonnes), Rajasthan (10.49 lakh tonnes), Karnataka (4.41 lakh tonnes), Gujarat (2.98 lakh tonnes), and Telangana (2.52 lakh tonnes) (Source: https://www.pjtsau.edu.in/ files/AgriMkt/2024/ April/ Soyabean-April-2024.pdf).

Nowadays different types of human foods are prepared from soybean such as soymilk, tofu, Ice cream, beverage etc. (Li and Hsieh 2004), Soymilk is a popular plant-based beverage made from soybeans that requires minimal processing, and is rich in nutrients like protein and is used in the preparation of products like, paneer, yogurt, cheese, tea and coffee whiteners, shrikhand, rasogolla and various indigenous milk sweets, confectionary product like chocolate (Gatade *et al.* 2009, Gatade *et al.* 2014). The growing demand for milk poses a significant problem in meeting future needs. After infancy, around 55-58% of the human population has limited or no ability to digest lactose (Paul *et al.* 2020). That is why there is a demand for a bovine milk alternative. Soy milk is an economical dairy replacement (Saini and Morya 2021). Soybeans are used in Singapore, Hong Kong, Australia, Canada, the United States of America, South America, Europe, China, and India, in the form of soymilk as well as processed products like soybean curd, tofu, etc. (Vong and Liu 2016). The manufacturing of soy-derived products produces soy residue, which is known as okara. It is known as "honorable hull" or "soy pulp" in Japan, 'douzha' in China, and 'biji' in Korea. The processing portion, approximately 45% of the soymilk and 55% of okara are produced from a kilo of soybeans. About 1.1 to 1.2 kg of okara is produced from every kilogram of soybeans processed into tofu or soymilk production (Li *et al*. 2012, Vong and Liu 2016, Prestamo *et al*. 2007). Dry okara comprises around 50% dietary fiber, 25% protein, and 10% lipids. Other components of soy products that are most likely present in okara include isoflavones, lignans, phytosterols, coumestans, saponins, and phytates (Lu *et al.* 2013). Okara is an important by product of soymilk, tofu, and soy-nut processing and over a hundred million tons of okara are produced annually, particularly in Asian nations with heavy soybean consumption, causing a serious disposal issue. The enormous amount of okara generated each year creates a severe disposal concern. Okara is sometimes utilized as animal feed, but the majority is discarded and burned as garbage. It may be considered a good source of dietary fiber due to its high fiber content and low cost. The okara has the bioactivities of preventing diabetes, hyperlipidemia, and obesity (Lu *et al*. 2013). Okara disposal is challenging due to its high moisture content, perishability, and large-scale generation, leading to environmental pollution and high management costs. Limited awareness, infrastructure, and regulatory restrictions further hinder its valorization, highlighting the need for sustainable solutions. This review explores the potential of okara, a nutrient-rich byproduct of the soymilk industry, focusing on its valorization to reduce waste and create sustainable, value-added products. Valorizing okara offers environmental benefits, economic opportunities, and alignment with global sustainability goals by promoting resource efficiency and waste reduction. Rich in protein and fiber, okara has significant applications in the food industry, including its use in bakery products, snacks, beverages, plant-based meat, dairy alternatives, functional foods, and fermented products. The review highlights current strategies, identifies research gaps, and proposes future directions to maximize okara's utilization in food innovations.

COMPOSITION AND NUTRITIONAL PROFILE OF OKARA

Okara is a nutritious raw material with high protein and fiber content, despite its inexpensive price. It comprises around 50% carbohydrate and 20-30% proteins, lipids (10-20%), dietary fiber (40-60%), minerals, and phytochemicals (e.g. isoflavones, saponins, phytosterols) are also present (O'Toole 1999). The nutritional values of dry okara reviewed from different sources are reported in Table 1. Fresh okara is high in moisture (putrefies quickly) and dietary fiber content. Okara also contains a high concentration of protein and carbohydrates. Linoleic acid, palmitic acid, stearic acid, oleic acid, and linoleic acid are the most prevalent essential fatty acids found in okara. Okara includes monosaccharides, oligosaccharides, and polysaccharides, including arabinose, glucose, galactose, fructose, stachyose, raffinose, sucrose, and starch. Okara contains phytochemicals such as phytates, saponins, coumestans, phytosterols, lignans, and isoflavones (genistein and daidzein) (Asghar *et al*. 2023). Okara's chemical structure can differ tremendously, according to various processing methods (O'Toole 1999). Okara flour is a powdered form of okara, the byproduct of soymilk and tofu production its stated to have a high percentage of proteins (24.5–37.5/100 g), dietary fiber (14.5–55.4/100 g), and lipids (9.3–22.3/100g) (Kamble and Rani 2020). The graphical representation of the nutritional composition of fresh and dried okara is given in Figure 1.

Studies have shown that okara protein outperforms other soy products in terms of protein quality. Specifically, its protein efficiency ratio (PER) is 2.71, exceeding that of soy milk protein, which has

Table 1. Composition of Okara per 100g on dry weight basis

Nutrient	Amount
Moisture	4.17±2.10
Ash	3.48±1.46
Carbohydrate	50.76±11.48
Protein	29.2±7.7
Fat	9.25±6.56
Dietary fiber	52.6±11.02
Insoluble dietary fiber	48.09±6.9
Soluble dietary fiber	9.32±5.4
Potassium(mg)	970.9±409.8
Phosphorus(mg)	404.39±84.69
Calcium (mg)	222.9±175.45
Magnesium (mg)	182.83±66.13
Iron (mg)	4.04±3.61

Note: Values in the table are presented as the mean ± standard deviation and reported based on number of literature available.

(**Sources:** Asghar *et al*. 2023, Kamble and Rani 2020, Kele *et al*. 2023, Ostermann Porcel *et al*. 2016, Swallah *et al*. 2021, Perussello *et al*. 2014, Lu *et al*. 2013, Ambawat and Khetarpaul 2018, Li *et al*. 2012, Zhongand Zhao 2015, Azanza and Gascon 2015).

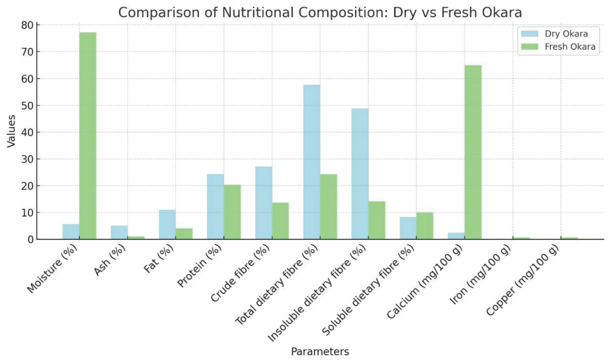

Fig. 1. Graphical representation of nutritional composition of fresh and dried okara

(**Sources:** Lu *et al*. 2013, O' Toole1999, Kamble and Rani 2020, Mbaeyi-Nwaoha and Uchendu 2016, Guimaraes *et al*. 2018, O' Toole 2004, Asghar *et al*. 2023, Pérez-López *et al*. 2018.)

a PER of 2.11 (Kamble and Rani 2020). Okara is rich in proteins, carbohydrates, and other nutrients, making it a good material for fermentation by microbes. Fermenting soybean residue with bacteria, yeast, or fungi can reduce raw fiber content and increase proteins, soluble fiber, isoflavones, and amino acids. It also breaks down phytic acid, improving both the nutritional value and the processing quality of the material (Vong *et al*. 2017). Isoflavones, a group of phenolic compounds, are noted for their various biological functions, including estrogenic activity, antioxidant and immunomodulatory effects, anti-carcinogenic properties,and their role in reducing bone mass loss and lowering cholesterol levels (Queiroz Santos *et al.* 2018). Okara is rich in dietary fiber, protein, and isoflavones, along with important mineral elements, making it highly nutritious and potentially serving as a prebiotic. Therefore, it holds promise as a functional ingredient with health-benefiting properties (Jimenez-Escrig *et al.* 2008). Okara holds around 33% of isoflavonoids from soybean. Over the years, there has been growing interest in incorporating soybean-derived ingredients into various products to offer health benefits and functional properties to the body, a concept known as "functional foods" (Swallah *et al.* 2021). The use of soybean byproducts in food formulations, such as beverages, bread, sausages, pancakes, candies, biscuits, cakes, and nutritional flour, has been widely studied and documented in numerous reports (Pan *et al*. 2018, Kamble *et al*. 2019, Szulc *et al*. 2023).

HEALTH BENEFITS OF OKARA

Okara offers numerous benefits due to its rich nutritional composition, including high levels of dietary fiber, protein, and bioactive compounds. It has significant prebiotic potential, supporting gut health by promoting the growth of beneficial bacteria, regulating stool bulking, and reducing intestinal transit time. Okara helps regulate blood glucose and insulin levels, contributing to its hypoglycemic effects. Additionally, it fosters the production of short-chain fatty acids (SCFAs) while suppressing harmful bacteria, which positively impacts gut microbiota. Its role in protecting liver and kidney functions is attributed to its ability to reduce the translocation of pro-inflammatory bacteria. In the food industry, okara can partially replace traditional flour, enhancing the dietary fiber content of products, and making it a valuable ingredient in functional foods. Furthermore, its utilization aligns with sustainability goals by reducing food waste, provided effective processing techniques are adopted to maximize its usability and consumer acceptance (Swallah *et al.* 2021). Okara offers numerous health benefits due to its bioactive components, particularly isoflavones and dietary fibers. It helps reduce the risk of cancer, osteoporosis, and cardiovascular diseases by lowering cholesterol levels. Okara also supports weight management, improves metabolic health, and has prebiotic effects that enhance gut microbiota. Additionally, it has antioxidant properties that reduce oxidative stress and may protect against aging and cognitive decline. Okara is also beneficial for diabetes management by regulating blood glucose and improving insulin sensitivity. Overall, it is a valuable dietary supplement for promoting overall health (Asghar *et al.* 2023). Okara lowers triglyceride by inhibiting fatty acid synthesis in the liver and supports intestinal lipid metabolism through its high fiber improves digestion by increasing fecal bulk and bulk and promoting intestinal activity and also reduces cholesterol by enhancing bile acid production, aiding its conversion and reducing absorption (Nagata *et al*. 2016). Okara oil (OKO) and defatted okara powder (DFP) extracted via supercritical CO_2 offer heart-health benefits with essential fatty acids, antioxidants, and improved gut health. They show potential as sustainable, nutrient-rich food ingredients (Aussanasuwannakul *et al*. 2023).

CHALLENGES IN OKARA UTILIZATION

Okara is rich in beneficial components like phytochemicals (e.g., isoflavones), crude protein containing all essential amino acids, and dietary fiber, primarily insoluble fiber. Despite its nutritional value, the main challenge in processing okara is its high moisture content, which is around 70–80%, and poor digestibility and undesirable sensory properties (Szulc *et al*. 2023). Using okara in the food industry has been challenging because it spoils quickly, is hard to digest, and contains polyunsaturated fats that cause unwanted "fishy" or "beany" smells and putrefaction. It also has insoluble fibers that give it a gritty texture, making it difficult to use in food products (Feng *et al*. 2021). As a byproduct of soy milk, okara is not widely recognized or accepted by consumers, limiting its use. Therefore, disposing of okara in landfills should be minimized, and its transformation into innovative food products should be explored (Szulc *et al*. 2023).

VALORIZATION OF OKARA: METHODS AND APPLICATION

Drying of Okara

Being highly perishable and susceptibleto microbial decomposition, Okara has to dry before its utilization in multiple food applications. Below are the methods of drying implemented to dry the okara and convert it into a storable product. These methods have an impact on the nutritional value of dry okara, and thus comparative data for nutrient compositions of Dry Okara based on different drying methods is given in Table 2.

Tray and drum drying

The drying method is the most effective way to preserve this by-product, offering significant cost savings in terms of handling, storage, and transportation. Drying is a practical method for preserving okara, reducing handling, storage, and transportation costs. Tray drying at 65°C maintains protein quality with 96% destruction of trypsin inhibitors but has low productivity due to long drying periods. Drum drying offers better protein quality, with a Protein Dispersibility Index (PDI) of 8–20%, but involves high equipment costs. Preserving protein quality during drying is crucial, as okara proteins have a superior amino acid profile compared to soymilk. Additionally, okara retains about one-third of soybean isoflavones, making it a nutrient-rich, cost-effective resource for human consumption (Grizotto and Aguirre 2011). Okara pellets were dried in a pneumatic tube from 78% to 64% moisture, then in a rotational drum to 3%. The process involved temperatures of 130°C, 150°C, and 170°C in the tube, and 50°C, 60°C, and 70°C in the drum, with drum rotations of 27 and 47 rpm. Drying only in the tube caused darkening, but using both methods reduced it. The initial tube temperature did not affect drying time (Perussello *et al*. 2009). Okara dried at 100°C for 2 hrs. showed the highest antioxidant value, which was 26.2% more than

Table 2. Comparison between nutrient compositions of Dry Okara based on different drying methods

Drying Methods	Moisture (%)	CHO (%)	Protein (%)	Fat(%)	Ash	Fiber (%)	References
Tray Drying	8.73±5.83	46.10±15.71	31.73±7.68	8.98±5.91	3.52±0,46	41.73±16.17	Grizotto and Aguirre 2011, Yaseen *et al*. 2009, Aussanasuwannakul *et al*. 2023, Aussanasuwannakul *et al*. 2022, Hongsprabhas and Hongsprabhas 2012
Flash Drying	6.3±1.08	43.63±20.8	30.70±9.04	11.78±5.84	3.82±0.30	42.44±24.69	Grizotto and Aguirre 2011, Grizotto *et al*. 2010, Li *et al*. 2019
Vacuum Drying	5.03	33.05	25.00	15.00	2.05	20.33	Sengupta *et. al*. 2012
Freeze Drying	5.37±1.70	58.64±5.91	22.73±5.30	8.89±3.20	3.29±1.01	56.22±2.62	Ahlawat *et al*. 2018, Guimarães *et al*. 2020, Lu *et al*.2013, Quintana *et al*. 2017
Microwave Drying	6.40±3.67	34.4±12.44	28.52±5.0	13.53±4.26	2.9±0.7	35.74±19.60	Guimarães *et al*. 2020, Sengupta *et al*. 2012, Porcel *et al*. 2016
Oven Drying	6.9±3.23	54.67±2.91	23.66±5.7	10.73±2.80	3.93±1.4	55±6.13	Ahlawat *et al*. 2018, Guimarães *et al*. 2020, Privatti and Rodrigues 2021
Solar Tunnel Drying	6.48	58.96	24.04	6.85	-	50.80	Ahlawat *et al*. 2018
Rotary / drum dryer	17.6±0.2	16.3±0.9	30.7 ±2.2	14.7 ±4.0	1.8±0.2	22.4 ± 0.16	Ostermann Porcel *et al*. 2016
Spray drying	3.23±2.25	56.06±0.51	27.91±9.91	4.5±4.4	2.53±0.47	76.20	Xia *et al*. 2019, Perussello *et al*. 2012, Perussello *et al*. 2014 and Osthoff *et al*. 2010

Note: Values in the table are presented as the mean ± standard deviation and calculated based on number of literature available.

drying at 70°C for 4 hrs. Thus, this process condition was chosen for drying fresh okara and making gluten-free rolls (Tridtitanakiat *et al.* 2023).

Vacuum and microwave drying

Wet Okara was spread on a Petri dish and placed in a vacuum traydryer (Model D 50, 8'' dia-12'' deep, up to 150°C) under a 758 mmHg vacuum. The temperature was maintained between 45–60°C for 5 hours until free-flowing, cooled, and stored in a food-grade plastic container. In microwave drying, wet Okara was spread on a polymer plate and heated in a Samsung MW83H/XTL microwave at 60°C for 10 minutes, then powdered, cooled, and stored in a food-grade plastic container. Vacuum Tray Drying removes 98% moisture, retains higher nutrient quality, offers better shelf life, and superior sensory properties due to slower, low-temperature drying. Microwave Drying removes 90% moisture faster, and is more energy-efficient, but reduces PUFAs and sensory quality. While both methods enhance Okara's nutritional value, Vacuum Tray Drying is better for long-term storage, while Microwave Drying is faster and more efficient (Sengupta *et al*. 2012).

Freeze-drying and spray-drying

Lactobacillus plantarum CIDCA 83114 was preserved in okara using freeze- and spray-drying. For freeze-drying, the bacteria were frozen at -80°C for 48 hours, then dried at 50°C for 48 hours, yielding the highest bacterial recovery. In spray-drying, okara suspensions were dried at an air inlet temperature of 180°C and an outlet temperature of 65-70°C, successfully preserving bacterial viability (Quintana *et al*. 2017). For okara flour, drying at 70°C using forced-air ovens, microwaves, and freeze-drying produced the best quality, while lower temperatures (40-60°C) resulted in poor color and odor. The optimal drying method for high-quality okara flour was at 70°C, supporting the demand for nutritious, high-fiber soy products (Guimarães *et al*. 2020).

Flash pneumatic drying

According to the study, okara was dried using a pneumatic flash dryer at temperatures of 252°C to 308°C for 120 seconds. The optimal recirculation rate (51%) resulted in a final moisture content of 6%. Flash drying preserved okara's nutritional quality, including protein, fiber, and lipids, while reducing drying time compared to tray drying. This method proved efficient and effective for drying soymilk residue, making it suitable for use in food products (Grizotto and Aguirre 2011).

Supercritical carbon dioxide extraction of Oil

The supercritical carbon dioxide (SCE) extraction process for extracting oil from okara involves placing 50 g of dried okara flour into a high-pressure stainless steel extractor. The extraction is performed at 300 bar pressure and 50°C, with CO_2 flowing at 3 L/min. The process includes a 60-minute static extraction phase followed by a 390-minute dynamic phase. In some cases, ethanol is added as a cosolvent at 25% (w/w) to improve oil recovery. After 450 minutes, the extracted oil is collected, and the remaining defatted okara is stored for further analysis. The extraction yield is calculated by comparing the mass of the oil to the original amount of okara, and the process is repeated in triplicate to ensure consistency and reliability (Aussanasuwannakul *et al*. 2023).

Enzymatic treatments and fermentation technique

The study identified optimal fermentation conditions for two micro organisms, *LPBG112* and *LA3*, in soymilk containing 3% okara flour. For *LPBG112*, the best conditions were pH 6.0 at 37°C, while for *LA3*, they were pH 5.0 at 31°C. At these conditions, after 24 hours of fermentation for *LPBG112* and 48 hours for *LA3*, the probiotic counts reached over 9.5 log CFU/g, and the samples had high levels of isoflavone aglycones and antioxidant activity. The model showed a good predictive ability ($R^2 > 0.80$), confirming that fermentation in okara-enriched soymilk is effective for producing probiotic-rich products with beneficial isoflavones and antioxidants (Moraes Filho *et al*. 2016). Okara fermentation was carried out under anaerobic conditions with two strains of lactic acid bacteria: *Lactobacillus plantarum* P1 (at 30°C) and *Lactobacillus acidophilus* 308 (at 37°C), both fermented for 24 hours. The study found that incorporating 6% okara fermented by *L. plantarum* P1 into meat analogues, followed by dough maturation at 4°C, significantly improved the quality of the meat analogues, including reduced protein oxidation, better water-holding capacity, enhanced taste, and overall acceptability. Future research will focus on the fermentation's role in producing bioactive compounds and reducing antinutrients in both okara and meat analogues (Razavizadeh *et al*. 2021). Fermenting okara increases isoflavone aglycones and improves tempeh's nutritional quality. Specific microbial strains, like *R. oligosporus*, enhance genistein content. This fermentation process is energy-efficient, reduces food waste, and promotes sustainable food production (Kuligowski *et al.* 2024). Fermenting okara with probiotics improves its nutritional value and flavor. It increases bioactive isoflavones, reduces unpleasant odors, and creates a natural fruit aroma. Probiotic-fermented okara beverages also maintain high viable counts and good storage stability. This process enhances the potential of okara as a sustainable ingredient for plant-based beverages (Li *et al.* 2024). According to the study, *B. subtilis* J12 was used to ferment okara, producing 983 U/g of amylase in 24 hours. The optimal amylase activity occurred at pH 6.0 and 50°C, with stability between 30°C and 50°C for 120 minutes. The enzyme was activated by ferric ions and inhibited by organic solvents. The amylase was purified into two fractions, each containing different types of amylases. This process using okara as a low-cost medium highlights the potential for producing eco-friendly, commercially valuable amylase with energy-saving benefits for industrial applications (Mahfudz *et al*. 2024).

FOOD APPLICATIONS OF OKARA

Bakery and flour confectionery products

Bread

A study explored the use of dried okara as a flour mixture for bread-making. The research found that incorporating 10% dried okara into the flour mixture resulted in the best quality bread, with a score of 82.8% of the expected criteria. The bread was evaluated based on texture, flavor, color, and aroma. White bread with 10% dried okara had a pleasant color, flavor, and aroma, similar to the control bread without okara. In contrast, higher percentages of okara (20% and 30%) negatively affected the bread's flavor and color, with the 30% mixture scoring the lowest due to sourness and pale color. The study concluded that 10% dried okara is the optimal amount for making high-quality bread (Paramita and Budi 2015).

A study developed a gluten-freebread using 30% soy okara, combined with buckwheat, rice, and millet flours. The bread had high sensory scores (4.30 by evaluators, 4.59 by consumers), with excellent taste, texture, and overall quality. It was rich in dietary fiber (14%), protein (8.8%), and minerals, while being low in energy (136.37 kcal/100g) and saturated fat (0.8%). The bread also showed strong antioxidant properties. Enriching gluten-free bread with okara not only improves its nutritional value but also supports sustainable soy waste management, making it a healthy, eco-friendly product (Pešić *et al*. 2023).

Biscuit and falafel

This study explored using okara (up to 30%) in biscuits and falafel. Adding 20% okara increased the protein content in biscuits from 6.04% to 9.9%. Sensory evaluations showed that 20% of Okara was most preferred in both products. Okara improved essential amino acids like lysine (5.83 g), threonine (4.10 g), and leucine (8.10 g). The biological evaluation showed high digestibility (PER 2.78 for biscuits, 2.76 for falafel), close to casein. Okara also increased water absorption and dough stability in biscuits. Overall, okara enhances nutrition and helps reduce wheat flour use and food waste (El-Reffaei *et al*. 2012).

Waffles

This study explored adding okara flour (10-40%) to gluten-free waffles. The best balance of nutrition and texture was found with 30% okara, improving fiber and protein but increasing hardness. Waffles maintained good moisture and safety for 60 days. Okara flour offers a sustainable way to enhance gluten-free products while reducing food waste (Aussanasuwannakul *et al*. 2024).

Brownies

The best formulation for the brownies involved a 1:2 ratio of wheat flour to okara flour (F2). This formulation yielded brownies with 12% wet gluten, 4.3% dry gluten, 0.07% protein, and 47.46% fiber. The inclusion of flaxseed further enhanced the nutritional profile, making the brownies a low-gluten, high-fiber option (Walgiyanti *et al*. 2024)

Okara based cookies

Okara was added to cookies in varying ratios (20–100%). The best results were found with 60% okara, which was most liked by consumers. These cookies had 8.72% protein and 5.98% dietary fiber. They were microbiologically stable for up to one week. The main challenge in these cookies was the beany flavor caused by lipoxygenase enzymes, though the taste was still acceptable at the 60% ratio (Liand Lu 2012, Khare *et al.* 1995). Cookies with 30% okara flour had higher fiber (3.52%) and isoflavones (47.4 µg/mg). Nutritional values ranged as follows: moisture (2.16–4.01%), ash (1.39–1.65%), protein (9.1–17.09%), lipids (17.20–21.07%), and carbohydrates (60.24–65.86%). Okara flour boosts cookies' nutritional value (Fadhila *et al*. 2024).

Dairy alternatives and fermentedproducts

Fermented Beverage

Fermented okara beverages showed probiotic stability and potential antihypertensive and antioxidant effects. They offer a lactose-free alternative to milk and may reduce agricultural waste. However, taste improvements are needed for better consumer acceptance, possibly by adding fruit pulp in future research (Voss 2021).

Vegan soft cheese

The process of making vegan soft cheese from okara involves several steps. First, pasteurized okara is ground in a Grindomix GM 200 at 15,000 rpm for 1 minute to achieve a smooth texture. It is then mixed with sugar (3 g per 200 g of okara) and a starter culture of bacteria designed for vegan cheese fermentation (*L. lactis, Streptococcus salivarius* and others). Optionally, microbiological rennet is added. The mixture is incubated at 36°C for 24 hours, then molded, salted, and seasoned before being chilled at 2-4°C for at least 24 hours for maturation. The resulting soy soft cheese is high in protein (28.0–28.3% DM) and contains probiotics (107–108 cfu/mL *lactic acid bacteria*). The process is economically viable, offering a dairy-free cheese substitute and the potential for further applications in products like cheese cakes and dumplings, with additional research for refinement (Szulc *et al*. 2023).

Breakfast cereal

A study created breakfast cereals by blending acha flour with unfermented and fermented okara (at 0–48 hours). Fermentation increased moisture (4.71% to 6.11%), fiber (36.62% to 46.18%), and carbohydrates (2.50% to 2.71%), while reducing fat (16.29% to 13.27%) and protein (30.32% to 33.53%). The best sensory scores were for 70:30 blends of acha with unfermented or 48-hour fermented okara. Proximate analysis showed higher protein (17.86% to 21.30%), fat (0.83% to 2.21%), and minerals, while moisture and carbohydrates decreased. The cereals were nutrient-dense with improved texture and flavor, making them suitable for both children and adults. Further studies on health benefits and shelf stability are recommended (Mbaeyi-Nwaoha and Uchendu 2016).

Protein Concentrate

A study used microfiltration (MF) and ultrafiltration (UF) membranes to concentrate protein from okara, improving protein content from 68% to 81%. The UF-500 membrane was preferred due to its higher flux and shorter processing time. The final protein content reached 80%, falling short of the 90% target due to retained soluble fibers. The okara protein concentrate (MOPC) had lower solubility than soy protein concentrate but had better water absorption and fat-binding capacities. While membrane processing is more expensive than traditional methods, it is environmentally friendly and produces higher-quality protein. This is the first study to show the potential of membrane technology for enhancing okara's value (Vishwanathan *et al*. 2011).

Prebiotic Food

Fortified yogurt with a probiotic (*L. plantarum*) and okara (1%, 2%, and 3%). They also concluded that okara dietary fiber improves the probiotic count and chemical properties of yogurt with storage time. Therefore, okara can be used in food industries as a value-added food and as a supplement food (Roslan *et al*. 2021).

Ice-cream

A synbiotic ice cream study aimed to improve ice cream by using synbiotics, which combine probiotics (*Lactobacillus rhamnosus* GG) and prebiotics (like okara, a soybean byproduct). The researchers added 1-3% okara to ice cream and observed its effects over 60 days. They found that 3% okara kept the probiotics alive and healthy, while at least 2% okara improved texture, thickness, and probiotic viability. The ice cream with okara also had more protein and less fat compared to regular ice cream. This approach not only enhanced the nutritional value but also helped reduce food waste (Farooq *et al*. 2023).

Meat analogue

A study investigated the use of fermented ultrasound-treated okara in meat analogues. Fermentation with *L. plantarum* P1 improved the water-holding capacity, texture, and sensory properties while reducing protein oxidation and hardness. The best results were achieved with 6% okara fermented by *L. plantarum* P1, and dough maturation at 4°C for 2 hours. The research concluded that fermented okara enhances the

Table 3. List of products incorporated with Okara and level of utilization in percentage

Product category	Product name	Level of Okara used* (%)	References
Bakery	Bread	7.5±2.5	Paramita and Budi 2015, Sari and Syamsudin 2019, Bowles and Demiate 2006
	Gluten free bread	30	Pešić *et al*. 2023
	Biscuit	20.24±7.08	El-Reffaei *et al*. 2012, Agu *et al*. 2023, Maria and Olaitan 2020, Grizotto *et al*. 2010
	Waffle	30	Aussanasuwannakul *et al*. 2024
	Brownies	66.67	Walgiyanti *et al*. 2024
	Cookies	39±15.26	Khare and Sinha 1995, Ahmed *et al*. 2018, Rakhmadevi *et. al*. 2024, Hawa *et al*. 2018, Ahlawat and Punia 2012
	Doughnut	15±5	Huq *et al*. 2021, Ahlawat and Punia 2012
Dairy Products	Okara yogurt	3	Roslan *et al*. 2021, Asghar *et al*. 2022 and Mansor *et al*. 2022
	Synbiotic ice cream	2.5±0.5	Farooq *et al*. 2023
Analogues Products	Vegan soft cheese	100	Szulc *et al*. 2023
	Meat Analogue	6	Razavizadeh *et al*. 2021
Meat Products	Beef pattis	7.5	Turhan *et al*.2009
	Beef sausage	20	Noriham *et al*. 2016
	Frankfurter sausage	1.5	Grizotto *et al*. 2012
Snacks and candy	Soya snack	10	Varsha and Mohan 2016
	Soya candy	18.3	Genta *et al*. 2002
	CoconutBasedBaked Snack	35±5	Radočaj and Dimić 2013
	Extruded snacks	34.5±5.5	Aussanasuwannakul *et al*. 2022
Other	Ready to cook Patty	20	Rehal and Beniwal 2022
	Falafel	25±5	El-Reffaei *et al*. 2012
	Noodles	14.5±8.5	Pan *et al*. 2018, Colletti *et al*. 2020, Lu *et al*. 2013, Kang *et al*. 2018, Xie *et al*. 2023, Ahlawat and Punia 2012
	Peanut Butter	15	Nasution *et al*. 2012
	Macroni	20	Ahlawat and Punia 2012

Note: The value reported represents the amount of Okara used in product which does not impacted much on characteristic attributes of the product and thus considered as acceptable level.

quality of meat analogues, making it a promising ingredient for sustainable, plant-based meat alternatives (Razavizadeh *et al.* 2021).

Others products

Soya candy with okara

Okara was used in soy candy formulations to increase soy product consumption. The most compatible formulation contained 18.3 g of okara per 100 g. Despite its nutritional benefits, the beany taste remained a barrier to widespread acceptance of the candy (Genta *et al*. 2002).

Soyabean-based snack with okara

In the production of extruded snacks from okara and broken rice, several key parameters - such as moisture content (14-22%), blend ratio (70-30 to 90-10 rice: okara), barrel temperature (120-160°C), and screw speed (50-90 rpm)—significantly influence the physical properties of the extrudates, including bulk density, specific length, and expansion index. Optimal extrusion conditions were found to be 90% broken rice, 10% okara, with a screw speed of 76 rpm, barrel temperature of 159°C, die head temperature of 160°C, and 18% moisture content. (Varsha and Mohan 2016). A snack was created using commercially dried okara powder (7.7% moisture) from soybeans with lipoxygenase and a partly dried okara (44.3% moisture) from low-linolenic soybeans. The snack was prepared using low-saturated-fat soybean oil, with an optimal recipe found for both baked and deep-fried versions. The snack aimed to improve the flavor and reduce the undesirable odor associated with okara (Swallah *et al*. 2021).

Okara enriched noodles

Noodles with added okara powder (10–15%) showed reduced extensibility, tensile strength, and flexibility, but their antioxidant capacity and free radical scavenging properties improved. The best results were achieved with 5–10% okara powder and 6% essential soy protein, producing noodles with good cooking and sensory qualities, along with enhanced flavonoid content (Pan *et al*. 2018).

CONCLUSION

Okara, a byproduct of soymilk production, is rich in bioactive compounds like dietary fiber, proteins, and essential minerals, making it a valuable resource for the food industry. It can be incorporated into products such as baked goods, beverages, snacks, and meat alternatives, enhancing texture, taste, and health benefits like gut health and weight management. Valorizing Okara addresses food waste and supports sustainability by reducing the environmental footprint of soybean products and promoting a circular economy. Its use adds economic value and contributes to resource efficiency. Further research could unlock more innovative applications, advancing a sustainable and health-conscious food system.

CONFLICT OF INTEREST STATEMENT

The authors declared that they have no conflicts of interest to this work. We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

REFERENCES

Agu H, Ihionu J and Mba J. 2023. Sensory and physicochemical properties of biscuit produced from blends of whole wheat, soy okara, and tigernut residue flours. Heliyon **9** (e15318): 1-13.

Ahmed H, Hawa A, Satheesh N and Dibaba Tolera K. 2018. Functional, physical and sensory properties of cookies prepared from okara, red teff and wheat flours. Croatian Journal of Food Science and Technology **10**(1): 23-32.

Ahlawat D, Poonia D, Ahlawat M and Ahlawat SS. 2018. Effect of drying techniques on functional and physico-chemical properties of okara. International Journal of Current Microbiology and Applied Sciences **7**(5): 582-590.

Ahlawat D and Punia D. 2012. Effect of solar tunnel and freeze drying techniques on the organoleptic acceptability of products prepared incorporating okara (soy by-product). International Journal of Food and Sciences **3**(3): 10-13.

Ambawat S and Khetarpaul N. 2018. Comparative assessment of antioxidant, nutritional and functional properties of soybean and its by-product okara. Annals of Phytomedicine **7**(1): 112-118.

Asghar A, Afzaal M, Saeed F, Ahmed A, Ateeq H, Shah YA, Islam F, Hussain M, Akram N and Shah MA. 2023. Valorization and food applications of okara (soybean residue): A concurrent review. Food Science and Nutrition **11**(7): 3631-3640.

Asghar A, Afzaal M, Nosheen F, Saeed F, Nayik GA, AL-Farga A, Alansari WS, Eskandrani AA and Shamlan G. 2022. Isolation and molecular characterization of processed soybean waste for the development of synbiotic yogurt. Fermentation **8**(11): 622.

Aussanasuwannakul A, Teangpook C, Treesuwan W, Puntaburt K and Butsuwan P. 2022. Effect of the addition of soybean residue (okara) on the physicochemical, tribological, instrumental, and sensory texture properties of extruded snacks. *Foods* **11**(19): 2967.

Aussanasuwannakul A, Boonbumrung S and Pantoa T. 2023. Valorization of soybean residue (okara) by supercritical carbon dioxide extraction: Compositional, physicochemical, and functional properties of oil and defatted powder. Foods **12**(14): 2698.

Aussanasuwannakul A, Puntaburt K and Pantoa T. 2024. Enhancing gluten-free crispy waffles with soybean residue (okara) flour: Rheological, nutritional, and sensory impacts. Foods **13**: 2951.

Azanza MPV and Gascon FS. 2015. Shelf-stable dried okara from the wet by-product of Philippine soybean curd processing. Philippine Journal of Science ***144:*** 171-185.

Bowles S and Demiate IM. 2006. Physicochemical characterization of the soymilk by-product—okara. Food Science and Technology **26**: 652-659.

Cao Z, Zhou L, Gao S, Yang C, Meng X and Liu Z. 2024. Effects of different amounts of okara on texture, digestive properties, and microstructure of noodles. Food Science and Nutrition **12**(5): 3433-3442.

Colletti A, Attrovio A, Boffa L, Mantegna S and Cravotto G. 2020. Valorisation of by-products from soybean (*Glycine max* (L.) Merr.) processing. Molecules **25**(9): 2129.

El-Reffaei W, Ragheb E, El-Ghandour H and Badr S. 2012. Nutritional and technological studies on using okara as by-product for fortified common foods falafel and biscuit. Journal of Food and Dairy Sciences **3**(9): 481-506.

Fadhila PT, Rakhmadevi AG, Mardiyanto M and Nurwahyuningsih. 2024. Nutritional value and fiber content of cookies prepared from okara flour substitution: Study on dietary fiber, isoflavone, and chemical properties. 6th International Conference on Food and Agriculture (ICoFA). IOP Conference Series: Earth and Environmental Science **1338**(012036): 1-7.

Farooq R, Fedrick S, Saeed F, Ahmad A, Asghar A, Riaz S, Ateeq H, Shah Y, Khan M, Li Y and Afzaal M. 2023. Characterization and valorization of soybean residue (okara) for the development of synbiotic ice cream. Food Science and Nutrition **11**(e3606): 1-11.

Feng JY, Wang R, Thakur K, Ni ZJ, Zhu YY, Hu F, Zhang JG and Wei ZJ. 2021. Evolution of okara from waste to value-added food ingredient: An account of its bio-valorization for improved nutritional and functional effects. Trends in Food Science and Technology **116**: 669-680.

Gatade AA, Ranveer RC and Sahoo AK. 2014. Effect of treatments, CMC, and storage conditions on sensorial quality of mango flavoured soymilk. Journal of Microbiology, Biotechnology and Food Science **4**(1): 6-9.

Gatade A, Ranveer R and Sahoo A. 2009. Physico-chemical and sensorial characteristics of chocolate prepared from soymilk. Advance Journal of Food Science and Technology **1***:* 1-5.

Genta HD, Genta ML, Alvarez NV and Santana MS. 2002. Production and acceptance of a soy candy. Journal of Food Engineering **53**(2): 199-202.

Grizotto RK and Aguirre JMD. 2011. Study of the flash drying of the residue from soymilk processing - "okara". Food Science and Technology International **31**: 645-653.

Grizotto RK, Rufi CRG, Yamada EA and Vicente E. 2010. Evaluation of the quality of a molded sweet biscuit enriched with okara flour. Food Science and Technology **30**: 270-275.

Grizotto RK, Andrade JCD, Miyagusku L and Yamada EA. 2012. Physical, chemical, technological and sensory characteristics of Frankfurter type sausage containing okara flour. Food Science and Technology **32**: 538-546.

Guimaraes RM, Silva TE, Lemes AC, Boldrin MCF, da Silva MAP, Silva FG and Egea MB. 2018. Okara: A soybean by-product as an alternative to enrich vegetable paste. LWT - Food Science and Technology **92**: 593–599.

Guimarães RM, Ida EI, Falcão HG, De Rezende TAM, Silva JDS, Alves CCF, da Silva MA P and Egea MB. 2020. Evaluating technological quality of okara flours obtained by different drying processes LWT-Food Science and Technology **123**. 109062.

HawaA, Satheesh N and Kumela D. 2018. Nutritional and anti-nutritional evaluation of cookies prepared from okara, red teff, and wheat flours. International Food Research Journal **25**(5): 2042-2050.

Huq S, Das PC, Islam MA, Jubayer MF, Ranganathan TV and Mazumder MAR. 2021. Nutritional, textural, and sensory quality of oil fried donut enriched with extracted dietary fiber and okara flour. Journal of Food Processing and Preservation **45**(3): 1-14.

Hongsprabhas P and Hongsprabhas P. 2012. Controlling of viscosity and gelation in pasteurised high-calorie oil-in-water emulsion: use of okara as dietary fiber. Proceedings of the Polymer Processing Society 28th Annual Meeting PPS- **28**: 1-5

Jimenez-Escrig A, Tenorio MD, Espinosa-Martos I and Rupérez P. 2008. Health-promoting effects of a dietary fiber concentrate from the soybean byproduct okara in rats. Journal of Agricultural and Food Chemistry **56***:* 7495–7501.

Kang MJ, Bae IY and Lee HG. 2018. Rice noodle enriched with okara: Cooking property, texture, and in vitro starch digestibility. Food Bioscience **22**: 178-183.

Kamble DB, Singh R, Rani S and Pratap D. 2019. Physicochemical properties, in vitro digestibility and structural attributes of okara enriched functional pasta. Journal of Food Process and Preservation **43**(e14232): 1-9.

Kamble D and Rani S. 2020. Bioactive components, in vitro digestibility, microstructure and application of soybean residue (okara): A review. Legume Science **2**(1): e32.

Kele V, Kele A., Chudasama M and Goyary J. 2023. A review: Preparation of products from seed-based okara and corn (*Zea mays*). TechnischeSicherheit **23**: 231-245.

Khare SK, Jha K and Sinha LK. 1995. Preparation and nutritional evaluation of okara fortified biscuits. Journal of Dairying, Foods and Home Science **14***:* 91-94.

Kuligowski M, Radziejewska-Kubzdela E, Górna O, Jasińska-Kuligowska I and Kidoń M 2024. Sustainable use of by-products (okara and linseed cake) in tempeh fermentation: Effects on isoflavones and lignans. Sustainability **16**(22): 9936.

Li B, Qiao M and Lu F. 2012. Composition, nutrition, and utilization of okara (soybean residue). Food Reviews International **28**(3): 231-252.

Li B, Yang W, Nie Y, Kang F, Goff HD and Cui SW. 2019. Effect of steam explosion on dietary fiber, polysaccharide, protein and physicochemical properties of okara. Food Hydrocolloids **94**: 48-56.

Li J and Hsieh YHP. 2004. Traditional Chinese food technology and cuisine. Asia Pacific Journal of Clinical Nutrition **13**:147-155.

Li Y, Song H, Zhang Z, Li R, Zhang Y, Yang L, Li J, Zhu D, Liu J, Yu H and Liu H. 2024. Effects of fermentation with different probiotics on the quality, isoflavone content, and flavor of okara beverages. Food Science and Nutrition **12**(4): 2619-2633.

Lu F, Liu Y and Li B. 2013. Okara dietary fiber and hypoglycemic effect of okara foods. Bioactive Carbohydrates and Dietary Fibre **2**(2): 126-132.

Lu F, Cui Z, Liu Y and Li B. 2013. The effect of okara on the qualities of noodle and steamed bread. Advance Journal of Food Science and Technology **5**: 960-968.

Mahfudz MK, Jaikhan S, Phirom-on K and Apiraksakorn J. 2024. Cost-effective strategy and feasibility for amylase production from okara by *Bacillus subtilis* J12. Fermentation **10**(11): 561.

Maria MF and Olaitan AE.2020. Effect of supplementing cassava with okara on biscuit quality. Sumerianz Journal of Biotechnology **3**: 99-105.

Mbaeyi-Nwaoha IE and Uchendu NO. 2016. Production and evaluation of breakfast cereals from blends of acha and fermented soybean paste (okara). Journal of Food Science and Technology **53**(1): 50–70.

Mansor A, Mahadi SK and Othaman MA. 2022. Okara yoghurt–a high value-added fermented product from soybean curd residue. Food Research **6**: 97-106.

Moraes Filho ML, Busanello M and Garcia S. 2016. Optimization of the fermentation parameters for the growth of *Lactobacillus* in soymilk with okara flour. LWT-Food Science and Technology ***74**:* 456-464.

Nagata Y, Yamasaki S, Torisu N, Suzuki T, Shimamoto S, Tamaru S and Tanaka K. 2016. Okara, a by-product of tofu manufacturing, modifies triglyceride metabolism at the intestinal and hepatic levels. Journal of Nutritional Science and Vitaminology **62**(3): 162-169.

Nasution Z, Tung M Y and Faridah Y. 2012. Okara: An alternative ingredient for partial substitution of peanuts in peanut butter. Peanut Science **13**(1): 18-20.

Noriham A, Muhammad Ariffaizuddin R, Noorlaila A and Faris Zakry AN. 2016. Potential use of okara as meat replacer in beef sausage. Journal Teknologi **78**(6): 13-18.

Osthoff G, Hugo A, Van Wyk P, De Wit M and Meyer S. 2010. Characterization of a spray-dried soymilk powder and changes observed during storage. Food Science and Technology International **16**(2): 169-178.

OstermannPorcel V, Rinaldoni A, Rodriguez Furlán L and Campderros M. 2016. Quality assessment of dried okara as a source of production of gluten-free flour. Journal of the Science of Food and Agriculture **97***:* 2675-3080.

O'Toole DK. 1999. Characteristics and use of okara, the soybean residue from soy milk production - a review. Journal of Agricultural and Food Chemistry **47**(2): 363-371.

O'Toole DK. 2004. Soybean. In *Soymilk* and OC Wrigley (Eds.), *Encyclopedia of Grain Science*. Cambridge: Elsevier Ltd.: 185–195.

Pan WC, Liu YM and Shiau SY. 2018. Effect of okara and vital gluten on physico-chemical properties of noodle. Czech Journal of Food Science **36**: 301–306.

Privatti RT and Rodrigues CE.da C. 2021. An overview of the composition, applications, and recovery techniques of the components of okara aimed at the biovalorization of this soybean processing residue. Food Reviews International **39**(2): 726-749.

Paul AA, Kumar S, Kumar V and Sharma R. 2020. Milk Analog. Plant-based alternatives to conventional milk, production, potential and health concerns. Critical Reviews in Food Science and Nutrition **60**(18): 3005-3023.

Paramita VS and Budi AP. 2015. Utilization of dried okara as a flour mixture for bread-making. Journal of Business on Hospitality and Tourism **1**(6): 1-10.

Pešić MB, Pešić MM, Bezbradica J, Stanojević AB, Ivković P, Milinčić DD, Demin M, Kostić AŽ, Dojčinović B and Stanojević SP. 2023. Okara-enriched gluten-free bread: Nutritional, antioxidant, and sensory properties. Molecules **28**(10): 4098.

Préstamo G, Rupérez P, Espinosa-Martos I, Villanueva MJ and Lasunción MA. 2007. The effects of okara on rat growth, faecal fermentation, and serum lipids. European Food Research and Technology **225**(5): 925–928.

Pérez-López E, Veses AM, Redondo N, Tenorio-Sanz MD, Villanueva MJ, Redondo-Cuenca A and Rupérez P. 2018. Soybean okara modulates gut microbiota in rats fed a high-fat diet. Bioactive Carbohydrates and Dietary Fibre **16**: 100-107.

Perussello CA, Mariani VC and Do Amarante ÁCC. 2014. Thermophysical properties of okara during drying. International Journal of Food Properties **17**(4): 891-907

Perussello CA, Mariani VC and Do Amarante ÁCC. 2012. Numerical and experimental analysis of the heat and mass transfer during okara drying. Applied Thermal Engineering **48***:* 325-331.

Perussello CA, Do Amarante ÁCC and Mariani VC. 2009. Convective drying kinetics and darkening of okara. Drying Technology **27**(10): 1132-1141.

Quintana G, Gerbino E and Gómez-Zavaglia A. 2017. Okara: A nutritionally valuable by-product able to stabilize *Lactobacillus plantarum* during freeze-drying, spray-drying, and storage. Frontiers in Microbiology **8***:* 641.

Queiroz Santos VA, Nascimento CG, Schmidt CAP, Mantovani D, Dekker RFH and da Cunha MAA. 2018. Solid-state fermentation of soybean okara: Isoflavones biotransformation, antioxidant activity, and enhancement of nutritional quality. LWT-Food Science and Technology **92**: 509-515.

Radočaj O and Dimić E. 2013. Valorization of Wet Okara, a Value-Added Functional Ingredient, in a Coconut-Based Baked Snack. Cereal Chemistry **90**: 256-262.

Razavizadeh S, Alencikiene G, Salaseviciene A, Vaičiulytė-Funk L, Ertbjerg P and Zabulionė A. 2021. Impact of fermentation of okara on physicochemical, techno-functional, and sensory properties of meat analogues. European Food Research and Technology **247**: 1801–1811.

Roslan IND, Kamaruding NA, Ismail N and Shaharuddin S. 2021. Sensory attributes and other properties of yogurt fortified with immobilized *Lactobacillus plantarum* and soybean residue (okara). International Journal of Probiotics and Prebiotics **16**: 1–6.

Saini A and Morya S. 2021. A review-based study on soymilk: Focuses on production technology, prospects, and progress scenario in the last decade. The Pharma Innovation **10**(5): 486-494.

Santos DCD, Oliveira Filho JGD, Silva JDS, Sousa MFD, Vilela MDS, Silva MAPD and Egea MB. 2019. Okara flour: Its physicochemical, microscopical, and functional properties. Nutrition and Food Science **49**(6): 1252-1264.

Sari AM and Syamsudin AB. 2019. Effect of tofu waste flour composition to hedonic test level and proximate test of bread. In IOP Conference Series: Materials Science and Engineering **674**(1): 1-5.

SenguptaS, Chakraborty M, Bhowal J and Bhattacharya DK. 2012. Study on the effects of drying process on the composition and quality of wet okara. *I*nternational Journal of Science, Environment and Technology **1**(4): 319-330.

Swallah MS, Fan H, Wang S, Yu H and Piao C. 2021. Prebiotic impacts of soybean residue (okara) on eubiosis/dysbiosis condition of the gut and the possible effects on liver and kidney functions. Molecules **26**(2): 326.

Szulc J, Błaszak B, Wenda-Piesik A, Gozdecka G, Żary-Sikorska E, Bąk M and Bauza-Kaszewska J. 2023. Zero waste technology of soybeans processing. Sustainability **15**(20): 14873.

Turhan S, Temiz H and Sagir I. 2009. Characteristics of beef patties using okara powder. Journal of Muscle Foods **20**(1): 89-100.

Tridtitanakiat PC, Hernández-Estrada ZJ and Rayas-Duarte P. 2023. Modeling the influence of okara flour supplementation from time-temperature drying treatment on the quality of gluten-free roll produced from rice flour. Foods **12***:* 3421.

Varsha K and Mohan S. 2016. Production of value-added snacks from rice broken and okara by extrusion cooking technology. International Journal of Agricultural Sciences **8**(51): 2321-2325.

Vishwanathan KH, Govindaraju K, Singh V and Subramanian R. 2011. Production of okara and soy protein concentrates using membrane technology. Journal of Food Science **76**(1): E158–E164.

Vong WC and Liu SQ. 2016. Biovalorisation of okara (soybean residue) for food and nutrition. Trends in Food Science and Technology **52**: 139-147.

Vong WC, Lim XY and Liu SQ. 2017. Biotransformation with cellulase, hemicellulase, and *Yarrowialipolytica* boosts health benefits of okara. Applied Microbiology and Biotechnology **101***:* 7129-7140.

Voss GB, Vera S, Paulo R, Manuela EP and Luísa MPV. 2021. Okara (by-product of soya beverage): Potential application in food and aquafeed. Animals **11**(590): 1-17.

Walgiyanti I, Mahardika A and Murti PDB. 2024. The substitution of different concentrations of okara flour in brownies formulation added with flaxseed (*Linum usitatissimum*) as low-gluten healthy food. Journal of Functional Food and Nutraceutical **5**(1): 79-86.

Xia T, Cai Y, Liu T, Long Z, Huang L, Deng X, Zhao Q and Zhao M. 2019. Effects of pretreatments on the structure and functional properties of okara protein. Food Hydrocolloids **90**: 394-402.

Xie L, Zhou W, Zhao L, Peng J, Zhou X, Qian X and Lu L. 2023. Impact of okara on quality and in vitro starch digestibility of noodles: The view based on physicochemical and structural properties. International Journal of Biological Macromolecules **237**(1): 124105.

Yaseen A, Shouk A and Abousalem F. 2009. Effect of okara addition on bread quality. Journal of Food and Dairy Sciences **34**(12): 11147-11155.

Zhong Y and Zhao Y. 2015. Chemical composition and functional properties of three soy processing by-products (soy hull, okara and molasses). Quality Assurance and Safety of Crops and Foods **1**: 1-10.