# Nutritional importance of okara (soybean by-product) and its utilization in food industry

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**Introduction**

Okara is the residue left from ground soybean after obtaining the water-extractable fraction used to produce bean curd (tofu) or soymilk. It is a Japanese word meaning "honorable hull" or soy pulp. It is also called as soybean residue, bean curd residue, douzha or tofuzha in Chinese. It has a nut (almond and coconut) like taste and beige in color with light, crumbly, fine-grained texture, which makes it look like moist sawdust or grated coconut. It is a by-product with low commercial value generated during the manufacture of soymilk and is potentially a nutritious product high in fiber, protein, carbohydrates, vitamins, minerals and fat and has excellent functional properties.

Currently, it is used as stock feed and fertilizer or dumped in landfill. Particularly in Japan, most of the okara is burnt which creates carbon dioxide. Meanwhile, discarding of okara as waste is a potential environmental problem because it is highly susceptible to putrefaction. In fact, it contained high moisture content (70%–80%), which makes it difficult to handle and possesses high capacity for deterioration. However, it must be dried quickly to avoid spoilage to prolong its shelf life. The environmental problems arising from the massive generation of residues and its high moisture content have been attracting considerable attention towards drying of okara.

Drying method have a significant effect on the sensory qualities and functional properties of okara. In terms of water holding capacity, swelling capacity and lipid binding capacity, freeze dried okara is best, followed by vaccum drying and hot-air drying. During drying one of the most important aspects to be considered is the preservation of the protein quality, which can be affected by the drying conditions. The high-quality protein fraction is responsible for water holding capacity, fat binding capacity, emulsifying and foaming properties and anti-hypertension effects and these non-nutritional properties influence the production and quality of a determined food product. Protein solubility improved with higher levels of deamination especially in acidic and alkaline conditions while water holding capacity decreased with acid modification, and it is of important concern that intense heat treatment denatured the proteins and fibres present in okara which reduced the protein solubility and water holding capacity. Vacuum tray drying is more effective to produce good quality okara in respect of its nutritional- non nutritional composition and shelf life characteristics than microwave drying.

Okara has high protein content (40% on a dry weight basis) with good essential amino acid profile and *in vitro* digestibility. The fat that remains in okara is approximately 10%, with a high polyunsaturated fatty acid content. Small amounts of starch, sugars and significant levels of B group vitamins and potassium are also recovered in okara. Despite the high nutritional and excellent functional properties like protein solubility, water holding capacity, emulsification, foaming, and binding properties of okara makes it suitable for potential application in food products, the most common use of this by-product is in the manufacture of animal feed. Okara also contains high amounts of dietary fiber and is considered as an excellent dietary fibre source and as such could be added to different foods. The composition of fibres, has been described as 12% hemicellolose, 5.6 % cellulose, 12% lignin.

Soybeans are usually incorporated into a human diet either as fermented or as non-fermented foods. The most commonly fermented soy-based foods include sufu, miso, natto, soy sauce, tempeh, and douchi, while the non-fermented food comprise fresh soybeans, soybean sprouts, soymilk, tofu, and protein-enriched foods such as soy protein flours and/or grits, textured soy protein, and soy protein concentrates or isolates. Since okara is a cheap and rich source of good quality protein and dietary fiber, many Asian countries have found a variety of ways to make use of okara in many food items such as soups, salads, baked goods and fermented food products such as tempeh . The presence of 95% of the solid grain components in okara makes it a very high nutritional value and may be utilized as an ingredient in a variety of processed foods, because it reduces calorie intake and increase dietary fibre.

**Functional properties of okara**

Fibres obtained from dried okara presented good water-holding capacities. The oven drying of crude okara seemed to alter fibre structure and lowered the water-holding capacities (WHC) as compared to the flash drying. *L*ower water holding capacity (WHC) values of okara were obtained after drying (80ºc). They reported that the purification process by allowing the wet okara to undergo proteolysis, followed by soxhlet fat extraction generated a total dietry fibre yield of 75% which had the best water holding capacity (WHC) and concluded that extracted fibers should not be dried at high temperatures as this can lead to a change in the isoflavones as well as alter the microstructure of the fibers and decrease overall water holding capacity (WHC).

Water holding capacity of okara flour from decorticated soybean seeds was 28.33, 19.74, 22.8 g water/g protein and protein solubility was 29.98, 25.17, 41.29 g soluble protein/100 g material at 3, 5 and 7 pH respectively. Similarly, okara flour from whole soybean seeds contained 22.03, 19.84, 17.10 g water/g protein water holding capacity and 25.55, 21.15, 29.81 g soluble protein/100 g material protein solubility at 3, 5 and 7 pH respectively. Okara dried by flash drier at 260ºc contained water holding capacity 22.23, 18.65, 24.96 g water/g protein and 14.36%, 12.44%, 14.74% protein solubility at pH 3, 5 and 7 respectively, whereas in tray dryer water holding capacity was 20.55, 17.10, 21.41 g water/g protein and protein solubility was 18.32%, 15.14%, 16.62% at 3, 5 and 7 pH, respectively.

**Drying of okara**

The high moisture content and water activity of okara bring significant problems with its utilization in handling because fresh okara can be spoiled by yeasts in hours and it is very bulky or “messy”, containing about 80% water. Therefore, it is important to preserve okara prior to its utilization. These are two wo ways to preserve okara. One is to ferment it using lactic acid bacteria to preserve against microbial spoilage. Another way to preserve okara is to dry it soon after production. The drying technique is the most viable means of conserving this residue, allowing for considerable economy in handling, storage and transportation costs. They dried okara to about 13% moisture and observed that higher inlet air temperature led to a faster rate of drying, especially at higher inlet air velocity and the change in protein content was not significant with minimal changes in colour. Drying methods have a significant effect on the sensory qualities and functional properties of okara. In terms of water holding capacity, swelling capacity and lipid-binding capacity, freeze dried okara is best, followed by vacuum drying and hot-air drying. On the contrary, as for cation- exchange capacity, hot-air-dried okara is best, followed by vacuum drying and freeze drying.

Microwave-vacuum drying would be a potential and competitive option on drying okara for its fast-drying and small volume. This combined drying method can save more than 90% of drying time compared to hot-air drying and lyophilization, and the quality of the dried product was close to that obtained by lyophilization. The effect of vacuum and microwave drying on okara and stated that okara dried in vacuum tray drying gives better sensory evaluation in respect of colour, flavour and all over acceptance and found that vacuum tray dried method is safe for health since in this process okara is dried in minimum temperature (45ºc - 50 ºc) for long hour. They concluded that vacuum tray drier method is more effective to produce okara of good quality compared to the microwave process.

**Nutrient composition of okara**

Okara contained 25.4-28.4% protein, 9.3-10.9% fat, 52.8-58.2% fibre on dry matter basis. Okara contained 84.5% moisture, 4.7% protein, 1.5% fat, 1.5% crude fibre and 0.4% ash on wet basis. On dry matter basis okara contained 30.10% crude protein, 27.53% crude fat, 11.38% crude fibre and 5.89% total ash. On fresh basis it contained moisture 80.50%, crude protein 5.87%, fat 5.37%, fibre 2.22% and ash 1.15%. Calcium and iron content on fresh basis was 62.49 and 1.48 mg/100g and 320.46 and 7.58 mg/100g, respectively, on dry basis. Calcium availability was 42.53 percent and iron availability was 24.99 percent. They observed that okara contained 611.80 mg phytic acid/ 100g and 80.06% *in vitro* protein digestibility. Okara comprised 49% total dietary fiber, of which only 0.55% was soluble and observed that in okara-fed rats, *in vivo* colonic fermentation of okara resulted in a lower pH, but a higher faecal weight and higher total short chain fatty acid production, compared to controls. There were no significant differences between the two groups in any of the analyses, with the exception of decreased body weight and increased faecal fermentation in the okara-fed group. Thus, stated that okara might be useful as a dietary weight-loss supplement with potential prebiotic effect.

**Antioxidant activity**

One third part of the soy isoflavone content is transferred to okara and it contains mostly crude fiber, about 25% protein and 10 to 15% oil. It is a suitable dietary additive in biscuits and snacks because it reduces calorie intake and increases dietary fiber. *In vitro* experiments have indicated that okara is a potential source of antioxidant components, showing that protease hydrolysate from okara yielded antioxidant activity. Okara contains isoflavones that are also found in whole soybeans and other soybean products. The three main isoflavones in soy are: daidzein, genistein, and glycitein. These can occur in four different chemical forms: aglycons, glucosides, acetylglucosides and malonylglucosides. Total phenolic content of okara is almost half of the soybean seeds. It was observed that radical scavenging ability increased with the increase in temperature and solvent fraction up to 50°c and 33 % respectively, but with further increase in these parameters, the percentage of inhibition of DPPH radicals started declining. A wide range of total phenolic content in soymilk has been reported, varying from 104 to 676 mg/100 g and between 96 and 320 mg gallic acid equivalent/100 g (determined by Folin–Cioclateu), depending on the soybean variety and the processing conditions to produce soymilk.

**Effect of drying on nutrient composition**

The nutrient composition of okara after drying (100◦c) and found that either soymilk preparation process (especially the grinding step) or the quality of the raw material (seed variety and quality) effects the nutrient composition in okara and observed that dried okara contained protein 37.5% and fat 20% dry matter basis.

The conservation of okara by drying in a flash dryer observed that the drying of okara in a flash dryer was technically viable, and the okara flour obtained showed protein contents between 36.71 and 41.39percent, lipid contents between 13.19 and 16.45percent, fiber from 21.43 to 43.74percent, ash between 3.61 and 4.59 percent. Freeze-dried okara, the main by product from soymilk and tofu processing, contained 40.3% total sugar (dry weight basis) from nonstarch polysaccharides (NSP). Other main components of raw okara were protein 28.5–33.4%, fat 9.8–19.8% and ash 3.5%.

Effect of tray drying at 68ºc for 8 hours on proximate composition of decorticated soybean okara. They reported that tray dried decorticated soybean okara contained 19.69% moisture, 43.68% protein, 16.23% lipid, 19.17% fibre and 3.98% ash. Dried okara has more calorific value in comparison to wet okara because of its higher protein, carbohydrate and fat content and found that vacuum drying (45-50ºc) for long hours is safe, have good nutritional quality and gives better sensory evaluation in respect of colour, flavour and all over acceptance. The effect of dehydration treatments on antinutrient factors and also on protein digestibility in legume flours (chickpea, lentil and bean) and found a decline of phytic acid in case of lentil (44%), followed by white beans and pink-mottled cream beans. The dehydration did not cause further effects in reduction of the concentration of polyphenolic compounds of flours. However, a higher increase of *in vitro* protein digestibility (IVPD) was produced in all legumes from 12% to 15%.

**Development of value-added products**

Supplemented okara in cookies with the addition of up to 30% of the dried powder of okara without adverse effect on the sensory properties of the products. Soy/rice cakes were puffed from the mixture of okara pellets and parboiled rice using a rice cake machine. Main ratio was okara pellets and parboiled rice: 90/10, 70/30, 40/60, and 0/100 (w/w). The cakes were evaluated for specific volume (SPV), texture, color, flavour, aroma and integrity.

Consumers liked best the rice cakes containing 70% okara in which beany flavor and aroma was not a significant factor.

About 80% of the judges attributed scores between 5 (“liked slightly”) and 7 (“liked a lot”) for the flavour and overall quality of the biscuit with 30 percent decorticated soybean okara flour which signified that the addition of 30% (w/w) of decorticated soybean okara flour in the formulation of biscuits was considered adequate, demonstrating the potential for its application in confectionery products. The sausage formulations containing 1.5% and 4% of okara flours from decorticated (A) and non-decorticated (B) soybean were equally accepted by the panelists, with emphasis on the formulation containing 1.5% okara flour A, which received the highest frequencies of scores in the acceptance range (92%) for the parameters of colour, odour, and taste.

When okara addition exceeded 25%, the total score of sensory quality of the steamed bread decreased markedly, representing low specific volume, rough skin, uneven gas pore, weak elasticity and unacceptable for eaters which revealed that with the addition of okara, springiness, cohesiveness and resilience of steamed bread reduced gradually. Cakes with the substitution of 5% okara obtained the highest sensory scores and concluded that okara could be used to improve the nutritional values of cakes.