BIO Web of Conferences **241**, 03014 (2026) https://doi.org/10.1051/bioconf/202624103014
ICRAHOR 2026

Valorization of Okara as Soy Fiber for the Development of Functional Cookies

Iqra Liaqat[1,2]*, *Naveed* Ahmad[2], *Nayab* Rao[2,3], *Maham* Nasir [2], *Shazia* Batool [2], and *Saiqa* Amjad [2]

[1] School of Food Technology, Nutrition and Bio-Engineering, Makerere University, Kampala, Uganda
[2] National Institute of Food Science and Technology, University of Agriculture Faisalabad, Faisalabad, Pakistan
[3] Islamabad Food Authority, Islamabad, Pakistan

*Corresponding author (s) Email: iqra.liaqat@students.mak.ac.ug; iqraliaqat274@gmail.com

Abstract. The present study was focused on the development of okara (soy fiber) enriched cookies. Soy fiber (okara) enriched cookies were developed from five different combinations such as: T0 (referred to as control, contained 100 % wheat flour), T1 contained (5 % okara flour and 95 % wheat flour), ; T2 contained (10 % okara flour + 90 % wheat flour), T3 contained (15 % okara flour + 85 % wheat flour) and ; and T4 contained (20 % okara flour + 80 % wheat flour). The physicochemical analysis of okara flour and the developed cookies was performed to assess the quality of the flour and its effects across all treatments. A sensory evaluation of fiber-enriched cookies was conducted to assess the organoleptic characteristics of the different treatments. The findings showed that the T3 exhibited significantly higher physicochemical and nutritional properties, including spread ratio, color attributes, fiber, protein, fat, ash, and antioxidant activity and sensory quality. While the higher value of diameter and spread ratio was found in T0. Sensory qualities of T3 indicated that no significant differences were observed across all treatments except the control.

1 Introduction

At present, the various health issues are associated with the low fiber diet around the globe, which may be responsible for various diseases such as diabetes, obesity, cardiovascular, etc. However, soybeans are considered valuable sources for the natural fibers, micronutrients, nutrients, vitamins, bioactive compounds etc. The fiber content in soybeans helps reduce cholesterol levels and is crucial for a healthy digestive system [1]. Soy products are categorized as fermented (e.g., tempeh, natto, miso, soy sauce) or unfermented (e.g., soy milk, tofu). Tofu, a popular processed soybean food in Asia and increasingly favored in Europe for its health benefits and affordability, produces common byproducts such as okara and soy whey during soymilk and tofu production. Both insoluble and soluble fractions of okara dietary fiber offer distinct health benefits. Soluble fiber has been linked to improved glucose absorption and lower cholesterol levels, while insoluble fiber helps materials move through the intestines and promotes the growth of probiotic bacteria. Produced in huge quantities annually, the by-products of bean processing are mostly used as animal feed. Cattle, not humans, consume most soy protein, which is soybean meal. Identifying long-term uses for these by-products is essential for addressing environmental challenges. Okara is a popular choice for those seeking an economical source of beneficial components due to its nutritional and functional properties. Researchers are exploring ways to use food industry waste to reduce the industry's environmental impact and create higher-value commodities. Materials with high nutritional value and functional qualities should be the primary focus of future research on waste streams [2].

Okara, sometimes called soy pulp, is a fibrous byproduct generated at a rate of 1.1 to 2.5 kg for every kilogram of tofu produced. The main fatty acid in okara is linoleic acid, and it is also high in dietary fiber (42.5–58.1%), protein (15.2%–33.4%), and fat (8.3%–10.9%). A minor amount of starch is also present, along with various monosaccharides and oligosaccharides. Factors such as soybean farming and production practices can cause variations in the composition of okara. The huge amounts of okara have been generated after processing of soybean and often discarded as waste in various countries including Japan, China, Korea, etc. [3-5]. The World Health Organization reported that many individuals still fail to meet the recommended daily fiber intake. Composite flours work wonderfully in cookies due to their nutritional density and immense popularity as snack food. Zucco [6] found that adding okara to cookies improved both their nutritional content and texture, making them more pleasant. The present study aims to develop okara-enriched cookies and to examine their effects on the physicochemical and sensory properties.

2 Materials and Methods

2.1 *Sample Preparation*

Soybeans were cleaned to remove impurities such as other grains, dust, metals, and unwanted plant material. The processing steps involved are shown in Fig 1 [7].

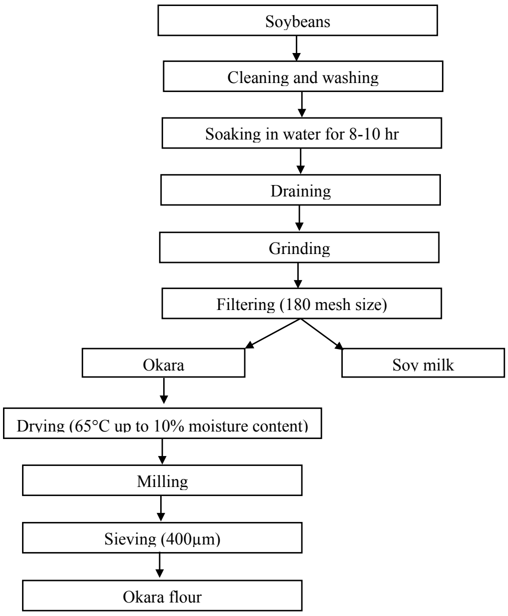

Fig 1. Flow chart for the preparation of Okara Flour

2.2 *Preparation of composite flour*

Wheat and okara flour were blended in different combinations, i.e., T0 (100:0), T1 (95:5), T2 (90:10), T3 (85:15), T4 (80:20), as mentioned in Table 1. The composite flours were stored for future use in air-tight polyethylene bags.

Table 1. Cookies formulations

Formulations	Wheat Flours (g)	Okara Flours (g)
T_0	100	0
T_1	95	5
T_2	90	10
T_3	85	15
T_4	80	20

Where, T_0 = Control group; T_1 = 5% okara flour+ 95 % whole wheat flour; T_2 =10% okara flour+ 90 % whole wheat flour; T_3 =15% okara flour+ 85 % whole wheat flour; T_4 = 20% okara flour+ 80% wheat flour

2.3 *Preparation of cookies*

Cookies were developed following the procedure outlined by [8]. Common ingredients such as sugar, salt, baking powder, egg, ghee, and water were used in all treatments, whereas wheat flour and okara flour were used as optional ingredients based on the treatment plan. The ingredients such as wheat flours, okara flours, salt, sugar, baking powder, eggs, ghee were mixed thoroughly in a laboratory mixer bowl for 10 min, and after a 10–15 min rest, the dough was rolled into a 5-mm-thick sheet and cut into cookies with molds. The baking process was performed at 170°C for 12–15 min, followed by cooling at room temperature. The cookies were stored for further analysis.

2.4 *Proximate analysis*

The proximate composition, such as moisture content, ash content, crude protein, and crude fat, of the flours and cookies was determined using specific methods outlined in the AACC [9] guidelines.

2.5 *Physical and textural properties*

The physical properties, including spread factors, thickness, and diameter, of the flour- and soy fiber (okara)-enriched cookies were determined using the methodology outlined by Park [10]. The color properties (LAB) of the cookies were measured using the colorimeter technique detailed by Momin [11]. The texture properties of the cookies were determined using the method reported by Porcelet [12].

2.6 *Antioxidant activity*

DPPH method, following an altered protocol [13], was used to determine antioxidant activity. 4 mL of a solution containing 6 × 10 -5 mol/L of 2,2-diphenyl-1-1-picrylhydrazone was added to a 100-liter sample of cookie extract. Absorbance was measured at 515 nm at 0 and 30 min using 95% methanol as the blank (B).

2.7 *Sensory evaluation*

Sensory evaluation was carried out at the laboratory of NIFSAT, University of Agriculture, and Faisalabad, using a trained panel of 10 members (4 males and 6 females, aged 22 to 45). A sensory evaluation form was used to assess preferences for color, taste, texture, flavor, and overall acceptability, employing a 9-point hedonic rating scale (9 = like extremely; 1 = dislike extremely) for each characteristic. Judges were instructed to carefully examine and deeply sniff each sample. The sensory evaluation took place in a sensory booth equipped with normal lights [14].

2.8 *Statistical Analysis*

The significance of the obtained data was analyzed statistically using one-way ANOVA. The average value of the triplicated reading has been reported as the result.

3 Results and Discussions

3.1 *Proximate analysis*

The proximate compositions of the okara flour, wheat flour, and the developed cookies are shown in Table 2. Okara flour had a moisture content (9.17±0.229%) and ash content (3.07±0.098%) and exhibited higher protein (19.97±0.09%), crude fat (17.08±0.08%), and crude fiber (42.02±0.04%) than wheat flour. These analyses provide insights into the nutritional composition of okara flour, highlighting its potential as a source of protein, fat, and fiber for human consumption. The proximate analysis of the developed fiber-enriched cookies involved incorporating okara flour (OF) into wheat flour to create composite flour. Five treatments were established with varying ratios of wheat and okara flours: T0 (100:0), T1 (95:5), T2 (90:10), T3 (85:15), and T4 (80:20). The protein, fat, ash, and fiber content in the cookies increased with higher levels of okara. The significantly higher values of moisture (7.25%), ash (1.08%), protein (7.29%), fat (21.18%), and fiber (1.74%) were found in T4 samples, followed by T3. These findings suggest that incorporating okara flour into the cookies not only influenced their nutritional composition but also enhanced their mineral, protein, fat, and fiber content, providing potential health benefits and functional properties to the products. These findings on proximate composition align with previous studies by Momin [11], Lian [15], Ibidapo [16], Awuchi & Godswill [17], and Porcel [18].

Table 2. Proximate composition of flour and okara-enriched cookies

Proximate composition	Flours		Cookies				
	Okara	Wheat	T_0	T_1	T_2	T_3	T_4
Moisture	9.17±0.229	8.98±0.08	5.65±0.12	1.78±0.05	3.58±0.06	5.44±0.04	7.25±0.05
Ash	3.07±0.098	0.55±0.41	0.21±0.03	0.25±0.04	0.52±0.03	0.76±0.04	1.08±0.03
Protein	19.97±0.09	11.85±0.055	3.21±0.03	1.8±0.01	3.60±0.01	5.36±0.15	7.29±0.17
Fat	17.08±0.08	1.67±0.037	15.4±0.02	5.29±0.03	10.60±0.02	15.91±0.01	21.18±0.05
Fiber	42.02±0.04	0.57±0.050	-	0.48±0.04	0.9±0.07	1.37±0.05	1.74±0.04

Mean±SD (N=3), Where, T0 = Control group; T1 = 5% okara flour+ 95 % whole wheat flour; T2 =10% okara flour+ 90 % whole wheat flour; T3 =15% okara flour+ 85 % whole wheat flour; T4 = 20% okara flour+ 80% wheat flour

3.2 *Physical and textural properties of cookies*

The diameter of the cookies decreased progressively as the quantity of okara flour increased. On the one hand, we have T0 at 5.15 cm and T4 at 4.98 cm (Table 3). Park [10] found that cookies with increased okara flour content had a smaller diameter, and Ryan and Brewer [19] found that cookies with added soy flour had a smaller diameter. As the okara flour content increased, cookie thickness decreased. For T1, the average thickness was 1.71 cm, whereas for T4, it was 1.59 cm. Both the Momin [11] and Ryan and Brewer [19] investigations on COOKIESs and soy flour-added cookies, respectively, found similar outcomes. An essential cookie quality, the spread ratio, decreased as the okara content increased. Among the groups tested, T0 had the greatest spread ratio and T4 the lowest. Preference was given to cookies with greater spread ratios. Protein increases dough viscosity and water retention, which, in turn, reduces the spread ratio as okara content rises. Results from research on cookies [10] and the spread ratio of cookies [20] corroborated. The fracture force of the cookies increased as the percentage of okara flour in the treatments increased from T0 to T4 (Table 3). The mean texture values for cookies in treatments T0, T1, T2, T3, and T4 were 22.35 ± 0.55, 23.54 ± 0.56, 24.56 ± 0.91, 25.53 ± 2.00, and 26.52 ± 2.32, respectively. The texture of the cookies showed a gradual increase from T0 to T4 as the okara flour content increased from 0% to 20%. The analysis of variance for the texture of different treatments indicated that the force required to break the cookies increased with higher okara flour content, due to the presence of fibers and proteins that compact the dough structure. Significant differences in texture profiles were observed between certain treatments, such as T0 and T4, with p-values < 0.05. The findings of the present study align with the results reported by Porcel [18], who observed an increase in texture as the percentage of okara flour in the product increased. The fracture force of the cookies increased as the percentage of okara flour in the treatments increased from T0 to T4. The mean texture values for cookies in treatments T0, T1, T2, T3, and T4 were 22.35 ± 0.55, 23.54 ± 0.56, 24.56 ± 0.91, 25.53 ± 2.00, and 26.52 ± 2.32, respectively. The texture of the cookies showed a gradual increase from T0 to T4 as the okara flour content increased from 0% to 20%. The analysis of variance for the texture of different treatments indicated that the force required to break the cookies increased with higher okara flour content, due to the presence of fibers and proteins that compact the dough structure. Significant differences in texture profiles were observed between certain treatments, such as T0 and T4, with p-values < 0.05. The findings of the present study align with the results reported by Porcel [18], who observed an increase in texture as the percentage of okara flour in the product increased.

Table 3. Physical and antioxidant (DPPH) properties of cookies

Cookies	Diameter (cm)	Thickness (cm)	Spread ratio	Hardness	Total Antioxidants (mg/100g)
T_0	5.15±0.04	1.20±0.17	3.99±0.12	$22.35±0.55^{b}$	46.29±0.34
T_1	5.013±0.01	1.63±0.07	3.07±0.12	$23.54±0.56^{ab}$	48.58 ±0.26
T_2	5.05±0.02	1.65±.05	3.02±0.06	$24.56±0.91^{ab}$	50.51 ±0.34
T_3	5.02±0.02	1.75±0.04	2.87±0.05	$25.53±2.00^{ab}$	52.59 ±0.34
T4	4.98±0.01	1.73±0.09	2.860.11	$26.52±2.32^{a}$	54.47±0.28

Mean±SD (N=3), Where, T0 = Control group; T1 = 5% okara flour+ 95 % whole wheat flour; T2 =10% okara flour+ 90 % whole wheat flour; T3 =15% okara flour+ 85 % whole wheat flour; T4 = 20% okara flour+ 80% wheat flour

3.3 *Antioxidant activity*

The cookies were tested for radical-scavenging capacity using the DPPH assay, a widely used method for measuring antioxidant activity. At a concentration of

100 µg/ml, the control cookies had a DPPH free radical scavenging activity of 46.29%, while the optimized cookies enhanced with okara flour showed a higher percentage of 54.47% (Table 3). The ANOVA results showed a significant difference ($p < 0.05$) in the treatments' ability to increase the DPPH value, with higher values indicating greater antioxidant activity. The inclusion of antioxidant-rich phenolic and flavonoid components explains why the enriched cookies are so much better at scavenging DPPH. Shafi [21] found the same when they tested wheat and water chestnut flour blends in cookies; the cookies showed greater DPPH radical-scavenging activity. Voss [13] found a rise in total antioxidants in prebiotic okara beverage formulation, while Pan [22] found the same thing in noodles enhanced with okara flour. The inclusion of okara flour in the cookies may have enhanced their antioxidant properties, leading to higher DPPH radical-scavenging activity and potential health benefits.

3.4 *Color*

The color value of the cookie samples is shown in Table 4. The L* value was noticeably lower in the soy flour group than in the control group, indicating that the cookies were darker in color. The presence of genistein and other natural anti-browning chemicals in soy flour caused this effect. Light brown pigment production and reduction in brown pigments were suggested by the lower L* values of cookies with okara flour compared to wheat flour cookies; the lowest L* value was achieved with 20% okara flour. The increasing* values, which indicate more redness in the cookies, were caused by the addition of okara flour.

Table 4. Color (LAB) properties of cookies

Cookies	L*	a*	b*
T_0	81.23 ± 1.12^{a}	2.57 ± 0.60^{b}	18.64 ± 0.88^{b}
T_1	80.67 ± 1.12^{ab}	3.44 ± 0.88^{ab}	20.66 ± 0.64^{a}
T_2	80.01 ± 1.00^{ab}	3.79 ± 0.91^{ab}	20.29 ± 0.65^{ab}
T_3	79.42 ± 1.23^{ab}	4.80 ± 0.75^{ab}	20.35 ± 0.72^{ab}
T_4	78.22 ± 1.05^{b}	5.04 ± 0.97^{a}	20.15 ± 0.69^{ab}

Mean±SD (N=3), Where, T0 = Control group; T1 = 5% okara flour+ 95 % whole wheat flour; T2 =10% okara flour+ 90 % whole wheat flour; T3 =15% okara flour+ 85 % whole wheat flour; T4 = 20% okara flour+ 80% wheat flour

Similarly, studies on cookies with soy flour added by Park [15], Porcel [18], and Momin [11] also reported comparable color values. When comparing the control and mixed-flour cookies, the former had marginally higher positive b* values, indicating more yellowness. Because okara flour contains phytochemicals and crude fiber, it turns out to be more yellow than white flour. Adding okara flour browned the crust, which turned the cookies a noticeable reddish-dun color and made them more yellow. When comparing the soy- and okara-flour-infused cookies to the control cookies, the results showed that adding these two ingredients altered the color parameters, specifically the L*, a*, and b* values. The results show that using alternative flours, such as okara flour, consistently improves color qualities, which is consistent with prior research on cookies and soy-flour-added cookies.

3.5 *Sensory evaluation of cookies*

The results of the sensory evaluation of the development of okara-enriched cookies are shown in Table 5. The results demonstrated that the inclusion of okara in cookies significantly affects their quality and sensory characteristics. The color score, flavor score, and texture score gradually decreased as the level of soy fiber in cookies increased. All the samples were found acceptable, including the control and all treatment cookies. The overall acceptability of the developed cookies ranged from 7.33 to 8.33. Overall acceptability scores did not significantly differ among treatments, with the control group having the highest score. Consumers generally preferred traditional flavors, and while cookies with 5%, 10%, and 15% okara flour had similar acceptability to the control, the 20% okara flour cookies were less favoured. Despite this, the 20% okara flour sample exhibited favourable sensory characteristics in color and flavor.

Table 5. Sensory evaluation of cookies

Treatments	Colour	Flavor	Texture	Taste	OAA
T_0	7.67±0.2	8.01 ±0.01	8.17±0.2	7.5±0.1	8.17±0.2
T_1	7.33±0.3	7.76±1.9	7.4±0.4	7.5±0.3	7.33±0.1
T_2	6.83±0.2	7.68±0.12	7.3±0.4	7.83±0.2	8.17±0.2
T_3	6.67±0.2	7.65±0.21	6.93±0.37	8.17±0.2	8.33±0.2
T_4	6.17±0.2	7.67±0.15	6.7±0.1	7.73±0.2	7.73±0.2

4. Conclusions

The present study showed that the replacement of wheat flour with okara significantly varied the functional properties of the cookies. The nutritional, sensory and antioxidant properties of the cookies samples were improved with addition of okara. The study also concluded the no negative impacts on the sensory properties of cookies with addition of okara. The developed cookies should be considered as high fiber rich functional cookies, and the further study should be required to explore their in vivo and invitro effects.

References

1. L. Nolan, P.W. O'Toole, Soy and the gut microbiome: a bi-directional relationship shaping nutrition and health, Eur. J. Nutr. 65 (2026):53.
2. G. MeDina, D. Muy-Rangel, A.L. de-la-Garza, W. Rubio-Carrasco, B. Perez-Meza, A.P. Araujo-

Chapa, K.A. Gutierrez-Alvarez, V. Urias-Orona, Dietary fiber from chickpea (Cicer arietinum) and soybean (Glycine max) husk byproducts as baking additives: functional and nutritional properties, Molecules, 24 (2019):991-996.

3. A. Aman, Valorizing Soybean By-Products: Strategies for Effective Utilization and Sustainability, Soybeans: Processing Techniques and Food Valorization. (2026):291-313.
4. W.C. Vong, S.Q. Liu, Biovalorisation of okara (soybean residue) for food and nutrition, Trends Food Sci. Technol. 52 (2016):139-147.
5. B. Li, M. Qiao, F. Lu, Composition, nutrition, and utilization of okara (soybean residue), Food Rev. Int. 28 (2012):231-252.
6. F. Zucco, Y. Borsuk, S.D. Arntfield, Physical and nutritional evaluation of wheat cookies supplemented with pulse flours of different particle sizes, Food Sci. and Tech. 44 (2011):2070-2076.
7. M. Curnutte, I. Forrester, Sensory Findings of Value-Added Product Formulated with Okara, J. Acad. Nutr. Diet. 117 (2017):130-139.
8. M. Deepak, B. Sheweta, B. S. Khatkar, Cookie texture, spread ratio, and sensory acceptability of cookies as a function of soluble dietary fiber, baking time, and different water levels, Food Sci. and Tech. 80 (2017):537-542.
9. AACC, Approved Methods of the American Association of Cereal Chemists, 11th Ed. American Association of Cereal Chemists, Inc., St. Paul, Minnesota, USA, (2016).
10. J. Park, I. Choi, Y. Kim, Cookies formulated from fresh okara using starch, soy flour, and hydroxypropyl methylcellulose have high quality and nutritional value, Food Sci. and Tech. 63 (2015):660-666.
11. M.A. Momin, A.B. Anjuman, H.N. Asmaul, V.R. Thottiam, A.R.M. Md, Substituting wheat flour with okara flour in biscuit production, Foods Raw Mater. 2 (2020):422-428.
12. O. Porcel, M.V. (Author), A.N. Rinaldoni, L.T. Rodriguez Furlan, M.E. Campderros, Influence of the Particle Size and Level of Substitution of Okara Flour in the Development of Gluten-Free Cookies, Food Sci. and Tech. 2017 (2016):407-585.
13. G.B. Voss, M.J.P. Monteiro, P. Jauregi, L.M. Valente, M.E. Pintado, Functional characterization and sensory evaluation of a novel synbiotic okara beverage, Food Chem. 340 (2021):12-23.
14. S. Akhtar, T. Ismail, M. Riaz, A. Ismail, Effect of pomegranate peel supplementation on nutritional, organoleptic, and stability properties of cookies, Int. J. Food Sci. Nutr. 65 (2014):661-666.
15. H. Lian, K. Luo, Y. Gong, S. Zhang, L. Serventi, Okara flours from chickpea and soy are thickeners: they increase dough viscosity and moisture content in gluten-free bread, Int. J. of Food Sci. and Tech. 55 (2019):805-812.
16. O.P. Ibidapo, F.O. Henshaw, T.A. Shittu, W.A. Afolabi, Quality evaluation of functional bread developed from wheat, malted millet (Pennisetum Glaucum), and ‘Okara’ flour blends, Sci. Afr. 10 (2020):01-22.
17. C.G. Awuchi, Proximate composition and functional properties of different grain flour composites for industrial applications, Int. J. Food Sci. 2 (2019):43-64.
18. O. Porcel, M.V. (Author), M.E. Campderros, A.N. Rinaldoni, Effect of okara flour addition on the physical and sensory quality of wheat bread, Food Sci. and Tech. 4 (2017):1-7.
19. K.J. Ryan, M.S. Brewer, Physical properties of sugar-snap cookies using granule surface de-proteinated wheat starch, J. Texture Stud. 37 (2006):442–57.
20. D.P.S. Lee, A.X. Gan, J.E. Kim, Incorporation of biovalorised okara in biscuits: Improvements of nutritional, antioxidant, physical, and sensory properties, Food Sci. and Tech. 134 (2020):01-05.
21. M. Shafi, W.N. Baba, F.A. Masoodi, R. Bazaz, Wheat-water chestnut flour blends: effect of baking on antioxidant properties of cookies, J. of Food Sci. and Tech. 53 (2016):4278-4288.
22. W.C. Pan, Y.M. Liu, S.Y. Shiau, Effect of okara and vital gluten on physico-chemical properties of noodle, Czech J. of Food Sci. 36 (2018):301-306.