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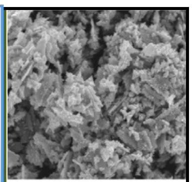

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Okara-Fortified Wheat Bread: Effect on Nutritional, Physicochemical and Sensory Properties

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ABSTRACT

The increasing demand for low-calorie diets underlines the importance of creating food with a higher fiber content. This is particularly relevant regarding bread, as a significant proportion of the population consumes it. Okara is an underutilized insoluble residue rich in fiber and protein that is produced in large quantities in the soymilk processing industry. This study aims to investigate the effects of okara levels (0, 10, 15 and 20 %) on wheat bread's physicochemical, sensory, and storage properties. The fiber and protein content significantly increased, while the carbohydrate content decreased in okara-fortified bread. The browning index increased, while the specific volume of the bread decreased with increasing okara content. Nevertheless, the samples fortified with 10 % okara showed comparable textural properties to the okara-free samples. Okara delayed the retrogradation of bread, as demonstrated by a 5-day storage at room temperature. Bread fortified with a maximum of 15% okara was considered acceptable by the panelists, especially regarding taste and odor. This study suggests that okara could be potentially exploited as a new sustainable source of dietary fiber for bakery product applications.

INTRODUCTION

Okara is the insoluble by-product that remains after the extraction of the water-soluble fraction of soybeans during the production of soymilk. It consists of 55.0 - 58.6% fiber, 15.2 - 33.4% protein, 8.3 - 10.9% fat (dry matter), and a considerable amount of bioactive compounds [1-3]. The high moisture content (75-88%) of wet okara [4] and its susceptibility to microbial growth limit its utilization in food. The high nutrient density of okara makes the by-product a promising alternative food ingredient, especially in the development of high-fiber products. However, its effective use poses a significant challenge due to its undesirable odor, poor digestibility [5] and high insoluble dietary fiber (IDF) content [3]. High IDF content is associated with a detrimental effect on fiber-fortified food. Several authors reported an improvement in the nutritional quality of okara-fortified bakery products. However, a reduction in dough extensibility and specific volume as well as an increase in hardness of gluten-free cake and bread, was observed when 10 to 40% okara was added [6-7]. The technological properties of bread are the most common challenges in the production of high-fiber bread. Therefore, the effect of okara level was investigated in this study in order to determine the optimal level that may be introduced into bread manufacturing without negatively impacting the bread's physicochemical and sensory attributes.

MATERIALS AND METHODS

Materials and ingredients

Wet okara obtained from soymilk processing was dried at 60°C for 6 h. The sample was ground and sieved to less than 600 mm. The ingredients for bread making, high protein wheat flour (12% protein), bread improver, vegetable shortening, and instant yeast were purchased from a local store.

Formulation and Preparation of Okara-Fortified Bread

The bread was made from (in percent by weight) high protein wheat flour (100 %), sugar (6.0 %), salt (1.5 %), yeast (1.5 %), bread improver (0.1 %), vegetable shortening (6.0 %) and water (55 %). The control bread was prepared without okara, while okara-fortified breads were made by replacing wheat flour with dried okara at 10, 15 and 20 % (w/w). The other ingredients were kept constant. The dried ingredients were mixed, then water and shortening were added. The dough was manually kneaded and subjected to the first stage of proofing for 10 min. The dough was divided into 380 g portions, flattened and rolled before being placed in baking tins and proofed for 1 h, followed by baking at 180 °C for 25 min.

Chemical composition, color, loaf volume and sensory properties were determined on fresh bread (day 1), while texture analysis was performed for both fresh and stored bread (day 5). The bread loaf was individually packed in PE plastic bag and stored at 25°C.

Evaluation of Chemical Composition

The chemical composition: moisture content, crude protein, crude fat, ash and crude were analyzed according to AOAC [8]. Carbohydrate content was obtained by difference.

Analysis of Color Parameters

The color of crumb and crust was analyzed with a chromameter (CR300, Japan). The color parameters L*, a* and b* were recorded. Browning index and total color difference (ΔE) were calculated according to Buera et al. [9] and Carocho et al. [10], respectively. The ΔE was determined by comparing the color of bread with added okara with that of the control bread.

Loaf volume

The loaf volume was measured according to the seed displacement method. The bread was placed in a container of known volume (1900 mm^3) and filled with mung beans until the container was full. The volume of beans replaced by the loaf was calculated as the loaf volume. The specific volume was calculated as loaf volume/bread weight.

Textural properties

The textural properties of the breadcrumb were determined using a texture analyzer (Stable Micro System TA .XT2i, United Kingdom). The bread was cut into slices of 25 x 25 x 25 mm (length x width x thickness). The sample was subjected to a two-cycle compression (50 %) using a cylinder probe (P/36). The extent of retrogradation was determined by comparing the hardness of the bread measured on days 1 and 5.

Sensory evaluation

Sensory evaluation of the bread was performed by 20 untrained panelists using a five-point hedonic scale to determine crust color, crumb color, odor, taste, appearance, and overall acceptability. A scale of '5' corresponds to extremely like and '1' corresponds to extremely dislike.

Statistical analysis

All data were analyzed using one-way ANOVA, Minitab, version 19 (Pennsylvania, USA). Differences between means were compared using Tukey's test ($p<0.05$). All analysis were performed in triplicate, except for texture analysis (n = 6).

RESULT AND DISCUSSION

Incorporating okara improved the breads' nutritional content (**Table 1**). The okara-fortified bread showed a 16.8 to 89.8 % increase in protein content, while crude fibre values increased 24 to 29.6-fold, with the highest increase observed in the sample with 20 % okara. This finding is due to the high protein and fiber content of the okara flour. The addition of okara significantly reduced the carbohydrate content of the breads, making them suitable for a lower-calorie, high-enhanced diet option.

The crumb and crust of the okara-fortified breads were darker, particularly with an okara content of 20 %, which was reflected in a higher a*, b*, browning index and ΔE (Table 2). The darkening of high-fiber bread was associated with the Maillard reaction [11]. The higher protein content in the okara-fortified bread perhaps increased the rate of non-enzymatic browning. Bread made with 10 % okara showed a crumb and crust color comparable to the control bread.

The loaf and specific volumes decreased with increasing okara content (**Fig. 1**). At 10 % okara, the bread showed a volume reduction of 10.0 %, while a 35.7 % reduction was observed when 20 % okara was added. Uniform distribution of pores was observed in both the control and 10 % okara-fortified samples, while ≥15 % okara led to a denser crumb structure with smaller pores (**Fig. 2**). A higher number of larger gas cells in 10% okara bread could be due to the coalescence of the cells during the proofing or baking processes.

Table 1. Chemical composition of okara flour and wheat bread fortified with different levels of okara.

Composition (%)	Dried okara	Bread at different levels of okara			
		0 %	10 %	15 %	20 %
Moisture	-	27.38 ± 0.14^a	27.49 ± 0.06^a	29.17 ± 1.56^a	28.41 ± 1.34^a
Cruder fat	15.45 ± 0.30	4.52 ± 0.16^c	6.43 ± 0.34^a	4.97 ± 0.20^b	5.33 ± 0.20^b
Crude protein	27.31 ± 4.35	5.29 ± 0.58^c	6.18 ± 0.64^c	8.64 ± 0.73^b	10.04 ± 0.37^a
Crude fibre	8.76 ± 0.22	0.05 ± 0.00^b	1.20 ± 0.26^a	1.44 ± 0.25^a	1.48 ± 0.03^a
Ash	5.36 ± 0.06	1.40 ± 0.01^a	1.40 ± 0.08^a	1.77 ± 0.06^b	1.50 ± 0.16^a
Carbohydrate	42.35 ± 4.19	61.18 ± 0.82^a	57.14 ± 0.83^b	53.83 ± 0.74^c	53.33 ± 1.56^c

Superscripts with different letters within the same row indicate significant differences at $p<0.05$. The composition of dried okara was calculated based on dry basis.

Table 2. Color intensity, browning index and total color difference of okara-fortified bread.

Okara levels	Crust			Total color difference (ΔE)		Browning index
	L*	a*	b*	Crumb	Crust	(Crumb)
0 %	58.31 ± 5.06^b	15.30 ± 0.29^b	28.09 ± 0.84^a	-	-	5.52 ± 1.80^b
10 %	67.45 ± 1.60^a	15.93 ± 0.52^b	28.78 ± 0.48^a	16.45 ± 5.72^a	10.16 ± 3.48^a	4.95 ± 0.71^c
15 %	66.62 ± 1.16^a	18.75 ± 0.32^a	30.48 ± 0.60^a	17.65 ± 4.70^a	11.67 ± 3.02^a	7.64 ± 0.35^b
20 %	68.43 ± 2.96^a	19.37 ± 0.55^a	29.97 ± 1.99^a	22.49 ± 4.45^a	12.03 ± 1.73^a	12.10 ± 1.21^a

Superscripts with different letters within the same column indicate significant differences at $p<0.05$.

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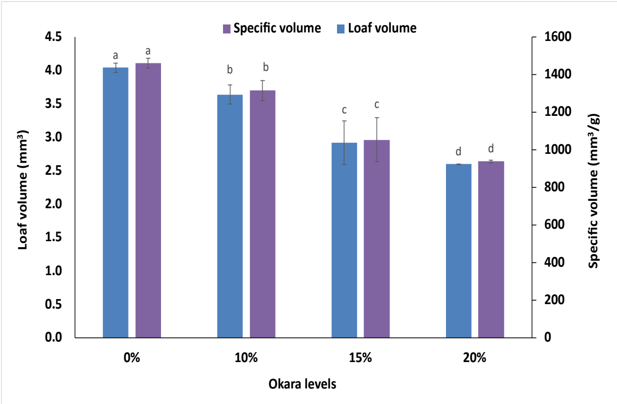

Fig. 1. Loaf volume and specific volume of bread.

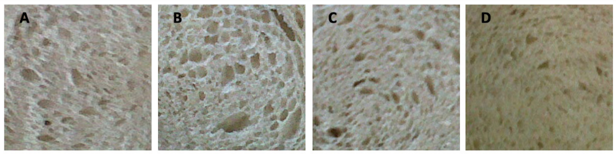

Fig. 2. Crumb structure of bread.(A) 0 (B) 10 (C) 15 (D) 20 % okara.

Textural analysis of day-1 bread showed that the hardness and chewiness significantly increased with the addition of ≥15 % okara, while at 10 % okara the hardness was comparable to that of the Control. The increase in hardness of breads with okara (≥15 %) was accompanied by a loss of springiness and cohesiveness, reflecting the elasticity of the bread, suggesting that the breads had less shape recovery after compression (**Fig. 3**).

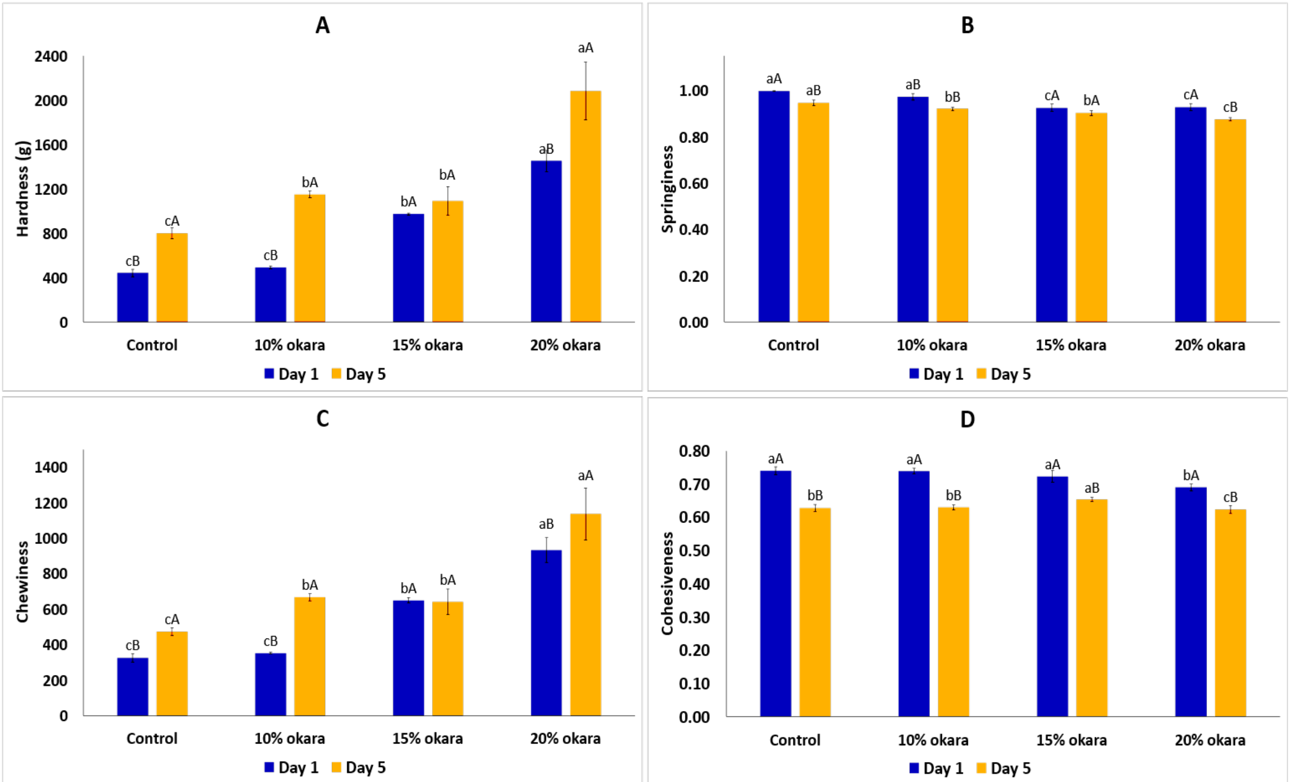

Fig. 3. Textural characteristics such as (A) hardness, (B), springiness, (C) chewiness, and (D) cohesiveness of fresh (day 1) and stored (day 5) breads. Different lowercase letters indicate significant differences at p<0.05 within the same day. Different upper cases with different letters indicate significant differences at p<0.05 among different days.

The denser and harder texture of okara-fortified bread is attributed to the lower gluten content and the altered arrangement of the protein network. The addition of fiber was associated with a disruption in the formation of continuous gluten networks. Water competition between fibers and proteins caused incomplete gluten network formation, resulting in impaired intermolecular interactions and, thus a reduced ability to hold air during fermentation [12-13]. The stored breads showed an increase in hardness and chewiness. The control sample showed a 81.4 % increment in hardness, while a smaller increase (12.3 – 43.4 %) was observed with ≥15 % okara, indicating a lower degree of retrogradation in the okara-fortified breads.

The lower starch content in the okara-added bread perhaps reduced the degree of amylose and amylosepectin recrystallization. In addition, the multi-hydroxyl groups in the fiber molecules delayed the retrogradation of the starch [13]. Breads with 10 and 15 % okara did not differ significantly (p<0.05) from the Control in terms of color, taste and overall acceptability, while sample with 20 % okara was the least acceptable due to the greatest hardness, density and browning of the crumb (**Fig. 4**). The results showed that up to 15 % okara can be added during bread making to produce high-fiber bread of acceptable quality.

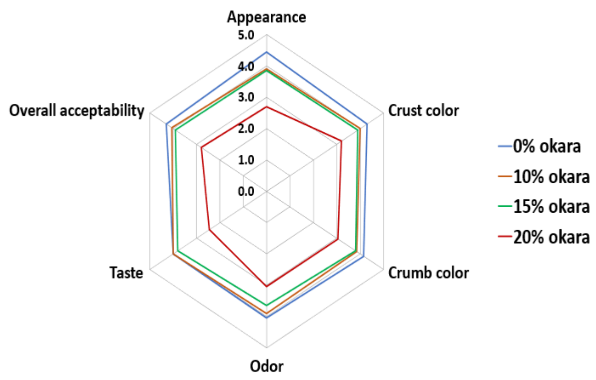

Fig. 4. Sensory profile of okara-fortified bread.

CONCLUSION

Okara can be successfully exploited to produce high-fibre bread. Okara-fortified bread has an improved nutritional quality with a higher protein and fiber content and a significantly lower carbohydrate content, making it suitable for a low-calorie diet. Bread with 10% okara has comparable color and textural properties to bread from 100% wheat flour. The addition of okara delays retrogradation and thus improves the storage quality of the bread. Adding up to 15% okara in the bread making is considered acceptable by consumers. A higher addition of okara in bread production could be possible by adjustment of the ingredients or processing techniques.

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