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Impact of Fermentation Duration of Okara on Dough and Bread Properties †

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Abstract: Okara, a nutrient dense by-product of soybean product processing contains a high insoluble fiber fraction that might be detrimental to product quality. In this study, microbial fermentation technique was performed to manipulate fiber properties. Wet okara was fermented at various duration (0, 4, 8 and 20 h) using baker's yeast and incorporated in high-fiber bread making. Addition of okara significantly decreases dough expansion and loaf volume. However, bread made with okara fermented at longest duration (20 h) had the highest increment in dough expansion. Fermentation of okara improved bread loaf volume, with increasing fermentation time enhanced the volume. Longer fermentation time resulted in bread with lower L* value and crumb firmness. In conclusion, manipulating fermentation duration of fiber source can be an alternative for enhancement for soluble fiber content in developing high-fiber products with improved quality.

Keywords: microbial fermentation; high-fiber bread; soluble fiber; dough expansion

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1. Introduction

Okara is the surplus material of soybean products processing and it is normally regarded as waste [1]. This food by-product has a good potential as a nutritive food ingredient. On dry basis, it contains 50–58% dietary fiber and 20–27% protein [2]. The wide utilization of okara at commercial level is limited, not only because of its high moisture content, making it prone to microbial spoilage [3], but it contains a high percentage of insoluble fiber (55.6%) and very low level of soluble fiber (1.9%) [4], that might negatively affect product quality.

High fiber bread holds a promising trend in food industry, due to its enhanced nutritional quality. In addition, adding fiber in bread making maintains softness of crumb by binding and retaining water, eventually reduces staling [5]. Nevertheless, fiber incorporation in bakery products causes some detrimental effects on final product quality. Addition of fiber such as wheat bran and okara results in lower loaf volume, poor crumb structure, higher hardness and bitter flavour [6,7]. Hence, this limits the amount of dietary fiber that can be incorporated in bakery products.

Modification of okara can be an alternative technique to manipulate its dietary fiber properties, hence its prevents it negative effect in product applications. Microbial fermentation of fiber and its effects on fiber and product characteristics have been reported by several authors. Pre-fermentation of wheat brans [8] and brown rice grains [9] with baker's yeasts resulted in better loaf volume and crumb softness. This was attributed to the partial degradation of fiber and softening of bran particles [8]. Understanding the effect of microbial fermentation conditions such as duration of incubation is crucial in manipulating the functional properties of fiber. Therefore, the objective of this study is investigate the effect of fermentation duration of the dough and bread characteristics.

2. Materials and Methods

2.1. Materials

Wet okara was obtained a soy products manufacturing company in Shah Alam (Selangor, Malaysia). The okara was stored at −18 °C until further use. High protein flour, bread improve, vegetable shortening and instant yeast (Mauri-Pan, AB Mauri Malaysia Sdn. Bhd, Malaysia) were purchased from a local store.

2.2. Fermentation of Okara

Wet okara (80–85% moisture content) was mixed with water at 1:3.5 ratio. Baker's yeast (Mauri-Pan, AB Mauri Malaysia Sdn. Bhd, Malaysia) was added at 1.25% (*w*/*w*, based on okara weight basis). The mixture was mixed well and then incubated at 32 °C for three consecutive duration, namely 0, 4, 8 and 20 h. After incubation period, water was decanted and the okara was dried at 60 °C to a constant moisture content of 5–6%. Dried okara was ground to a fine powder of 500 μm using a centrifugal mill. The dried powder was vacuum packed until further used.

2.3. Bread Making Procedure

Bread was made by mixing high protein flour (100%), bread improver (0.1%), vegetable shortening (6.0%), sugar (6%), salt (1.5%), instant yeast (1.5%) and water (55%). Okara powder was added at 10% (*w*/*w*) to substitute the wheat flour. Bread prepared without addition of okara was used as Control. Non-fermented okara was also used, and the sample was labeled as FO0. Bread made by substitution wheat flour with fermented okara at different duration (4, 8, 20 h) was labeled as FO4, FO8 and FO20, respectively. The ingredients was mixed (Kitchen Aid, USA) for 15 min, then the dough manually kneaded into round-shape and rested for 10 min at room temperature. It was then divided into 380 g dough, flatten, rolled and placed in baking pan. Proofing was performed at 35–40 °C and 85–90% RH for 1 h, followed by baking at 180 °C for 20 min.

2.4. Dough Expansion

Dough expansion was determine according to the method of Sangnark and Noomhorm (2004) [10]. Dough (50 ± 0.01 g) was compressed to 70 mL in a 250 mL measuring cylinder. The cylinder was placed in a proofer (40 °C) for 20 min, and removed from the proofer after 20 min. Volume of dough was recorded for 110 min.

2.5. Loaf Volume

Loaf volume was measured using seed displacement method according to the method of Mongi et al. (2011) [11] after 1 h of baking. The loaf volume was calculated following the equations by AACC method 10-05.01 [12].

2.6. Crust Color

Color of bread crust was measured using a chromameter (Hunterlab D65, USA). Parameters of lightness (L*), redness (a*) and yellowness (b*) were recorded.

2.7. Bread Firmness

Bread loaf was cut into 2.5 × 2.5 × 2.5 cm (length × width × thickness). Firmness of the sample was measured using a texture analyzer (TA.XT2i, Stable Micro System, UK). Sample was subjected to a two cycle-compression test using a cylinder probe P/36R with pretest speed of 1 mm/sec, post-test speed of 5 mm/sec, 5 g of trigger force, return speed of 10 mm/sec, and return distance of 35 mm, and contact force of 10 g.

2.8. Statistical Analysis

All the experimental data was analysed using statistical software (Minitab Version 16, Penn. State, USA). The significant difference was calculated using one-way ANOVA and Tukey's least significant difference was used to distinguish the means ($p \leq 0.05$).

3. Results and Discussion

3.1. Dough Expansion

Figure 1 shows final dough expansion volume measured recorded at 110 min of proofing. Control dough showed the highest expansion compared to the okara-enriched bread with a final volume of 228 ± 4 cm^3. Addition of okara significantly decreased the dough expansion. Dough made with okara fermented for 4 (FO4) and 8 h (FO8) recorded comparable values as the dough made with non-fermented okara (FO0), with values ranging from 121 ± 7 to 124 ± 2 cm^3 implying that fermentation of wet okara for the stated durations does not improve gas retaining ability of the dough. It has been reported that dough development depends on the strength of gluten network [13]. The addition of okara increases dietary fiber content of dough. Previous research demonstrated that a high dietary fiber in bread formulation such as grape peel pomace [14] and wholemeal wheat flour [15] decreased gas retaining and leavening ability during dough proofing. This behavior is attributed to disruption of starch-gluten network by the fiber particles [16], weakening the gluten network, reducing its ability to retain the expanding gas cells.

Nevertheless, dough made with okara fermented for 20 h (FO20) significantly ($p \leq 0.05$) improved dough volume with a final expansion value of 145 ± 1 cm^3. Similarly, Hugo et al. (2000) [17] demonstrated an increase in dough expansion with the use of pre-fermented sorghum. The improvement of dough expansion at higher fermentation duration perhaps attributed to increment of soluble fiber content of okara. *S. cerevisiae* has been reported to secrete extracellular hydrolytic enzymes such as amylase, lipase and cellulase [18]. The activation of enzymes has been reported to increase fiber solubility due to degradation of the fiber structure [19]. Therefore, fermentation of okara with the baker's yeast (*S. cerevisiae*) possibly caused microbial enzyme hydrolysis of insoluble fiber, causing an increase in soluble fiber of okara. In contrast, the minimal improvement of dough expansion in FO4 and FO8 could be attributed to very minimal increment of soluble fiber during the stated fermentation duration, hence less effect on preventing disruption of gluten network development.

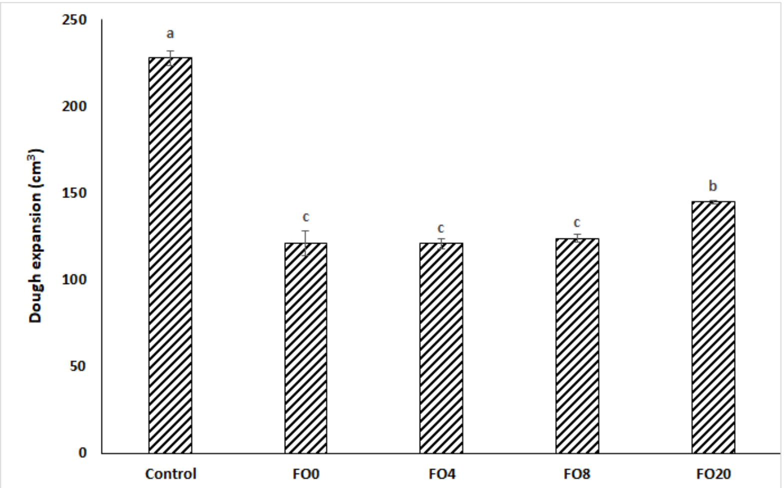

Figure 1. Final dough expansion of bread made with 10% substitution of non-fermented and fermented okara.

3.2. Loaf Volume

Figure 2 illustrates the loaf volume of bread made with and without okara substitution. Bread made without incorporation of okara (Control) showed the highest loaf volume (1331.3 ± 18.8 cm^3). Substitution of okara in bread formulation significantly decreased the bread volume, with non-fermented okara had exhibited lowest loaf volume (706.3 ± 21.4 cm^3). This findings were in agreement with several authors that reported addition of fiber such as oat fiber [20] and pineapple peel fiber [21] decreased bread volume.

The loaf volume showed a strong positive correlation (r is 0.9641) with dough expansion, concluding that higher dough expansion leads to greater bread volume. This concludes that the incorporation of fiber not only causes dilution of gluten protein [22], but disrupted gluten network, hence restrict gas retention and bubble expansion [15] during baking process attributed to the weak gluten network. This phenomenon leads to a more compact bread structure, hence lowering its porosity and final baked volume. Fermentation of okara significantly improved the loaf volume. Both FO4 and FO20 had the highest values. Similarly, bread substituted with fermented brown rice exhibited an increase in loaf volume compared to the non-fermented counterparts [9]. The presence of okara soluble fiber perhaps minimize the disruption of gluten network hence the ability to withstand the expanding gas during baking process.

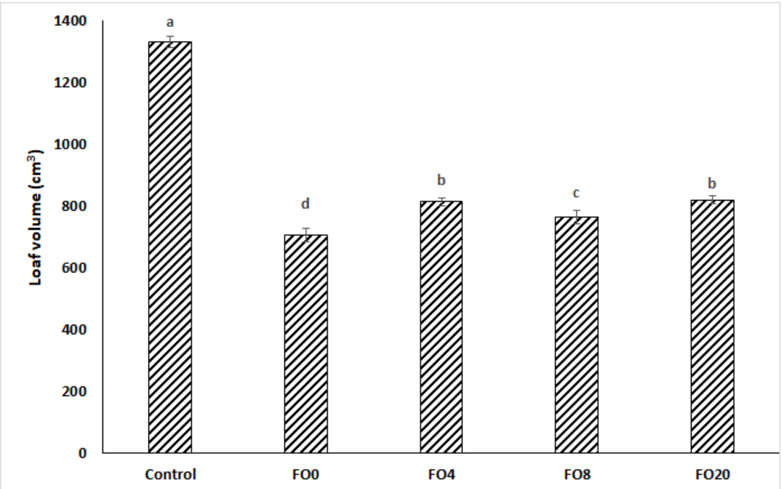

Figure 2. Loaf volume of bread made with 10% substitution of non-fermented and fermented okara.

3.3. Crust Color

Table 1 depicts the color of bread crust made with and without okara. The L* value of crust from bread made without addition of okara (Control) was 56.22. The L* value increased when bread was substituted with non-fermented okara, that indicated a lighter crust color. Incorporation with fermented okara caused a decreased in L* in FO4 sample, which then increases with increment in fermentation duration. Bread crust of FO20 had the highest L* value, implying the lightest crust color of all samples tested. A similar trend was observed for a* and b* values. Nevertheless, higher a* and b* values for some samples contradicts the L* value data, in which higher values of the former indicates darker color.

The reduction in L* and a* values in FO4 is attributed to higher degree of Maillard reaction that mainly occurs during baking process. The extracellular enzymes of *S. cerevisiae* such as amylase, proteinase [18,23] that were secreted during the fermentation of okara possibly resulted in hydrolysis of carbohydrate and protein into simple sugars and amino acids. The hydrolysis of these components increase the reactants for the Maillard reaction. therefore, leading to a higher degree of the non-enzymatic browning. Hence, results in darker crust color.

Nonetheless, increasing fermentation duration not only increased the simple sugars and amino acids, but caused an reduction in pH of fermented okara. A reduction of pH has been reported by Song et. al. (2008) [24] in okara fermented for 48 h at 37ºC. Therefore, incorporation of FO8 and FO20 in bread making perhaps leads to a decrease in dough pH, hence a lower rate of Maillard reaction. At low pH, the amino group was protonation, so only a few amino groups were available for Maillard reaction [25]. It can be concluded that the L* and a* values are mainly regulated by Maillard reaction, whereas the b* value perhaps is a function of caramelization of the crust during baking process.

Table 1. Color of bread crust made with and without fermented okara.

Samples	L*	a*	b*
Control	56.22 ± 1.52 ^{c}	14.70 ± 0.46 ^{a}	25.27 ± 2.59 ^{ab}
FO0	59.25 ± 1.35 ^{b}	15.01 ± 0.28 ^{a}	29.37 ± 2.97 ^{a}
FO4	50.29 ± 1.27 ^{c}	13.30 ± 0.54 ^{b}	23.83 ± 2.06 ^{b}
FO8	57.84 ± 1.32 ^{bc}	13.29 ± 0.51 ^{b}	27.30 ± 2.51 ^{ab}
FO20	63.84 ± 0.37 ^{a}	13.28 ± 0.33 ^{b}	29.55 ± 2.97 ^{a}

3.4. Bread Firmness

Figure 4 shows the firmness of Control bread is significantly ($p \leq 0.05$) lower that the okara-enriched bread. The higher firmness of fiber-enriched bread has been reported by previous authors [26,27]. The competition for water between dietary fiber and wheat flour components [28] and formation of less air bubbles [26] has been associated with harder texture due to their correlation with gluten network properties.

Breads made with FO4 and FO8 showed comparable firmness with the bread made with non-fermented okara (FO0). However, a softer texture was observed in bread made with FO20. The no positive effect of 4 and 8 h okara fermentation of bread texture could be attributed to minimal changes on dietary fiber molecules during the incubation process. Therefore, both fermented samples (FO4 and FO8) still constitute a high level of insoluble fiber. In contrast, longer duration of fermentation (20 h) possibly caused a significant hydrolysis of okara fiber, resulting in higher level of soluble fiber, hence minimizing the negative effects of insoluble fiber on gluten network development.

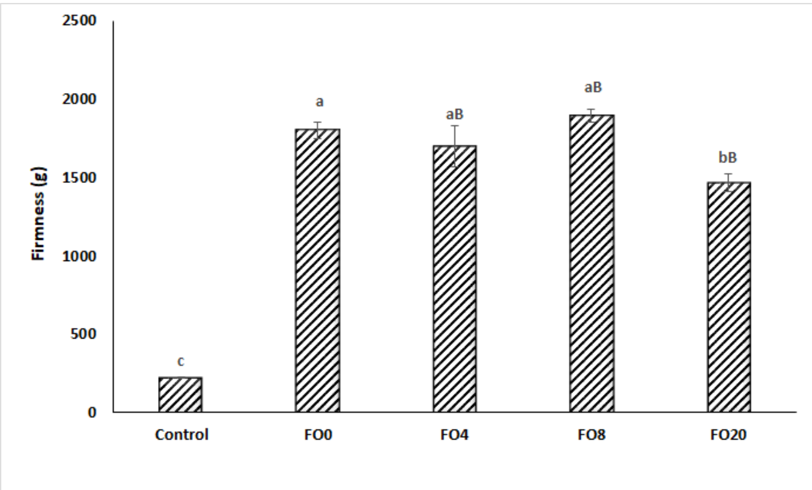

Figure 3. Firmness of bread made with 10% substitution of non-fermented and fermented okara.

4. Conclusions

Addition of okara, a fiber enriched material negatively affect bread properties. Microbial fermentation of okara improves dough and bread characteristics, attributed to changes in fiber components of okara, perhaps by increasing the soluble fiber content. Manipulation of fermentation is leads to different bread properties, with longer fermentation results in bread with softer texture and higher volume.

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