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Physicochemical characteristics of dough and white bread added with arrowroot juice

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Abstract

The applications of arrowroot in functional foods have been limited largely to noodles and rice cakes, and there is little or no currently available data regarding the physical characteristics of arrowroot juice as an additive to white bread. The physicochemical characteristics of dough and bread added with different quantities of arrowroot juice (0, 15, 25 and 35%) were investigated. The pH values of the dough to which arrowroot juice had been added during the first and second fermentations showed that the addition of arrowroot juice affected an increase in pH values. Our results also revealed a discontinuous weakening of the starch-protein matrix structures of the dough and bread crumbs, attendant to increasing quantities of added arrowroot juice. The scanning electron micrographs obtained from the second fermented dough and the bread crumbs (baked for 30 minutes) evidenced a significant reduction in gas bubble sizes, a greater quantity of collapsed gas bubbles and a greater quantity of thickened cell walls, in comparison to the other samples evaluated in the study. In conclusion, the volume of experimental baked loaves of bread decreased as the result of the addition of arrowroot juice, which contributed to a general decline in the quality characteristics of the white breads, via a reduction of CO_2 in the fermented dough, a thickening of gas bubble walls, and a weakening of gas bubble walls within the bread crumbs after baking. The quality characteristics of the white breads to which 25% arrowroot juice had been added were determined to be optimal among the tested variants.

Key words: Arrowroot juice, white bread, scanning electron microscopy, quality characteristics.

Introduction

The arrowroot (*Pueraria thunbergiana*) grows very well throughout the mountainous regions of Korea, China, Japan and North America. Although this plant has previously been asserted to exert a variety of medicinal effects, including the clarification of blood, the alleviation of fever, the relief of pain and a mitigating effect on obesity and alcoholic intoxication issues [1], the plant's current uses are rather limited, as the arrowroot is principally employed in teas and juices served in tea houses and residences in regions in which it is popular.

The arrowroot is associated with a bitter taste, which has been attributed to its tannin, which binds to the gluco-protein receptors of the taste buds in the tongue. This results in a characteristic temporary numbness of the taste buds, as well as the aforementioned bitter sensation. With regard to useful chemicals contained in arrowroot juice extract, Jung [2] previously reported that 100 ppm of the pueraria isolated from arrowroot proved effective in protecting against the *in vivo* production of fat peroxides.

The major nutritional components of arrowroot [3] are as follows: 65.8% moisture, 5.7% crude protein, 2.0% crude ash, 0.45% crude fat and 9.9% crude fiber, and the plant also harbors high levels of calcium and magnesium [2, 4]. Thus far, the applications of arrowroot in functional foods have been limited largely to noodles and rice cakes, and there is little or no currently available data regarding the physical characteristics of arrowroot juice as an additive to white bread.

Recently, the development of functional foods has become a matter of mounting interest, and this notion has also been explored in the manufacture of wheat flour-based products, including noodles and bread [5]. In a previous study, we addressed the sensory properties and flavor components of arrowroot juice as an additive to white bread [6]. In addition, other studies sought to provide more detailed information on the use of arrowroot juice for those experiencing problems with obesity or alcoholic intoxication [7, 8]. Such problems have been demonstrated to be affected directly by the addition of antioxidants to white bread [7, 8], as well as by the alcoholytic components contained in arrowroot extract [4].

In this study, the characteristics of bread crumbs were determined in accordance with the conditions of gas bubbles observed after slicing the baked loaves. Such gas bubble formation is known to be intrinsically related to the quantities of CO_2 gas generated during dough fermentation, as well as to the gluten structures within the dough. The pH measurements, loaf volume and weight of bread, and scanning electron micrographs (SEM) image analyses were to: 1) characterize the starch-protein matrix of the dough added with arrowroot juice, 2) determine the condition of gas bubbles and pots of vented gases forming in the dough during second fermentation and 3) observe the morphology of gelatinized starches and the condition of gas bubbles appearing after 30 minutes of baking. The objective of this study was to determine the optimal mixing conditions of the dough for the addition of arrowroot juice, with regard to the physical characteristics of the bread.

Materials and Methods

The arrowroot juice used in this experiment was extracted from arrowroot excavated on Mt. Kaya, which is located within Kyung-Nam Province, Korea. The flour (Dae-Han Flour Mills Co., Seoul, Korea) with 12.5% protein content, 13.0% moisture and 0.41% ash content (14.0% mb) was used. Instant dry yeast (Nisshin Flour Milling Co., Ltd, Marco, France), yeast food (Samlip Co., Siheung, Korea), shortening (LotteSamkang Co., Seoul, Korea), sugar (Samyang Co., Ulsan, Korea), salt (Hanju Co., Muan, Korea), nonfat skim milk power (Seoul Milk Co., Seoul, Korea), improver (Puretos Co., Belgium) and ascorbic acid (Hebei Welcome Pharmaceutical Co., China) were also used for making dough. All other reagents were analytical grade.

Preparation of the white bread dough: Dough formulation was as follows: flour 100%, instant dry yeast 2.5%, yeast food 0.5%, sugar 6%, salt 2%, skim milk powder 3%, shortening 4%, ascorbic acid 40 ppm, and water (85, 75 and 65%, flour basis). Arrowroot juice (15, 25 and 35%) was incorporated into dough prepared in accordance with the formula provided above. As the tested arrowroot juice quantity was increased, identical volumes of water were deducted from the original volume of water used in dough preparation.

The dough was prepared using a straight-dough method (AACC Approved Method 10-10B)[9] with some modifications (Fig. 1). Mixing was done in a spiral mixer (PM-250 S. South Korea) and accomplished stepwise; 2 min at 100 rpm, 2 min at 190 rpm, 2 min at 100 rpm after adding margarine and 5 min at 190 rpm. For optimizing the loaf volume, 1% of improver was added to the dough. Dough was molded and packaged on polyethylene bag and stored at –20°C until needed.

The first fermentation of dough persisted for 40 minutes at 32°C, 80% relative humidity (RH) and the second fermentation was conducted for 40 minutes at 35°C, 90% RH in a fermentation cabinet. The fermented doughs were then baked for 40 minutes at 160 and 180°C in a deck oven (Sin-sin Machinery, Korea) (Fig. 1).

Measurement of pH of dough: The pH values were measured after the first and second fermentation steps. The dough samples were frozen for 20 h in a quick freezer at -20°C. The dough samples were then placed on a 10 g scale, and thawed for 20 h in a refrigerator at 5°C. After the addition of 50 ml distilled water to each of the samples, these were homogenized using a Biomixer (Hamilton Beach, USA) and centrifuged with a SUPPA-21 centrifuge (Han-il Tech. Korea) at 8,000 rpm. The supernatants were then used in measurements of the pH of the dough samples.

Moisture content of bread: Moisture content was determined by AOAC (Association of Official Analytical Chemists) vacuum-oven method (16.192) for breads [10].

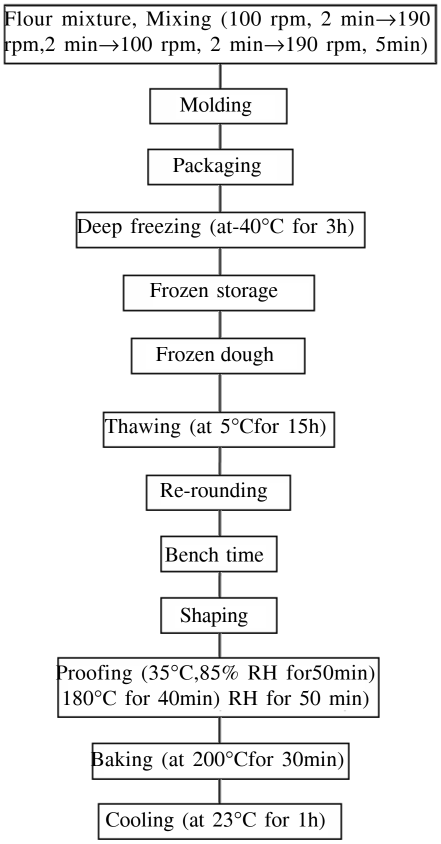

Figure 1. Procedure for preparing dough by straight dough method and making bread from the dough.

Scanning electron microscope analysis (SEM): For the SEM analysis of samples, we employed mixed doughs, second fermented doughs and white bread crumbs that had been baked for 30 minutes. The cryotreatment technique was used in accordance with the method developed by Varriano-Marston [11]. Each of the SEM samples was frozen for 20 h in a quick freezer at -20°C. These samples were then cut to 10 mm × 10 mm × 2 mm and treated with liquid nitrogen. They were then dried for 24 h in a freeze dryer (FDU-830, Eyela, Japan). The dried dough and crumb samples were coated with gold-palladium at 100°C. Each of the samples was photographed using an SEM (Hitachi, Japan) at an accelerating voltage of 20 kV.

Measurement of loaf volume and weight: The volume and weight of the white bread loaves were measured in accordance with the Cereal Substitution Methods [9], and the baked white breads were cooled for 1 h at room temperature (23°C) prior to the weight measurements.

Data analysis: All experiments and measurements were performed in triplicate and the results were expressed to means of three replications.

Results and Discussion

The pH values were measured in order to characterize the yeast activity occurring in the first and second fermented dough samples [12]. The change in pH occurring in the fermented dough is considered to be intrinsically related to the initial gelatinized temperature of starches and, consequently, to the ultimate volume of the baked bread loaf [13]. The pH values of the water and arrowroot

Table 1. The pH value of dough of the arrowroot juice added white breads.

Sample	After 1st fermentation	After 2nd fermentation
Control[1]	4.92	4.67
15[2]	4.96	4.70
25[2]	5.03	4.75
35[2]	5.06	4.78

Values represent means of three replications. [1]Control: Bread without arrowroot juice. [2]15: Bread made with 15% arrowroot juice; [2]25: Bread made with 25% arrowroot juice. [3]35: Bread made with 35% arrowroot juice.

Table 3. The loaf volume and weight of white bread added with the arrowroot juice.

Sample	Loaf volume (ml)	Weight (g)
Control[1]	2272	485
15 [2]	2197	497
25[2]	1951	510
35[2]	1873	514

Values represent means of three replications. All legend abbreviations are the same as in Table 1.

juice used in the experiment were 6.82 and 5.70, respectively (Table 1). However, the pH measured in fermented doughs and baked white bread to which arrowroot juice had been added evidenced higher pH values than the control. The pH of the dough and baked bread samples tended to increase as the arrowroot juice content increased. This elevation in pH value was attributed to the anti-microbial components and high mineral contents of the arrowroot juice [14]. The increased pH values of the fermented doughs subsequently effected a reduction of the final volume of the baked bread loaf, which was induced by the reduced production of CO_2 gas during the fermentation stages, as well as by the elevated initial gelatinized temperature of the starches.

The moisture contents of the white breads to which arrowroot juice had been added were slightly less than the 38.9% moisture content of the control (Table 2). The moisture contents of the white breads decreased as concentration of the arrowroot juice increased. Bread to which 15% arrowroot juice had been added had moisture content of 38.5%, whereas moisture contents of 38.2 and 38.0% were recorded in the 25% juice-added and 35% juice-added samples, respectively.

Table 2. Moisture content of white bread added with the arrowroot juice.

Sample	Moisture content (%)
Control[1]	38.9
15 [2]	38.5
25[2]	38.2
35[2]	38.0

Values represent means of three replications. All legend abbreviations are the same as in Table 1.

The loaf volume of the white bread samples tended to decrease as the concentration of the arrowroot juice increased. However, the weight of the bread samples increased with increasing the concentration of the arrowroot juice (Table 3). This inverse relationship was intensified as the amount of added arrowroot juice increased, consequently inducing an increase in pH, as the increase in pH value due to the influence of antimicrobial [2, 4, 15] components was fairly minimal. This also resulted in a degradation of the gas bubble conditions. The effects of the addition of arrowroot starch and crude fiber also weakened the starch-protein matrix structure.

When the SEM analysis micrographs were compared, the size and shape of the starches, as well as the starch-protein matrix structures, were found to be remarkably different between the hydrated arrowroot starch and the wheat flour starch.

Fig. 2 shows that properties associated with bread-making were decreased as the result of the addition of the arrowroot starch and crude fiber to the arrowroot juice. This may be responsible for the discontinuous starch-protein matrix structure observed in the baked white bread samples.

The micrograph [16-19] of the mixed dough, shown in Fig. 3, shows that the structure of the starch-protein was slightly weakened, with a more discontinuous structure. Dough generally showed a very dense structure with few spherical voids, and starch granules are firmly embedded in the gluten matrix [20].

The micrograph of the second fermented dough, shown in Fig. 4, shows the observed reduction in gas bubble size, which may represent the primary reason for the coalescence of collapsed gas bubbles, as well as the increased appearance of these collapsed bubbles.

When the fermented dough samples were baked for 30 min at 200°C, we noted smaller gas bubbles, more abundant coalesced gas bubbles and pots of vented gas in the bread crumbs, as can be seen in Fig. 5. Anti-microbial components, including tannin, pueraria, daidzin and daidzein have previously been shown to inhibit yeast activity in fermented dough, and can also be related directly to insufficient CO_2 gas generation during the fermentation of bread dough.

Fig. 6 shows the linear increase of non-gelatinized starches within the bread crumbs after 30 minutes of baking, attendant to an increase in the quantity of added arrowroot juice. The gelatinization temperature of the arrowroot starch [3] is known to be higher than that of wheat flour starch, as was previously reported by Kim *et al.*[21]. In their study, the moisture content of bread crumbs was identified as the principal factor in influencing the degree of gelatinization in the starches. There is a report on the proportional increase of heat, moisture and pH values to degree of gelatinization [22] but that study assumed that a small increase in pH had no detectable influence on the degree of gelatinization in the starches. A reduction in the degree of starch gelatinization after baking, as well as the weakening of the starch-protein matrix structure, can crucially influence the thickness of the cell wall by inducing a reduction in its capacity to hold CO_2 gas generated during the early stages of baking.

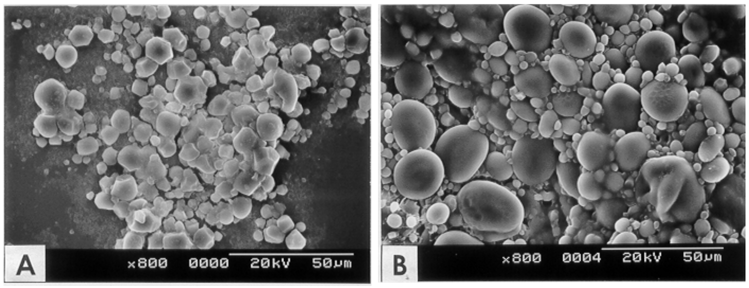

Figure 2. Micrograph of the hydrated arrowroot starch and wheat starch showing shape and size of the starches. A: Micrograph of the hydrated arrowroot starch; B: Micrograph of the hydrated arrowroot starch and wheat starch.

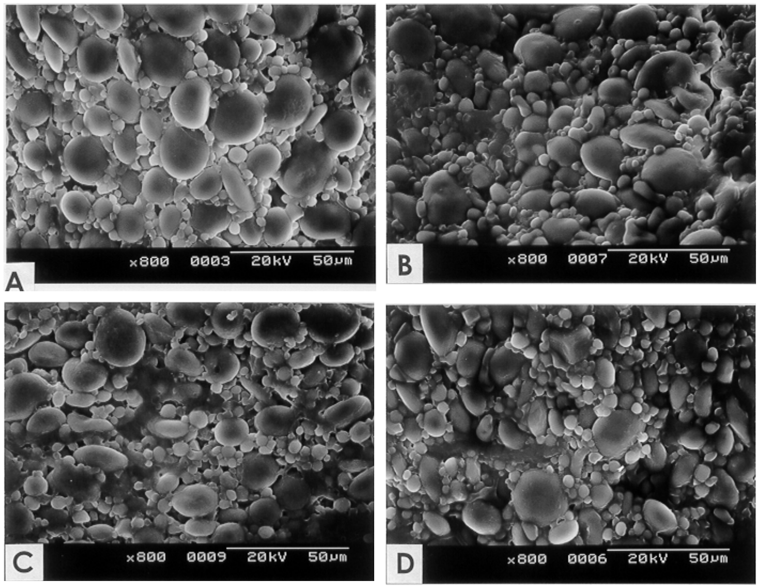

Figure 3. Micrograph of dough mixed with wheat flour and arrowroot juice showing starch-protein matrix structure. A: Control; B: Added with 15% arrowroot juice; C: Added with 25% arrowroot juice; D: Added with 35% arrowroot juice.

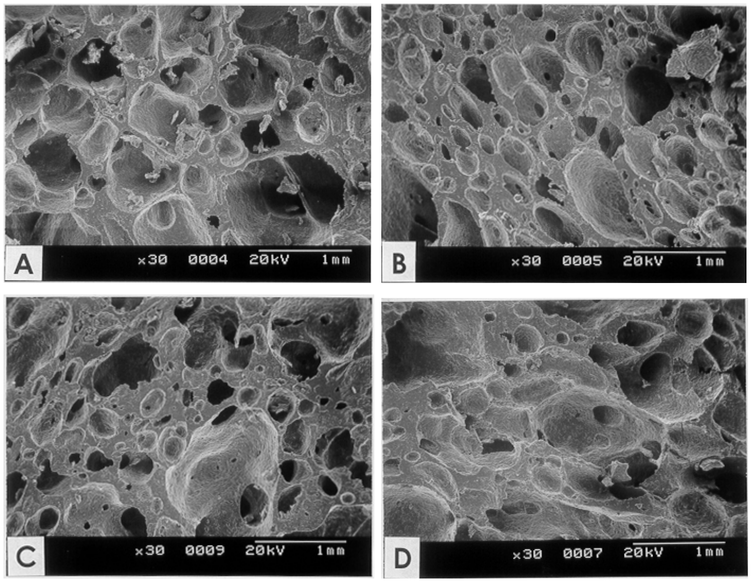

Figure 4. Micrograph of dough mixed with wheat flour and arrowroot juice for white bread after 2nd fermentation showing air cell size and shape. A: Control; B: Added with 15% arrowroot juice; C: Added with 25% arrowroot juice; D: Added with 35% arrowroot juice.

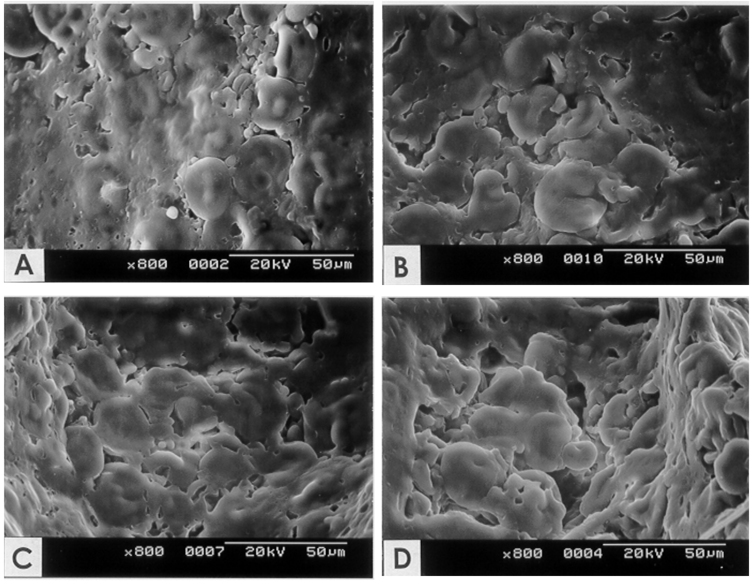

Figure 5. Micrographs of white bread with arrowroot juice showing shape of air cells after baking for 30 min. A: Control; B: Added with 15% arrowroot juice; C: Added with 25% arrowroot juice; D: Added with 35% arrowroot juice.

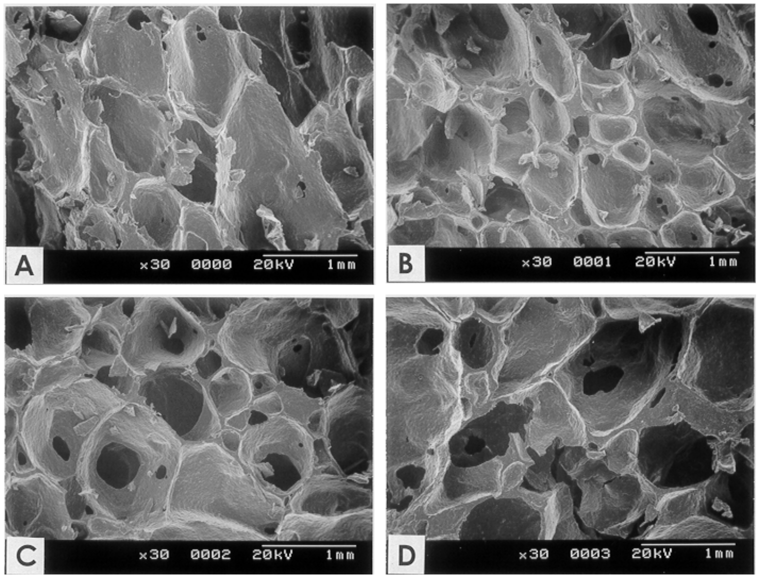

Figure 6. Micrographs of white bread with arrowroot juice showing gelatinization of starch after baking for 30 min. A: Control; B: Added with 15% arrowroot juice; C: Added with 25% arrowroot juice; D: Added with 35% arrowroot juice.

Conclusions

In conclusion, the volume of experimental baked loaves of bread decreased as the result of the addition of arrowroot juice, which contributed to a general decline in the quality characteristics of the white breads, via a reduction of CO_2 in the fermented dough, a thickening of gas bubble walls and a weakening of gas bubble walls within the bread crumbs after baking. The quality characteristics of the white breads to which 25% arrowroot juice had been added were determined to be optimal among the tested variants.

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