Increased Volume of Kasutera Cake (Japanese Sponge Cake) by Dry Heating of Wheat Flour

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A soft wheat flour, Tokutakaragasa (protein 9.69 %), was dry-heated at 120°C for 10, 20, 30, 60, and 120 minutes, and baked into Kasutera cakes (Japanese sponge cakes). The volume of Kasutera cake increased with duration of dry heating. Also, the stability of foam in Kasutera cake batter increased with the dry-heating time of wheat flour. The mixograph profile of dry-heated wheat flour also suggests the hydrophobicity of wheat flour. Thus, the results suggest that the hydrophobicity of the dry-heated wheat flour could stabilize the foam in Kasutera cake batter and contribute to increasing Kasutera cake volume.

Keywords: Kasutera cake baking, dry-heated wheat flour, hydrophobicity, foam of cake batter

Introduction

Kasutera cake is a popular cake in Japan. It was first imported from Portugal in the 1500s (Kariyazono, 2004), and has been changed to suit Japanese tastes. The Kasutera cake is composed of 100 parts by weight soft wheat flour, 176 parts sugar, 184 parts whole egg, 32 parts egg yolk, 52 parts syrup, 24 parts honey, and 40 parts water; the proportion of whole egg is higher than that of wheat flour. The leavening of the cake is due to air bubbles stabilized by egg white protein, and the role of wheat flour is as a cement or support among egg white air bubbles. Nakamura et al. (2007) observed that storage of wheat flour at room temperature increased the volume of Kasutera cake, and they discussed that this might be due to the interaction between the prime starch and tailings fractions in stored wheat flour. They further reported that mixograph data of the stored wheat flours showed a strong hydrophobicity, which could be related to the increase in volume of Kasutera cake. The increase in Kasutera cake volume resulting from storage of wheat flour indicates that hydrophobic wheat flour in storage could bind to the surface of egg white protein membrane surrounding air bubbles and further stabilize the bubbles even in an oven.

Seguchi (1990) and Ozawa and Seguchi (2006) reported that dry heating of wheat flour improved pancake springiness, and that the improvement could be due to the interaction between the prime starch and tailings fractions in dry-heated wheat flour. Furthermore, Seguchi et al. (1993) and Seguchi (1984 and 1990) indicated that the interaction between the prime starch and tailings fractions involved a change in starch granule surface protein from hydrophilic to hydrophobic nature due to the dry heating of wheat flour. If dry heating of wheat flour could increase the volume of Kasutera cake, this would be useful for the Kasutera cake industry in Japan, because long-term storage of wheat flour at room temperature could be replaced with dry heating treatment. Since the maximum condition for dry heating wheat flour was found to be 120°C for 2-3 h to obtain complete springiness of a pancake (Seguchi, 1990, Nakamura and Seguchi, 2007), the same condition was selected in our Kasutera cake baking test, in order to examine if it could increase the volume of Kasutera cake. We examined the possibility of increasing the foam stability in the Kasutera cake batter by using dry-heated wheat flour. The dry-heated wheat flour was also fractionated to water solubles, gluten, prime starch, and tailings fractions by acetic acid (pH 3.5) fractionation, in order to ascertain if the interaction between the prime starch and tailings fractions was related to the increase
in volume of Kasutera cake. Seguchi (1984) reported that dry heating of heat flour imparted oil-binding ability to prime starch granules. Therefore, we further examined the oil-binding ability of prime starch fraction in dry-heated wheat flour Tokutakaragasa and analyzed the rheological changes in the dry-heated wheat flours by mixograph tests.

Materials and Methods

Wheat flour  Tokutakaragasa wheat flour was donated by Masuda Flour Milling Co., Ltd., Kobe, Japan. Moisture content was 14.2% (w/w). Nitrogen-to-protein conversion factor was 5.7 (AACC method 46–10, 2000), and ash was determined according to the AACC method (08–01, 2000). Protein and ash contents on dry basis were 9.69 % (w/w) and 0.43 % (w/w), respectively.

Dry heating of wheat flour  Wheat flour (400 g) was put onto an iron plate (25 x 34 x 3 cm height) and dry-heated at 120°C for 10, 20, 30, 60, and 120 min in a Sanyo drying oven (Sanyo Co., Ltd., Osaka, Japan). Samples after dry heating were kept at -20°C.

Preparation of Kasutera cake batter  Whole egg (66.4 g), egg yolk (13.3 g), and sugar (73.5 g) were mixed evenly with a spatula, and added to a mixture of 82.5% (w/v) syrup (21.8 g), honey (10.0 g), and water (84.0 mL) that was preliminarily prepared on boiling water. This mixture was put into the cup (11.2 cm dia. and 13.2 cm depth) of an Izumi Hand Mixer HM-400 (Izumi Products Company Co., Ltd., Matsumoto, Japan) and homogenized by two beaters at 1200 rpm at room temperature for 5.5 min. Specific gravity was 0.52. To this suspension, 41.8 g of wheat flour was added and the mixture was homogenized at 1200 rpm for 45 s. The specific gravity of the resulting mixture was estimated, and the height (cm) of foam in a 500 mL-measuring cylinder (5.5 cm dia. and 34 cm height) was also measured.

Kasutera cake baking  Whole egg (266 g), egg yolk (53 g), sugar (249 g), 82.5% (w/v) syrup (87 g), honey (40 g), and water (67 mL) were mixed and slightly homogenized with warming to 35°C in a Kitchen Aid mixer (Kenmix Chef Aicoh Mixers & Aicoh Systems Co., Ltd., Toda, Japan). The mixture was homogenized at 128 rpm for 1 min and at 75 rpm for 10 min at room temperature. The specific gravity of the resulting mixture, known as kijihiju in Japanese, was 0.52. Next, wheat flour (dry weight, 167 g) was added to the mixture, and it was homogenized at 48 rpm for 5 min. The specific gravity of the resulting batter is called kijihiju in Japanese. The kijihiju and temperature of the batter were 0.58-0.60 and 25°C, respectively. The batter was poured into a paper-laid Kasutera case (22.3 x 18.8 x 7.0 cm height), which was made of a wooden frame and iron bottom, and was placed into an oven (230°C-upper and 200°C-bottom) for 90 s. After removal from the oven, the batter was stirred with a rubber spatula for 30 s to obtain uniformity; this step is known as awakiri in Japanese. The awakiri process was repeated three times, and the batter was baked for 8 minutes. Next, two sets of the same wooden frame and iron cover were placed upon the Kasutera case and the batter was further baked for 25 min. The Kasutera cake volume (cm³) was measured by rapeseed displacement (Seguchi and Matsuki, 1977). The change in volume of the Kasutera cake was continuously measured for 3 h after removal from the oven. Shrinkage (%) of Kasutera cake was calculated as follows: shrinkage (%) = cake volume after 3 h (cm³) / cake volume immediately after baking (cm³) x 100. The moisture content of the Kasutera cake was measured with a Moisture determination balance FD-600 (Ketto Electric Laboratory Co., Ltd., Tokyo, Japan).

Fractionation of Wheat Flour with Acetic Acid (pH 3.5)  Wheat flour was fractionated by the method of Seguchi et al. (1998). The homogenization step was performed by means of a mortar and pestle (Nittokagaku Co., Ltd., ANM-150 Type, Nagoya, Japan; the mortar and pestle were rotated at 120 and 70 rpm, respectively) (Seguchi et al., 1998). Flour (50 g) was mixed with 150 mL of water and the mixture was homogenized for 20 min at room temperature. After centrifugation at 1700g for 20 min at room temperature, the supernatant was freeze-dried to recover the water-soluble fraction. The pellet was homogenized in 125 mL of 0.136 N acetic acid solution (pH 3.5) for 20 min and centrifuged. The resulting pellet was further homogenized in 75 mL of 0.0283 N acetic acid solution (pH 3.5) and centrifuged. The two supernatants after centrifugation were mixed and freeze-dried to recover the gluten fraction without elimination of acetic acid. The pellet was homogenized in 150 mL of water, and the pH was adjusted to 5.0 with 5 N NaOH solution. After centrifugation, two layers of the pellet appeared; the upper yellowish and viscus layer was the tailings fraction, while the white and non-viscous layer in the bottom was the prime starch fraction. The fractions were collected separately with a spatula and air-dried.

Microscopic observation of the oil-binding ability of the prime starch fraction  A portion (5 mL) of 10% aqueous solution of prime starch fraction was added to 1 mL corn oil in a graduated centrifuge tube. The mixture was vigorously agitated using a mixer MW-S (Miyamoto Riken Kogyo Co., Ltd., Oosaka, Japan) at an amplitude of 0.1 cm for 10 s, and the agitation was repeated 20 times. The agitated mixture was observed by microscopy (Seguchi, 1984).

Ten-gram mixograph test  Wheat flour (10 g; moisture content, 14%) and water 5 mL were mixed and tested in a ten-gram mixograph (National MFG. Company Nebr. USA).
Sample weight (g) and added water (mL) were calculated from the dry weight (8.6 g) and water (6.4 mL) of a model system. The mixing speed of the mixograph was 86 rpm.

**Statistical Analysis** A statistical software package (SPSS Inc., Chicago, IL.) was used for the statistical analyses. *Kasutera* cake baking was performed six times (n=6) with dry-heated wheat flour (at 120°C for 0, 10, 20, 30, 60, and 120 min), and the volume was measured by rapeseed displacement. In each case, *Kasutera* cake was baked twice, and when the difference in volume of *Kasutera* cake was more than 10%, the experiment was repeated. Analysis produced significant F values by analysis of variance, followed by Duncan’s multiple range test for a comparison of means.

**Results and Discussion**

*Kasutera* cake baking *Tokutakaragasa* wheat flour was dry-heated at 120°C for 10, 20, 30, 60, and 120 min. The moisture content of each wheat flour after dry heating is indicated in Table 1. Since water content of dry-heated wheat flour decreased with increasing dry heating time, 167 g (dry basis) of dry-heated flour was used, and total water content was adjusted to 67 mL for baking *Kasutera* cakes, which resulted in moisture contents (32.5-34.3%) comparable to that of the control wheat flour (34.5%). The volume of *Kasutera* cake just after baking gradually increased up to 30 min of dry heating at 120°C of wheat flour, and afterward was almost constant (Table 1). Table 1 also shows data for the shrunken volume of baked *Kasutera* cake left at room temperature for 3 h. With increased dry heating time, shrinkage of *Kasutera* cake was suppressed from 25.2% (0 min) to 20.5% (30 min), and it did not change significantly at dry heating times of 60 and 120 min. Figure 1 shows the appearance of sectioned *Kasutera* cakes baked with control (A) and dry-heated (120°C, 120 min) wheat flour (B), which indicates the

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**Table 1.** Effect of dry heating of wheat flour on the moisture content of wheat flour, volume (cm$^3$) and moisture content (%) of *Kasutera* cake, and change in the volume 3 hrs after baking.

<table>
<thead>
<tr>
<th>120°C min</th>
<th>Moisture content of wheat flour</th>
<th>Moisture content of cake</th>
<th>Volume (just after baking)</th>
<th>Volume (3 hrs after baking)</th>
<th>Shrinkage %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13.8</td>
<td>34.5</td>
<td>1817.5 a (10.6)</td>
<td>1359.0 a (36.8)</td>
<td>25.2</td>
</tr>
<tr>
<td>10</td>
<td>6.90</td>
<td>33.6</td>
<td>1895.0 b (35.4)</td>
<td>1422.5 a (3.5)</td>
<td>24.9</td>
</tr>
<tr>
<td>20</td>
<td>5.40</td>
<td>34.3</td>
<td>1995.0 c (21.2)</td>
<td>1532.5 b (24.8)</td>
<td>23.2</td>
</tr>
<tr>
<td>30</td>
<td>1.70</td>
<td>34.3</td>
<td>2252.5 d (17.7)</td>
<td>1790.0 c (0.0)</td>
<td>20.5</td>
</tr>
<tr>
<td>60</td>
<td>1.40</td>
<td>32.5</td>
<td>2237.5 e (3.5)</td>
<td>1825.0 d (56.6)</td>
<td>18.4</td>
</tr>
<tr>
<td>120</td>
<td>0.90</td>
<td>33.3</td>
<td>2325.0 f (21.2)</td>
<td>1837.5 e (24.8)</td>
<td>21.0</td>
</tr>
</tbody>
</table>

Values represent means of 2 replicates with the standard deviations in parentheses. The mean values followed by different letters in rows are significantly different at p=0.05 according to Duncan’s multiple range test.

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**Fig. 1.** Sections of *Kasutera* cakes. (A), control; (B), dry-heated wheat flour (120°C, 120 min).
increase in height of Kasutera cake by dry heating of wheat flour.

**Acetic acid fractionation of wheat flour, oil binding ability, and mixograph tests** Nakamura et al. (2007) reported that the volume of Kasutera cakes increased with storage time of wheat flour at room temperature, and the phenomenon was highly related to binding of prime starch to the tailings fraction in stored wheat flour. In the case of dry heating of wheat flour, an increased volume of Kasutera cake was observed with longer dry heating (Table 1). The results of acetic acid fractionation of the dry-heated wheat flour (Fig. 2) showed results similar to those with stored wheat flour (Nakamura and Seguchi, 2007): the amounts of water soluble and gluten fractions were almost constant, whereas those of prime starch and tailings fractions decreased and increased, respectively; that is, prime starch fraction was gradually mixed in tailings fraction and finally completely mixed. In the case of control wheat flour, separation between the yellowish and viscous tailings fraction and white and non-viscous prime starch fraction was clearly and visually observed after centrifugation of flour/water mixture. However, the separation was not observed with dry-heated wheat flour (Fig. 2). This observation indicated the interaction between the prime starch and tailings fractions of dry-heated wheat flour. Ozawa and Seguchi (2006) reported that interaction between the prime starch and tailings fractions in dry-heated wheat flour would contribute to the improvement of pancake springiness. Figure 2 indicates the relationship between the amounts of prime starch and tailings fractions in dry-heated wheat flour.

In order to clarify the mechanism of the interaction between prime starch and tailings fractions, we showed the change of hydrophilic nature of prime starch fraction to hydrophobic nature by dry heating (Fig. 3). Seguchi (1984) showed that prime starch fractionated from heat-treated wheat flour possesses high oil-binding ability, and prime starch heat-treated at 100-160°C for 1 h also possessed this ability, and suggested that the oil-binding ability was caused by hydrophobicity of proteins on the surface of starch granules. Figure 3A indicates that dry-heated (120°C, 2 h) prime starch fraction (PS) shows a strong oil-binding ability (hydrophobicity) and almost all of oil was deposited with PS; however, oil-binding ability was not observed in control PS (Fig. 3B). This hydrophobic nature of prime starch fraction occurred in dry-heated wheat flour, and interaction between prime starch and tailings fractions may occur by hydrophobic force. Thus, with increase of dry heating time, the oil-binding ability (hydrophilic nature) of prime starch fraction increased (data not shown here), and the amount (%) of prime starch fraction decreased and tailings fraction increased by the inclusion of prime starch fraction to the tailings fraction (Fig. 2).

**Fig. 2. Acetic acid fractionation of dry-heated wheat flour.**

**Fig. 3. Oil-binding ability of (A) dry-heated (120°C, 120 min) prime starch granules; O, oil phase; W, water phase; PS, prime starch deposit and (B) control.**
The relative coefficient (r) between the interaction of prime starch and tailings fractions in dry-heated wheat flour and increase in volume of Kasutera cake was calculated from two sets of data. Data of interaction in dry-heated wheat flour were obtained from the decrease (%) in the prime starch fraction or increase (%) in the tailings fraction in wheat flour with dry heating time (Fig. 2). Data of increase in volume of Kasutera cake with dry heating time are indicated in Table 1. The decrease in the prime starch fraction and increase in the tailings fraction were highly correlated to the increase in volume of Kasutera cake; that is, r = -0.92 and +0.89, respectively.

Next, in order to ascertain the change in whole wheat flour for Kasutera cake from hydrophilic to hydrophobic nature by dry heating, a mixograph experiment was performed. Mixograph evaluates physical properties of dough. General use of mixogram mixing time of wheat flour is suggested, to predict bread loaf volume, dough oxidation requirement, and breadmaking water absorption (Finney and Shogren, 1972). When water is added, the dough development starts, and this is seen as saw-toothed parts of the mixing profile. In general, wheat flour does not absorb water immediately (Eliasson and Larsson, 1993). In the mixograph profile of control wheat flour (Fig. 4A), as dough began to coil around the mixograph pins, large swings of the pen arm were observed for 60 s at the early stage. Afterward, the constant swings indicated that dough became creamy and showed low resistance to the pins (Fig. 4A). Dry-heated wheat flour at the early stage of the measurement showed the pen arm's large swings, which correspond to high resistance to mixing. This indicates that the flour had difficulty in absorbing water, attached to the pins, and caused the high resistance. Constant small swings (low resistance) in the profile (Fig. 4B) did not appear until elapse of more than 200 s, which is longer than the 60 s observed in the control. One may suggest that higher hydrophobicity of dry-heated wheat flour as compared with the control one might retard the water absorption and require longer time for obtaining creamy dough. Storage of wheat flour would also induce hydrophobicity (Nakamura and Seguchi, 2007).

Stability of foam in Kasutera cake batter by dry-heated wheat flour In order to clarify the role of dry-heated wheat flour in the increase of volume of Kasutera cake, we examined its role in the stability of foam in Kasutera cake batter. Firstly, a mixture of whole egg, egg yolk, and sugar was vigorously homogenized, and then dry-heated wheat flour was added to the mixture, which was further homogenized under the same condition. Table 2 shows that the height of the foam significantly increased after 10 min dry heating and then

Fig. 4. Mixograph profiles of wheat flour samples. (A), control; (B), dry-heated wheat flour (120°C, 120 min).
Table 2. Change in foam height and specific gravity of Kasutera cake batter by dry-heating of wheat flour.

<table>
<thead>
<tr>
<th>Temperature (℃)</th>
<th>Height of foam (cm)</th>
<th>Specific gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>23.6 (0.907)</td>
<td>0.52 (0.0058)</td>
</tr>
<tr>
<td>110</td>
<td>28.3 (0.851)</td>
<td>0.50 (0.025)</td>
</tr>
<tr>
<td>20</td>
<td>28.6 (1.89)</td>
<td>0.51 (0.031)</td>
</tr>
<tr>
<td>30</td>
<td>29.3 (1.06)</td>
<td>0.48 (0.023)</td>
</tr>
<tr>
<td>60</td>
<td>29.6 (1.21)</td>
<td>0.48 (0.021)</td>
</tr>
<tr>
<td>120</td>
<td>30.2 (1.74)</td>
<td>0.47 (0.0058)</td>
</tr>
</tbody>
</table>

Values represent means of 3 replicates with the standard deviations in parentheses.

gradually increased with increased dry heating time. In view of the high relative coefficient \( r = +0.94; \ Y = 0.01X + 9.20 \) between (X) the increase in Kasutera cake volume just after baking (Table 1) and (Y) the foam height of Kasutera cake batter (Table 2), a close relationship is indicated.

Thus, we can conclude that the dry-heated wheat flour further stabilized the foam of the Kasutera cake batter, and the stability of the foam of the Kasutera cake batter was maintained throughout Kasutera cake baking in the oven.

The results indicate that dry-heating treatment increases hydrophobicity in the wheat flour, and that the hydrophobicity further stabilizes the liquid-gas interface formed by egg white protein in the batter. As a result of the increased stability of the Kasutera cake batter, an increased volume of Kasutera cake could be obtained.

**Conclusion**

Dry heating (120℃) of wheat flour was found to lead to an increase in the stability of foam in Kasutera cake batter and an increase in the volume of Kasutera cake. From the results of mixograph profiles and oil-binding ability of dry-heated wheat flour, the dry-heating treatment was implicated to impart hydrophobicity to wheat flour. We concluded that a greater Kasutera cake volume could be obtained via the stability of Kasutera cake batter which would be pronounced by increased hydrophobicity of dry-heated wheat flour.

**References**


