Endogenous Factors Responsible for the Textural Characteristics of Buckwheat Products

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Summary Endogenous factors responsible for the textural characteristics of buckwheat products were studied. An analysis with various buckwheat samples showed that there were variations in protein, starch, amylose and amylopectin contents among the various buckwheat flours examined. The protein contents of the buckwheat flours were significantly negatively-correlated to the starch, amylose and amylopectin contents of buckwheat. A texturometric analysis showed that the springiness of heated-dough made from buckwheat flour was positively correlated to its starch content and amylopectin content, and the springiness and chewiness was negatively correlated to the protein content. Experiments adding isolated buckwheat protein or starch to buckwheat dough confirmed the above-mentioned correlation between texture and components. This study suggests that both the protein and starch present in buckwheat flour may be important factors responsible for the textural characteristics of buckwheat products.

Key Words buckwheat, Fagopyrum, esculentum, texture, protein, starch, amylose, amylopectin

Buckwheat (Fagopyrum esculentum Moench) is an important crop in some areas of the world. Buckwheat seed contains some essential nutrients such as protein (1) and minerals (2) at high levels. Thus, buckwheat contributes as an important dietary source of such essential nutrients. Especially, the protein of buckwheat consists of well-balanced amino acids (3) with high biological value (4), whereas its protein digestibility is relatively low (5) because of both the presence of some antinutrients such as protease inhibitors and the low digestibility of the

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protein (1, 6). Thus, the improvement of protein digestibility is a subject of intense investigation. The components in buckwheat seed have not yet been well characterized from the standpoint of both nutrition and functionality. Careful characterization of the components is needed to better understand their nutritional and functional properties. For this purpose, we recently conducted a near-infrared diffuse reflectance spectroscopic analysis of the components in buckwheat flours (7).

There are a variety of buckwheat dishes around the world (8). Noodles made from buckwheat flour-water dough are popular in some countries such as Japan, China and Italy (9). In view of their processing and cooking, considerable attention has been paid to the palatability and acceptability of buckwheat products such as noodles. The texture of food is an important quality attribute which affects consumer acceptance of and preference for foods (10). Although the textural characteristics of buckwheat products are considered to depend largely on the inherent characteristics of the components present, endogenous factors responsible for the textural characteristics of buckwheat products remain largely uncertain.

This study was designed to clarify endogenous factors responsible for the textural characteristics of buckwheat products.

MATERIALS AND METHODS

Buckwheat samples. Thirty different samples of common diploid buckwheat seeds (Fagopyrum esculentum Moench) harvested from 1978 through 1990 were obtained from eight different countries: Slovenia (19), Austria (3), Poland (2), Russia (2), Italy (1), Croatia (1), India (1) and Korea (1). The 30 seed samples were analyzed for texture and constituents. Another seed (Fagopyrum esculentum Moench, Akisoba local variety), which was harvested in autumn 1994, was used for both the isolation of protein and starch, and experiments of incorporation of protein or starch into dough. All the seeds were milled before analysis with a roller mill (Quadramat Junior Model No. 279002, Brabender Co., Germany) under exactly the same milling conditions with constant milling quantity of seeds and constant milling time to uniform flour yield from the various seeds. The percent flour yield from the 30 buckwheat seeds was 65.6±3.0% (M±SD, n=30). The milled samples obtained were analyzed. Wheat starch, maize starch and potato starch were obtained from Nacalai Tesque Co., Ltd. All other chemicals used were of analytical grade.

Analyses. The total protein content in buckwheat was analyzed by the micro-Kjeldahl method (N×6.25), which is similar to the method recommended by the Association of Official Analytical Chemists (11). For the determination of starch content, the samples were washed in a solution of 8% potassium hydroxide in ethanol. Starch was hydrolyzed by the direct acid hydrolysis method (12). Glucose was determined by high-performance liquid chromatography (Säulentechnik, Knauer HPLC, Bad Homburg, Germany) using a EuroKat Ca column.
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(300 × 8 mm) at 65°C, distilled water as the mobile phase and a different refractive index detector (Knauer, Germany). The starch content was calculated from the glucose obtained. The amylose content was analyzed according to the method developed by Sowbhagya and Bhattacharya (13). In brief, buckwheat flour was mixed with a solution (1 N) of sodium hydroxide in ethanol, after which petroleum ether was added. After shaking, the layer of petroleum ether was aspirated off and carbon tetrachloride was added. The amylose content of the aqueous layer was determined by absorbance at 630 nm, as measured by a Unicam PU 8630 spectrophotometer. Amylopectin content was estimated by subtracting the amylose content from the total starch content.

Protein was isolated from buckwheat flour according to the method of Javornik and Kreft (14) with a slight modification. Buckwheat flour was extracted with a solution (0.2 M) of sodium chloride and stirred for 2 h at 4°C. After centrifugation at 17,000 × g for 20 min, the supernatant obtained was dialyzed exhaustively against distilled water. The soluble fraction of the dialyzate was lyophilized, and the powdered fraction obtained was used as buckwheat albumin. After dialysis, the precipitate obtained was lyophilized and the powdered fraction was used as buckwheat globulin. Starch was isolated from buckwheat flour according to the method described by Taniguchi (15). Buckwheat flour was immersed in 0.02 M acetate buffer (pH 6.5). The immersion was then squeezed through a layer of gauze. Toluene was added to the squeezed suspension to remove protein. The suspension was then centrifuged at 11,000 × g for 10 min, and the layer of toluene with protein was aspirated. Deproteinization with toluene was repeated ten times, and the resultant precipitate was collected. The final precipitate was lyophilized, and the powder obtained was used as buckwheat starch.

Texture was measured according to a procedure described previously (16). Routinely, all buckwheat flour samples were freeze-dried prior to analysis under the same conditions with a FD-5 freeze-dryer (Tokyo Rikadenki Co., Ltd.) until the moisture of the buckwheat flours, as determined with an IB-30 infrared moisture analyzer (Chyo Balance Co.), became approximately 1%. Immediately after freeze-drying, approximately 2.5 g of the freeze-dried buckwheat flour was mixed with approximately 0.8-volumes (v/w) of distilled water by hand, and then a column (approximately 1.5 cm height and 1.5 cm diameter) of dough was prepared. In experiments incorporating additives (buckwheat protein or starch), buckwheat dough was prepared with approximately 5.0 g of lyophilized buckwheat flour to make mixing with the additives easy. As buckwheat products are usually cooked prior to consumption in countries such as Japan, China, and Slovenia, the prepared dough was heated for 3 min in boiling water, immediately cooled at 20°C in an electric cooler and then analyzed for texture. Texture was analyzed with a rheometer (Asuka Kiki Co., Model RX 1600). All determinations were performed three or four times with each sample. Relative texturometric value was estimated from the ratio of texturometric value without additives (buckwheat protein or starch) (designated as “ADD0%” or “ADD00%” in Figs. 5 and 6) to

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texturometric value with additives; the value without additives was taken as 100. The additives were freeze-dried with a FD-5 freeze-dryer prior to analysis under essentially the same conditions as buckwheat flour in the texture analysis described above.

Statistical analysis. Data were subjected to statistical analysis of variance, and the significance of difference was determined by a t-test.

RESULTS AND DISCUSSION

Protein and starch contents in various buckwheat flours

Figure 1 shows the contents of total protein, total starch, amylose and amylopectin in the buckwheat samples examined. There were large variations in the contents of these components. The total protein content (g/100 g dry matter (DM)) of 30 buckwheat flours ranged from 7.7 to 12.0 with an average of 10.1. The content of total starch (g/100 g DM) in the buckwheat samples ranged from 67.8 to 80.7 with an average of 71.0. The content of amylose (g/100 g DM) ranged from 23.4 to 29.1 with an average of 25.9, and the content of amylopectin (g/100 g DM) ranged from 40.9 to 52.9 with an average of 45.0. Figure 2 shows the relationship between each buckwheat component examined in Fig. 1. Interestingly, the total protein content of the buckwheat flours was significantly negatively correlated to the total starch content ((A) in Fig. 2, correlation coefficient \( \gamma = -0.731, p<0.001 \)), amylopectin content ((B) in Fig. 2, \( \gamma = -0.499, p<0.01 \)) and amylose content ((C) in Fig. 2, \( \gamma = -0.474, p<0.01 \)). In addition, the total starch content was significantly correlated to the amylopectin content ((D) in Fig. 2, \( \gamma = 0.837, p<0.001 \)) and amylose content ((E) in Fig. 2, \( \gamma = 0.389, p<0.05 \)). On the other hand, as amylopectin and amylose were expressed as percent of total starch content respectively, there was no significant correlation (\( p>0.05 \)) between percent amylopectin to total starch and protein content, and also no significant correlation (\( p>0.05 \)) between percent amylose to total starch and protein content.

Texture profiles of various buckwheat samples and their relationship to the components

Figure 3 shows the texture profiles of heated dough made from various buckwheat flours. There was a large variation in the texture profiles among the various buckwheat samples examined. The relationship of texture to the components in buckwheat samples was analyzed. Figure 4 shows the relationship of the springiness and chewiness of buckwheat heated dough to the constituents present. The total starch and amylopectin of the buckwheat flours exhibited significantly positive correlations to the springiness of heated doughs made from the buckwheat flours with a correlation coefficient of \( \gamma = 0.442 (p<0.05) \) for starch and \( \gamma = 0.411 (p<0.05) \) for amylopectin ((A) and (B) in Fig. 4). The amylose content of the buckwheat flours exhibited no significant correlation to springiness ((C) in Fig. 4). On the other hand, the protein content of the buckwheat flours exhibited a

significantly negative correlation to the springiness and chewiness of the heated doughs made from buckwheat flours with a correlation coefficient of $-0.599$ ($p < 0.001$) for springiness and a correlation coefficient of $-0.489$ ($p < 0.01$) for chewiness ((D) and (E) in Fig. 4). There was no other statistically significant correlation between the texture profiles and the components ($p > 0.05$). In addition, as amylopectin and amylose were expressed as percent of total starch content.
respectively, there was no significant correlation \( (p > 0.05) \) between percent amylopectin to total starch and the texture profiles, and also no significant correlation \( (p > 0.05) \) between percent amylose to total starch and the texture profiles. On the other hand, both the total starch content and the total protein content of the buckwheat flours exhibited significant multiple correlations to the springiness and chewiness of heated dough with a multiple correlation coefficient of \( R = 0.599 \ (p < 0.01) \) for springiness and \( R = 0.506 \ (p < 0.05) \) for chewiness. Similarly, both the total protein content and the amylose content exhibited significant multiple correlations to the springiness and chewiness of heated dough with a multiple correlation coefficient of \( R = 0.634 \ (p < 0.01) \) for springiness and \( R = 0.513 \ (p < 0.05) \) for chewiness. Thus, protein and starch, including both amylopectin and amylose, may be important endogenous factors responsible for the textural characteristics of buckwheat products. On the other hand, we analyzed the textures of a variety of buckwheat seed samples from different production places and from varying production years in this study. In this connection, post-harvest storage and the preparation of cereal grains, in general, may have a profound influence on quality characteristics. There may be few changes in protein and starch during storage or preparation of buckwheat seeds, but changes in some enzymes or lipid components in buckwheat itself during storage or preparation, if any, might affect the textural characteristics of the buckwheat products. Further investigation concerning these problems is needed.

Fig. 3. Texture profiles of heated doughs made from various buckwheat flours. Cohesiveness, adhesiveness and springiness were expressed by multiplying 10-fold. Sample numbers from Bl to B30 expressed those in Fig. 1, respectively. Values are means (n=3).

Direct effects of buckwheat protein and starch on texture

Figure 5 shows the effect on texture from the incorporation of albumin and globulin, major components of buckwheat protein, into buckwheat flour. The incorporation of buckwheat albumin into the flour significantly reduced ($p < 0.01$) some texture values such as cohesiveness, springiness and chewiness, whereas it
enhanced adhesiveness significantly \((p < 0.01)\) ((I) in Fig. 5). Buckwheat albumin had no significant effect on hardness ((I) in Fig. 5). On the other hand, the incorporation of buckwheat globulin into the flour significantly reduced \((p < 0.01)\) all texture values except for adhesiveness ((II) in Fig. 5). Figure 6 shows the effect on texture from the incorporation of various starches, including buckwheat starch, into buckwheat flour. The incorporation of buckwheat starch enhanced all texture values except for adhesiveness ((C) in Fig. 6). There were variations in the effects on the texture of buckwheat dough among the various starches examined (Fig. 6). The observed variations in the effects on texture caused by the various starches (Fig. 6) may be associated with the properties inherent of each starch such as water absorption capacity and swelling properties, but further analysis concerning this phenomenon is needed. Generally, both of the buckwheat proteins (globulin and albumin) reduced the texture values of heated buckwheat dough (Fig. 5), including springiness and chewiness, whereas buckwheat starch enhanced the texture values of the dough, including springiness (Fig. 6). Therefore, the findings in Figs. 5 and 6 support the relationship of the texture of heated buckwheat dough to the components as shown in Fig. 4. But, all of the alterations observed in texture by the incorporation of buckwheat protein and starch into buckwheat dough (Figs. 5 and 6) did not completely agree with the correlation relationship shown in Fig. 4. This
suggests the possibility that there may be some other factor, in addition to protein and starch, responsible for the overall textural characteristics of buckwheat dough. In relation to textural characteristics, further characterization of buckwheat components is needed.

There is a large variety of buckwheat foods globally. Most buckwheat products have been prepared by many traditional methods around the world. However, the scientific basis involved in such traditional methods still remains obscure. A molecular basis of the determinants of the palatability and acceptability of buckwheat products should be established. We conclude in this study that the protein and starch in buckwheat flour may be important factors responsible for the textural characteristics of buckwheat products. Research is currently underway by our research group to reveal the favorable ratio of protein and starch in buckwheat products for good palatability.
Fig. 6. Effects of incorporating various starches into buckwheat flour on the texture characteristics of heated dough. Each starch was added to buckwheat flour at 5% (ADD5%), 10% (ADD10%), 15% (ADD15%) or 20% (ADD20%) concentrations, respectively. (A) hardness; (B) cohesiveness; (C) adhesiveness; (D) springiness; and (E) chewiness. Values are means (n=4). *Significantly different from the value without starch (ADD00%) (p<0.01).
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