Note

A Farinograph Study on Dough Characteristics of Mixtures of Wheat Flour and Potato Starches from Different Cultivars

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Received December 6, 2006; Accepted December 26, 2007

The dough characteristics of mixtures of wheat flour and potato starches from three different cultivars (Eniwa, Benimaru and Norin No. 1) were investigated using a Brabender farinograph. The water absorption of control wheat dough was higher than that for all mixture doughs and decreased significantly with increases in potato starch. The peak time of wheat flour-potato starch mixtures ranged from 21.0 to 22.5 min, with no large difference with increase of potato starch. Dough stability significantly increased with increase of potato starch. The increase of potato starch in the mixtures decreased the tolerances of mixing, indicating that they were weaker than the control flour. Breakdown time of mixtures tended to be the same as for control wheat flour up to 5 % potato starch, above which it increased significantly. Results are applicable to the substitution of potato starch in certain wheat-based foods such as noodles, breads, biscuits, and crackers.

Keywords: Dough, Farinograph, Wheat flour, Potato starch, Mixtures

Introduction

Potato starch and wheat flour blends are frequently used in the food industry. In Japan, potato starch is commonly used to improve the textural properties of wheat-based noodles, such as alkaline instant noodles, at a level of 5 to 15% (Noda *et al.*, 2006). Protein content of wheat flour ranges between 6 to 14%, and lipids constitute 1% of the whole grain weight, with surface lipid content of up to 0.05% (Eliasson *et al.*, 1981; Morrison, 1988; Zaidul *et al.*, 2002). Protein content has effects on rheological profiles, e.g., viscosity, viscoelasticity and breakdown (Zaidul *et al.*, 2002, 2003a, 2003b, 2004). Lipids are present at lower levels and affect the swelling of wheat flour (Morrison *et al.*, 1993; Zaidul *et al.*, 2002, 2003a, 2003b, 2004). It has also been reported that surface lipids oxidize and contribute to the so-called cereal odour of wheat starch.

Farinograph is an empirical instrument, commonly used to evaluate the mechanical behaviour of wheat flour doughs

(Walker and Hazelton, 1996). Although these tests are destructive, imposing high deformations, they are useful because they reproduce process conditions rather well. Results are not given in terms of fundamental rheological properties. Thus, for studying dough rheology, researchers have also used basic rheometrical instruments, with well-defined geometries providing results in absolute physical units rather than in arbitrary units. Schofield and Scott-Blair (1932) were the first researchers interested in testing the fundamental viscoelastic properties of dough systems. Due to the unique characteristics of wheat protein for forming dough with viscoelastic properties, the majority of studies on dough rheology concentrate on wheat flour dough (Bloksma, 1990; Szczesniak *et al.*, 1983). Other studies focus on the rheology of wheat gluten, a constituent of wheat flour that is considered the main factor in the elasticity of wheat flour dough (Dreese *et al.*, 1998). The effect of dough components is also significant for understanding dough rheological behaviour. Starch (Szczesniak *et al.*, 1983), lipids (Eliasson, 1981), gluten (Dubois, 1983) and water content (Slade *et al.*, 1998) have all been considered extensively, and the effect of addition of

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sago starch to wheat flour dough has been a subject of interest (Zaidul *et al.*, 2004). However, no literature is available based on analysis of different potato starches in wheat flour using farinograph. Therefore, the aim was to study the feasibility of substituting potato starch in wheat-based foods.

Materials and Methods

Materials Commercial hard-wheat flour milled from a Japanese cultivar, Kitanokaori, was purchased from Ebetsu Flour Milling Co. Ltd., Ebetsu, Hokkaido, Japan. Three potato starch samples of different granule sizes, phosphorus and amylose contents were purchased from Jinno Starch Co., Sarabetsu, Hokkaido, Japan. These samples were derived from three potato cultivars, Eniwa, Benimaru and Norin No. 1, grown in 2005.

Analytical methods The moisture content, median granule size, protein, and fat content of wheat flour and potato starches of Eniwa, Benimaru and Norin No. 1 were determined as described by Zaidul *et al.* (2007).

Preparation of blended samples Potato starches from the Eniwa, Benimaru and Norin No. 1 cultivars were blended individually with wheat flour at ratios of 0/100 (potato starch/wheat flour), 5/95, 10/90, 20/80, 30/70, and 100/0. Mixing was on a weight (w/w) basis, as described by Zaidul *et al.* (2007).

Determination of dough properties The rheological characteristics of doughs prepared from control wheat flour and mixtures of wheat flour and potato starches were determined by Brabender farinograph model 820603 (Brabender OHG, Duisberg, Germany) according to AACC method Nos. 54-21 (2000). The thermostat of the farinograph was adjusted to maintain the temperature at 30 °C. Sample weight on 14% moisture basis (mb) was calculated using the eq. (1)

$$\text{Flour weight on 14\% mb} = \frac{100 - 14}{100 - M} \times \text{flour weight} \quad (1)$$

where M = flour moisture content in %.

Sample (50 g on 14% mb) was placed in the mixing bowl. The burette was filled with water. The pen was adjusted to the 9-min position and the instrument was allowed to run. When the pen reached the zero position, water from the burette was added. For the dough formation, the sides of the mixing bowl were scraped and the addition of water was continued until the curve levelled off at the 500-BU (Brabender units) line. If the first titration did not produce a curve peak centred on 500 BU, the titration was repeated to get the correct water absorption (1.8 to 2.4 ml) for 20 BU. The curve at maximum dough development should centre on the 500 BU line. Parameters for each farinogram were determined according to Locken (1972). Flour strength was

evaluated in terms of farinograph water absorption, dough expansion time or peak time, initial time, final time, stability tolerance index and 20-min drop. Water absorption was calculated using the eq. (2)

$$\text{Water absorption (\%)} = 2 (x + y - 50) \quad (2)$$

where x = ml of water require to produce the curve with maximum consistency centred on the 500-BU line and y = g of flour used equivalent to 50 g on 14% mb.

Statistical analysis The averages of the triplicate measurements and Duncan-t-test were computed to measure the variations in wheat flour and potato starches of different cultivars, as well as in the mixtures of wheat flour and potato starch. The least significant difference at the 5% probability level ($P < 0.05$) was calculated for each parameter.

Results and Discussion

The median granule size and the moisture, protein and fat contents of the samples were analyzed in our previous report (Zaidul *et al.*, 2007). According to this report, the median granule size of wheat flour was found to be larger than that of all potato starches used in the experiments. It was also reported that the moisture contents of wheat flour and Eniwa, Benimaru, and Norin No. 1 potato starches were 15.0, 15.5, 16.4, and 15.7%, respectively. Further, the protein and fat content of wheat flour was 13.2 and 1.4%, respectively, whereas negligible amounts of protein and fat were found in the potato starches.

The water absorption of dough formation for determining farinograph parameters of control wheat flour and wheat-Eniwa, wheat-Benimaru and wheat-Norin No. 1 mixtures for different percentages of potato starch are shown in Table 1. Wheat flour from Kitanokaori cultivar had relatively high water absorption (71.6%), which is in agreement with the report of Nishio *et al.* (2004). Control wheat flour dough required more water than the mixture dough; thus, the required amount of water for dough formation decreased significantly ($P \leq 0.05$) with increasing potato starch in the mixtures. This values was significant ($P \leq 0.05$) for all potato starch and wheat flour mixtures. Water absorption is related to the protein content of the flour and high protein content flour absorbed higher amount of water (Locken, 1972). Hallen *et al.* (2004) found the similar trend in studying dough characteristics of mixtures of fermented/germinated cowpea flour and wheat flour. They noted that flour water absorption increases with higher flour protein content. A similar trend was also observed for the dough characteristics of mixtures of wheat flour with different protein contents and sago starch (Zaidul *et al.*, 2004).

Faubion and Hosene (1989) reported that the water-

Table 1. Water absorption of control wheat and wheat-Eniwa, wheat-Benimaru and wheat-Norin No. 1 mixtures with different potato starch contents.

% Potato starch	Water Absorption (%)		
	Wheat-Eniwa	Wheat- Benimaru	Wheat-Norin No. 1
5	69.6 ± 0.2 ^a	69.2 ± 0.2 ^a	69.4 ± 0.2 ^a
10	67.8 ± 0.2 ^b	67.4 ± 0.1 ^b	66.8 ± 0.2 ^b
20	64.4 ± 0.1 ^c	63.4 ± 0.2 ^c	63.4 ± 0.2 ^c
30	60.8 ± 0.2 ^d	59.8 ± 0.2 ^d	60.2 ± 0.2 ^d

Control wheat: 71.6%

Values followed by the different letters (a, b, c and d) in the same column are significant at P < 0.05 level.

Fig. 1. Typical farinogram for control wheat flour dough (A) and dough containing a mixture of wheat-Benimaru of 20% potato starch (B).

binding capacity of starch granules has been postulated to have a strong effect on dough rheology. It is evident that the adsorption depends not only on the types of protein but also on the percent of starch. However, higher absorption indicates that more water is required to reach a desired consistency in a commercial process, but does not indicate the exact amount (Faubion and Hosney, 1989). In addition to water absorption, the shape of the farinogram is characterised by the flour. Various indices have been defined; usually, they refer to dough with a maximum consistency of 500 BU. Perhaps the most important is dough development time or

peak time, which increases with an increase in the water content of the dough (Locken, 1972). However, it is related to the optimum mixing time in the same way that absorption is related to optimum water content.

Typical farinogram curves are shown in Figure 1 for the control wheat flour dough (A), and for the mixture of wheat-Benimaru dough (B) with 20% potato starch. Figure 2 shows the arrival time for control wheat and mixtures of wheat-Eniwa, wheat-Benimaru, and wheat-Norin No. 1. Compared to control wheat flour, the arrival times for wheat-Benimaru and wheat-Norin No. 1 mixtures significantly decreased in

Fig. 2. Arrival time for control wheat flour dough and dough containing mixtures of ■ wheat-Eniwa, ● wheat-Benimaru and ▲ wheat-Norin No. 1 with different potato starch contents. Values are the means of the triplicate measurements. Bars indicate standard deviations.

the added range from 10% to 30%, whereas wheat-Eniwa mixture showed much lower arrival times than others with 20% and 30% addition. The arrival time is a measure of the rate at which water mixes with flour. Generally, for a given variety of wheat, as protein content increases, arrival time also increases. Normally, flour with good bread-making characteristics has higher absorption, takes longer to mix and is more tolerant of over-mixing than poor-quality bread flour (William, 2001). The results for arrival time could be attributed to the dilution of protein by potato starches. Therefore, we could conclude that arrival time decreases with increasing potato starches in the mixtures. Miyazaki and Morita (2005) reported that substitution of heat-moisture treated maize starch or normal maize starch decreased water absorption compared to the control. They observed that the values of the arrival and development times decreased by the substitution.

Two peaks were usually found, the first of which appeared within short time when dough development was incomplete. Thus, the first peak was considered a false peak. The second peak was considered the dough development time. In such situations, Locken (1972) also suggests considering the second peak as the dough development time, during which time dough consistency increases up to the maximum and then decreases. At the beginning of mixing, there is a large quantity of free water. Flour particles are independent of each other, and there is no resistance to mixing; thus, the dough is considered to be under mixing condition. Next, the flour is progressively hydrated and the amount of free water

Fig. 3. Stability time for control wheat flour dough and dough containing mixtures of ■ wheat-Eniwa, ● wheat-Benimaru and ▲ wheat-Norin No. 1 with different potato starch contents. Values are the means of the triplicate measurements. Bars indicate standard deviations.

was decreased so that the cohesion of the system increased. The consistency reaches a maximum when all flour particles are hydrated. The dough development time or optimum mixing time is associated with the maximum Brabender consistency (Létang *et al.*, 1999). In our experiments, most of the peak times existed within 21.0 to 22.5 min, which was characteristic of extremely hard flour. Although a certain trend in peak time was not found with increase of potato starch, further studies are needed to account for this result. Longer times of mixing lead to a weakening of the system of breakdown of the dough (discussed later).

Dough stability increased significantly ($P \leq 0.05$) with increase of potato starch in the mixture (Figure 3) for all types of potato starch. The values tended to increase rapidly from 20% for all types of potato starch, and the highest value was observed in wheat-Eniwa mixture; a similar observation was reported by Miyazaki and Morita (2005). Regarding stability time and time to breakdown, dough containing heat-moisture treated maize starch showed higher values than the control maize. This suggests that the dough containing potato starch caused the decrease of elasticity. Lorenz and Kulp (1981) reported that potato starch did not interact readily with gluten to form dough when it was used for bread making. Our results in Figure 3 also suggested that potato starch would not interact readily with gluten to form elastic dough. Stability, in general, gives some indication of the tolerance of mixing the flour (Faubion and Hosenev, 1989). This means that with increase of potato starch in the mixture decreased the tolerance, from the trends in Figure 4. Decrease of tolerance

Fig. 4. Tolerance for control wheat flour dough and dough containing mixtures of ■ wheat-Eniwa, ● wheat-Benimaru and ▲ wheat-Norin No. 1 with different potato starch contents. Values are the means of the triplicate measurements. Bars indicate standard deviations.

results in weakness of the flour, as the protein content decreased with increasing potato starch in the mixture. Higher stability was observed in wheat-Eniwa, wheat-Benimaru and wheat-Norin No.1 mixtures; thus, the lower tolerance was found. The values of the stability time and tolerance were found to be significant ($P \leq 0.05$) for all mixtures except for 5% potato starch in wheat-Eniwa mixture. However, the dependency of the stability time on the added amount of starches from the different potato cultivars incompletely corresponded to that of their tolerance.

Breakdown time tended to remain same as control wheat up to 5% and then started to increase significantly ($P \leq 0.05$) at 20% followed by 30% (Figure 5). The breakdown time follows the same trend in all types of potato-wheat mixtures. The highest values were found in the mixtures with the highest percentage (30%) of potato starch. This value generally gives the rate of breakdown and strength of a flour; the higher the value, the weaker the flour (Locken, 1972). The dough characteristics evaluated in this study using a farinograph are in agreement with those for sago starch and wheat flour mixtures (Zaidul *et al.*, 2004). Pedersen *et al.* (2004) studied rheological properties of biscuit dough from different cultivars and found that low protein (8.7 to 9.7%) flours behaved as weak flours, with short mixing times, poor stability, and a high degree of breakdown. However, the use of suitable flour to produce baked products is generally influenced by the quantity and quality of gluten and also the minor components in wheat flour (Pyler, 1979). Obviously, addition of any non-wheat constituent will change the flour characteris-

Fig. 5. Breakdown time for control wheat flour dough and dough containing mixtures of ■ wheat-Eniwa, ● wheat-Benimaru and ▲ wheat-Norin No. 1 with different potato starch contents. Values are the means of the triplicate measurements. Bars indicate standard deviations.

tics significantly (Vratanina and Zabik, 1978). The change in a characteristic can be seen in farinograph results for flour mixture at different percentage of non-wheat constituent.

Conclusions

Dough characteristics of control wheat flour and mixtures of wheat flour and potato starches of Eniwa, Benimaru and Norin No. 1 cultivars were investigated using a farinograph to observe the feasibility of diversifying potato starches in wheat based foods. The arrival time measures the water absorption of flour; thus, arrival times tended to decrease slightly with decrease of protein content in the mixtures. Dough stability significantly increased with increase of potato starch in the mixture. The increase of potato starch in the mixtures decreased the tolerance of the dough, indicating the weakness of the flour as the protein of wheat flour was diluted. Breakdown time tended to be increased at 20 to 30% potato starch in the mixtures. However, the findings of this study could be helpful for the substitution of potato starches in wheat-based foods, e.g., noodles, breads, biscuits, and crackers. Further studies are recommended to determine the rheological/textural properties of gels containing potato starch and wheat flour mixtures using rheoner/rheometer.

Acknowledgements This work was supported in part by Japan Society for the Promotion of Science (JSPS) and by a Grant-in-Aid for the Research and Development Project for New Bio-industry Initiative from the Bio-oriented Technology Research Institution (BRAIN), Japan. The authors would like to thanks to Ms. Keiko

Shimizu (National Agricultural Research Center for Hokkaido Region, Japan) for her technical support.

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