Effects of Preharvest Sprouting on Flour Pasting Viscosity in Common Buckwheat (*Fagopyrum esculentum* Moench)

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Abstract: Rain before harvest often causes buckwheat to sprout. Preharvest sprouting reduces the processing suitability of buckwheat flour. We examined the effects of preharvest sprouting on buckwheat flour quality by rapid visco-analysis (RVA) of milled sprouting grains of six buckwheat cultivars. Both artificial and natural rainfall increased the frequency of sprouting and decreased pasting viscosity. The difference in pasting viscosity between sprouting and non-sprouting buckwheat grains was not decreased by adding wheat flour. These results suggest that the mechanical characteristics of dough and boiled noodle may be affected by flour made from sprouting grains. Differing responses of the cultivars to rainfall indicate that higher pasting viscosity could be achieved by using cultivars that are resistant to preharvest sprouting caused by rain.

Key words: Flour quality, Noodle, Pasting property, Preharvest sprouting resistance, Rain, Wheat flour.

Common buckwheat (*Fagopyrum esculentum*) is widely cultivated around the world, although it is a minor crop (Campbell, 1997). Buckwheat flour has high nutrient value and is processed into various foods, such as noodles and pancakes (Vinning, 2001; Ikeda, 2002), and noodles are most popular in Japan. Buckwheat noodles are often made from a mixture of buckwheat flour and wheat flour, egg or yam to reduce their fragility; wheat flour is the most effective adjuvant (Tsutsumi et al., 1990; Ikeda, 2002).

Rain after grain maturity before harvesting induces germination of grains on plants (Fig. 1), as reported in Australia, Korea and Japan (Choi et al., 1992; Bluett, 2001; Morishita and Tetsuka, 2001). Sprouting buckwheat grains have little market value (Bluett, 2001), because some buckwheat millers and manufacturers speculate that flour made from sprouting grains leads to fragile noodles. Preharvest sprouting occurs in other cereals such as wheat, and seriously degrades grain quality (Kruger, 1990; Noda et al., 2001; Ichinose et al., 2002; Chakraborty et al., 2003).

Knowledge about the effect of preharvest sprouting on buckwheat flour quality would allow producers to maximize the quality of their buckwheat products. However, to our knowledge, there have been no reports on the effect of preharvest sprouting on buckwheat flour quality or the effect of wheat flour blending on the quality of buckwheat flour derived from sprouted grain.

We examined (1) the effect of rainfall after maturity on the occurrence of preharvest sprouting, (2) the effect of the use of flour made from sprouting grains on pasting viscosity, (3) the effect of adding wheat flour to buckwheat flour made from sprouted grains on pasting viscosity, and (4) sprouting resistance of different cultivars.

Materials and Methods

1. Plant materials

We used six common buckwheat (*Fagopyrum esculentum* Moench) cultivars, ‘Kitawasesoba’, ‘Shinanonatusoba’, ‘Hashikamiwase’, ‘Botansoba’, Kyukei9’ and ‘Kyushu5’. Shinanonatusoba and Kitawasesoba are summer eco-type cultivars and Hashikamiwase is an intermediate summer eco-type. ‘Kyukei9’ and ‘Kyushu5’ are lines bred by mass-selection of low sprouting individuals under artificial wetting treatment, from Botansoba and Hashikamiwase, respectively. In the experiment in 2002, only the three cultivars of Kitawasesoba, Shinanonatusoba and Hashikamiwase were used. All six cultivars can be grown under long-day conditions.

Seeds of Kitawasesoba and Botansoba were supplied by the National Agricultural Research Center for the Hokkaido Region. Seeds of Hashikamiwase and Shinanonatusoba were supplied by Aomori Prefectural Agriculture and Forestry Research Center and Nagano Chushin Agricultural Experiment Station, respectively. Plants were grown at the National Agricultural Research Centre for the Kyushu Okinawa Region, Koshi, Kumamoto, Japan.
2. Rainfall treatment

Two rainfall treatments were used: artificial and natural. Both experiments were conducted in 2002 and 2003.

In the artificial rainfall treatment, seeds were sown at a rate of 100 m$^{-2}$ on 28 August in 2002 and on 8 April in 2003. Fertilizer consisting of 2 g m$^{-2}$ N, 4 g m$^{-2}$ P$_2$O$_5$, and 3 g m$^{-2}$ K$_2$O was applied prior to seeding. Each plot was comprised of a row 1.7 m long, with a row spacing of 60 cm. Experimental plots were arranged in a split-plot design with duplications, in which artificial rain treatments were assigned to the main plots and cultivars were assigned to the subplots. Plants were harvested on 12 November in 2002 and 19 June in 2003. Natural rain was blocked by a transparent plastic film roof from 9 September in 2002 and from 22 May 2003. The maturity date, defined as the day when about 80% of the grains matured, was 21 October in 2002. The maturity date, in 2003 was 9 or 10 June depending on cultivars. Artificial rain was applied for 1 min at 10 min intervals for 5 days from 4 November or for 11 days from 29 October until 9 November in 2002. In 2003, artificial rain was applied for 2 days from 13 June or for 5 days from 10 June until 15 June. A plastic irrigation tube (Kiriko KH, MKV Platech Co., Ltd. Japan) was set horizontally at 1.5 m high from the surface of the earth and was connected to automatic valve (DC-1S, Sunhope Aqua Co., Ltd. Japan). The amount of artificial rainfall was adjusted to 86 mm day$^{-1}$.

In the natural rain treatment, seeds were sown on 10 April in 2002 and 13 April in 2003. Fertilizer (2 g m$^{-2}$ N, 4 g m$^{-2}$ P$_2$O$_5$, and 3 g m$^{-2}$ K$_2$O) was applied prior to seeding. Experimental plots were arranged in a randomised block design with duplicates. Each plot was comprised of five rows 4 m long, with a row spacing of 60 cm. The exterior rows of each plot were assigned to Kitawasesoba as a border, while the interior three rows were assigned to one of the three cultivars. The maturity dates were 5 to 6 June in 2002. On those dates, the centre row of the three in each plot was harvested. On 27 June, the remaining rows were harvested. In 2003, maturity dates were 8 to 14 June, and the centre rows were harvested on 20 June.

3. Determination of sprouting proportion and preparation of buckwheat flour

Sprouting proportion was determined by counting germinating grains in samples of 200 threshed seeds from each plot. Buckwheat flour was obtained by milling grain with a Quadrumat Junior laboratory mill (Brabender OHG, Disberg, Germany), equipped with a 231-µm-mesh sieve. Arcsine transformation was applied to the visible sprouting proportion prior to the analysis.

Table 1. Effect of artificial rainfall on flour peak viscosity and sprouting of three buckwheat cultivars in 2002.

| Cultivars       | Peak viscosity (RVU) | Sprouting (%) |
|-----------------|----------------------|---------------|
|                 | 0  | 5  | 11 | Average | 0  | 5  | 11 |
| Shinanonatsusoba| 399| 232| 91 | 162a    | 0.0| 4.3| 15.3|
| Hashikamiwase   | 388| 345| 233| 289b   | 0.0| 2.8| 6.8 |
| Kitawasesoba    | 428| 269| 236| 252ab  | 0.0| 1.8| 6.8 |

| Treatment (A)   | ns | ns |
|-----------------|----|----|
| Cultivar (B)    | *  | ns |
| A × B           | ns | ns |

Buckwheat stands were treated with continuous artificial rainfall for 0, 5 and 11 days. *: Significant at 5% level. The figures with the same alphabet are not significantly different at 5% level by the Fisher's LSD test.
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4. Measurement of pasting viscosity

The rapid-visco analyser is used to determine pasting properties, for evaluation of sprout damage in wheat (Kruger, 1990; Noda et al., 2001) and predicting processing quality in crops (Yun et al., 1997; Noda et al., 2001; Mukasa et al., 2003). We measured the pasting viscosity of the paste made from 3.5 g of buckwheat flour and 23 ml of distilled water with a Rapid-Visco analyser RVA-3D (Newport Scientific Pty Ltd, Warriewood, NSW, Australia). The temperature was held initially at 50°C for 1 min, and then ramped up linearly to 95°C for 3 min 42 s, held for 2 min 30 s, and cooled to 50°C for 3 min 48 s; and held at 50°C for 2 min (Qian and Kuhn, 1999).

5. Effect of wheat flour blending on buckwheat pasting viscosity

The flour from Kitawasesoba and Shinanonatsusoba grains harvested before and after natural rainfall in 2002, were mixed with commercial wheat flour at three mixing ratios by weight (Table 5). We also used buckwheat flour alone and wheat flour alone as samples. We measured the viscosity of 3.2 g of the composite flour mixed with 23 ml of distilled water.

Results

1. Effect of rainfall on sprouting and pasting viscosity

The artificial rainfall treatment successfully induced preharvest sprouting and allowed us to detect genotypic differences (Table 1, 2). Preharvest sprouting decreased the pasting viscosity of buckwheat flour (Table 1, 2). The correlation coefficient between sprouting proportion and peak viscosity was \( r = -0.92^{***}, \) significant at 0.1 % level (Table 1) and \( r = -0.88^* \), significant at 5 % level (Table 2). This suggests that preharvest sprouting is a primary cause of variance in pasting viscosity. The peak viscosity significantly varied with the cultivar (Table 1, 2), suggesting that cultivars respond differently to rain. The peak viscosity was the lowest and germination proportion was the highest in Shinanonatsusoba among the cultivars in 2-day rainfall treatment in 2003 and in both rainfall

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Table 2. Effect of artificial rainfall on flour peak viscosity and sprouting of six buckwheat cultivars in 2003.

| Cultivars     | Peak viscosity (RVU) | Sprouting (%) |
|---------------|----------------------|---------------|
|               | 2                    | 5             | 2              | 5               |
| Shinanonatsusoba | 163a 89a           | 22.4a 16.2a   |
| Hashikamiwase  | 285b 119a           | 7.7b 18.9a    |
| Kitawasesoba   | 286b 84a            | 6.2bc 17.1a   |
| Botansoba      | 384c 121a           | 3.3cd 14.2a   |
| Kyuken9        | 416d 228b           | 2.4d 4.8b     |
| Kyushu5        | 401d 309c           | 2.9cd 4.9b    |

Buckwheat stands were treated with continuous artificial rainfall for 2 and 5 days. The figures with the same alphabet within a column are not significantly different at 5% level by the Fisher’s LSD test.

Table 3. Effect of natural rainfall after maturity on flour peak viscosity and sprouting of three buckwheat cultivars in 2002.

| Cultivars     | Peak viscosity (RVU) | Sprouting (%) |
|---------------|----------------------|---------------|
|               | Harvesting H1 H2 Average | H1 H2     |
| Shinanonatsusoba | 361 177 269a         | 0.0 36.0     |
| Hashikamiwase  | 421 221 321b         | 0.0 27.0     |
| Kitawasesoba   | 423 229 326b         | 0.0 30.6     |

Buckwheat stands were harvested on the day of maturity (H1), and three weeks after maturity (H2). The mixture of 3.5 g of buckwheat flour and 23 ml of distilled water was used for the measurement. **, ***: Significant at 1% and 0.1% levels, respectively. The figures with the same alphabet are not significantly different at 5% level by the Fisher’s LSD test.
Table 4. Effect of natural rainfall after maturity on flour peak viscosity and sprouting of six buckwheat cultivars in 2003.

| Cultivars       | Peak viscosity (RVU) | Sprouting (%) |
|-----------------|----------------------|---------------|
| Shinanonatsusoba| 109a                 | 18.4a         |
| Hashikamiwase   | 134a                 | 21.3a         |
| Kitawasesoba    | 117a                 | 18.0a         |
| Botansoba       | 183b                 | 16.0ab        |
| Kyukei9         | 262c                 | 4.2b          |
| Kyushu5         | 274c                 | 3.3b          |

Buckwheat stands were harvested after natural rainfall. The figures with the same alphabet within a column are not significantly different at 5% level by the Fisher's LSD test.

Discussion

The effect of preharvest sprouting on palatability and processing quality in buckwheat has not been reported previously. The processing quality of preharvest grain has been studied in detail in wheat. Wheat sprouting increases α-amylase activity (Noda et al., 2001; Ichinose et al., 2002) and causes stickiness of dough and poor handling (Hirano, 1971; Lorenz et al., 1983), greater cooking loss and decrease in stickiness of boiled pasta (Grant et al., 1993), and greater cooking loss and inferior palatability in udon noodles (Nagao, 1984). In buckwheat cultivars, RVA peak viscosity is negatively correlated with hardness of boiled dough (Mukasa et al., 2003). In our experiment, RVA peak viscosity was lowered by preharvest sprouting (Table 1–4). These results suggest that the lower RVA viscosity caused by preharvest sprouting affects the mechanical characteristics of
Buckwheat noodles are often made from buckwheat–wheat composite flour (Ikeda, 2002) and the mechanical characteristics of boiled buckwheat noodles are changed by wheat flour blending (Tsutsumi et al., 1990; Asami et al., 2004). In our experiment, the difference in peak viscosity between sprouted and non-sprouted buckwheat flour was not eliminated by adding wheat flour (Table 5). Starch degrading enzymes such as α-amylase in sprouted buckwheat flour may have digested wheat starch as well as buckwheat starch. Pasting viscosity is associated with the mechanical characteristics of noodles in both buckwheat (Mukasa et al., 2003) and wheat (Noda et al., 2001). These findings suggest that the difference in pasting viscosity of the buckwheat–wheat composite flour caused by preharvest sprouting may affect noodle palatability. Concerning the palatability and acceptability of buckwheat products, further studies are necessary to relate the sensory evaluation by an experienced noodle manufacturer with the pasting viscosity of buckwheat flour, which would establish a standard for practical acceptability of sprouting buckwheat grain.

In our experiment, the pasting viscosity in Shinanonatusoba was lower even without sprouting (Table 3). Intermittent rainfall (Fig. 2) might have increased α-amylase before visible sprouting. There are some reports that sprouting proportion is negatively correlated with pasting viscosity in wheat (Barnard, 2001; Humphreys and Noll, 2002), and the degradation of pasting viscosity was suggested to be caused by α-amylase, which was activated by water or humidity in the grain. Some wheat cultivars produce α-amylase in the absence of visible sprouting (Ichinose et al., 2002).

The cultivar difference in pasting properties of purified starch is small in buckwheat (Yoshimoto et al., 2004). We found a cultivar difference in peak viscosity induced by preharvest sprouting (Table 1 –4). Genotypic differences in preharvest sprouting have not been reported yet, although several hundred germplasms in Japan and several thousands around the world have been collected (Campbell, 1997). Identifying the cultivars and germplasms that are resistant to preharvest sprouting would allow us to grow them in environments with preharvest sprouting risk, and to use them in breeding programs. A close correlation was observed between the results obtained by artificial (Table 2) and natural rainfall (Table 4). The artificial rainfall treatment leads to progress in selection, even in growth environments lacking in natural rainfall.

Although preharvest sprouting causes degradation of grain quality, artificially sprouted buckwheat seeds have a higher nutritional value with a higher GABA content (Shindoh et al., 2001; Miyake et al., 2004). The effect of sprouting on the mechanical characteristics of the dough and boiled noodles must also be considered carefully when sprouting buckwheat grain is used for food processing.

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