

Hydration and Pasting Properties of Oat (*Avena sativa*) Flour

– Research Note –

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Abstract

Three oat cultivars and one oat breeding line were evaluated for chemical, hydration and pasting properties. Protein, starch and β -glucan levels ranged 11.13~14.37, 56.37~64.86 and 3.44~4.76%, respectively. The oat cultivars *Daeyang* and *Seonyang* contained higher β -glucan levels of 4.76 and 4.35%. The *Daeyang* variety had a higher water absorption index (WAI) of 2.83~3.35 (g/g), but a lower water solubility index (WSI) of 8.67~11.08%. *Daeyang* and *Seonyang* cultivars showed higher peak and trough viscosity, but lower breakdown and setback, indicating that they easily swell, and thus could possibly provide the desirable viscosity of an oat product. The β -glucan levels were correlated positively with WAI, peak and trough viscosity, and negatively to WSI, breakdown and setback viscosity.

Key words: oat flour, cultivars, chemical, hydration, pasting profiles

INTRODUCTION

Oats (*Avena sativa*) are one of the most valuable cereal grains since they contain naturally many health-promoting components, and, because of this, have achieved positive consumer attention. Oats are commercially available in several forms: rolled, flaked or as a flour. Most commonly, oatmeal is eaten as porridge, but it is also used in a variety of baked goods, such as oatcake, breakfast cereal, and cookies. The health effects of oats have been attributed to their β -glucan content, because β -glucan can help to decrease a number of chronic diseases, such as coronary heart disease (1), type II diabetes (2,3), and certain cancers (4-6). Components of oat, primarily β -glucan, starch and protein, have been known to impact the pasting properties of oat slurries (7-10). β -glucan is an unbranched homopolysaccharide composed of (1 \rightarrow 4)-linked (~70%) and (1 \rightarrow 3)-linked (~30%) D-glucopyranosyl units. The β -glucans with a high water-binding capacity exhibit high viscosity even at relatively low concentrations. Starch also interacts with other components, such as sugars, lipids, proteins, emulsifiers, gums and salts, which also influences the pasting properties (10).

Pasting profiles are widely used to assess the quality of oat products and consumer acceptance (11). Zhou et al. (8) described the pasting parameters for oatmeal characterization, calling the thickness of porridge during cooking *peak viscosity*, the time porridge takes to reach

peak viscosity *pasting time*, the temperature at which porridge begins to thicken *pasting temperature*, and the consistency of cooked porridge at eating temperature *setback*. Glennie-Holmes (12) studied the consumer acceptance of rolled oats according to pasting properties, and reported that rolled oats with relatively low pasting peak viscosity and a delay in time to peak viscosity are unacceptable to consumers. Increasing consumer's concern on the health benefits of oats has led to greater characterization of oats and their processing properties, and also an increase the number of oat-based products in the markets. There have been some studies on oat breeding, grain qualities and functionalities, but less investigation on the grain qualities of domestically developed oat cultivars. Therefore, this study was conducted to observe the characteristics of chemical, hydration and pasting profiles of domestic oat cultivars for their enhanced utilization.

MATERIALS AND METHODS

Materials

Three naked oat cultivars of *Choyang*, *Daeyang* and *Seonyang* and one breeding line of Oat61 have been developed in the National Institute of Crop Science, RDA. Oat grains, which were harvested in the 2008 growing season, were ground in a hammer mill (Laboratory Mill 3100, Pertent Co. Ltd., Huddinge, Sweden) equipped with a 0.5 mm screen, and the oat flour was stored at

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-20°C for the analysis.

Chemical composition analysis

Ash contents were determined according to the AACC official method (AACC 08-01). Crude protein contents were measured by analyzing total nitrogen contents using an elemental analysis (Perkinelmer 2410, Elemental Analyzer System, Vario MACRO, Jena, Germany). Crude lipid content was analyzed by the Soxhlet extraction method with absolute ethyl ether as a solvent using a Soxtec 2050 (Foss Tecator, MN, USA). Total starch and β -glucan contents were determined according to the official procedure of the AACC (AACC 76.13 and 32-23, respectively) using an enzymatic assay kit (Megazyme International Ireland Ltd., Wicklow, Ireland).

Hydration properties analysis

Water absorption index (WAI) and water solubility index (WSI) were measured as hydration properties by the method of Anderson (13) with slight modification. Oat flour (3.0 g) was dispersed in 30 ml distilled water and heated in a water bath at 60°C for 1 hr. After centrifuging the dispersion at $3000 \times g$ for 15 min, the supernatant was collected in pre-weighed dry aluminum dishes, and the residues were drained off by allowing the sample tube to stand inverted for 10 min. The collected supernatant was dried in a hot air oven at 105°C overnight for WSI measurement. Values were expressed as the g water absorbed from oat flour and as the % water solubility index.

$$\text{WAI (g/g)} = \frac{\text{wt. of water uptake in hydrated residue}}{\text{wt. of oat flour}}$$

$$\text{WSI (\%)} = \frac{\text{wt. of dissolved solids in supernatant}}{\text{wt. of oat flour}} \times 100$$

Pasting properties analysis

The viscosity of oat flour slurries was measured as the function of temperature and time by a Rapid Visco™ Analyser (RVA-4, Newport Scientific Pty, Ltd., Warriewood, Australia) in accordance with the AACC official method (AACC 61-02). Oat flour (3.0 g) was placed

in a clean RVA test canister, and 25 mL distilled water was carefully dispensed into the canister, to which a paddle was placed. The RVA test profile included (1) a stirring speed of 960 rpm for the initial 10 sec and 160 rpm for the remainder of 12.5 min test, and (2) a temperature program equilibrating at 50°C for 1.0 min, ramping up to 95°C in 4.8 min, holding at 95°C until 7.5 min, ramping down to 50°C at 11 min, and holding at 50°C until 12.5 min. The RVA pasting parameters were peak viscosity (maximum viscosity developed during after sample heating), trough (minimum viscosity after peak viscosity), breakdown (peak viscosity minus trough viscosity), final viscosity (viscosity at the end of test), setback (final viscosity minus trough viscosity), and peak time (time to reach peak viscosity). The viscosity was read directly from the RVA and reported in arbitrary rapid visco units (RVU). All viscosity measurements were conducted in triplicate.

Statistics

Results were analyzed for analysis of variance (ANOVA) using the Statistical Analysis System (V. 9.1, SAS Institute, Cary, NC, USA). Means were compared at the 5% significance level using Duncan's multiple comparison.

RESULTS AND DISCUSSION

Chemical compositions

The chemical compositions of oat flour were analyzed and the mean values are presented in Table 1. The ANOVA (*F*-value) indicates that there are significant differences in chemical compositions among oat cultivars. Protein contents were between 11.13% and 14.37% with the highest protein content in *Seonyang*. Starch contents were between 56.4% and 64.8% with the highest concentration in Oat61 and the lowest in *Seonyang*. The β -glucan concentrations in *Daeyang* and *Seonyang* were 4.76 % and 4.35%, respectively, which were similar to the level of β -glucan (4.4%) reported by Liu et al. (14). however, the Oat61 cultivar showed a lower β -glucan level (3.44%) compared to the other three oat cultivars.

Table 1. Chemical composition of oat flours

Cultivars	Composition (%)				
	Ash	Protein	Fat	Starch	β -glucan
Choyang	1.65 ± 0.05 ^{bc}	12.17 ± 0.08 ^b	10.01 ± 0.05 ^a	61.52 ± 1.77 ^{ab}	3.97 ± 0.11 ^c
Daeyang	1.70 ± 0.01 ^b	11.13 ± 0.06 ^d	9.27 ± 0.01 ^a	60.40 ± 1.32 ^{ab}	4.76 ± 0.18 ^a
Seonyang	1.89 ± 0.04 ^a	14.37 ± 0.09 ^a	7.89 ± 0.06 ^b	56.37 ± 1.86 ^b	4.35 ± 0.11 ^b
Oat61	1.58 ± 0.02 ^c	11.51 ± 0.04 ^c	8.31 ± 0.04 ^b	64.86 ± 3.07 ^a	3.44 ± 0.20 ^d
ANOVA (<i>F</i> -value)	32.30 ^{***}	793.71 ^{***}	486.77 ^{**}	5.54 [*]	38.37 ^{***}

Values are means ± SD.

^{a-d}Mean values followed by the same letter in the same column are not significantly different at $p < 0.05$.

Significant at ^{***} $p < 0.01$, ^{**} $p < 0.05$, and ^{*} $p < 0.1$, respectively.

Table 2. Water absorption capacity (WAI) and water solubility index (WSI)

Cultivars	Functional properties	
	WAI	WSI
Choyang	2.85 ± 0.03 ^c	11.08 ± 0.24 ^a
Daeyang	3.35 ± 0.06 ^a	8.67 ± 1.05 ^b
Seonyang	3.08 ± 0.09 ^b	10.81 ± 0.74 ^a
Oat61	2.83 ± 0.04 ^c	10.79 ± 0.54 ^a
ANOVA (F-value)	51.55 ^{***}	7.51 ^{**}

Values are means ± SD.

^{a-c}Mean values followed by the same letter in the same column are not significantly different at $p < 0.05$.

Significant at ^{***} $p < 0.01$ and ^{**} $p < 0.05$, respectively.

Hydration properties

Water absorption index (WAI) and water solubility index (WSI) of oat flour were presented in Table 2. The ANOVA (F -value) showed significant differences in WAI and WSI measurement among oat cultivars. The WAI values ranged from the highest in *Daeyang* (3.35 g/g) and the lowest in Oat61 (2.83 g/g). On the other hand, the WSI ranged from 8.67 to 11.08% with the highest in *Choyang* and the lowest in *Daeyang*. The WAI is an indicator of the ability of flour to absorb water and swell for desirable consistency in food system, which improves yield and consistency, and gives body to the food. The WSI is used to indicate starch degradation, and thus it determines the amount of free polysaccharide or polysaccharide released from the granule on the addition of excess water (15). As shown in the results, the *Daeyang* had higher WAI but lower WSI, meaning that *Daeyang* oat flour swells easily, providing greater viscosity. The higher β -glucan content (4.76 g/g) in *Daeyang* could contribute to the higher WAI value. Bhatti (16) reported that the WAI could be attributed to the β -glucan content, because there are positive correlations between β -glucan content and WAI values. Bryant et al. (17) suggested that flour with higher WAI and lower WSI could be used in a product where the main concern is a high viscosity.

Pasting properties

The pasting properties of oat flour were analyzed by

Rapid Visco Analysis (RVA) shown in Table 3. The ANOVA (F -value) indicates significant differences in the RVA parameters among oat cultivars. Oat cultivars *Daeyang* and *Seonyang* showed high peak viscosity (PV) of 194.5 and 194.4 RVU with high trough viscosity (TV) of 184.9 and 161.2 RVU, respectively. The PV is related to the degree of swelling of granules during heating, and the starch with higher swelling capacity causes higher PV values. Breakdown viscosity (BD) varied significantly, ranging from 59.5 to 9.6 RVU. The highest BD value was found in Oat61 and the lowest in *Daeyang*, suggesting that *Daeyang* could form the most stable hot paste than other oat flours. During the setback viscosity (SB) phase, cooling causes the re-association of starch molecules (especially linear chains such as amylose) which results in gel structure formation and an increase in final viscosity due to retrogradation. Thus, a lower setback value is an indicative of low retrogradation (18). The SB viscosity ranged from a high of 226.8 RVU in Oat61 to a low of 133.6 RVU in *Daeyang*. This result suggests that *Daeyang* has lower retrogradation tendency, whereas Oat61 had higher retrogradation properties. No significant difference in final viscosity (FV) was observed, which indicates FV is not feasible for differentiating the properties of oat cultivars in the present study. Peak time (PT), which measures the time to reach PV, was the highest in *Daeyang* (7.0 min), whereas Oat61 exhibited the lowest PT (5.94 min). The results indicate that oat cultivar *Daeyang*, with the highest PV but the lowest BD and SB viscosities, had higher starch stability during heating with a lower retrogradation, although it took more time to reach PV. The Oat61 variety, with the lowest PV but the highest BD and SB viscosities, could reach PV within a shorter time, but it could have a lower starch stability and higher retrogradation characteristic. Symonas and Brennen (19) reported that pasting properties of flours depend on starch characteristics, such as swelling potential, degree of gelatinization and the subsequent re-association of amylose and amylopectin after granules disruption. Robertons (20) reported that vis-

Table 3. Pasting properties of oat flour by Rapid Visco Analysis (RVA)

(unit: RVU)

Cultivars	RVA parameters					
	Peak viscosity	Trough	Breakdown	Setback	Final viscosity	Peak time (min)
Choyang	178.21 ± 3.34 ^b	159.14 ± 1.00 ^b	19.07 ± 2.35 ^c	142.07 ± 9.09 ^b	301.20 ± 10.08 ^a	6.80 ± 0.04 ^b
Daeyang	194.58 ± 5.16 ^a	184.97 ± 2.23 ^a	9.62 ± 2.93 ^d	133.65 ± 4.69 ^b	318.61 ± 6.92 ^a	7.00 ± 0.02 ^a
Seonyang	194.42 ± 1.29 ^a	161.21 ± 4.86 ^b	33.21 ± 3.57 ^b	163.41 ± 14.89 ^b	324.62 ± 10.03 ^a	6.64 ± 0.05 ^c
Oat61	158.60 ± 0.35 ^c	99.07 ± 0.35 ^c	59.53 ± 0.58 ^a	226.80 ± 37.58 ^a	325.87 ± 37.23 ^a	5.94 ± 0.08 ^d
ANOVA (F-value)	58.75 ^{***}	360.43 ^{***}	140.59 ^{***}	8.16 ^{***}	0.63	157.36 ^{***}

Values are means ± SD.

^{a-d}Mean values followed by the same letter in the same column are not significantly different at $p < 0.05$.

Significant at ^{***} $p < 0.01$.

cosity is a measure of the resistance to flow, and is an important attribute to both quality and nutritional properties of foods. High viscosity and β -glucan content in barley is linked with cholesterol lowering (21) and hypoglycemic effects in human subjects (22).

From the data in this study, a correlation was observed between β -glucan and hydration and pasting properties (data not shown). A significant positive correlation was found between β -glucan content and PV, TV and WAI, whereas, a significant negative correlation was found between β -glucan content and BD, SV and WSI. The increased water-binding capacity, which resulted in the formation of more stable hot paste induced by β -glucans, was attributable to the increase in PV and TV in oat flour with high β -glucan content. The increased WAI from the β -glucan would be desirable in food systems to improve yield and consistency, and to give concrete body to the food.

The present study showed a significant variability among domestic oat cultivars, including one breeding line, in terms of chemical, hydration and pasting profiles. Oat cultivars *Daeyang* and *Seonyang* contained higher β -glucan compared to the other oat flours. Oat flour with higher β -glucan content showed higher PV and TV, but lower BD and SB. Also, it was observed that the WAI value was higher in oat cultivars with high β -glucan content. As hydration and pasting properties significantly affected the end-use quality and consumer acceptance, it is assumed that oat cultivars with higher β -glucan levels would be preferred for uses when a high gelatinization index is required. The information from this study is expected to enhance the efficiency of oat breeding programs by streamlining new cultivar development and improving the ability to objectively select for desired quality traits.

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