

# Physicochemical Properties of Common and Tartary Buckwheat Starch

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## ABSTRACT

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Physicochemical properties of starch of three common (*Fagopyrum esculentum*) and three tartary (*F. tataricum*) buckwheat varieties from Shanxi Province, China, were compared. Starch color, especially *b*\*, differed greatly between tartary (7.99–9.57) and common (1.97–2.42) buckwheat, indicating that removal of yellow pigments from tartary buckwheat flour may be problematic during starch isolation. Starch swelling volume in water of reference wheat starch (2.8% solids and 92.5°C) was 20.1 mL; for the three common buckwheat starches it was 27.4–28.0 mL; and for the three tartary buckwheat starches it was 26.5–30.8 mL. Peak gelatinization temperature ( $T_p$ ) in water was 63.7°C for wheat starch, 66.3–68.8°C for common buckwheat and 68.8–70.8°C for tartary buckwheat.  $T_p$  of all samples was similarly delayed (by 4.0–

4.8°C) by 1% NaCl. Enthalpy of gelatinization ( $\Delta H$ ) was higher for all six buckwheat starches than it was for wheat starch. However, one common buckwheat sample had significantly lower  $\Delta H$  than the others. Starch pasting profiles, measured by a Rapid Visco-Analyzer, were characteristic and similar for all six buckwheat starches, and very different from the reference wheat starch. A comparison of pasting characteristics of common and tartary buckwheat starches to wheat starch indicated similar peak viscosity, higher hot paste viscosity, higher cool paste viscosity, smaller effect of NaCl on peak viscosity, and higher resistance to shear thinning. Texture profile analysis of starch gels showed significantly greater hardness for all buckwheat samples when compared to wheat starch.

Buckwheat has a long history of cultivation in China. Buckwheat cultivation in China comprises mainly two species: common buckwheat (*Fagopyrum esculentum* Moench) and tartary buckwheat (*F. tataricum* (L.) Gaertn.). The annual cultivated area for buckwheat in China is about 1.5–2 million hectares (Lin et al 1992). Common buckwheat seeds (actually a fruit or achene) are characteristically three-angled, whereas tartary buckwheat seeds are round in cross-section and somewhat smaller than common buckwheat (Marshall and Pomeranz 1982). Common buckwheat flour is used in some food products, especially composite flour products such as Japanese-style *so-ba* (buckwheat noodles). The use of buckwheat has taste, textural, and nutritional implications. Especially in recent years, nutritional aspects (Kusano et al 1992) and medicinal effects in clinical applications (Lu et al 1992, Song 1992) for tartary buckwheat have been widely investigated. Some products with health or functional food claims have been developed from tartary buckwheat in China, such as noodles (He 1992). Tartary buckwheat has high potential in the health food market.

The physicochemical properties of buckwheat starch will affect the functional properties of foods, especially composite flour products, containing buckwheat. Relatively little published information on buckwheat starch is available. Kim et al (1977) reported that buckwheat starch granules are polygonal but slightly larger than rice; have a 25% amylose content by iodine colorimetry; a gelatinization temperature of 61–65°C; and high cool paste viscosity in a Brabender ViscoAmylograph. Lorenz and Dilsaver (1982) also studied starch properties of one sample of buckwheat, finding a low water binding capacity compared to reports on most other species, but high susceptibility to enzyme degradation. Soral-Smietana et al (1984) tested a Polish and a Brazilian buckwheat sample, finding amylograph peak similar to the Lorenz and Dilsaver (1982) study, but a perhaps questionably high amylose content of ≈50% in both samples. Fornal et al (1987) found very high swelling power of buckwheat starch relative to barley and maize. Very little work has been done on the physicochemical characteristics of

tartary buckwheat starch, and little information is available on regionally common Chinese buckwheat starches. Shanxi Province is a major buckwheat producer; additionally it is a less developed province in China which is trying to develop new value-added uses for its local agricultural raw materials. The objective of this study was to investigate and compare some physicochemical properties of starch of Chinese common and tartary buckwheat varieties grown in Shanxi Province, and hence to assess their suitability for use in development of new food products. Because of the major use of buckwheat in diverse noodle products made of wheat-based composite flours, comparisons of buckwheat starch to a reference wheat starch were made. Further, because of the use of salt (NaCl) in many noodle formulations, we tested its effects on the starch properties.

## MATERIALS AND METHODS

### Buckwheat Grain Samples

Three common buckwheat and three tartary buckwheat grain samples were obtained from the Small Grains Program, Shanxi Academy of Agricultural Sciences, Taiyuan, China. The three common buckwheat varieties were: 1) a locally selected line, named Fuyuan Common Buckwheat (CB-F); 2) a line of U.S. origin but cultivated in China, and named American Common Buckwheat (CB-A); 3) a selection from Chinese material, regarded as a high quality buckwheat in China (CB-83-230). The three tartary buckwheat varieties were of different origins in China: 1) a line coded as TB-87-1; 2) TB-90-2; 3) Tangwan Tartary Buckwheat (TB-T).

### Starch Isolation

Starch isolation was performed using a modified method based on Kim et al (1977) and Wu et al (1995). Buckwheat flour was obtained by milling grain with a Quadrumat Junior laboratory mill (Brabender OHG, Duisberg, Germany). The flour was suspended in distilled water for 24 hr at 5°C, then blended for 5 min in a Waring blender. The slurry was screened through a 200-mesh sieve and washed with a small amount of water. The filtrate was centrifuged at 3,000 rpm for 10 min, the supernatant was decanted, and the protein layer above the starch sediment was removed. The starch sediment was resuspended in water, screened again through a 200-mesh sieve, and centrifuged again. The small protein layer above the pure starch sediment was removed again. The final pure

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starch cake was air-dried at 40°C. After drying, the starch cake was powdered and passed through an 80-mesh sieve. The buckwheat starch preparations were allowed to equilibrate at room temperature for two days. Wheat starch (S-5127, Sigma Chemical Co., St. Louis, MO) was used as a reference standard for all tests.

### Determination of Starch Content and Characteristics

Surface lipid content in starch was determined by extraction in Soxhlet apparatus for 6 hr with petroleum ether. An improved Kjeldahl method (copper-titanium dioxide catalyst modification), using a nitrogen conversion factor of 6.25, was used for determination of crude protein content in flour and starch (AACC 1995). Amylose content (apparent amylose) was determined using a standard colorimetric method (Morrison and Laignelet 1983). Starch color (dry powder) was determined with a chromameter (CR-300, Minolta Camera Co., Ltd., Tokyo, Japan), using the CIE 1976  $L^*a^*b^*$  color system. The chromaticity coordinate  $L^*$  represents lightness,  $a^*$  is red to green, and  $b^*$  is yellow to blue (Pomeranz and Meloan 1987). Swelling volume of starch was determined following Crossbie (1991). Starch (0.35 ± 0.001 g, dwb) was weighed into culture tubes and distilled water or 1% NaCl solution (12.5 mL) added. A mixing and heating protocol was followed so the starch was heated for 30 min at 92.5 ± 0.5°C on a constant temperature water bath before cooling rapidly in an iced water bath, and centrifugation. The swelling volume was calculated from the height of the gel. All tests were performed in duplicate.

### Differential Scanning Calorimetry

Thermal characteristics of starches were measured using a Mettler DSC20 instrument (Mettler, Naenikon-Uster, Switzerland) equipped with a Mettler TC11 data analysis station following Chinachoti et al (1990) and Kim et al (1995). Starch samples (4.0 ± 0.1 mg, dwb) were weighed directly into a 40 µL pan and then either deionized water or 1% NaCl solution was added to achieve a starch-water suspension total weight of 17 ± 0.1 mg. Sample pans were sealed and allowed to stand ≥1 hr at room temperature before heating. Samples were heated at 10°C/min from 30 to 120°C. An empty pan was used as reference. The onset temperature ( $T_o$ ), peak temperature ( $T_p$ ), completion temperature ( $T_c$ ), and enthalpy of gelatinization ( $\Delta H$ , J/g) were calculated. The average value of two to three replicates is reported.

TABLE I  
Protein and Crude Lipid Contents of Buckwheat Flours and Starches

Source	Protein (%)		Crude Lipid (%)	
	Flour	Starch	Flour	Starch
CB-F	14.8	1.04	2.74	0.98
CB-A	15.3	1.30	2.43	0.81
CB-83-230	15.2	1.16	2.73	0.95
TB-87-1	11.5	0.94	2.44	0.93
TB-90-2	11.3	0.97	2.43	0.88
TB-T	15.9	1.35	2.78	1.06

TABLE II  
Apparent Amylose Content (%) and Swelling Volume (mL) of Buckwheat Starches and Wheat Starch in Water and Difference in Swelling Volume in 1% NaCl Solution Relative to Water

Starch Source	Apparent Amylose Content, %	Swelling Volume in Water, mL	Swelling Volume Change in 1% NaCl, mL
CB-F	25.3	27.4	-5.1
CB-A	24.4	27.8	-3.8
CB-83-230	21.5	28.0	-3.2
TB-87-1	23.8	26.5	-2.6
TB-90-2	25.7	27.4	-4.3
TB-T	22.7	30.8	-5.1
Sigma wheat	23.8	20.1	-4.3

### Viscoamylography

A Rapid Visco-Analyzer (RVA) (Newport Scientific Pty. Ltd., Narrabeen, Australia) was used to determine the pasting properties of the starch samples. Starch (2.5 g, dwb) was weighed directly in the aluminum RVA canister. Distilled water or 1% NaCl solution was added to a total constant sample weight of 28 g. The mixture was mixed for 30 sec by the paddle to produce a lump-free starch slurry. A programmed constant shear rate 27-min RVA test cycle was activated, where the sample was held at 50°C for 2 min, heated to 95°C in 7.5 min, held at 95°C for 5 min, cooled to 50°C in 7.5 min, and then held at 50°C for 5 min. Apparent viscosity was recorded in RVU (1 RVU ≅ 10 cp). Peak viscosity (PV), time to peak viscosity ( $P_{time}$ ), temperature at peak viscosity ( $P_{temp}$ ), hot paste viscosity (HPV) (minimum viscosity in the trough during heating at 95°C), and cool paste viscosity (CPV) (viscosity at 50°C at the end of the RVA cycle) were recorded.

### Texture Analysis

After RVA testing, the paddle was removed and the starch pastes were kept at room temperature in the RVA canister for 24 hr to allow them to gel and begin retrogradation. Then texture profile analysis of the gel directly into the RVA canister was performed with a QTS-25 texture analyzer (Stevens Advanced Weighing Systems, Leonard Farnell and Co. Ltd., England) fitted with a cylindrical flat-ended probe of 6 mm diameter. A two-cycle program was used in compression with test speed of 30 mm/min, trigger point of 2.0 g, and target value of 15.0 mm. Five to six repetitions on the same sample were conducted in each case.

## RESULTS AND DISCUSSION

### Analysis of Buckwheat Flour and Starch

There were no consistent differences in crude protein and crude surface lipid contents for common and tartary buckwheat flours or their starches (Table I). All common genotypes were high in protein (≈15%), and two of the tartary genotypes were low (≈11.5%). The protein content of starch was 0.94–1.35% and was correlated to the content in the flour. Lipid content of flour varied in a narrow range from 2.43 to 2.78%. Crude protein and crude lipid contents of TB-T flour and starch were the highest of all six genotypes. Water was used during isolation of the starches, and during removal of crude protein and associated contaminants layered on the wet mass after centrifugation. The starch layer flowed as a thick slurry, making it difficult to get very pure buckwheat starches. The apparent amylose content of the six buckwheat samples varied from 21.5 to 25.7%, similar to the value of 23.8% for the wheat starch sample (Table II), and consistent with the value of 25% reported by Kim et al (1977).

Color of buckwheat flour or starch is important for its utilization in particular food products. Tartary buckwheat flours were somewhat more gray (lower  $L^*$ ), redness ( $a^*$ ) was not consistently different, and yellowness ( $b^*$ ) was much higher than in common buckwheat flours (Table III). For starch, differences in brightness

TABLE III  
Color of Buckwheat Flours, Buckwheat Starches, and Wheat Starch

Source	$L^*$		$a^*$		$b^*$	
	Flour	Starch	Flour	Starch	Flour	Starch
CB-F	62.78	72.23	0.35	0.48	6.90	1.97
CB-A	63.08	70.75	0.33	0.61	6.60	2.42
CB-83-230	62.60	71.15	0.21	0.57	6.93	2.27
TB-87-1	57.92	71.05	0.87	-1.47	12.80	9.57
TB-90-2	56.36	67.66	0.61	-1.53	10.07	9.12
TB-T	59.17	70.97	0.15	-1.28	11.99	7.99
Sigma wheat	...	74.40	...	0.26	...	0.50
LSD ( $P < 0.05$ ) <sup>a</sup>	0.14	0.18	0.03	0.05	0.05	0.03

<sup>a</sup> Least significant difference for comparison of means or differences in the same column

between common and tartary buckwheat starches were slight and not consistent, but differences in  $a^*$  and  $b^*$  were highly statistically significant (Table III). Tartary buckwheat starches were less red and more yellow than common buckwheat starches. Yellowness of tartary buckwheat cannot be avoided by the distilled water starch isolation procedure. Tartary buckwheat starches were visually a light yellow powder compared to the white powder of common buckwheat starches and wheat starch.

### Swelling Volume

Starch swelling volume under the conditions used may be related to aspects of starch gel texture and to amylose content. Swelling volumes of common and tartary buckwheat starches were clearly higher than in wheat starch (Table II), indicating that the buckweats may have a high fraction of starch soluble in water. The swelling volume in water of the three common buckwheat starches was very similar, but wider differences were observed in tartary buckwheat. Starch swelling volume in 1% NaCl solution decreased, but the relative decrease for different genotypes varied widely. A greater decrease in starch swelling volume in NaCl solution indicated greater sensitivity to NaCl action in delaying gelatinization.

### Thermal Properties

$T_o$  of all the buckwheat starches was higher than in wheat starch, with the exception of CB-F starch, which had an unusually low  $T_o$  of 57.8°C (Table IV).  $T_p$  and  $T_c$  of all the buckwheat starches were higher than in wheat, and did not show much variation. CB-F had the lowest  $T_p$ , but its  $T_c$  was within the range of the other buckwheat samples. Comparing common and tartary buckwheat starches,  $T_o$  and  $T_c$  of tartary buckwheat starches were all higher than common buckwheat starches, and although  $T_p$  of TB-87-1 equaled that of CB-A, the  $T_p$  of the other two tartary buckwheat starches was also higher than the common buckwheat starches.  $\Delta H$  of all the buckwheat starches were generally quite

similar to each other and to wheat starch, except for TB-90-2 ( $\Delta H$  11.0) which was statistically significantly higher than all the others except CB-A. Kim et al (1977) reported a gelatinization temperature range of 61–65°C for a common buckwheat starch and Lorenz et al (1982) reported  $T_o$  61.5°C,  $T_p$  69.5°C and  $T_c$  76.0°C for a common buckwheat starch sample, although these values were determined by polarized light hot-stage microscopy. When 1% NaCl solution was used,  $T_o$ ,  $T_p$ , and  $T_c$  of all the samples increased, as expected according to the hypothesis proposed by Oosten (1982). The extent of increase was similar among all samples, including the wheat starch.  $\Delta H$  of common and tartary buckwheat starches also increased in the presence of 1% NaCl, indicating increased difficulty in starch gelatinization in the presence of salt, and explaining the swelling volume decrease of buckwheat starches in 1% NaCl solution. In contrast, the  $\Delta H$  of wheat starch was virtually unchanged in the presence of 1% NaCl, although its swelling decreased to the same extent as the buckwheat samples.

### Pasting Properties

The RVA curves of buckwheat and wheat starches were very different, but the differences among common and tartary buckwheat starches were relatively slight (Fig. 1).

*In water.* The peak viscosity (PV) of buckwheat starches was 23–40 RVU higher than for the wheat starch sample, HPV was 45–65 RVU higher, and CPV 50–85 RVU higher. Time-to-peak viscosity ( $P_{time}$ ) of buckwheat starches was slightly lower than in wheat starch, the greatest difference being only 0.75 min, and there were effectively no differences in temperature at peak viscosity ( $P_{temp}$ ) among all the samples. There were no systematic differences in PV, HPV, and CPV between the common and tartary buckweats, and overall differences among samples were slight for these traits. However, the angle and shape of the slope from initiation of viscosity increase to the peak viscosity was clearly different in the common compared to tartary buckweats. The common buckweats had a linear increase at a lower angle compared to the curved line and greater angle of slope in the tartary buckweats (Fig. 1).

TABLE IV  
Thermal Characteristics of Buckwheat/Wheat Starches in Water and NaCl<sup>a</sup>

Starch Source	Temperature (°C)			Enthalpy $\Delta H$
	$T_o$	$T_p$	$T_c$	
CB-F	57.8 (+4.5)	66.3 (+4.8)	77.9 (+4.3)	9.3 (+0.75)
CB-A	62.4 (+3.4)	68.8 (+4.5)	79.2 (+5.1)	10.0 (+1.90)
CB-83-230	61.1 (+3.1)	68.3 (+4.0)	77.3 (+7.5)	9.1 (+3.00)
TB-87-1	63.3 (+2.9)	68.8 (+4.5)	79.9 (+6.0)	9.7 (+2.70)
TB-90-2	62.8 (+3.9)	69.3 (+4.5)	80.8 (+5.4)	11.0 (+0.80)
TB-T	64.3 (+2.9)	70.8 (+4.5)	81.3 (+4.5)	9.8 (+2.10)
Sigma Wheat	59.2 (+4.1)	63.7 (+4.6)	74.3 (+4.2)	9.3 (-0.20)
LSD (P<0.05) <sup>b</sup>	0.45 (1.27)	0.14 (0.81)	1.48 (1.96)	1.29 (1.24)

<sup>a</sup> Change in value in 1% NaCl (in brackets).

<sup>b</sup> Least significant difference for comparison of means or differences in the same column.

TABLE V  
Comparison of Textural Characteristics<sup>a</sup> of Buckwheat and Wheat Starch Gels formed in Water and NaCl<sup>b</sup>

	AF, g	HD, g	WD g/sec	TP	TN
CB-F	11.4 (+1.4)	82 (+7)	1,354 (+2)	1,515 (+111)	156 (-16)
CB-A	8.2 (+2)	70 (+1)	1,122 (+105)	1,300 (+102)	101 (+37)
CB-83-230	12.0 (-1.8)	79 (0)	1,319 (+33)	1,595 (-68)	115 (+8)
TB-87-1	13.4 (-0.8)	91 (-5)	1,734 (-151)	1,933 (-156)	203 (-23)
TB-90-2	10.8 (+1.6)	75 (+8)	1,321 (+126)	1,522 (+100)	143 (+28)
TB-T	8.0 (+2.8)	62 (+7)	1,011 (+214)	1,177 (+220)	103 (+48)
Sigma wheat	13.2	37	849	916	193
LSD (P<0.05) <sup>c</sup>	2.40	6.6	135.7	157.4	35.3

<sup>a</sup> Adhesive force (AF), hardness (HD), work done to hardness (WD), total positive area in cycle 1 (TP), and total negative area in cycle 1 (TN).

<sup>b</sup> Change in value for gels formed in 1% NaCl (in brackets).

<sup>c</sup> Least significant difference for comparison of means or differences in the same column.

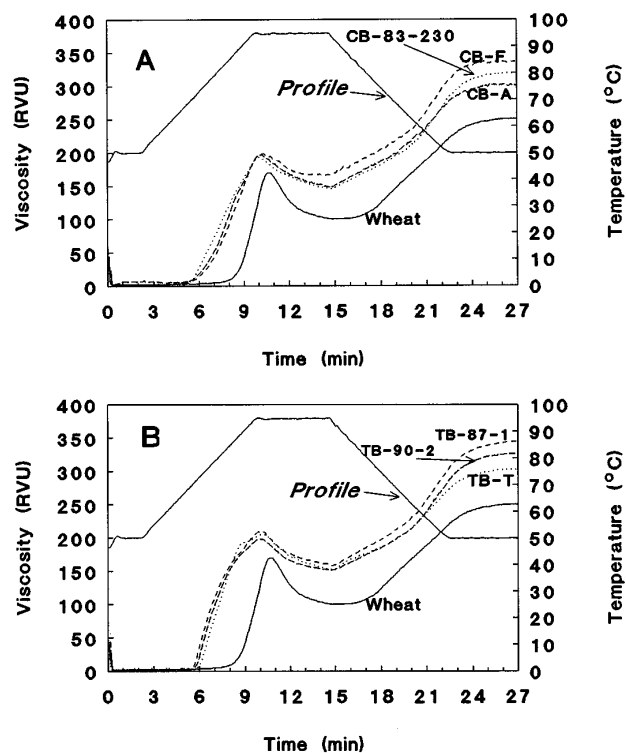


Fig. 1. Pasting curves of common buckwheat starches in water (A) and tartary buckwheat starches in water (B).

In 1% NaCl solution. The PV of wheat starch in 1% NaCl increased by 34 RVU when compared to the treatment using water. The effect of NaCl on viscosity of buckwheat starch was much less, from -4 to 9 RVU. The effect of NaCl on HPV was fairly uniform with increases from 8 to 34 RVU, compared to 27 RVU for wheat starch. For CPV the effect was wider, with decreases in the buckwheat starches in 1% NaCl from -2 to -35 RVU, but an increase in wheat starch of 14 RVU.

### Gel Textural Properties

Textural properties of a starch gel closely relate to their utilization in food and other applications. Many parameters can be used to describe texture, but hardness, adhesive force (AF) (g), work done up to hardness value (WD) (g/sec), total positive area (TP area) in cycle 1, and total negative area (TN area) in cycle 1 were chosen for this study. Hardness (maximum load on cycle 1) relates to the firmness of the starch gel and AF (peak negative load in cycle 1) relates to the ability of the gel to stick to other objects. The experimental error in measurement of the textural parameters was quite high, as indicated by the least significant difference values (Table V). However, some trends were apparent. Hardness of buckwheat starch gels was higher than in the wheat starch gel. This is consistent with the higher CPV for buckwheat starches compared to wheat starch, and is also consistent with a previous study for a common buckwheat starch (Kim et al 1977). AF was fairly similar among all samples including the wheat starch. For WD and TP all buckwheat samples had higher values than the wheat sample, but for TN only one buckwheat starch was higher than wheat starch. The effects of NaCl on textural properties of buckwheat starch gels were varied but generally hardness was slightly increased, AF was not consistently affected, and WD increased for all buckwheat samples except one. The RVA results for PV have been shown to be highly correlated to gel hardness, and this can be used in screening wheat for noodle quality (Crosbie 1991).

### CONCLUSIONS

Wide differences were found in various physical properties comparing six buckwheat starches to a standard wheat starch sample. Considerably less variation was found between common and tartary buckwheat, and among genotypes within the same species. Yellowness of wet milled tartary buckwheat flour was high, and this could be a problem for some applications. The important pasting properties of common and tartary buckwheat starches were high HPV, high CPV, improved retrogradation resistance in 1% NaCl, minimal effect of NaCl on peak viscosity, and good resistance to shear thinning. We would have expected greater differences between common and tartary buckwheat genotypes, and even among the three genotypes of each species studied. Greater variation in buckwheat starch properties should be sought to give additional opportunities in new product development.

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