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Effect of A- and B-type granules on the physical properties of starch from six wheat varieties

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RESEARCH ARTICLE

Abstract

Six wheat varieties (3 hard and 3 soft genotypes) produced in China were selected to study the effect of granule types on physical properties of starch. Difference in freeze-thaw stability, solubility, gelatinisation, pasting and swelling properties were compared. The results demonstrated that the pasting properties were directly correlated with the granule type of starch, and the A-type granules of starch showed the highest peak viscosity, trough viscosity, final viscosity and breakdown viscosity. The B-type starch displayed poor pasting and textural properties, however, its freeze-thaw stability was satisfactory. Furthermore, the solubility (5.20-29.06) and swelling power (6.31-9.27) of starches also depended on the starch types and wheat varieties. Results revealed that an appropriate wheat and starch type choice would provide the basis for desired starch-based production.

Keywords: wheat starch, A-type granule, B-type granule, physical property

1. Introduction

Wheat is the second biggest cereal grain in China. Its major component, starch, is the most important and fundamental sources of energy for humans. Starch is composed of two major types of polysaccharide molecules, i.e. a linear 1,4-α-d-glucan amylose, and amylopectin, made from a branched, bush-like structure containing mainly 1,4-α-d-glucan residues and 1,4-α-d branch points (Dias *et al.*, 2008; Dundar *et al.*, 2009). These two types of polymers form amorphous lamellae, crystalline lamellae and amorphous growth ring in starch structure (Thitisaksakul *et al.*, 2012).

The crystalline structure of starch granules mainly contains two types: the large, disk-shaped A-type granules (diameter >10 μm) and the small, spherical and irregular B-type granules (diameter <10 μm) (Conforti and Lupano, 2007; Dai, 2009; Wang *et al.*, 2007). Both the A- and B-type granules possess differing composition, relative crystallinity, amylose and amylopectin chain length distribution, which have been summarised in detail (Kim and Huber, 2010a; Liu *et al.*, 2007). Compared to the A-type granules, the B-type granules displayed a lower crystallinity and greater lipid-complexed amylose and phospholipid contents (Kim and Huber, 2010b; Yin *et al.*, 2012). The supramolecular structure of two type granules was also reported, the B-type granules possessed a higher degree of ordering, but less average thickness than A-type granules in the lamellar regions (Zhang *et al.*, 2013).

Recently, much attention has been focused on the pasting properties of wheat starch. A previous study showed that the final viscosity, the highest breakdown and lowest through viscosity parameters of fifteen winter wheat starch could be varied by an appropriate wheat choice, grain preparation and mill-choice, setup and adjustments (Rakszegi *et al.*, 2010). Furthermore, the A- and B-type granules from waxy and normal wheat varieties were compared, the results showed that A-granule starch had higher peak, final and setback viscosity than that of B-granules (Kim and Huber, 2010b). However, Zeng *et al.* (2011) found that the B-granules of varieties ZM18 and YZ4110 displayed higher peak, trough and finial viscosity than A-granules (Zeng *et al.*, 2011). It seems that the pasting properties of starch depended on wheat genotype. In addition, the pasting properties of wheat starch were also affected by the ratio of A- and B-type granules, for the difference between amylopectin chain length distributions (Srichuwong and Jane, 2007). Nonetheless, few of them were focused on the detailed comparison of the physical properties of derivated native, A- and B-type starches with wider single kernel characterisation system (SKCS) index.

In this study, the native, A- and B-type starch from six wheat varieties (SKCS indexes 24-88) were prepared. The freeze-thaw stability, solubility, gelatinisation, pasting and swelling properties of starch were systematically investigated. The results of this study would form the basis for the further investigations on the physicochemical properties of the derivated starch to develop genetic recombination and widen the industrial application.

2. Materials and methods

Materials

Six wheat varieties (JIAN1, YU50, CHANG6154, LONG26 and AN6) were provided by the National Engineering Laboratory of Wheat and Corn Processing (Zhengzhou, Henan). The wheat grain was milled to flour in a Brabender mill (Brabender, Duisburg, Germany) according to the approved procedure 26-31 (AACC, 2000). All reagents and chemicals used were of analytical grade.

Separation of the A- and B- type granules starch

The A- and B-type granules starch were separated by repeated sedimentation method (Takeda *et al.*, 1999). Wheat starch (100 g) and deionised water (800 ml) was mixed into a graduated cylinders for 1 h. The upper 500 ml suspension was collected as the B-type granules in a breaker while another 500 ml deionised water was added to the cylinder. The processes were repeated until the upper suspension was clear. Then, the A-type granules were collected from the rest precipitated in the cylinder. After achieving separation, both A- and B-type granules were centrifuged at 4,000×*g* for 20 min and then dried in vacuum freeze drying for 24 h.

Pasting properties

Pasting properties of the starch samples were determined by AACC method 76-21 (AACC, 2000), using a rapid visco analyser (RVA; Newport Scientific, Sydney, Australia). The starch suspension (10%, w/w) was equilibrated at 50 °C for 1 min, heated to 95 °C with a rate of 6 °C /min, maintained at 95 °C for 5 min, and cooled to 50 °C with a rate of 6 °C/min. The initial speed was 960 rpm at the first 10 s followed by 160 rpm for the resting experiment.

Gelatinisation properties

The starch suspension (10%, w/w) was heated at 100 °C for 30 min, then cooled to 20 °C and deposited for 24 h. The gel formed was evaluated for gelatinisation properties by a TA-XT2 texture analyser (Stable MicroSystems, Surrey, UK) using the texture profile analysis mode. The penetration speed of probe was 1.0 mm/s, and the penetration depth was 20 mm.

Freeze-thaw stability

A 3% starch paste was heated by boiling for 15 min. After cooling, the starch paste was frozen at -40 °C for 24 h, then thawed for 60 min in a 24 °C water bath. The paste was then centrifuged at 6,000 g for 15 min at 20 °C. The free liquid was separated and its weight was determined. The precipitate was turned to above process again and the freeze-thraw cylce were repeated 5 times. The percentage of syneresis was calculated according to Equation 1:

$$\text{Syneresis (\%)} = \frac{\text{weight of free liquid from gel}}{\text{weight of gel before centrifuging}} \times 100 \quad (1)$$

Solubility and swelling properties

The solubility and swelling properties of the starch were determined according to precipitation and separation method described by Lauzon *et al.* (1995) with slight modifications. Briefly, 3% starch paste (50 ml) was heated at 85 °C for 30 min, After cooling down to room temperature, the paste was centrifuged at 3,000×*g* for 15 min. The separated supernatant and precipitate were dried by vacuum freeze drying, and weighing as soluble starch and swelling starch, respectively. The solubility and swelling powder were calculated as follows:

$$\text{Solubility (\%)} = \frac{\text{weight of soluble starch}}{\text{weight of total starch}} \times 100 \quad (2)$$

$$\text{Swelling power (\%)} = \frac{\text{weight of swelling starch}}{\text{weight of soluble starch}} \times 100 \quad (3)$$

Statistical analysis

Statistical analyses were performed through ANOVA (level of significance $P<0.05$) followed by Duncan's test using SPSS software (version 13.0; SPSS Inc., Chicago, IL, USA).

3. Results and discussion

Pasting properties

Pasting properties of the native, A- and B-type starch of six wheat varieties are summarised in Table 1. During the RVA pasting test, starch granules started to imbibe water with an increase in temperature. Meanwhile, starch molecules tended to leach out into the solution, then the viscosity of the suspension increased. In Table 1, it can be seen that the pasting temperature of samples varied from 56.45 to 93.70 °C, and the maximum for Chang6154 B-type starch and a minimum for JIAN1 native starch. The high pasting

Table 1. Pasting properties of the native, A- and B-type starch from six wheat varieties.

Variety[1]		Pasting temperature (°C)	Peak (cp)	Trough (cp)	Final viscosity (cp)	Breakdown (cp)	Setback (cp)
JIAN1	N	56.45	2,107	1,573	2,618	534	1,045
	A	69.40	2,983	2,408	3,524	575	1,116
	B	92.00	1,091	625	1,550	466	925
YU50	N	90.30	2,322	1,649	2,906	673	1,257
	A	80.70	2,957	2,246	3,337	711	1,091
	B	92.85	962	535	1,314	427	779
CHANG6154	N	81.50	1,844	1,258	2,247	586	989
	A	75.10	2,352	1,697	2,763	655	1,066
	B	93.70	678	378	1,015	300	637
LONG26	N	59.20	2,565	2,126	3,030	439	904
	A	58.35	2,935	2,473	3,471	480	998
	B	92.00	1,160	698	1,562	462	864
AN6	N	75.80	2,253	1,808	2,838	445	1,230
	A	86.30	2,587	2,060	3,197	527	1,137
	B	67.70	507	264	1,007	243	743
NING13	N	87.00	2,345	1,794	2,797	551	1,003
	A	83.05	2,700	2,127	3,137	573	1,010
	B	92.00	1,315	704	1,775	611	1,071

[1] A = A-type granule starch; B = B-type granule starch; N = native starch.

temperatures of starch indicated a higher resistance to swelling and rupture. The A-type granules of four wheat varieties (JIAN1, CHANG6154, LONG26 and NING13) had the highest peak, trough, final, breakdown, and setback viscosity, while B-type granules showed the lowest. The reason for this could be due to the presence of granules with a wide size distribution range, leading to different swelling patterns (Pinto *et al.*, 2012). In addition, larger granule sizes possess a loose packing ability and occupy a relatively larger volume. However, the setback viscosity of native starch for YU 50 and AN6 was higher than that of A-type granules, which could be attributed to their different amylose content, ratio of A- and B-type granules and protein content.

Gel textural properties

The textural properties of wheat starches are shown in Table 2. Except for the AN6 gel, the A-type granules of the other five varieties had the higher hardness than that of total starch, both of them were higher than B-type granules. In addition, the starch gel from CHANG6154 A-type starch showed the highest hardness (136.72), whereas CHANG6154 B-type starch showed the lowest (7.3). It was closely associated with the syneresis of water and crystallisation of amylopectin (Miles *et al.*, 1985). The starch samples tended to be harder with a higher amylose content and longer amylopectin chains. All the starch samples showed the similar springiness (0.92-0.98) and cohesiveness (0.41-0.70). Furthermore, both of gumminess and chewiness were found to be highest for CHANG6154 A-type granule (79.16 and 73.88 respectively), and lowest for CHANG6154 B-type granule (5.08 and 5.01, respectively). Comparing the data, the A-type granules showed the highest gumminess and chewiness, while the B-type granules showed the lowest. The results indicated that the texture of starch gels depended on starch source, especially for its rheological characteristics, ratio and structure of amylose and amylopectin.

Freeze-thaw stability

During the cooling and freezing periods, the starch molecule tended to align, forming hydrogen bonds. The intermolecular forces increased and water began to be released. As a result, the bonds between starch and water were destroyed, leading to poor water holding capacity and anti-freezing ability. After cooling and melting, the paste lost cohesion and water separated out with the texture becoming spongy structure with a low transparency. It can be observed from Figure 1 that the syneresis values varied from 52 to 70%. A-type granules had highest syneresis values irrespective of wheat varieties, which indicated a good water-holding capacity. However, B-type granules showed the lowest syneresis values, probably due to difference of amylose content, which has a major influence on the characteristics of freeze-thaw stability. The starch with higher amylose content is more easily to become aging and anabiosis, and the formed gel network is more

Table 2. Textural parameters of the native, A- and B-type starch from six wheat varieties.

Variety[1]		Hardness (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness
JIAN1	N	59.09	0.97	0.55	32.51	31.50
	A	75.97	0.95	0.44	33.27	31.37
	B	16.15	0.95	0.64	10.27	9.8
YU50	N	81.97	0.97	0.48	38.97	37.86
	A	122.68	0.99	0.41	50.68	50.35
	B	26.30	0.97	0.54	14.12	13.61
CHANG6154	N	60.73	0.94	0.51	30.43	28.64
	A	136.72	0.93	0.59	79.16	73.88
	B	7.3	0.99	0.7	5.08	5.01
LONG26	N	50.80	0.92	0.53	26.91	24.84
	A	84.8	0.99	0.53	45.44	45.02
	B	19.01	0.94	0.58	11.07	10.44
AN6	N	63.89	0.98	0.50	31.21	30.56
	A	48.53	0.97	0.51	24.59	23.81
	B	11.25	0.95	0.50	5.65	5.38
NING13	N	75.51	0.96	0.48	35.88	34.52
	A	139.7	0.95	0.42	58.64	55.92
	B	20.70	0.96	0.58	11.9	11.37

[1] A = A-type granule starch; B = B-type granule starch; N = native starch.

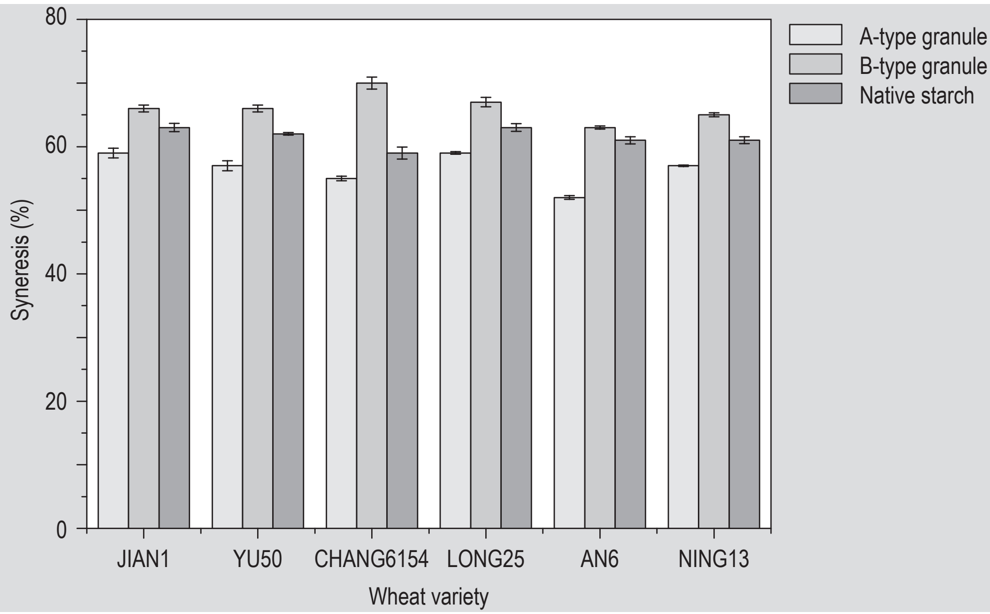

Figure 1. Freeze-thaw stability of the native, A- and B-type starch from six wheat varieties.

stable (Arunyanart and Charoenrein, 2008). Meanwhile, it was difficult to release water from gels under extreme conditions, as a result, a better freeze-thaw stability formed.

Solubility and swelling properties

The interaction between starch and water can be characterised by solubility and swelling properties, which are associated with the size of starch particle, composition, ratio of amylose and amylopectin, and ratio of long and short chains. As can be seen from Figure 2, the solubility of starch samples at 85 °C was around from 5.20 to 29.06 depending on the granule types and wheat varieties. A-type granules and native starches have similar solubilities, lower than B-type granules, which was mainly due to the composition differences. B-type granules had higher protein and soluble carbohydrate contents than A-granule or native starch (Cruz *et al.*, 2013). These molecules can

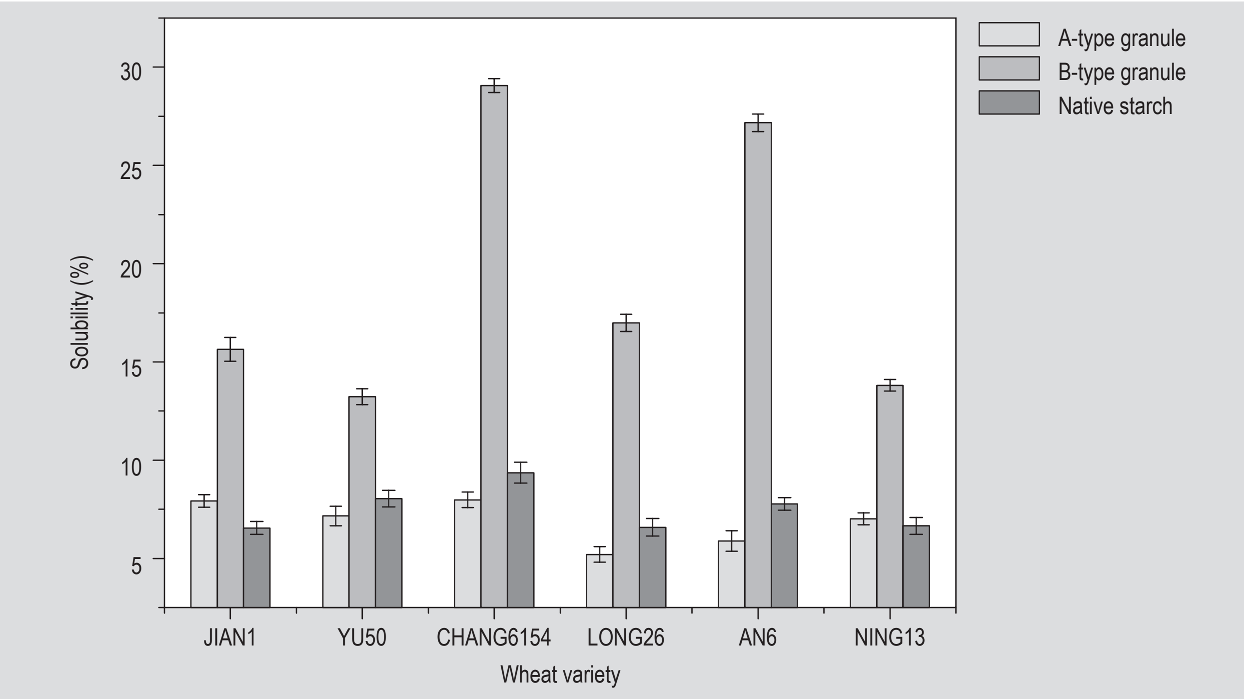

Figure 2. Solubility of the native, A- and B-type starch from six wheat varieties at 85 °C.

serve as the hydrogen bond donor for the starch to improve dissolving during heating.

In the heating process, starch granules swell in the excess water and form a starch paste with increased viscosity and lower transparency, which had an enormous influence on processing characteristics, texture flavour. The dynamics process of starch swelling generally consisted of three stages (Marchant and Blanshard, 1978). The first stage is relaxation, a process of absorbing water and structure modification, and the second stage is expansion, involving starch dissolving and amylose separation. The final stage was contraction, which is the pressure changes of granules without amylose. In Figure 3, it can be seen that the swelling power at 85 °C showed a minimum for AN6 B-type granules (6.31) and a maximum for CHANG6154 native starch (9.27). A-type and native starch had similar swelling powder, higher than B-type granules The reason

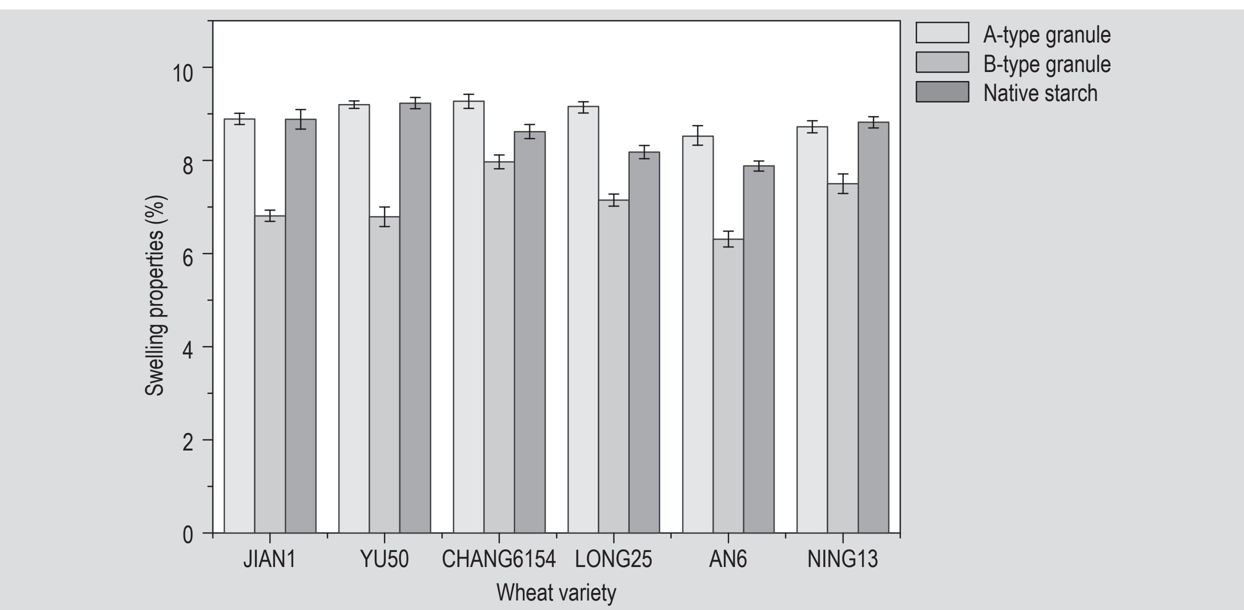

Figure 3. Swelling properties of the native, A- and B-type starch from six wheat varieties at 85 °C.

for this could be attributed to particle size as well as starch and lipid content (Dai, 2010). The resistance of expansion increased with a decrease in the particle size of the starch granules. Meanwhile, lipid and its complexes with amylose in B-granules also decreased swelling power.

4. Conclusions

This work investigated the effect of granule type on the physical properties of soft and hard wheat starches for Chinese wheat varieties. The pasting temperature showed a maximum for Chang 6154 B-type granules (93.7) and minimum for JIAN1 native starch (56.45 °C). Compared to the B-type granules, the A-type granules of six wheat varieties displayed higher hardness, chewiness, gumminess, peak, trough, final, and breakdown viscosity. Furthermore, similar springiness (0.92-0.98) and cohesiveness (0.41-0.70) were observed irrespective of granule type or wheat varieties. The A-type granules had higher syneresis values and swelling power than B-type granules, which was confirmed by solubility of granules. These results suggested that a suitable granule type or genotypes might lead to a desired physical properties, which could serve as the key material for expanding application in starch-based industry.

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References

American Association of Cereal Chemists (AACC), 2000. Approved methods of the AACC (10th Ed.). AACC, St. Paul, MN, USA.

Arunyanart, T. and Charoenrein, S., 2008. Effect of sucrose on the freeze-thaw stability of rice starch gels: correlation with microstructure and freezable water. Carbohydrate Polymers 74: 514-518.

Conforti, P.A. and Lupano, C.E., 2007. Starch characterisation of *Araucaria angustifolia* and *Araucaria araucana* seeds. Starch-Stärke 59: 284-289.

Cruz, B.R., Abraao, A.S., Lemos, A.M., Nunes, F.M., 2013. Chemical composition and functional properties of native chestnut starch (*Castanea sativa* Mill). Carbohydrate Polymers 94: 594-602.

Dai, Z.M., 2009. Starch granule size distribution in grains at different positions on the spike of wheat (*Triticum aestivum* L.). Starch-Stärke 61: 582-589.

Dai, Z.M., 2010. Comparison of starch granule development in hard and soft winter wheat. Journal of Food Agriculture and Environment 8: 772-774.

Dias, R.P., Fernandes, C.S., Mota, M., Teixeira, J. and Yelshin, A., 2008. Starch analysis using hydrodynamic chromatography with a mixed-bed particle column. Carbohydrate Polymers 74: 852-857.

Dundar, E., Turan, Y. and Blaurock, A.E., 2009. Large scale structure of wheat, rice and potato starch revealed by ultra small angle X-ray diffraction. International Journal of Biological Macromolecules 45: 206-212.

Kim, H.S. and Huber, K.C., 2010a. Impact of A/B-type granule ratio on reactivity, swelling, gelatinization, and pasting properties of modified wheat starch. Part I: hydroxypropylation. Carbohydrate Polymers 80: 94-104.

Kim, H.S. and Huber, K.C., 2010b. Physicochemical properties and amylopectin fine structures of A- and B-type granules of waxy and normal soft wheat starch. Journal of Cereal Science 51: 256-264.

Lauzon, R.D., Shiraishi, K., Yamazaki, M., Sawayama, S., Sugiyama, N. and Kawabata, A., 1995. Physicochemical properties of cocoyam starch. Food Hydrocolloids 9: 77-81.

Liu, Q., Gu, Z., Donner, E., Tetlow, I. and Emes, M., 2007. Investigation of digestibility *in vitro* and physicochemical properties of A- and B-type starch from soft and hard wheat flour. Cereal Chemistry 84: 15-21.

Marchant, J.L. and Blanshard, J.M.V., 1978. Studies of the dynamics of the gelatinization of starch granules employing a small angle light scattering system. Starch-Stärke 30: 257-264.

Miles, M.J., Morris, V.J., Orford, P.D. and Ring, S.G., 1985. The roles of amylose and amylopectin in the gelation and retrogradation of starch. Carbohydrate Research 135: 271-281.

Pinto, V.Z., Vanier, N.L., Klein, B., Zavareze, E.D., Elias, M.C., Gutkoski, L.C., Helbig, E. and Dias, A.R.G., 2012. Physicochemical, crystallinity, pasting and thermal properties of heat-moisture-treated pinhao starch. Starch-Stärke 64: 855-863.

Rakszegi, M., Bognar, Z., Li, Z., Bekes, F., Lang, L. and Bedo, Z., 2010. Effect of milling on the starch properties of winter wheat genotypes. Starch-Stärke 62: 115-122.

Srichuwong, S. and Jane, J.L., 2007. Physicochemical properties of starch affected by molecular composition and structures: a review. Food Science and Biotechnology 16: 663-674.

Takeda, Y., Takeda, C., Mizukami, H. and Hanashiro, I., 1999. Structures of large, medium and small starch granules of barley grain. Carbohydrate Polymers 38: 109-114.

Thitisaksakul, M., Jimenez, R.C., Arias, M.C. and Beckles, D.M., 2012. Effects of environmental factors on cereal starch biosynthesis and composition. Journal of Cereal Science 56: 67-80.

Wang, S.J., Yu, J.L., Gao, W.Y., Pang, J.P., Liu, H.Y. and Yu, J.G., 2007. Granule structural changes in native Chinese Yam (*Dioscorea opposita* Thunb var. Anguo) starch during acid hydrolysis. Carbohydrate Polymers 69: 286-292.

Yin, Y.A., Qi, J.C., Li, W.H., Cao, L.P. and Wang, Z.B., 2012. Formation and developmental characteristics of A- and B-type starch granules in wheat endosperm. Journal of Integrative Agriculture 11: 73-81.

Zeng, J., Li, G.L., Gao, H.Y. and Ru, Z.G., 2011. Comparison of A and B starch granules from three wheat varieties. Molecules 16: 10570-10591.

Zhang, B.J., Li, X.X., Liu, J., Xie, F.W. and Chen, L., 2013. Supramolecular structure of A- and B-type granules of wheat starch. Food Hydrocolloids 31: 68-73.