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Physicochemical and structural properties of A- and B-starch isolated from normal and waxy wheat: Effects of lipids removal

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ABSTRACT

Normal and waxy wheat and their A- and B-type starch granules were defatted by using soxhlet extraction method. The effects of defatting treatment on morphology, structure, and physicochemical properties on starches were investigated. The defatting result in more pores on the granule surface of normal and waxy A-type starch, while no obvious change of the B-type granules could be observed. The defatting treatment did not change the X-ray diffraction pattern of all starch granules, while the crystallinity degree of the starch samples decreased. The above structural changes on defatting decreased the light transmittance and increased swelling power of all starch samples. Meanwhile, defatting treatment changed the peak, trough, final, and setback and breakdown viscosity, gelatinization transition temperatures, and the gelatinization enthalpy of all starch samples. However, the extent of changes to starch properties on defatting was different among different samples due to differences in their amylose content and amylopectin chain mobility. Results of the present study indicate that the surface lipids on the starch granule surface have obvious effects on the physicochemical and structural properties of wheat A- and B-starch.

1. Introduction

Starch is the main component of wheat (*Triticum aestivum* L.) endosperm and flours apart from proteins, and it is the main resource of energy in wheat plants, which accounts for 65–75% of the final dry weight of wheat grains. Wheat starch is more frequently used in various foods, feed, pharmacy, building and other industrial applications. After all, wheat starch belonged to refined grains, and is mainly used in food as thickener, gelling agent, adhesives, or stabilizer, etc., and also used in the production of starch derived sugar such as lucose (syrups), fructose (syrups), and the polyols mannitol, sorbitol and maltitol (Li et al., 2013; Waterschoot, Gomand, Fierens, & Delcour, 2015).

It is widely acknowledged that there are two types of starch granules in wheat grains based on the size, shape, relative proportion and timing of their initiation in the endosperm: A-type starch granules, which are disk-like or lenticular in shape and contained a higher amount of amylose with diameters greater than 10 μm, and B-type starch granules, which are roughly spherical or polygonal in shape and contained a higher amylopectin/amylose ratio with diameters smaller than 10 μm (Karlsson, Olered, & Eliasson, 1983; Wilson, Bechtel, Todd, & Seib, 2006; Li et al., 2013).

Structurally, common starch is a glucan homopolymer composed of one-quarter amylose and three-quarters amylopectin, and linear chains are formed by α-1, 4 glucosidic linkages, while branches are formed by α-1, 6 glucosidic linkages (Ahuja, Jaiswal, Hucl, & Chibbar, 2014). Whereas, waxy starch differs from common starch as it contains essentially 100% amylopectin. Besides, wheat starches with high amylose content (about 74%) are also available (Regina et al., 2006). Apart from amylose and amylopectin, cereal starch granules usually contain lipid, the lipid content of normal cereal starches is around 1% (w/w), and the type and amount of lipid present depends on the botanical source of the starch (Liang, King, & Shih, 2002; Uthumporn, Karim, & Fazilah, 2013). The lipids within starch granules could be classified lipids into three categories: non starch lipids, starch surface lipids, and internal starch lipids, internal starch lipids in cereals are exclusively monoacyl lipids, while surface lipids have a more complex composition (Morrison, 1981).

The lipid in the starch granules has been well documented and

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has a significant effect on the physicochemical, structural and functional properties of starch. It can reduce starch retrogradation, decrease enzymatic hydrolysis, and affect the thermal and mechanical properties of starch (Biliaderis & Tonogai, 1991). The presence of lipid in starch is believed to be able to decrease the susceptibility of amylose to hydrolysis and prevent leaching of amylose during gelatinization, and inhibit swelling of starch granules during heating and reduce the water-binding capacity of starch (Eliasson & Krog, 1985; Uthumporn et al., 2013). Liang et al. (2002) reported that addition of lipids to commercial rice starch caused a decrease in granule swelling.

Perera, Hoover, and Martin (1997) reported that defatting treatment can lead great changes in the physical arrangement of the starch chains within the amorphous and crystalline domains of the potato starch granules. According to Uthumporn et al. (2013), the hydrolysis degree of corn, wheat and rice starch could be increased due to enhance the amorphous excretion and the occurrence of porous structures inside the granules after defatting treatment. Nevertheless, little information is available on the effects of defatting on wheat starch properties. Accordingly, A- and B-starch were isolated from normal and waxy wheat in this study, and the effects of defatting treatment on physicochemical and structural properties of native, A- and B- wheat starch were investigated. The information obtained from this study is expected to be helpful in understanding the effect of defatting on the quality and nutrition of wheat starch based food products.

2. Material and methods

2.1. Materials

The normal and waxy wheat (*T. aestivum* L.) were provided as grains by the College of Agriculture, Northwest A&F University, Yangling, China, from the 2013 harvest. The wheat grain was milled by using a laboratory mill (mill type Perten 3100, Swedish Perten Company, Sweden) to obtain a whole-wheat meal. All the chemicals and reagents used were of analytical grade.

2.2. Wheat starch isolation

The wheat starch granules were isolated from the flours following the method described by Singh, Singh, Isono, and Noda (2010). Briefly, stiff dough was prepared by mixing 100 g flour and 50 ml water in a pan, and the dough ball was subsequently kept at 30 °C for 1 h. The dough ball was then kneaded by hand in distilled water, and the starch slurry was collected. Starch was suspended in distilled water, passed through a 100–mesh nylon cloth for twice to remove bran and endosperm cell–wall impurities. The material retained on the cloth was discarded. Starch slurry was then centrifuged at 2500 g for 10 min. The upper pigmented layer was carefully removed, and decanted from any more starch, which had settled after 30 min. The starch fraction along with starch from decanting step was purified by resuspending in distilled water and centrifugation before drying in an oven at 40 °C for 24 h.

2.3. Separation of the A–and B–Granule starch

The A–and B–granules were separated by the method as described by Zeng, Li, Gao, and Ruv (2011). The wheat starch suspension with a concentration about 10% (w/v) was sedimented using a 2 L graduated. The fraction of 1 h precipitate was collected as A–granules and the sediment resuspended and sedimented as before after three times was collected as B–granules. The separated A–and B–granule suspensions were centrifuged at 7000 rpm for 20 min and washed with ethanol (50%) for one time. These starches were recovered by using filter and then dried in a convection oven at 40 °C for 24 h.

2.4. Preparation of defatted starch

Defatted starch was prepared using Soxhlet extraction with anhydrous diethyl ether at 45 °C for 12 h. The solvent was removed by vacuum evaporation and the starch was air dried to moisture content about 10%.

2.5. Determination of chemical composition

The starch content, lipid, protein and ash content were performed by the standard AACC Methods 76–13, 30–25, 46–30 and 08–01, respectively (AACC, 2000).

2.6. Microscopy analysis

2.6.1. Light microscopy

Starch sample was suspended in a glycerol solution (glycerol/H_2O_2, V/V) and was observed using a polarizing light microscope (DMBA400, Motic China Group Co., Ltd, Guangzhou, China) with a × 40 objective.

2.6.2. Scanning electron microscopy (SEM)

A starch sample was mounted on an SEM stub with double–sided adhesive tape and coated with gold. Scanning electron micrographs were taken using a scanning electron microscope (JSM–6360LV, JEOL, Japan).

2.7. Determination of swelling power

Swelling power was determined following the modified method of Leach, McCowen, and Schoch (1959). The starch suspension was stirred at 90 °C for 30 min, cooled, and centrifuged at 3000 g for 15 min. The values for swelling power were calculated in grams per gram and that of solubility index in percent at 50, 60, 70, 80 and 90 °C.

2.8. X–ray diffraction analysis

X–ray powder diffraction (XRD) measurements were performed using an X–ray diffractometer (Rigaku D/max–2551/PC, Rigaku Corporation, Tokyo, Japan). The samples were analyzed with the following operating conditions: radiation source, CuKa; angle of diffraction scanned from 5 to 60°; step size, 0.02; step time, 2 s. To avoid the influence of relative humidity on relative crystallinity, the starch samples were equilibrated in a 100% relative humidity chamber for 48 h at room temperature. The relative crystallinity degree of the samples was calculated as the proportion of crystalline area to total area multiplied by 100.

2.9. Determination of light transmittance

Light transmittance of starch solution was conducted according to the method of Craig, Maningat, Seib, and Hoseney (1989) with little modification. An aqueous suspension of starch samples (1%, g/g) was heated in a water bath at 95 °C for 15 h with constant stirring. The pastes were cooled at 25 °C for 1 h, and then stored at 4° C in a refrigerator, and transmittance was determined at 0, 12, 24, 48, 60 and 72 h by measuring the absorbance at 620 nm with UV visible Spectrophotometer (UV-1700, Shimadzu, Japan).