Structural and Physicochemical Mical Characteristics of Buckwheat Starch

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***Abstract*—The starch extraction process from tartary and common buckwheat improved so that the tartary and common buckwheat could be more comprehensive utilizatied. The buckwheat and common buckwheat has separated into buckwheat starch, proteins and flavonoids by ethanol extraction. The obtained starch has a purity of 97.23% and 95.4%, total starch extraction rate of 83.52% and 81.3%, and the antioxidation properties of bioactive proteins and flavonoids are retained well in the extracted products. Then its structural and physicochemical characteristics were analyzed and correlated. Scanning electron microscopy and laser light scattering showed that starch granules from tartary and common buckwheat had a polyhedron shape with an average size of 58.2 and 12.8nm respectively. The X-ray diffraction patterns showed that both starch granules had a typical A-type pattern and the relative degree of crystallinity of the tartary and common buckwheat starch were about 34.95 and 26.92% respectively. The swelling power and solubility study showed that tartary buckwheat reached the highest swelling power of 3.6wt.% at 80 ℃ while common buckwheat reached the highest swelling power of 4.7wt.% at 60 ℃. The solubility of common buckwheat starch was higher than tartary buckwheat. These observations indicated that buckwheat starch had significant physical and chemical characteristics, which might be important in several food applications.**

***Index Terms*—tartary buckwheat, common buckwheat, starch, physicochemical properties**

I. Introduction

Buckwheat is a member of the Polygonaceae family, which in-cludes common buckwheat (Fagopyrum esculentum) and tartary buckwheat (Fagopyrum tataricum). Buckwheat originated from China belongs to dicotyledonous Polygonaceae foliage. It is also planted in the other areas of Asia, Europe and some mountainous areas of America. There are more than 10 species distributed in all over the world [1], [2].

Buckwheat has a starch content of 60-70%, especially a high resistant starch content of 35-48%. At present, at home and abroad are mostly concentrated in buckwheat buckwheat protein separation, purification and rutin flavonoids extraction, separation, etc. [3]. Research on buckwheat starch extraction methods are also concerned only the separation of starch extraction yield, but they ignore the problem buckwheat protein and utilization of flavonoids and other biologically active substances.

The buckwheat starch is as a new resource in starch. Buckwheat is known to be used as a basic material for noodle, pasta, blended bread and the other types of flour products. The chemical components of buckwheat starch are similar to those in corn. In recent years, the starch separated from buckwheat has been paid more and more attention by researchers like Christa K *et al.* [4]. It was reported that buckwheat starch contained 21~26wt.% amylose [5]. Its physicochemical properties have some significant effects on quality of buckwheat products.

Buckwheat starch has a high biological value, but its digestibility is relatively low. The factors that contribute to the starch digestibility may be dependent on the starch structure and constituent characteristics. The starch separated from tartary and common buckwheat may have significant different properties. This contributes to the various applications of them in food formulations and processing. A better understanding of physicochemical properties of buckwheat starch, such as thermal properties, can greatly enhance their potential utilization as a kind of food ingredient. Recently, efforts are made to develop new foods with the aims to improve health and well-being and to reduce the risk of certain diseases. Several food processing techniques have been applied to foods in order to increase the functional property and to reduce the levels of obesity.

The main purpose of the present investigation is to determine different physicochemical properties of buckwheat starch fractions in order to make full use of the resource of buckwheat and to widen its industrial application.

II. Materials and Methods

A. Materials

Buckwheat flour used in this study was obtained from Shan Xi Province, China. All chemicals reagents used in experiments were of analytical grade (Chemical Company, Shanghai, China).

B. Isolation of Starch

Tartary buckwheat (Fagopyrum tataricum (L.) Gaertn) and common buckwheat (Fagopyrum esculent tum Moench) were cultivated in Shanxi province of China, the impurities and damaged seeds were discarded. Intact seeds were immersed in water (1:2.5, w/w) at 400 ℃ for 18h and then milled with water. The resulting slurry was

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passed through 100, 200 gauge mesh after sedimented for 30 min to eliminate the finest fibers. After sieved, the slurry was centrifuged at a force of 3500g for 15 min and then the starch was collected. Finally, the as-prepared starch was dried at 450 ℃ for 48h and ground into powder sufficiently fine to pass through a 100 mesh sieve [6].

C. *The Improved Isolation of Starch*

Alcoholic extraction of flavonoids and protein during the starch processing follow as Fig. 1.

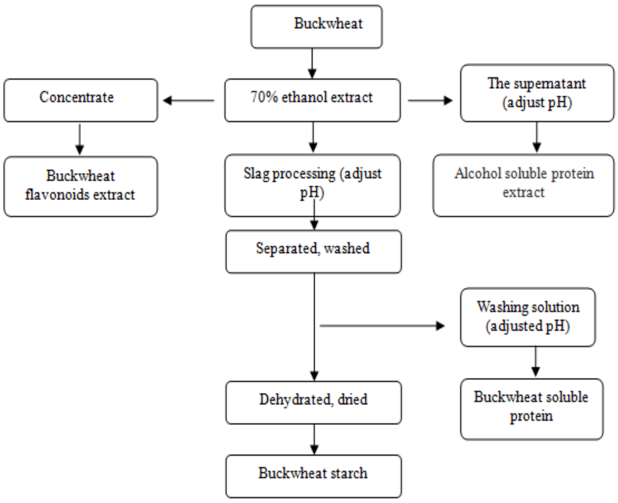

Figure 1. Alcoholic extraction of flavonoids and protein during the starch processing

D. *Morphological Property Analysis*

The procedure to determine morphological properties of starch was the same as the previous reported [7]. Scanning electron micrographs were obtained by using a Morphologi G2 scanning electron microscopy (Philips, Netherlands). The starch was spreaded on the conductive adhesive that was fixed on the base. The samples were put under the object stage to take micrographs using an accelerating potential of 20kV.

E. *Particle Size Analysis*

Particle size analysis of starch from tartary and common buckwheat seeds was done using a laser light scattering particle size analyzer (Mastersizer2000, Malvern instruments Ltd., Malvern, UK). The samples were put into the test box, conditions of which were set according to the literature about Luengwilai K *et al.* [8].

F. *X-Ray Diffractometry*

X-ray diffraction pattern was obtained according to the Literature [9] with some modification using a D/MAX 2000 diffractometer (Rigaku, Japan). The samples were exposed to the X-ray beam from the X-ray generator running at 40kV and 30mA. The scanning region of the diffraction angle 2θ was 5°~40°, which covered most of significant diffraction peaks of starch crystallites. Duplicate measurements were made at ambient temperature. The degree of crystallinity of samples was quantitatively estimated by the Jade 5.0 software.

G. *Swelling Power and Solubility Measurement*

Swelling Power (SP) and solubility(S) were determined in triplicate according to the modified method of Maninder Kaura *et al.* Solubility and Swelling power of starch was determined as followed: flour samples of 2g starch were dispersed in 100ml distilled water in centrifuge tubes and heated from 60 to 90 ℃ at 5 ℃ intervals and holding at each interval for 30 min. The sample was centrifuged at 3000r/min for 20 min. Supernatants were drawn and dried at 100 ℃ to constant weight. The following equation could be applied to calculate solubility and swelling power as follows:

$$\text{Solubility } (\%) = W_1/W$$

$$\text{Swelling power } (\%) = (W2\times 100)/[W\times(100-S)]$$

where W1 was weight of soluble starch (g); W was weight of dry starch (g); W2 was weight of swelling starch (g) and S was the solubility of starch (%).

III. Results and Discussion

A. *Synchronization Ethanol Extraction Process Effectiveness Analysis*

Ethanol sync separator according buckwheat flavonoids, starch protein preparation can be synchronized to get buckwheat starch, buckwheat flavonoids concentrate, buckwheat protein product, see Fig. 2 and Fig. 3 that is for explanating the preparation of buckwheat starch with different results compared. From Fig. 2, buckwheat starch new process for the preparation of the flavonoid content and protein residues were below the conventional starch preparation process, and buckwheat starch extraction rate can reach 83.52%, the total starch content of 97.23%. It showed improved starch extraction process can be better to remove the flavonoids and protein, improve the extraction rate of starch. At the same time, we can see from Fig. 3, a new process for the preparation of buckwheat protein and separation of flavonoids are also very good, the extraction rate of more than 95%. And retained a good oxidation resistance, wherein the capability buckwheat protein and free radical scavenging flavonoids, respectively 84.34% and 95.56%

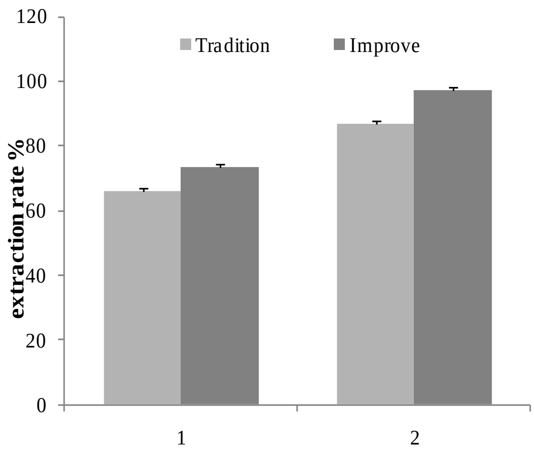

Figure 2. The comparison of different process method (1 in figure represents starch extraction rate, 2 in figure represents the total starch content)

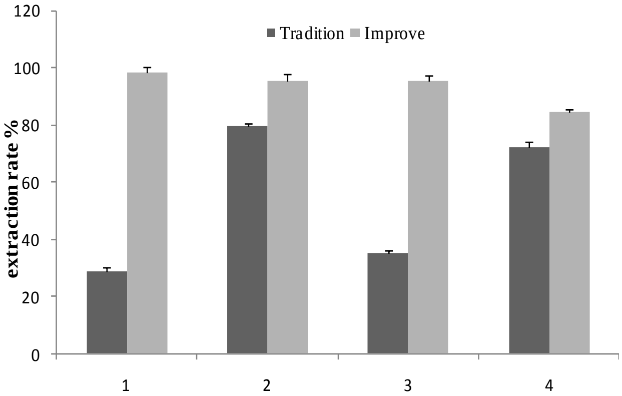

Figure 3. The comparison of different process method (1-the extraction rate. 2-represents the antioxidant activity. 3-represents protein extraction rate. 4-the protein antioxidant activity)

B. Shape and Size of Tartary and Common Buckwheat Starch Granules

SEM micrographs of buckwheat starches extracted from tartary and common buckwheat are showed in Fig. 4 and Fig. 5. The shape of two starch granules did not show significant difference. The starch granules showed nearly round or polygonal shapes. The granular size of tartary and common buckwheat starch ranged from 4 to 11μm as shown in Fig. 6. The granular size of tartary starch was bigger than that of common buckwheat starch at the same condition. Some starch granules also showed hollow surface morphology possibly due to the detachment of combined granules and/or granule-tissue. That maybe for that starch granule is an ordered collection of amylose and amylopectin from. Wherein the molecular weight of amylopectin is generally 1 ×107~1 ×109.

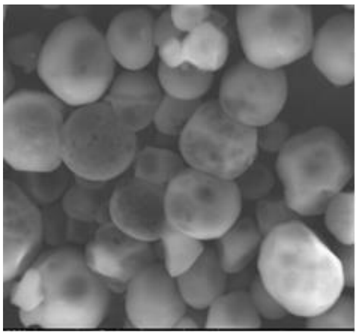

Figure 4. Scanning electron microscopy images of tartary buckwheat starch

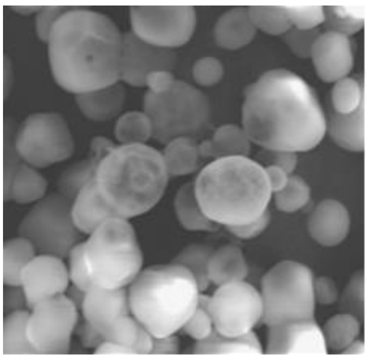

Figure 5. Scanning electron microscopy images of common buckwheat starch

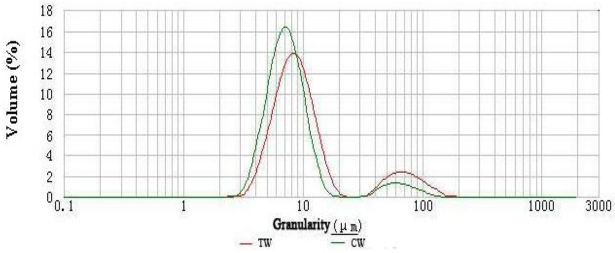

Figure 6. Particle size distributions of buckwheat starch.

C. Crystalline Properties of Tartary and Common Buckwheat Starch

Particle size distribution of starch was measured in dry state with a laser diffraction system (D/MAX 2000, Rigaku, Japan). The starch crystalline structure was analyzed and the degree of relative crystallinity was calculated by Jade 5.0 software, shown in Fig. 7 and Fig. 8. It was found that the crystalline type of starch separated from tartary and common buckwheat cultivars was a typical A-type pattern. The relative degrees of crystallinity of the tartary and common buckwheat starch were about 34.95 and 26.92% respectively.

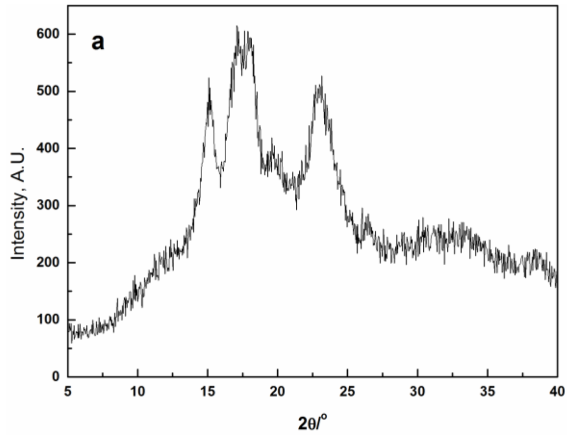

Figure 7. X-Ray diffraction patterns of tartary buckwheat starch.

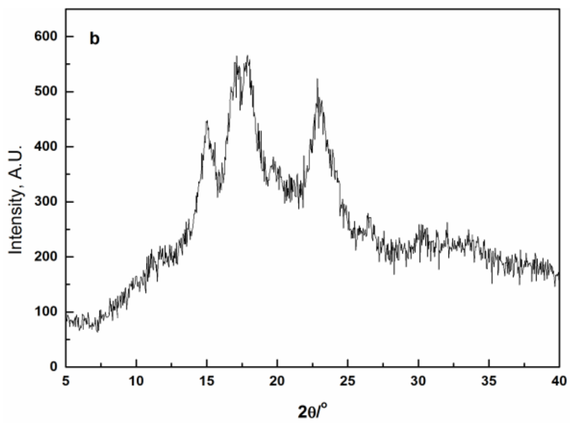

Figure 8. X-Ray diffraction patterns of common buckwheat starch.

D. Physicochemical Characteristics of Tartary and Common Buckwheat Starch

Starch swelling occurs concomitantly with loss of birefringence and precedes solubilization [10]. Swelling Power (SP) and solubility can be used to assess the extent of interaction between starch chains, within the amorphous and crystalline domains of the starch granules. For tartary buckwheat starch, the swelling power didn't change much up to 70 ℃, but dramatically increased in temperature range 75-85 ℃. Common buckwheat swelling power increased rapidly in temperature range 60-75 ℃. The two kinds of starch were similar to each other in swelling power when temperature exceeds 85 ℃ as shown in Fig. 9. Tartary buckwheat showed the highest swelling power of 3.6% at 80 ℃ and common buckwheat showed the highest swelling power of 4.7% at 60 ℃.

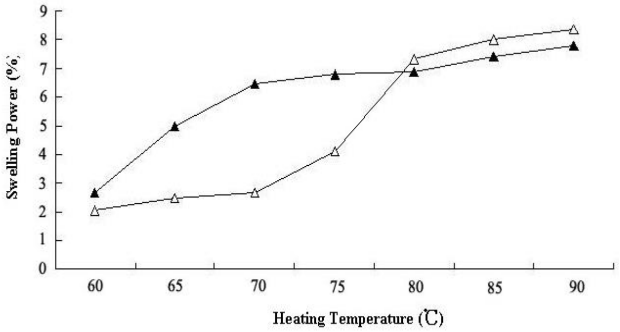

Figure 9. Changes in swelling power of buckwheat starch. tartary buckwheat starch (△), common buckwheat starch (▲).

It has been reported that the swelling power of starch is highly dependent on the granular size. When granular size of starch is similar, crystallinity of starch granule greatly influences the swelling power. Additionally, starch with high swelling power revealed weak starch granule structure (i.e. less dense structure) [11]. Although the common buckwheat starch granule showed a rapid swelling before 75 ℃ compared to the tartary buckwheat, its swelling power was lower than tartary buckwheat at 90 ℃. Solubility of common and tartary buckwheat starches ranged from 2.1% to 8.4%. Tartary buckwheat starch can be classified as two-phase swell and restricting swell.

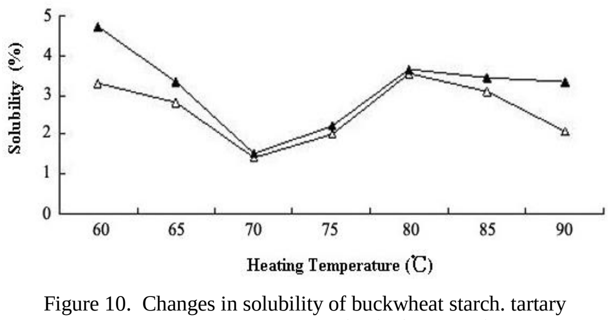

Figure 10. Changes in solubility of buckwheat starch. tartary buckwheat starch (△), common buckwheat starch (▲).

The solubility change of buckwheat starches, during heating with extra water, showed that the amount of soluble starch was excluded from granule during swelling. The solubility of common and tartary buckwheat starch revealed similar trends with increasing temperature. Both of tartary and common buckwheat had the minimum solubility at 70 ℃, and the maximum solubility at 60 ℃. During the whole process, solubility of common buckwheat starch was higher than that of tartary buckwheat. Tartary buckwheat starch showed the highest solubility of 3.6wt.% at 80 ℃, and common buckwheat showed the highest solubility of 4.7wt.% at 60 ℃ as shown in Fig. 10.

IV. Conclusion

In this paper, not only the buckwheat starch extraction rate reached 83.53%, the total starch content of 97.23%, but also the buckwheat protein and flavonoids extraction rate reached 95.43% and 98.34% respectively through use the new technology. Therefore, buckwheat is increased utilization.

The shape of starch granules separated from tartary and common buckwheat showed polyhedron. The surface of these starch granules appeared to be smooth without any fissure. The average particle diameter of starch from different tartary and common buckwheat ranged from 30 to 250μm. The crystalline type of starch separated from tartary and common buckwheat was a typical A-type pattern. The relative degrees of crystallinity of the tartary and common buckwheat starch were about 34.95 and 26.92% respectively. The gelation temperature of starch separated from tartary and common buckwheat was higher than mung bean starch and wheat starch, but lower than rice starch. The pastes of starch separated from tartary and common buckwheat are non-Newtonian fluids in the fake plastic fluid. Swelling power, pasting, and thermal properties may be affected by structural characteristics of the starch.

Acknowledgements

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