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Effects of different milling methods on physicochemical properties of common buckwheat flour

Didi Yu[a], Jincheng Chen[a], Jie Ma[a], Huaxing Sun[a], Yanqiu Yuan[a], Qian Ju[a], Yuzhao Teng[a], Mo Yang[a], Wenhao Li[a], Kaori Fujita[b], Eizo Tatsumi[b], Guangzhong Luan[a,*]

[a] College of Food Science and Engineering, Northwest A&F University, Yangling 712100, China
[b] Japan International Research Center for Agricultural Science, Ibaraki, 305–8686, Japan

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ABSTRACT

Physicochemical properties of common buckwheat flour processed using a high-speed universal grinder (UGBF), wet-milling (WMBF) and a stone mill (SMBF) were investigated and compared, since there is scarce information concerning the effect of different milling methods on physicochemical properties of common buckwheat flour. The results showed that WMBF had lower average particle size and damaged starch content than other samples. Scanning electron microscopy (SEM) observations showed that WMBF had more intact granular structures compared to UGBF and SMBF. The bulk densities of UGBF and SMBF increased as the particle size decreased, whereas WMBF exhibited a reverse trend according to bulk density analysis. Wet-milling method caused a significant lowering of the total flavonoid content. Colour measurements revealed that WMBF exhibited higher L^* value compared to other samples. Differential scanning calorimeter (DSC) analysis showed that WMBF had significantly lower T_p but higher ΔH compared to UGBF and SMBF. Rapid Visco Analyzer (RVA) measurements showed that the suspension viscosity of SMBF and WMBF was higher than UGBF. Furthermore, among different buckwheat flour, WMBF showed the highest water absorption index (WAI) value and swelling power (SP) value but the lowest water solubility index (WSI) value and water binding capacity (WBC) value.

1. Introduction

Buckwheat is a gluten-free pseudocereal belonging to the family *Polygonaceae* (Sanchez, Schuster, Burke, & Kron, 2011). The most cultivated species include common buckwheat (*Fagopyrum esculentum*) and tartary buckwheat (*Fagopyrum tataricum*). Common buckwheat is widely grown in Asia, Europe, Americas, while tartary buckwheat is most cultivated in Asia (e.g. China, India, Bhutan, and Nepal) (Bonafaccia, Marocchini, & Kreft, 2003). Common buckwheat has proved to be a good source of starch, protein, lipid, dietary fiber and minerals, and in combination with other beneficial health components, such as phenolic compounds and phytosterols, it has received increasing attention as a potential material for functional food development and production (Giménezbastida & Zieliński, 2015; Krkošková & Mrázová, 2005). Buckwheat and its flour have been utilized for enhanced processing and marketing opportunities by the food industry to manufacture products, for example alcoholic beverages, blended breads, and noodles due to their functional and organoleptic properties (Skrabanja et al., 2004; Yoshimoto et al., 2004).

The reduction of particle size is a major pre-process preparation prior to product development (Duodu et al., 2002). Grinding is the common method for particle size reduction and it has been widely used in the food industry. Buckwheat is normally ground on a stone mill or roller milled either to produce whole grain flour, or to obtain fractions/flours by combining streams (Ikeda, 2002; Skrabanja et al., 2004). In China, buckwheat flour is mainly prepared by dry-milling and wet-milling methods. Milling methods have important effects on the physical, functional properties and microstructures of cereal flour, and therefore affect the processing and quality of their products.

Up to now, many studies showed that when various cereal grains (e.g. wheat, rice, sorghum, barley and rye) were processed into cereal flours using different milling methods, milling methods might alter colours, particle size, surface areas, bulk densities, damaged starch, structures and functional properties of cereal flours, and thus lead to cereal flours with different physicochemical properties (Dayakar Rao, Mohamed Anis, Kalpana, Sunooj, Patil, & Ganesh, 2016; Drakos et al., 2017; Kadan, Bryant, & Miller, 2008; Liu et al., 2015; Protonotariou, Drakos, Evageliou, Ritzoulis, & Mandala, 2014). The difference in physicochemical property of cereal flour prepared by different milling methods is mainly due to difference in milling condition including

* Corresponding author.
E-mail address: qlgz@nwsuaf.edu.cn (G. Luan).

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mechanical forces, milling intensity and so on. Additionally, during cereal flour processing, damaged starch is a very significant and acknowledged criterion of flour quality. The changes of starch structures in damaged starch can alter starch properties including solubility, swelling, gelatinization and pasting, and thus affect the quality of flour. It was well documented that the rice flour produced by hammer milling and cryogenic milling, the damaged starch granule content was the primary determinant of the cold- and hot-water solubility of starch (Hasjim, Li, & Dhital, 2012). Wet-milled rice flour with less damaged starch had greater starch swelling on gelatinization, and several studies showed that starch damage in flour samples caused by preparation methods might decrease the gelatinization enthalpy and gelatinization temperature (Grant, 1998; Uriyapongson & Rayasduarte, 1994; Yoenyongbuddhagal & Noomhorm, 2002). The damage to starch granules has been also reported to strongly affect the RVA final viscosity of rice flour (Hasjim, Li, & Dhital, 2013).

As mentioned above, different milling methods influenced the quality of flour. And thus the milling process is an important factor in defining the quality of end products. Many researches have compared the effects of milling methods on the quality of products made from cereal flours. Dayakar Rao et al. (2016) reported that traditional milled sorghum flour had good functional properties to prepare sorghum biscuits. The addition of jet milled carob flour in rice-based gluten-free breads led to final products with quality characteristics and sensory acceptance resembling commercial breads and improved nutritional value (Kleopatra Tsatsaragkou, Theodora Kara, Christos Ritzoulis, Ioanna Mandala & Cristina M. Rosell, 2017). Ultrafine entire grain grinding process also has been shown to improve the colour of steamed bread (Liu et al., 2015). Furthermore, Yoenyongbuddhagal and Noomhorm (2002) studied the effect of raw material preparation on rice vermicelli quality and concluded that rice vermicelli made from dry-milled flour had softer texture and higher cooking losses than that made from wet-milled flour. Similar result was also observed by Heo, Lee, Shim, Yoo, and Lee (2013).

However, limited works have been published related to the influence of different milling methods on structural, physical and functional properties of common buckwheat flour. The objective of this study was to apply different milling methods including wet-milling method and dry-milling method to prepare common buckwheat flour and observe their effects on the physicochemical properties of buckwheat flour.

2. Materials and methods

2.1. Materials

Common buckwheat rice is made from common buckwheat grains via hulling and it usually can be used to prepare buckwheat flour. The common buckwheat rice, cultivar Xinong 9976, was purchased from Hongsheng Minor Crops Cooperatives, Shaanxi Province, China. Common buckwheat rice was cleaned (free from possible dust, other grains, stones, insects etc.) prior to milling. The chemical regents used were all analytical grade.

2.2. Milling of buckwheat flour

2.2.1. Milling of buckwheat flour by a high-speed universal grinder

Common buckwheat rice was ground using a high-speed universal grinder (FW-400A, Beijing Zhongxingweiye Instrument Co., Ltd, Beijing, China) for 2 min. During the milling process, the roll speed was 26000 rpm. The flour passed through a 90-mesh sieve was used as the buckwheat flour samples (UGBF). The buckwheat flour extraction rate was about 85%.

2.2.2. Preparation of buckwheat flour by wet-milling

Buckwheat rice grains (250 g) were soaked in distillated water at 20 °C for 24 h. The steeped buckwheat rice was drained and then ground using a soybean milk machine (JYL-C012, Joyoung Co., Ltd, Jinan City, Shandong Province, China) for 2 min with 500 mL distilled water. The rice slurry was manually sieved through a 90-mesh sieve. The remained fraction was ground for 1 min again and sieved. Then, the filtrated slurry was mixed and centrifuged at 3000 rpm for 10 min. After centrifugation, the sediment was dried at 50 °C for 24 h. Finally, the dried sediment was pulverized using a mill and screened through a 90-mesh sieve to obtain wet-milling buckwheat flour (WMBF). The buckwheat flour extraction rate of wet milling method was about 70%.

2.2.3. Preparation of buckwheat flour by a stone mill

The common buckwheat rice was milled by a stone mill (Xianlin Stone Mill Machinery Factory, Shandong Province, China) and sieved through a 90-mesh sieve. The roll speed of stone mill was 18 rpm, and the flour passed through a 90-mesh sieve was used as stone milling buckwheat flour (SMBF). The buckwheat flour extraction rate of stone milling method was about 90%.

All of the obtained flour samples were packed in airtight plastic bags and stored at a drug cool cabinet until further use.

2.3. Scanning electron microscopy (SEM)

The flour samples were fixed to SEM stubs with double adhesive tape and coated with gold. The micrographs of buckwheat flour samples were taken using a scanning electron microscopy (Nova Nano SEM-450, FEI, USA).

2.4. Physical properties of buckwheat flour

2.4.1. Particle-size distribution

The particle-size distribution of buckwheat flour was determined with a laser particle size analyzer (Mastersizer 2000, Malvern Instruments Ltd., UK). Water was used as dispersant, and the refractive index of the particles was 1.434.

2.4.2. Colour measurements

The colours of different buckwheat flour samples were determined using a spectrophotometer (CM-5, Konica Minolta, Co., Ltd., Japan). Each sample was individually measured in triplicate.

2.4.3. Damaged starch content and bulk density

Damaged starch content in flour samples was measured with a SDmatic (Chopin, France) which used the method of analysis based on the amperometric method (AACC, 2007). The bulk density of buckwheat flour was determined using the method reported by Kaur, Kaushal, and Sandhu (2013). Buckwheat flour was gently filled in a 10 mL graduated cylinder, and then the bottom of the graduated cylinder was tapped on a laboratory bench gently until there was no further diminution of the flour sample level after filling to the 10 mL mark. The bulk density was calculated as the weight of flour divided by flour volume (10 mL).

2.4.4. Determination of total flavonoid content

The total flavonoid content (TFC) was measured following the method reported by Tian et al. (2014) with slight modification. 1.5 g of buckwheat flour was extracted with methanol (m/v, 1:20) and then placed in ultrasonic cleaning bath at 40 kHz for 10 min at 25 °C. After centrifugation at 3500 r/min for 12 min, the supernatant was collected. The residue was re-extracted twice under the same conditions. All supernatants were combined and evaporated using a vacuum-evaporator at 45 °C. The extract was redissolved in methanol to a volume of 10 mL for the determination of total flavonoid. The total flavonoid content was determined by the aluminum nitrate colorimetry method. The final result was expressed as mg of rutin equivalents in per g of buckwheat flour.