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Comparison of pregelatinization methods on physicochemical, functional and structural properties of tartary buckwheat flour and noodle quality

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ABSTRACT

The microstructural, physicochemical, nutritional, functional and protein structural properties of buckwheat flour as affected by different pregelatinization treatment including roasting, steaming, extrusion, boiling and microwave before milling were investigated. Scanning electron microscopy studies showed that flours treated by boiling and extrusion displayed more swollen and more compacted flour particles than raw, roasted and microwave treated flours. Native buckwheat flours displayed lower values of gelatinization degree, swelling power and hydration capacity than pretreated flours, while pretreated flours were darker and more reddish than native flour. Regarding the functional ingredients, native flours have more total flavonoid, rutin and content than quercetin treated flours with the exception of steaming and extrusion. The different pregelatinization treated buckwheat flours showed a remarkably decrease in their viscosities as revealed by rapid visco analyzer (RVA). Furthermore, the primary structure of buckwheat protein did no change with different pretreatments, whereas the extrusion treatment seemed to induce a conjugation between protein molecules. The pregelatinized buckwheat flours were also observed to have potential for producing high quality and functional noodles.

1. Introduction

Buckwheat is a pseudocereal, which belongs to the Polygonaceae family, has been grown worldwide due to their strong adaptability to adverse environments. There are many buckwheat varieties distributed in different parts of the world, however, only two species are widely cultivated for human consumption: common buckwheat (or sweet buckwheat) (*Fagopyrum esculentum*) and tartary buckwheat (or bitter buckwheat) (*Fagopyrum tataricum*) (Bonafaccia et al., 2003a), depends mainly on the production zone. Buckwheat is widely cultivated in many countries, such as China, Russia, Poland, Canada, Brazil, USA, France, Germany, Italy, and some other countries (Bonafaccia et al., 2003b). Buckwheat is a rich source of starch, proteins, vitamins, dietary fibers, antioxidants and minerals (Sakac et al., 2011).

Buckwheat protein has high nutritional quality due to the well–balanced amino acid and relatively high levels of lysine and arginine, and it also acts similar function to dietary fiber through exhibiting cholesterol lowering, anti–hypertentive effects, reducing constipation and obesity (Li and Zhang, 2001; Ikeda, 2002). Buckwheat is also rich in fiber, vitamins including thiamine (VB_1), riboflavin (VB_2) and pyridoxine (VB_6) (Fabjan et al., 2003), and minerals such as Zn, Cu, Mn, Se K, Na, Ca, Mg, K, Na, Ca and Mg (Wei et al., 2003; Stibilj et al., 2004). Furthermore, it is also known for their high resistant starch content (Christa and Soral–Śmietana, 2008) and as an important source of antioxidative substances such as rutin, quercetin, hyperin, and catechins (Morishita et al., 2007). Generally, buckwheat has been used as a highly valuable supplement of food which can provide beneficial health effect and prevent food from oxidation during processing (Wronkowska et al., 2013). Therefore, buckwheat has been widely accepted as a type of functional food or food ingredient, and has been gaining popularity due to its unique nutrient component and health benefits. The food uses of buckwheat such as home–made dishes like porridge, stews, spaghetti, pilaffs,

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casseroles, pancakes, macaroni, biscuits, bread, grits (finely ground groats) or flour, and ready–to–eat breakfast cereals (Wronkowska et al., 2013). As one kind of gluten–free food or food raw materials, buckwheat flour has been simply incorporated into food formulations instead of wheat flour, or mixed with cereal flours to process related food products. Thus, buckwheat is still an underutilized crop in the food industry, compared to cereal grains (Min et al., 2010).

Increased utility of buckwheat would depend on development or application appropriate technologies to produce meal or flour with acceptable and functional properties. The physiochemical characteristic and functional properties of coarse cereals or staple grain flours can be physically modified through a variety of treatments such as fine grinding, dry and wet thermal treatments. The flour obtained after these treatments differs in their water absorption capacity, thickening power, emulsifying properties, pasting properties and chemical reactivity towards enzymes (Gómez and Martínez, 2016). Furtherly, these treatments could improve their suitability for the manufacturing of gluten–free products such as bread, cakes or cookies. Min et al. (2010) reported that the buckwheat flour has been successfully incorporated into cake formulations and the shortening could be successfully replaced with steam jet-cooked buckwheat up to 20% by weight with comparable volume and textural properties to the control.

Up to now, a wide range of physically treatments such as microwave, extrusion, autoclave steaming, roasting, toasting and infrared heating have previously been trialed to stabilize or modify the functionality of different kind of cereal flour. However, limited studies have been reported on different physically treatments on buckwheat flour functionality and processing behavior. The objective of this study was to determine changes in nutritional, functional, physicochemical and structural properties of tartary buckwheat flour properties as affected by roasting, steaming, extrusion, boiling and microwave treatment before milling. Meanwhile, the effects of different pregelatinizing ways on tartary buckwheat noodle textual and sensory quality were also investigated. This information would be useful in expanding the potential nutrition and application of buckwheat.

2. Material and methods

2.1. Materials

Commercial supplies of whole buckwheat grain (*cv.* Xinong 9940) were bought from local supermarkets in Jingbian County, Shaanxi Province, China. Grains were milled by a laboratory high–speed universal grinder (FW–400A). Different milling fractions were obtained: flour, bran and husk fraction, milling yields were: flour 46.0%, bran 23.6%, husk and impurity, 30.4%, milling losses 3.0%. The buckwheat flour was sieved through 40 mm sieve to obtain required flour from it. The obtained buckwheat flour had the following proximate composition: 10.83% moisture, 2.91% ash, 49.19% starch, 19.86% protein and 4.11% fat.

2.2. Pregelatinization treatment

2.2.1. Roasting treatment

Pan roasting was performed by placing the decorticated buckwheat grains onto the heated pan, and maintained at 130 °C for 3 h in a baking oven and stirred well during roasting.

2.2.2. Steaming treatment

Decorticated buckwheat grains were put into a circle perforated strainer (30 cm in diameter) at a depth of 0.5–1.0 cm for homogeneity in the heat steaming process and steam–treated at 100 °C for 10 min in a steamer. The steam–treated flour was left at room temperature for one hour, and then dried at 40 °C for 24 h in an oven.

2.2.3. Boiling treatment

For boiling, the ratio of grain to water was 1:5 (w/v), and the decorticated buckwheat grains were dispersed in distilled water under agitation for 1 h at 20 °C and boiled in a steamer at 100 °C for 5 min. And then, left at room temperature for one hour and dried at 40 °C for 24 h in drying oven.

2.2.4. Microwave treatment

The dehulled buckwheat grains were treated at 150 W (intermediate continuous power) in an open cylindrical glass plate (diameter 150 mm, height 75 mm) for 4 min. Samples were left into the oven for one additional minute till cooling down.

2.2.5. Extrusion treatment

The moisture of the buckwheat flour was adjusted to 21% (as determined in preliminary studies on the extruder performance) before being fed into the extruder. Extrusion runs were performed on a twin–screw extruder. The screw of the extruder was divided into 4 zones, with temperatures set at 55:70:90:110 °C (zone1: zone2: zone3: zone4). The screw speed was set at 200 r/min. The extruder barrel was fitted with a 4 mm diameter die at its exit.

2.3. Determination of total flavonoid, quercetin and rutin content

2.3.1. Preparation of flavonoid extracts

After treatment and drying the buckwheat flour, 2 g of flour sample was mixed with 40 mL of 100% of methanol. The ultrasonic extraction process was carried out by shaking the mixture with an ultrasonic frequency at 60 Hz for 10 min at room temperature (25 ± 1 °C). Then the mixture was centrifuged at 3500 rpm for 12 min, and the supernatant were collected, the procedure was repeated 3 times with 40 mL of solvent. The extracts (3 × 100 mL) were combined and dried by vacuum–evaporator. The dried extract was redissolved in 80% methanol to 25 mL volume and stored at 4 °C for further analysis.

2.3.2. Determination of total flavonoid content

Total flavonoid contents were determined using method described by Guo et al. (2012) with little modification. The total flavonoid content was calculated on the basis of a calibration curve of rutin standards (0–144 μ mol/L, $y = 13.88x+0.006$, $R^2 = 0.998$). Flavonoid content of the sample was expressed as μ mol of rutin eq./100 g DW.

2.3.3. Determination of quercetin and rutin content

The quercetin and rutin content was assayed by HPLC (SPD–M10A VP Shimadzu, LC–8A pump, Japan) using a Phenomenex C^{18} column (250 mm × 4.6 mm, 5.0 μm). The solvents for HPLC were A: methanol and B: Milli Q water adjusted with phosphoric acid to pH 3.0. The column temperature was 30 °C, and the quercetin and rutin were detected at 300 nm and separated using a linear gradient elution program. The gradient program was as follows: The initial conditions were: initial 10% B; 0–5 min, 10–45% B; 5–10 min, 45% B; 10–30 min, 65% A, 30 min 10% B. The flow rate used was set at 1.0 mL/min throughout the gradient. The final result was expressed as mg individual standards in 100 g of sample (mg/100 g DW).

2.4. Determination of color for buckwheat flour

Color value (L^*, a^* and b^*) analysis was performed using a