Original paper

Cooking Quality, Texture and Antioxidant Properties of Dried Noodles Enhanced with Tartary Buckwheat Flour

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Tartary Buckwheat dried noodles were prepared by substituting wheat flour with 0–80% content of Tartary Buckwheat flour mixtures (TBFM), which comprised extruded-micronized Tartary Buckwheat flour and micronized Tartary Buckwheat flour (1:1, w/w). Cooking properties, texture, colour, flavonoid content and antioxidant activities were investigated to evaluate the effect of Tartary Buckwheat flour content on the quality of the Tartary Buckwheat noodles. Hardness of the noodle samples increased slightly and the internal networks became more compact with content increase of TBFM. The noodles with 10–60% levels of TBFM performed similar or better cooking qualities including cooked breaking rate, cooking loss, optimal cooking time and water adsorption rate. The colour of whiteness of the noodles decreased, and the flavonoid content and antioxidant activities of ABTS and DPPH values increased significantly with the content increase of Tartary Buckwheat flour. 10–60% contents of TBFM can be used for noodle formulation with improved qualities.

Keywords: Tartary Buckwheat dried noodles, Cooking quality, Texture properties, Flavonoid, Antioxidant properties

Introduction

Buckwheat is originated in China and now widely cultivated throughout the world. Buckwheat belongs to the Polygonaceae family, and its species mainly comprise *Fagopyrum esculentum* Moench (common buckwheat or sweet buckwheat), *Fagopyrum tartaricum* (Tartary Buckwheat) and *Fagopyrum emarginatum* (Li and Zhang, 2001). Buckwheat is a good source of minerals, vitamins and fiber. Several flavonoids, such as rutin, quercetin, kaempferol, orientin/isoorientin, and vitexin/isovitexin, also have been identified in buckwheat (Choy *et al.*, 2013). Furthermore, buckwheat proteins are particularly rich in essential amino acid, such as lysine and arginine, and its amino acid content is well-balanced (Ikeda and Asami, 2000). Thus, buckwheat has beneficial health effects which may prevent the risk of high blood

pressure and the increase in cholesterol levels (Tanaka *et al.*, 2000; Kreft *et al.*, 2006; Sytar 2015).

Buckwheat has gained great attention as a food ingredient due to its nutritional excellence, and it is also utilized as an alternative crop to major cereals such as wheat and corn (Yoo *et al.*, 2012). Buckwheat food has been produced and are popular in China and other Asian countries, such as noodles, bread, etc. Because buckwheat protein is low in glutenin and prolamin, the application of high content of buckwheat flour in foods is difficult (Choy *et al.*, 2013).

As noodle is a kind of most popular staple food normally (Zhu *et al.*, 2014), many researchers have tried their best to increase the buckwheat content in noodles and improve the qualities of noodles, such as textural properties and cooking characteristics. Calcium

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Fig. 1. Procedure for producing Tartary Buckwheat dried noodles.

hydroxide and konjac glucomannan were used to reform the thermomechanical properties of buckwheat flour and textural properties of buckwheat noodles (Han *et al.*, 2012; Han *et al.*, 2014), but the dosage of these materials might be restricted as food additives. A certain amount of buckwheat flour was also incorporated to wheat flours for preparing buckwheat noodles. Hatcher *et al.* (2011) prepared soba noodles from brown tartary, green testa and common buckwheat with Canada Western Red Spring flour and Canada Prairie Spring Red flour. Buckwheat flour was also hydrothermally-treated to reduce rutin loss and improve the dough properties of buckwheat-wheat flour (Choy *et al.*, 2013). The properties of the noodles in these studies might be partially improved, however, the amount of buckwheat flour in noodles was less than 20%. Ma *et al.* (2013) prepared fresh buckwheat noodles with high nutritional quality, but the moisture of the noodles was up to 54.5% with time-critical shelf lives, and the other qualities, for example, color and cooking breaking rate, were not determined. No studies investigate the quality improvement of dried noodles which are prepared from buckwheat flour with extrusion cooking and micronization treatments, and the Tartary buckwheat flour in the noodles can be up to 80% in the this study.

Extrusion cooking can be used to physically modify the cereal-based expansible starchy and proteinaceous material. During the short-time high-temperature and continuous process of extrusion cooking, the starchy and proteinaceous material is swelled, and the physicochemical properties of the material are correspondingly changed with the altering of molecular structure of starch and proteins (Zhang *et al.*, 2014). Furthermore, bioactive compounds can be retained via controlling extrusion parameters and the protection of food structure (Hirth *et al.*, 2015; Brennan *et al.*, 2011). The micronization treatment can cause particle size reduction and uniformity, and affect a food system with the physicochemical changes due to the increase of surface area of a particle (Protonotariou *et al.*, 2014).

In the present study, the Tartary Buckwheat flour was treated by extrusion cooking and micronization, and mixed with unextruded and micronized Tartary Buckwheat flour (1:1, w/w). The Tartary buckwheat flour mixtures (TBFM) were used for substituting 0–80% wheat flour to produce noodles. The objective of this study was to prepare noodles with high contents of Tartary Buckwheat flour and good quality. Moreover, textural characteristics, morphology, cooking properties, colour, flavonoids content and antioxidant activities were employed for evaluating quality of the Tartary Buckwheat dried noodles.

Materials and Methods

Materials Tartary Buckwheat flour was provided by Xiangyuetian food company in Chifeng (inner Mongolia, China). Wheat flour and salt were purchased from a supermarket in Beijing. Standards of rutin and quercetin were obtained from Sigma Aldrich (St Louis, MO, USA). Other reagents and chemicals were analytical grade and provided by Rui Ze kang Chemical Co. (Beijing, China). Chemical composition of Tartary Buckwheat noodle samples was determined by AACC method (AACC, 2010), and expressed as dry weight basis (Table 1). AACC Methods of 44-15A, 08-01, 46-30, 76.13, 30-10, 32-10 and 32-21.01 were used to measure moisture, ash, crude protein, starch, crude fat, crude fiber and dietary fiber, respectively.

Procedure for producing Tartary Buckwheat dried noodles Tartary Buckwheat dried noodles were prepared as Fig.1. A part of Tartary Buckwheat flour was modified by using a SLG30-IV twin-screw extruder (Saibainuo Scientific Development Inc., Jinan, China) at moisture content of 17%, temperature of 170°C, and screw speed of 275 rpm/min, which exhibited higher water absorption and solubility capacity, and higher peak viscosity of pasting properties after extrusion treatment at this condition (Wang *et al.*, 2016). This was the selection basis of extrusion treatment conditions for Tartary buckwheat flour. Additionally, the screw

diameter and center distance were 30 mm and 26 mm, respectively. The ratio of length/diameter was 12.7.

The extruded buckwheat flour and non-extruded buckwheat flour were then respectively ground by a micronized jet mill at 10 MHz, and was then passed through 80 mesh screening. The treated buckwheat flour (with both extrusion cooking and micronization treatments) and the non-treated buckwheat flour (without extrusion cooking treatment, but with micronization treatment) were mixed at the ratio of 1:1 (w/w, dry basis), and the resulting Tartary Buckwheat flour mixtures (TBFM) was used for preparing noodles. In our previous studies, the content of Tartary buckwheat flour could not reach 30% for preparing noodles (Wang, 2016). The content of extruded Tartary Buckwheat flour could reach more than 50% for preparing noodles, however, the ductility of dough was worse and difficult to preparing noodles when the content of the extruded Tartary buckwheat flour was more than 30%. Thus, the mixture of extruded and un-extruded Tartary buckwheat flour was used to produce noodles. The un-extruded flour and extruded flour were mixed at ratio of 0:10, 3:7, 4:6, 5:5, 6:4, 7:3, restively. Each mixture was mixed with wheat flour at ratio of 50:50 to produce noodles. The effect of ratio on the noodle quality was studied (data not shown), and the results showed that the noodle had the best cooking quality among these noodle samples when the extruded/un-extruded Tartary buckwheat flour ratio was 5:5. Therefore, the extruded/un-extruded Tartary buckwheat flour ratio of 1:1 was adopted.

The TBFM (0–80%, dry basis) was to substitute the corresponding amount of wheat flour, and the mixed buckwheat-wheat flour (200 g) was then added with salt water to achieve water content of 32% and salt content of 0.3% in dough, stirred for 2 min and rested for 60 min at 30°C. Dough crumbs were passed through a pair of sheeting rolls to form a noodle dough sheet. The obtained dough sheet was cut into noodles at width of 2.0 mm and thickness of 1.0 mm, which was then dried to the moisture content of approximately 12% at 30°C and relative humidity of 85%. The desiccated noodles were cut into 20 cm length prior to use. The wheat flour noodles with substituting 0% TBFM were as the control sample.

Evaluation of noodle cooking quality The cooking properties of the dried noodles prepared with different content of mixture of wheat flour and TBFM are expressed as optimal cooking time, cooked breaking rate, cooking loss rate and water absorption capacity. The cooking and determination methods were described as follows.

Determination of the optimal cooking time The optimal cooking time for each buckwheat dried noodle sample was determined using AACC Method 66-50 (AACC, 2010). The noodle strands were removed from the cooking water at 10 s intervals and squeezed between two transparent glass slides. The optimal cooking time was evaluated by observing the time of disappearance of the core of the noodle strands during cooking. The

determinations for each sample were performed for three times.

Determination of the cooked breaking rate The cooked breaking rate (the ratio of the broken bar numbers after cooking to the total bar numbers of dried noodles before cooking) of buckwheat dried noodle samples was determined according to the Grain industry standard method LS/T3212-2014 in People's Republic of China (SAG, 2014). 40 bars of intact buckwheat noodle samples were placed into 500 mL of boiling distilled water until the optimal cooking time. The noodle samples were collected, and the cooked breaking rate for each sample was expressed as the ratio of the quantity of cooked breaking noodles vs. quantity of the starting material. The replicates for each measurement were carried out for three times.

Determination of the cooking loss rate and water adsorption rate Cooking loss rate (the amount of solid substance lost to cooking water) of buckwheat noodle samples was determined by AACC Method 66-50 (Li *et al.*, 2012a; AACC, 2010). A dried noodle sample (25 g) was placed into 400 mL of boiling distilled water until the optimal cooking time. Cooking water was collected, the volume was then measured in a 500 mL volumetric flask and 50 mL of the collected cooking water were taken into a pre-dried beaker (100 mL). After that, the beaker was placed into an air oven at 105°C and evaporated to dryness. The residue was weighed and the cooking loss rate was reported as a percentage of the starting material (calculated by dry basis). Simultaneously, the boiled noodle samples were removed from the cooking water and drained for 3 min, the weight was then evaluated and water sorption rate was calculated as the mass ratio after and before cooking. The determinations for both the cooking loss rate and water adsorption rate were performed for five times.

Noodle texture measurement The texture profiles of the noodle samples were determined by texture profile analysis (TPA) using a TA-XT2i texture analyzer (Stable Micro System Ltd., Godalming, UK) according to method of Li *et al.* (2012b) with modifications. The dried noodles were cooked in boiling distilled water until the optimal cooking time, and then rinsed immediately with cold water for 50 s. Five pieces of noodles were side by side placed in test board and evaluated within 5 min after cooling. Specific measurement conditions were: P/36R probe at the test speed of 0.5 mm/s, 80% compression ratio, 5.0 g triggering force, 5 s interval between the compressions. From the force-time curves of the TPA, the hardness, cohesiveness, springiness, chewiness and resilience were determined. The shearing force was measured by A/LKB-F probe on the samples prepared as previously, and the test speed was 0.17 mm/s. The speed before and after test were 1.0 mm/s and 10.0 mm/s, respectively. For these determinations, three specimens for each treatment were performed, the replicates for each measurement were carried out for four times, and the values for twelve times of measurements were averaged.

Morphology of Tartary Buckwheat noodles The morphology of the cross section in each Tartary Buckwheat noodle sample was

Table 1. Chemical composition of the dried noodles prepared with 0–80% Tartary Buckwheat flour mixtures (TBFM).

Tartary Buckwheat flour substitution	Fat (%)	Ash (%)	Protein (%)	Crude fibre (%)	Starch (%)	Dietary fibre (%)
0% (Control)	0.64±0.02b	1.83±0.03c	14.62±0.05a	0.64±0.06d	80.76±10.92ab	3.80±0.44b
10%	0.26±0.02d	1.89±0.03c	14.45±0.17b	0.82±0.02c	84.69±6.59a	4.06±0.04b
20%	0.29±0.05d	1.90±0.01c	14.32±0.11b	0.84±0.14c	82.28±6.90ab	3.94±0.44b
30%	0.35±0.03c	1.95±0.03bc	14.16±0.90c	1.28±0.00a	78.32±7.19ab	3.89±0.67b
40%	0.30±0.02d	2.13±0.03b	14.00±0.03d	1.10±0.11b	76.21±2.63ab	4.45±0.00ab
50%	0.39±0.01c	2.12±0.03b	13.72±0.04e	0.99±0.11bbc	76.47±0.76ab	5.20±0.20a
60%	0.65±0.01b	2.40±0.31a	13.62±0.09e	0.85±0.03c	75.01±2.59b	5.22±0.17a
70%	0.64±0.01b	2.37±0.03a	13.44±0.02f	1.13±0.13ab	75.98±3.59ab	5.22±0.27a
80%	0.74±0.01a	2.43±0.02a	13.17±0.12g	1.02±0.08b	75.72±2.93ab	5.21±0.19a

Data are expressed on dry weight basis and shown in mean ± standard deviation (n = 3)

Different letters in the same column following each figure indicate significant differences ($p < 0.05$)

examined using a Scanning Electron Microscope (SEM, S-300N, Hitachi, Co., Ltd., Tokyo, Japan). The dried noodles were cooked in boiling distilled water until the optimal cooking time, and then rinsed immediately with cold water for 50 s. The cooked noodles were stored at -18°C for more than 24 h, and then freeze-dried. The resulting samples were prepared by attaching onto a circular specimen stub using double-sided adhesive tape. The samples were then coated with gold, and examined under an acceleration voltage of 15 kV and a magnification of $250\times$.

Colour measurement A SP60 spectrophotometer (X-Rite, Michigan, USA) was used to determine CIE L^* (lightness), a^* (redness) and b^* (yellowness) of the noodle samples via a 8 mm aperture. The W value representing the whiteness of the noodle samples was calculated as described by Torbica *et al.* (2012) as follows:

$$W = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2}$$

Flavonoid determination in Tartary Buckwheat dried Noodles The Tartary Buckwheat dried noodles were ground and passed through 80 mesh screening, respectively. These obtained flours were used to extract the free and bound flavonoid according to Wu *et al.* (2016), which were determined according to Cho and Lee (2015) with modifications. The samples were filtered through a $0.22\text{ }\mu\text{m}$ membrane filter (Millipore, Billerica, MA, USA), and $20\text{ }\mu\text{L}$ of each sample were injected into a Waters e2695 Alliance HPLC system (Waters Co., USA) equipped with a 2489 UV detector and a Agilent Zorbox SB-C18 column ($250\times 4.6\text{ mm}$, $5\text{ }\mu\text{m}$). The mobile phase was comprised of methanol and 0.5% acetic acid (55:45, V/V). The column temperature, the flow rate and wave length were set at 30°C , 1.0 mL/min and 360 nm , respectively. Samples were quantified by comparing the retention times with the standards of rutin and quercetin.

Determination of antioxidant properties *Radical DPPH-scavenging activity.* The DPPH free radical-scavenging capacities were determined according to the method of Su *et al.* (2007). DPPH reagent (0.1 mM) was prepared by dissolving the DPPH reagent in methanol solution. Each flavonoid extract of noodle

samples was diluted with methanol to obtain records within the standard curve ranges of Trolox ($0.01\text{--}0.15\text{ }\mu\text{mol/mL}$). $600\text{ }\mu\text{L}$ of diluted flavonoid extract were homogeneously mixed with 3 mL of DPPH methanol solutions, and kept for 20 min in dark conditions. The absorbance of the reaction mixture was monitored at 517 nm using a UV-visible spectrophotometer. Trolox in methanol was used as a standard to convert the free radical-scavenging capability of the extract to the Trolox equivalent antioxidant activity. The DPPH antioxidant activity was shown as μmol Trolox equivalents (TE) vs. per 100 g of noodle samples (DW).

Radical cation ABTS $^{\cdot+}$ scavenging activity The ABTS radical scavenging capacity assay of noodle samples was performed using the method of Shen *et al.* (2009). Manganese dioxide was used to oxidize ABTS solution (5 mM) at 25°C for 30 min to prepare $\text{ABTS}^{\cdot+}$ solutions. The flavonoid extracts were diluted with methanol to obtain values within the standard curve ranges of Trolox ($0.02\text{--}0.25\text{ }\mu\text{mol/mL}$). $\text{ABTS}^{\cdot+}$ solutions (3.9 mL , absorbance of 0.700 at 734 nm) and the diluted flavonoid extract (0.1 mL) were homogeneously mixed, reacted at 25°C for 6 min. The absorbance values was immediately determined at 734 nm . The ABTS antioxidant activity was expressed as μmol Trolox equivalents (TE) vs. per 100 g of noodle samples (DW).

Statistical analysis All experiments were carried out at least three replications for each measurement. All data obtained in this study were analyzed with SPSS 16.0 for windows using one-way analyses of variance (ANOVA). Duncan's multiple-range test with a confidence interval of 95% was used to compare the means.

Results and Discussion

Proximate analysis of Tartary Buckwheat Noodles The proximate compositions of dried noodle samples with 0–80% TBFM incorporation are presented in table 1. The contents of fat, ash, protein, crude fiber, starch, and dietary fiber were $0.26\text{--}0.74\%$, $1.83\text{--}2.43\%$, $13.17\text{--}14.62\%$, $0.64\text{--}1.28\%$, $75.01\text{--}84.69\%$ and $3.80\text{--}5.22\%$, respectively. The protein and starch content decreased for the noodle samples with the content increase of TBFM,

Table 2. Cooking quality of the dried noodles prepared with 0–80% Tartary Buckwheat flour mixtures (TBFM).

Tartary Buckwheat flour substitution	Optimal cooking time (min)	Cooked breaking rate (%)	Water adsorption rate (%)	Cooking loss (%)
0% (Control)	14.50±0.17a	0.00±0.00b	156.43±2.15a	7.28±0.25e
10%	13.66±0.17b	0.00±0.00b	142.73±0.38b	7.98±0.21de
20%	11.00±0.34c	0.00±0.00b	141.61±2.75b	8.22±0.43cd
30%	9.00±0.17d	0.00±0.00b	140.37±7.08b	9.50±0.13b
40%	7.50±0.17e	0.00±0.00b	136.0±4.48b	8.11±0.35d
50%	5.66±0.17f	0.00±0.00b	135.01±2.08b	8.99±0.52bc
60%	5.33±0.00gh	0.00±0.00b	122.47±3.32c	8.37±0.66cd
70%	5.50±0.17fg	3.33±1.44b	109.95±1.06d	8.67±0.67cd
80%	5.17±0.00h	40.00±5.00a	103.26±9.14d	11.03±0.17a

Data show in mean ± standard deviation (n = 3)

Different letters in the same column following each figure indicate significant differences ($p < 0.05$)

however, the content of ash, crude fiber and dietary fiber increased with the content increase of TBFM. The content of crude fiber was 0.64–1.28%, which might contain insoluble cellulose, hemicellulose, lignin and cutin, etc. Except insoluble polysaccharides, dietary fiber contained soluble polysaccharides (Roberfroid, 1993; Plaami, 1997). Thus, the content of dietary fiber was higher than that of crude fiber (Table 1). Dietary fiber content in the noodles samples increased with the addition of TBFM, which have been shown to have enhanced health potential (Andersson *et al.*, 2008; Jha and Berrocoso, 2016).

Cooking quality analysis of Tartary Buckwheat noodles

Similar to pasta, cooking characteristics and textural properties of noodles are very important for the consumer (Chillo *et al.*, 2008). The cooking properties of the dried noodles prepared with mixture of wheat flour and TBFM (0–80%) are shown in Table 2. Compared to the control, adding TBFM significantly decreased the optimal cooking time and water absorption capacity of noodles, whereas the cooked breaking rate was only 0% and 3.3% at the TBFM content of 0–60% and 70%, respectively, and increased with 80% of TBFM. The cooking loss rate of noodles with 10–70% levels of TBFM was 7.98–9.50%, significantly lower than that of noodles with 80% levels of TBFM ($p < 0.05$). Generally, noodles or pasta products prepared from wheat flour substituted with different amount of another flour can bring negative changes to these products, as was reported for using common bean flour (Gallegos-Infante *et al.*, 2010) and banana flour (Choo and Aziz, 2010). However, in this study, adding TBFM had hardly any negative impact to noodle cooking quality, resulting in lower optimal cooking time, and effects on breaking rate and cooking loss were observed only with TBFM content of higher than 70%. These changes may be due to the pregelatinized effect of Tartary Buckwheat flour by extrusion cooking treatment, which can modify the starch structure of Tartary Buckwheat and pasting properties of flour mixtures of wheat and Tartary Buckwheat (Guha and Ali, 2002; Zhang *et al.*, 2014; Chauhan *et al.*, 2003). Therefore, the Tartary Buckwheat noodles with better cooking quality were

obtained from the mixtures of wheat flour and 10–60% levels of TBFM.

Texture properties of Tartary Buckwheat noodles The textural characteristics of the cooked Tartary Buckwheat noodle samples are listed in Table 3. The results illustrated that the addition of TBFM to the noodle formulation did not significantly affect the textural properties of cooked noodles, only hardness and chewiness of noodles prepared with 10–80% of TBFM appeared significantly higher than the control.

The SEM morphology of internal section in the noodles prepared with 0–80% TBFM are exhibited in Fig. 2. The holes of the internal section in wheat flour noodles (0% TBFM substitution) were irregular, and were larger than those of internal section in other noodles (10–80% TBFM substitution). Thus, the network of the internal section in wheat flour noodles might be looser, and the network of other noodles were more compact after 10–80% TBFM substitution. This might be formed by the contribution of extruded and pregelatinized Tartary buckwheat flour, which was different from that of the control. Martínez *et al.* (2014) also indicated that the addition of extruded flours produced doughs with a higher elastic modulus and consistency, and increased hardness of products. As well, the hardness of noodles prepared with 10–80% TBFM was higher, and water adsorption rate and optimal cooking time were lower than those of the control. These changes also might be due to the effect of extrusion-cooking treated buckwheat flour on the pasting properties of flour mixture of wheat and TBFM (Data were not shown), which showed that the peak and final viscosity decreased with the content increase of extruded Tartary Buckwheat flour. Li *et al.* (2012a) reported that most textural parameters were significantly ($p < 0.05$) correlated with the peak and final viscosity obtained in the pasting properties determined by RVA.

Colour of Tartary Buckwheat noodles Table 4 shows the L*, a*, b* and W values for the noodles with 0–80% content of TBFM before and after cooking. The whiteness of the noodles before and after cooking decreased from 73.91 to 46.29, and from 79.36 to

Table 3. Texture properties of the dried noodles prepared with 0–80% Tartary Buckwheat flour mixtures (TBFM).

Tartary Buckwheat flour substitution	TPA					Shearing force (kg)
	Hardness (kg)	Cohesiveness (kg)	Springiness	Chewiness	Resilience	
0% (Control)	5.96±0.12g	0.62±0.01ab	1.00±0.00ab	3.68±0.08e	−0.01±0.00ab	0.27±0.01bc
10%	6.42±0.07f	0.62±0.01ab	1.00±0.00a	4.00±0.07d	−0.01±0.00a	0.30±0.01a
20%	6.86±0.09e	0.62±0.01ab	1.00±0.00ab	4.28±0.01c	−0.01±0.00abc	0.28±0.02abc
30%	7.20±0.08d	0.61±0.00ab	1.00±0.00ab	4.39±0.07bc	−0.01±0.00bcd	0.29±0.01ab
40%	7.45±0.10bcd	0.63±0.02a	1.00±0.00ab	4.70±0.10a	−0.01±0.00abcd	0.28±0.01abc
50%	7.62±0.14bc	0.60±0.02abc	1.00±0.00b	4.60±0.23ab	−0.01±0.00d	0.26±0.01c
60%	8.05±0.17a	0.57±0.02c	1.00±0.00a	4.63±0.25ab	−0.01±0.00cd	0.27±0.02c
70%	7.39±0.33cd	0.59±0.04bc	1.00±0.00b	4.38±0.29bc	−0.01±0.00d	0.28±0.02bc
80%	7.78±0.46ab	0.61±0.03abc	1.00±0.00ab	4.70±0.09a	−0.01±0.00d	0.27±0.02c

Data show in mean ± standard deviation (n = 12)
Different letters in the same column following each figure indicate significant differences (*p* < 0.05)

Fig. 2. Micrographs of internal structure in the dried noodles prepared with 0–80% Tartary Buckwheat flour (TBFM).

Table 4. Colour of the dried noodles prepared with 0–80% Tartary Buckwheat flour mixtures (TBFM) before and after cooking.

Tartary Buckwheat flour substitution	Before cooking				After cooking			
	L*	a*	b*	W	L*	a*	b*	W
0% (Control)	80.46±1.13a	2.23±0.29e	17.13±0.34e	73.91±1.07a	82.54±0.73a	(-1.54)±0.13f	10.90±0.25f	79.36±0.53a
10%	65.84±1.59b	3.23±0.26d	23.92±0.71b	58.16±1.36b	70.59±0.32b	3.67±0.21d	20.92±0.30a	64.63±0.63b
20%	61.58±1.49c	3.65±0.18c	25.19±0.48a	53.90±1.09c	64.64±0.82c	4.83±0.10a	18.94±0.43b	58.75±0.72c
30%	59.85±0.72d	3.93±0.11cd	25.14±0.47a	52.47±0.51d	60.73±0.68d	4.41±0.08b	15.40±0.28d	55.54±0.85d
40%	56.46±0.64e	4.27±0.15ab	24.14±0.43b	50.03±0.69e	58.52±0.79e	4.02±0.16c	13.53±0.20e	54.14±0.63e
50%	56.10±0.86ef	4.03±0.21b	23.62±0.69bc	49.98±0.48e	56.02±0.56f	2.11±0.16e	19.53±0.72b	52.64±0.71f
60%	54.93±0.86f	3.66±0.31c	22.40±0.72d	49.54±0.87e	53.24±0.59g	4.53±0.14b	20.35±0.72a	50.57±0.61g
70%	52.05±0.87g	4.50±0.42a	22.90±1.09cd	46.67±1.21f	52.77±0.71g	4.75±0.15a	16.89±0.56c	50.64±0.86g
80%	51.61±0.48g	4.08±0.23b	22.94±0.71cd	46.29±0.68f	50.49±0.51h	3.92±0.18c	13.81±0.71e	48.51±0.55h

Data show in mean ± standard deviation (n = 3)

Different letters in the same column following each figure indicate significant differences ($p < 0.05$)

Table 5. Flavonoid Contents in free and bound forms, and DPPH and ABTS values of the dried noodles prepared with 0–80% Tartary Buckwheat flour mixtures (TBFM).

Buckwheat flour	Free (mg/100 g)	Bound (mg/100 g)	ABTS ^a		DPPH ^a	
			Free	Bound	Free	Bound
0% (Control)	4.14±0.22 ⁱ	0.20±0.01 ^g	240.07±12.38 ⁱ	78.40±7.68 ^b	27.03±1.32 ⁱ	3.54±0.30 ^d
10%	14.66±0.02 ^h	0.21±0.00 ^g	792.25±45.99 ^h	83.23±3.77 ^b	189.45±2.84 ^h	9.21±0.68 ^c
20%	24.80±0.19 ^g	0.25±0.00 ^f	2657.14±148.78 ^g	86.38±7.75 ^b	456.95±37.98 ^g	9.62±0.59 ^c
30%	51.25±0.25 ^f	0.29±0.02 ^e	3577.69±214.00 ^f	92.19±6.90 ^b	786.08±63.11 ^f	14.39±0.59 ^c
40%	77.77±0.74 ^e	0.38±0.01 ^d	4600.22±251.11 ^e	105.26±7.73 ^b	1036.87±66.99 ^e	17.65±2.70 ^{bc}
50%	106.68±0.33 ^d	0.39±0.01 ^d	5419.08±242.57 ^d	117.74±11.24 ^a	1276.43±56.35 ^d	19.03±0.69 ^{abc}
60%	128.41±1.20 ^c	0.47±0.02 ^c	5868.46±386.07 ^c	135.59±4.73 ^a	1466.17±67.96 ^c	20.27±1.83 ^{ab}
70%	160.23±0.42 ^b	0.53±0.04 ^b	6458.63±185.27 ^b	137.70±3.57 ^a	1679.19±98.61 ^b	20.42±0.84 ^{ab}
80%	176.90±0.40 ^a	0.59±0.00 ^a	6792.98±232.96 ^a	160.51±11.11 ^a	1857.35±95.68 ^a	21.09±0.89 ^a

Data are shown as mean ± standard deviation (n = 3).

Different letters in the same column following each figure indicate significant differences ($p < 0.05$).

^a μmol TE/100 g of sample (DW).

48.51 with the content increase of Tartary Buckwheat flour, respectively. This results showed that the whiteness of the noodles was significantly affected by the amount of Tartary Buckwheat flour ($p < 0.05$). Similar findings were reported by Chillo *et al.* (2008) and Choy *et al.* (2013). Tong *et al.* (2015) indicated that the contents of ash and polyphenolics were critical factors affecting the whiteness, thus the decrease of the whiteness in the noodles with content increase of Tartary Buckwheat flour might be related to the content increase of ash, dietary fiber and flavonoid (Table 1 and Table 5). Furthermore, the whiteness of the noodles before cooking was lower than that of the noodles after cooking. This may be because the loss of dietary fiber and flavonoid during cooking process of these noodle samples. The consumers normally reckon that the noodles with a darker colour associate rich in dietary fiber, thus the colour variation in the noodle samples does not penalize these noodle typologies (Chillo *et al.*, 2008).

Flavonoid compositions and antioxidant properties of Tartary Buckwheat noodles Rutin and quercetin standards were used to calculate the flavonoid compositions of Tartary Buckwheat

noodles, which were detected by HPLC (Fig. 3A). The chromatograms of free flavonoids shows excellent repeatability for all the noodle samples with 10–80% content of TBFM (Fig. 3B), but the bound flavonoids in these noodles were below the detectable limit (Figure not shown). Quercetin was the main detectable compound, and rutin was below the detectable limit as there was insignificant amount present in the noodle samples (Fig. 3B).

The flavonoid contents in the dried noodle samples with 0–80% content of TBFM are shown in Table 5. The free and bound flavonoid content increased from 4.14 to 176.90, and from 0.20 to 0.59 mg/100 g, respectively. The flavonoid contents increased significantly with the content increase of TBFM ($p < 0.05$). Choy *et al.* (2013) prepared instant noodles enhanced with 40% of common buckwheat flour, and the rutin content was approximately 40 mg/100 g. Kreft *et al.* (2006) found that the actual quantity of rutin extracted from the dry traditional form of soba noodles was 6.76 mg/100 g. In the present study, the noodles with 10–80% content of TBFM were successfully produced, and the free

Fig. 3. Chromatogram of rutin and quercetin standards (A) and chromatogram of the free flavonoid in the dried noodles with 10% Tartary Buckwheat flour (B).

flavonoid content was up to 176.90 mg/100 g, which was much higher than that of the previous studies of Choy *et al.* (2013) and Kreft *et al.* (2006).

The corresponding antioxidant activities of ABTS and DPPH values in the dried noodle samples with 0–80% content of TBFM were presented in Table 5. The ABTS values of free and bound flavonoids increased from 240.07 to 6792.98, and from 78.40 to 160.51 $\mu\text{mol TE}/100\text{ g}$ of sample (DW), respectively. The DPPH values of free and bound flavonoids increased from 27.03 to 1857.35, and from 3.54 to 21.09 $\mu\text{mol TE}/100\text{ g}$ of sample (DW), respectively. The results were consistent with the flavonoid contents in these noodle samples (Table 5). As the flavonoid contents increased with the content increase of Tartary Buckwheat flour, antioxidant activities of ABTS and DPPH values also significantly increased ($p < 0.05$). The Tartary Buckwheat noodles with higher flavonoid content and antioxidant abilities might have health benefits for people, since some researchers reported that flavonoid had antioxidative, anticarcinogenic, anti-inflammatory, antiaggregatory, and vasodilatory effects, and been linked to the prevention of various chronic diseases (Syta 2015; Ban *et al.*,

2015; He and Liu, 2008).

Conclusions

The dried noodles with 0–80% content of Tartary Buckwheat flour mixtures (TBFM) were successfully prepared, and the addition of Tartary Buckwheat flour had minimal effect on the textural attributes of noodles. The noodles prepared from wheat flour substituted by 10–60% content of TBFM exhibited similar or better cooking properties compared to the control wheat noodles. These noodles with higher content of dietary fiber exhibited lower whiteness values, which were corresponding to a brownish colour. Additionally, the flavonoid content and antioxidant activities of these dried noodles increased significantly with the increasing amount of Tartary Buckwheat flour. This indicates that these Tartary Buckwheat noodle samples have the potential to become a functional food.

Partially Tartary Buckwheat flour, which was used for making noodles in this study, was treated by extrusion cooking and micronization. It was an applicable way for producing noodles with high content of Tartary Buckwheat flour and good quality. It is beneficial for commercial production of Tartary Buckwheat dried

noodles and helpful for people's health.

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References

- AACC International (2010). *Approved Methods of Analysis, 11th Ed.*, AACC International, St. Paul, MN.
- Andersson, A.A.M., Lampi, A.M., Nyström, L., Piironen, V., Li, L., Ward, J.L., Gebruers, K., Courtin, C.M., Delcour, J.A., Boros, D., Fras, A., Dynkowska, W., Rakszegi, M., Bedö, Z., Shewry, P.R., and Åman, P. (2008). Phytochemical and dietary fiber components in barley varieties in the health grain diversity screen. *J. Agr. Food Chem.*, **56**, 9767-9776.
- Ban, C., Park, S.J., Lim, S., Choi, S.J., and Choi, Y.J. (2015). Improving flavonoid bioaccessibility using an edible oil-based lipid nanoparticle for oral delivery. *J. Agric. Food Chem.*, **63**, 5266-5272.
- Brennan, C., Brennan, M., Derbyshire, E., and Tiwari, B.K. (2011). Effects of extrusion on the polyphenols, vitamins and antioxidant activity of foods. *Trends Food Sci. Tech.*, **22**, 570-575.
- Chauhan, G.S., Sharma, P., and Bains, G.S. (2003). Effect of extrusion cooking on X-ray diffraction characteristics of rice and rice-legume blends. *Int. J. Food Prop.*, **6**, 127-133.
- Chillo, S., Laverse, J., Falcone, P.M., Protopapa, A., and Del Nobile, M.A. (2008). Influence of the addition of buckwheat flour and durum wheat bran on spaghetti quality. *J. Cereal Sci.*, **47**, 144-152.
- Cho, Y.J. and Lee, S. (2015). Extraction of rutin from Tartary buckwheat milling fractions and evaluation of its thermal stability in an instant fried noodle system. *Food Chem.*, **176**, 40-44.
- Choo, C.L. and Aziz, N.A.A. (2010). Effects of banana flour and β -glucan on the nutritional and sensory evaluation of noodles. *Food Chem.*, **119**, 34-40.
- Choy, A.L., Morrison, P.D., Hughes, J.G., Marriott, P.J., and Small, D.M. (2013). Quality and antioxidant properties of instant noodles enhanced with common buckwheat flour. *J. Cereal Sci.*, **57**, 281-287.
- Gallegos-Infante, A., Rocha-Guzman, N.E., Gonzalez-Laredo, R.F., Ochoa-Martínez, L.A., Corzo, N., Bello-Perez, L.A., Medina-Torres, L., and Peralta-Alvarez, L.E. (2010). Quality of spaghetti pasta containing Mexican common bean flour (*Phaseolus vulgaris* L.). *Food Chem.*, **119**, 1544-1549.
- Guha, M. and Ali, S.Z. (2002). Molecular degradation of starch during extrusion cooking of rice. *Int. J. Food Prop.*, **5**, 509-521.
- Han, L.H., Cheng, Y.Q., Zhang, Q., Ma, H.J., Tatsumi, E., and Li, L.T. (2014). Synergistic effects of calcium hydroxide and konjac glucomannan (KGM) on the thermomechanical properties of buckwheat flour and the quality of buckwheat noodles. *J. Texture Stud.*, **45**, 420-429.
- Han, L.H., Lu, Z.H., Hao, X.L., Cheng, Y.Q., and Li, L.T. (2012). Impact of calcium hydroxide on the textural properties of buckwheat noodles. *J. Texture Stud.*, **43**, 227-234.
- Hatcher, D.W., Bellido, G.G., Anderson, M.J., Dexter, J.E., Head, D., and Izydorczyk, M. (2011). Investigation of empirical and fundamental soba noodle texture parameters prepared with tartary, green testa and common buckwheat. *J. Texture Stud.*, **42**, 490-502.
- He, X.J. and Liu, R.H. (2008). Phytochemicals of apple peels: isolation, structure elucidation, and their antiproliferative and antioxidant activities. *J. Agr. Food Chem.*, **56**, 9905-9910.
- Hirth, M., Preiß, R., Mayer-Miebach, E., and Schuchmann, H.P. (2015). Influence of HTST extrusion cooking process parameters on the stability of anthocyanins, procyanidins and hydroxycinnamic acids as the main bioactive chokeberry polyphenols. *LWT - Food Sci. Technol.*, **62**, 511-516.
- Ikeda, K. and Asami, Y. (2000). Mechanical characteristics of buckwheat noodles. *Fagopyrum*, **17**, 67-72.
- Jha, R. and Berrococo, J.F.D. (2016). Dietary fiber and protein fermentation in the intestine of swine and their interactive effects on gut health and on the environment: A review. *Anim. Feed Sci. Technol.*, **212**, 18-26.
- Kreft, I., Fabjan, N., and Yasumoto, K. (2006). Rutin content in buckwheat (*Fagopyrum esculentum* Moench) food materials and products. *Food Chem.*, **98**, 508-512.
- Li, M., Zhang, J.H., Zhu, K.X., Peng, W., Zhang, S.K., Wang, B., Zhu, Y.J., and Zhou, H.M. (2012a). Effect of superfine green tea powder on the thermodynamic, rheological and fresh noodle making properties of wheat flour. *LWT - Food Sci. Technol.*, **46**, 23-28.
- Li, P.H., Huang, C.C., Yang, M.Y., and Wang, C.C.R. (2012b). Textural and sensory properties of salted noodles containing purple yam flour. *Food Res. Int.*, **47**, 223-228.
- Li, S. and Zhang, Q.H. (2001). Advances in the development of functional foods from buckwheat. *Crit. Rev. Food Sci.*, **41**, 451-464.
- Ma, Y.J., Guo X.D., Liu H., Xu B.N., and Wang, M. (2013). Cooking, textural, sensorial, and antioxidant properties of common and Tartary buckwheat noodles. *Food Sci. Biotechnol.*, **22**, 153-159.
- Martínez, M.M., Oliete B., Román, L., and Gómez, M. (2014). Influence of the addition of extruded flours on rice bread quality. *J. Food Quality*, **37**, 83-94.
- Plaami S P. (1997). Content of dietary fiber in foods and its physiological effects. *Food Rev. Int.*, **13**, 29-76.
- Protonotariou, S., Drakos, A., Evageliou, V., Ritzoulis, C., and Mandala, I. (2014). Sieving fractionation and jet mill micronization affect the functional properties of wheat flour. *J. Food Eng.*, **134**, 24-29.
- Roberfroid M. (1993). Dietary fiber, inulin, and oligofructose: a review comparing their physiological effects. *Crit. Rev. Food Sci.*, **33**, 103-148.
- SAG, 2014. Industrial standard of Dried Noodles (LS/T3212-2014). State Administration of Grain: Beijing, People's Republic of China.
- Shen, Y., Jin, L., Xiao, P., Lu, Y., and Bao, J. (2009). Total phenolics, flavonoids, antioxidant capacity in rice grain and their relations to grain color, size and weight. *J. Cereal Sci.*, **49**, 106-111.
- Su, L., Yin, J.J., Charles, D., Zhou, K., Moore, J., and Yu, L. (2007). Total phenolic contents, chelating capacities, and radical-scavenging properties of black peppercorn, nutmeg, rosehip, cinnamon and oregano leaf. *Food Chem.*, **100**, 990-997.
- Sytar, O. (2015). Phenolic acids in the inflorescences of different varieties

- of buckwheat and their antioxidant activity. *Journal of King Saud University-Science*, **27**, 136-142.
- Tanaka, K., Matsumoto, K., Akasawa, A., Nakajima, T., Nagasu, T., Iikura, Y., and Saito, H. (2000). Pepsin-resistant 16-kD buckwheat protein is associated with immediate hypersensitivity reaction in patients with buckwheat allergy. *Int. Arch. Allergy Immunol.*, **129**, 49-56.
- Tong, L.T., Gao, X., Lin, L., Liu, Y., Zhong, K., Liu, L., Zhou, X.R., Wang, L., and Zhou S.M. (2015). Effects of semidry flour milling on the quality attributes of rice flour and rice noodles in China. *J. Cereal Sci.*, **62**, 45-49.
- Torbica, A., HadnaCev, M., and HadnaCev, T.D. (2012). Rice and buckwheat flour characterization and its relation to cookie quality. *Food Res. Int.*, **48**, 277-283.
- Wang P. (2016). Study on the effect and mechanism of the buckwheat noodle quality by extrusion. The thesis for master's degree in Agricultural University of Hunan, China.
- Wang P., Wang L.P., Wu W.G., and Tan B. (2016). Effect of extrusion processing on the physicochemical properties of tartary buckwheat flour. *Chinese Journal of Science and Technology of Cereals, Oils and Foods*, **24**, 6-12.
- Wu, N.N., Tan, B., Li, S.S., Tian, X.H., Liu, M., Liu, Y.X., Wang, L.P., and Zhai, X.T. (2017). Cooking quality, antioxidant properties and starch digestibility of wheat noodles substituted with extruded brown rice flour. *Cereal Chem.*, **94**, 464-470.
- Yoo, J., Kim, Y., Yoo, S.H., Inglett, G.E., and Lee, S. (2012). Reduction of rutin loss in buckwheat noodles and their physicochemical characterization. *Food Chem.*, **132**, 2107-2111.
- Zhang, Y., Liu, W., Liu, C., Luo, S., Li, T., Liu, Y., Wu, D., and Zuo, Y. (2014). Retrogradation behaviour of high-amylose rice starch prepared by improved extrusion cooking technology. *Food Chem.*, **158**, 255-261.
- Zhu, K.X., Dai, X., Guo, X., Peng, W., and Zhou, H.M. (2014). Retarding effects of organic acids, hydrocolloids and microwave treatment on the discoloration of green tea fresh noodles. *LWT - Food Sci. Technol.*, **55**, 176-182.