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ORIGINAL ARTICLE

The compositional, physicochemical and functional properties of germinated mung bean flour and its addition on quality of wheat flour noodle

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Abstract Despite sprouted grains have high nutritional and functional properties, their exploration in mung bean and application in traditional foods are limited. The effects of germination of mung bean for 12, 24, 36, 48, 60 and 72 h on compositional, physicochemical and functional properties of its flour were investigated. The effects of incorporation of germinated mung bean flour at different levels (0, 10, 20 and 30%) on noodles making properties of wheat flour were evaluated 0. The protein content increased while the amylose increased initially and then decreased with increase in germination time. Water absorption index, oil binding capacity and water retention capacity increased, while water soluble index initially increased and then decreased. The germinated mung bean flour became darker with increase in germination time. The protein bound to starch in noodlesed to increase in hardness, cohesiveness, gumminess, chewiness, resilience and cooking time of noodles. Additionally, the water absorption, cooking loss, adhesiveness and springiness of raw noodles and springiness, cohesiveness and chewiness of cooked noodles decreased with the addition of germinated flour.

Keywords Germination · Mung bean · Quality · Noodle

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Introduction

Mung beans (*Vigna radiata*), known as green beans, is a kind of legume and consumes in large quantities throughout the world because of its favorable nutritional profile. It prefers warm temperature and mainly distributes in India, southern China, Thailand, Myanmar, the Philippines and other Southeast Asian countries, east Africa and the American tropics (Somta and Srinives 2007). Mung bean has high food value with 1.0–1.5% oil, 3.5–4.5% fiber, 4.5–5.5% ash and 62–65% carbohydrates and it's easy digestible protein (20–28%) serves as a major source of dietary protein for part of a nutritionally balanced diet in the vast majority of people from Asian countries (Somta and Srinives 2007). What's more, biological activities like peptide, flavonoid and tannic acid of mung bean also have potential function like strong detoxification effect, alleviating heat stress in traditional medicine, immunoregulation, anti-diabetic, antihyperglycemic and hepatoprotective (Yao et al. 2012).

Mung bean flour or starch has been successfully incorporated into a variety of products such as cookies, breads, vermicelli, noodles and snacks. However, to get better qualities, some processes such as dehulling, autoclaving, boiling, microwave and cooking are used to disposed mung beans or other beans. Recently, sprouting received more and more attention because of the very simple process, which needs less sunlight or soil and any season. Additionally, it has advantages to improve the nutritive value, physicochemical, functional properties and physiological activities of cereals and legumes through changing basic composition, antioxidant activity and phytonutrient content etc. (Ghavidel and Prakash 2006; Singh and Sharma 2017).

After sprouting, components such as protein, free amino acids, soluble carbohydrates, mineral and vitamins reportedly increased (Onimawo and Asugo 2004; Laila and Murtaza 2014; Wongsiri et al. 2015). Polysaccharides and proteins were broken down to provide energy and synthesize substrates for the early stages of seed germination, resulting in an accumulation of free amino acids and soluble carbohydrates including sucrose, glucose and myo-inositol (Laila and Murtaza 2014). Meanwhile, anti-nutritional components like trypsin, chymotrypsin inhibitors, phytic acid and tannin and other undesirable characteristics were reduced or eliminated by activating enzymes, which leaded to the nutritive value enhance (Ghavidel and Prakash 2007; Laila and Murtaza 2014; Wongsiri et al. 2015).

The physicochemical and functional properties of cereal and legume flours varied after sprouting as well. Loose bulk density and packed bulk density of maize flour decreased (Adedeji et al. 2014), the peak viscosity, trough viscosity, breakdown, final viscosity, setback and peak time of wheat decreased sharply after germination ($p < 0.05$) (Ding et al. 2018). Emulsion capacity and stability, water absorption capacity and oil absorption capacity increased significantly, whereas, foaming capacity and swelling power of maize flour decreased after sprouting (Adedeji et al. 2014), which may have different effect on swelling power, foaming, emulsifying and other properties of wheat and sorghum (Singh and Sharma 2017).

Up to now, researches on sprouting cereals and legumes such as brown rice, oat, sorghum, green gram, lentils and black gram have been performed to investigate and compare the changes in enzymatic, functional and bioactive attributes of their flours before and after germination under a fixed time. However, it failed to systematically characterize sprouting of mung bean at different time and investigated the germination process to find the variables of component, physicochemical and functional properties. Therefore, it is difficult to reveal the mechanism of germination on property changes of legume and cereal flours and match the best time and quality to the needs of products. In this study, the effects of germination at different time the components, the physicochemical and functional properties of flour from mung bean were systematically determined and compared, and the effects of addition of sprout flour on cooked quality and texture properties of noodle were studied as well. The findings may guide production of premium quality sprouts based on nutritive, physicochemical and functional quality traits, enhance the utilization of mung bean and also provide a baseline reference for fortified noodle making.

Materials and methods

Materials

Mung bean brought from Quanzhou Yun Shen Chu Developing Company in Fu Zhou Jiang Xi; wheat flour brought from Hebei Jinshahe Company; petroleum ether, anhydrous ethanol, sodium hydroxide, hydrochloric acid, potassium bromide, sulfuric acid, copper sulfate, sodium hypochlorite, etc. all of them brought from reagent company are pure.

Germination

Mung bean, which was strong at the germination potential, with the color fresh and the full grain without moth, rotten and broken germination potential was used. The mung bean seeds were rinsed with water 3–4 time to remove impurities in the basin, then, the seeds were soaked in 80 °C hot water for 5 min and added cold distilled water immediately. The mung bean was soaked at 45 °C for 4 h, then germinated at 25 °C for 0, 12, 24, 36, 48, 60 and 72 h to analysis under the conditions of temperature germination in the germination chamber (17D04256, Huasheng, China), which was set to shower water every 3 h for 5 s and removed ozone every 12 h for 20 min. After sprouting, the sample was immediately placed in drying oven at the figure of temperature, then the dry samples were milled and passed through a 80-mesh sieve, and the obtained samples were named as NMBF, SMBF-12, SMBF-24, SMBF-36, SMBF-48, SMBF-60, and SMBF-72, were stored in dryer until analysis.

Composition

Moisture, ash, protein and crude fat of samples were determined using standard methods (AACC 2000); starch and amylose content were determined by Chinese national standard methods GB 5009.9-2016 and GB/T 15683-2008.

Physiochemical properties of native and germinated mung bean flour

Color measurement

The samples were measured by CR-310 colorimeter (Konica-Minolta, Tokyo, Japan), which standardized with a standard white plate ($L_s = 94.43$, $a_s = 0.39$, $b_s = 1.80$), expressed as CIE Lab color space. Color difference ΔE by formula:

$$\Delta E = \sqrt{(L_S - L^*)^2 + (a_s - a^*)^2 + (b_s - b^*)^2} \quad (1)$$

where L^* is the brightness value; a^* is the red-green value; b^* is the yellow-blue value.

Pasting properties

The pasting characters of samples were measured by a Rapid Visco Analyzer (RVA-4500, Peter Instrument, Sweden). The samples (1.5 g, dry basis) were directly weighed into a RVA canister, followed by the addition of distilled water (25.0 mL). The plastic paddle was used to mix the slurry uniformly before the RVA run to avoid lump formation.

Functional properties of native and germinated mung bean flour

Water absorption index and water soluble index

WSI and WAI of samples were measured as Frederick et al. (2018) described with some modifies. The samples were added to centrifuge tubes that were weighted, and the solution was prepared by adding distilled water to a mass concentration of 8 g/100 mL, and the mixture was stirred continuously for 1 min to prepare suspension. Bathed in the water under the conditions of 70 °C for 30 min, cooled to room temperature and then centrifuged 3800 r/min about 20 min, then the supernatant was poured into the evaporating dish with constant quality, baked to constant quality at 105 °C, determined the content of precipitates, sediment, according to the formula WAI and WSI.

$$WAI = \frac{m_2}{m - m_1} \quad (2)$$

$$WSI = \frac{m_1}{m} \times 100\% \quad (3)$$

where WAI is the water absorption index (g/g); WSI is the water solubility index (%); m is the sample mass (g); m_1 is the dissolution mass (g); m_2 is the sediment mass (g).

Oil binding capacity and water retention capacity

The oil binding capacity (OBC) was measured according to Raghavendra et al. (2006) with a little modified. About 500 mg of sample with known dry matter content was accurately weighted for the dry sample weight (m_1) and mixed with 10 mL refined soybean oil in a centrifuge tube. It was allowed to equilibrate overnight at room temperature and then centrifuged at 10,000 g for 30 min. Then the supernatant was decanted and the residue was weighted (m_2). The WRC was calculated as: OBC = m_2/m_1.

According to Robertson et al. (2000), about 1.0 g of sample was accurately weighted for the dry sample weight (m_3). The sample was hydrated in 30.0 mL distilled water in a centrifuge tube at room temperature. After 18 h, the sample was centrifuged at 3000 g for 20 min. Then the supernatant was decanted and the residue was weighted (m_4).The WRC was calculated as: WRC = m_4/m_3.

Bulk density

The samples were placed in the 10 mL graduated cylinder and tapped the lower part of the graduated cylinder until the samples do not descend at 10 mL. Bulk density (g/mL) is expressed in unit volume sample quality.

Noodle preparation and quality evaluation

Noodle preparation

The mixed powder (48 h-SMBF occupied 0, 10%, 20% and 30%, respectively) was weighted 200 g in blender and slowly injected 40% water with 0.75% salt when it was stirring for 10 min and became a loose group of particles and then aged about 40 min at the room temperature of 25 °C; continuously compressed 6 time, and finally got thickness of 1.0 mm; the noodle was cut into a 1.0 mm thick, 3.0 mm wide and 220 mm long in the self-contained bag back to save.

Microscopy observe

The fresh noodle samples were freezing at − 80 °C and lyophilized in lyophilizer for 24 h, then the cross section was observed by a SEM stub with a double-sided adhesive tape, coated with a thin gold, then placed in the SEM chamber. Scanning electron micrographs were captured using a SEM (JSM-6360LV, Jeol, Japan).

Color measurement of noodles

A chroma meter (Konica-Minolta, Tokyo, Japan) was used to evaluate the CIE L^* (black-white), a^* (green–red), and b^* (blue-yellow) values of cooked noodle sheets. The noodles were cooked for 4 min. An average of eight readings was calculated for each measurement.

Cooking character

The noodles of 11 cm were prepared and added into the boiling water to cook with keeping the water in the state of slightly boiling. From 2 min started, noodles were sampled every half minute, took into 0 °C ice water and cooled for 2 min. Two pieces of glass were flattened to observe the internal hard white line of white bars, the best cooking time is the time when line disappeared.

Accurately, noodle samples were weighed 10 g, and added into the 500 mL boiling water with the water slightly boiling water. When arrived at the best cooking time, the noodles was picked out on the screen for 5 min and then weighed.

$$\text{Noodle water absorption}\,(\%) = \frac{(m_1 - m)}{m} \times 100\% \qquad (4)$$

where m: dry weight of noodles (g); m_1: the weight of noodles (g) after cooking.

The soup of after measuring the noodles water absorption was added into a 500 mL volumetric flask and 100 mL soup was took into the 250 mL beakers, which were constant weight, then weighted them on the electric furnace and evaporated to near dry, finally dried in the 105 °C oven to constant weight and calculated the cooking loss.

$$\text{Cooking loss}\,(\%) = \frac{5M}{G} \qquad (5)$$

where M: 100 mL soup in dry matter (g); G: sample weight (g).

Textural properties of noodles

Fresh and cooked SMBF-WF noodles were measured about textural properties included TPA, shear and stretch by a TA-XT Plus texture analyzer (Texture Technology Corp., Scarsdale, New York, US). Cooked noodles should be cooked for 4 min, fished out on the screen immediately and tapped water for 30 s, then stood for 5 min and measured. The determination of each sample measured 7 time the average.

Probe selection: P/6, A/LKD and A/SPR probe were selected to do noodle TPA, shear and stretch test, respectively.

Parameter setting: pre-test speed, test speed and post-test speed of TPA and shear were 1.00 mm/s 1.00 mm/s and 2.00 mm/s, respectively, test compression rate of TPA and shear was 75.00% and 95.00%, respectively. Wheel spacing, pre-test speed, test speed, post-test speed and test distance were 50 mm, 1.0 mm/s, 1.0 mm/s, 10 mm/s and 20.0 mm with 1 g of starting point induction, respectively.

Statistical analysis

Results were analyzed on basis of Analysis of Variance (on way SPASS 8.0), and expressed as mean value ± standard deviation. A Duncan multiple range test was used to determine significant differences data ($p < 0.05$).

Results and discussion

Composition of native and sprouting mung bean flour

The components of native and mung bean flour are shown in Table 1. It was clear that germination treatment had a significant ($p < 0.05$) effect on composition of mung bean flour with the content of protein increased and amylose increased intially and then decreased (Table 1). The content of starch decreased with increase in germination time (Table 1). Germination is a biological activation process, which triggers the enzymatic activity and activates dormant hydrolytic enzymes, resulting in breaking down of starch. Starch, as a kind of energy-supplying substance, provided energy for mung bean during germination. As a result, the content of starch decreased after germination. Additionally, endohydrolase enzymes including α-amylases, β-amylases, diphenoloxsydase, proteolytic enzymes and catalyze activated in cereal grains during germination, which enhanced the starch degradation and thus resulting the conversion of insoluble granules to soluble starch and dextrin (Singh and Sharma 2017).

Protein showed a tendency to decrease first after 24 h sprouted and then increase, which was in agreement with the study on mung bean flour of Zheng and Qu (2011). However, Wongsiri et al. (2015) found that 24 h of germination resulted in a significant increase in the protein of mung bean, which might because of the different varieties of mung bean and germination condition were used. Herein, a decrease in protein content was due to that the native mung bean was soaked for few hours before germination, where the soluble nitrogen was immersed in water and sprouting consumed part of protein to provide energy. However, the increase of it could be attributed to the respiration of mung bean during the germination process consumed most of the fat and carbohydrates, and the synthesis of new protein (Zheng and Qu 2011).

The crude fat shown in Table 1 decreased when germination time extended. The crude fat of green gram, cowpea, lentil and chickpea also decreased after 24 h sprouting compared with the raw (Ghavidel and Prakash 2007). The consumption of fat in the process of germination or the decomposition of the small molecule as a new component resulted the decrease in fat. Stored fat of pigeon pea flour was used in catabolic activities of the seeds during sprouting (Onimawo and Asugo 2004). Ash contents of non-germinated and germinated mung bean flour showed non-significant ($p < 0.05$) decreased (Table 1). Singh et al. (2017) also revealed that as time of germination increased from 12 to 48 h the values of the fat from sorghum decreased progressively sprouted at 25 °C. The

Table 1 The component, color and bulk density of mung bean flour before and after sprouting

Samples	Component (%)					Color parameters				Bulk density (g/mL)
	Starch	Amylose	Ash	Crude fat	Protein	L^*	a^*	b^*	ΔE	
NMBF	46.29 ± 1.15^{a}	0.135 ± 0.007^{cd}	5.477 ± 0.019^{a}	2.117 ± 0.019^{ab}	25.58 ± 0.21^{b}	58.10 ± 2.70^{b}	-4.930 ± 0.013^{g}	10.69 ± 0.03^{c}	94.01 ± 0.00^{bc}	0.742 ± 0.028^{a}
SMBF-12	23.39 ± 1.36^{b}	0.151 ± 0.008^{bc}	5.408 ± 0.036^{a}	2.001 ± 0.036^{abc}	25.47 ± 0.05^{b}	59.48 ± 1.37^{a}	-4.022 ± 0.027^{f}	8.43 ± 0.06^{g}	93.79 ± 0.01^{f}	0.689 ± 0.016^{b}
SMBF-24	22.66 ± 0.66^{bc}	0.173 ± 0.009^{a}	5.203 ± 0.029^{b}	2.312 ± 0.029^{a}	24.48 ± 0.25^{a}	56.11 ± 0.30^{c}	-3.651 ± 0.019^{e}	9.64 ± 0.03^{e}	93.90 ± 0.00^{d}	0.680 ± 0.002^{b}
SMBF-36	22.75 ± 3.28^{bc}	0.16 ± 0.003^{ab}	5.358 ± 0.013^{a}	1.834 ± 0.056^{bc}	25.92 ± 0.16^{b}	55.45 ± 0.03^{c}	-3.148 ± 0.010^{d}	9.40 ± 0.03^{f}	93.88 ± 0.00^{e}	0.713 ± 0.015^{ab}
SMBF-48	21.52 ± 1.85^{bc}	0.126 ± 0.003^{de}	5.373 ± 0.104^{a}	1.655 ± 0.034^{cd}	27.72 ± 0.16^{c}	53.90 ± 0.26^{d}	-2.192 ± 0.017^{c}	10.54 ± 0.08^{d}	94.00 ± 0.01^{c}	0.704 ± 0.000^{ab}
SMBF-60	19.09 ± 0.00^{c}	0.113 ± 0.004^{e}	5.385 ± 0.060^{a}	1.320 ± 0.022^{de}	27.86 ± 0.01^{c}	52.49 ± 0.38^{e}	-1.780 ± 0.031^{b}	10.81 ± 0.05^{b}	94.03 ± 0.01^{b}	0.701 ± 0.025^{ab}
SMBF-72	10.61 ± 0.61^{d}	0.075 ± 0.020^{f}	5.398 ± 0.022^{a}	0.957 ± 0.109^{e}	28.81 ± 0.38^{d}	51.60 ± 0.43^{f}	-1.414 ± 0.018^{a}	11.30 ± 0.16^{a}	94.08 ± 0.02^{a}	0.699 ± 0.009^{b}

[a]NMBF, SMBF-12, SMBF-24, SMBF-36, SMBF-48, SMBF-60 and SMBF-72 represent native mung bean flour and the flour of mung bean that sprouted for 12, 24, 36, 48, 60 and 72 h, respectively

[b]Values with different superscripts within a column are significantly different ($p < 0.05$)

decrease in ash content could be due to the rootlet and the removal of hull portion that have some amounts of minerals (Ghavidel and Prakash 2007).

Physiochemical properties of native and sprouting mung bean flour

Color analysis and bulk density

The color parameters including L^*, a^*, b^* and ΔE value of the mung bean flour from native and sprouted are list in Table 1. The color is affected by protein content, the color of testa, pigment including uranidin, brown pigment and flavonoids, etc. Sprouting time significantly affected the L^*, a^*, b^* and ΔE of mung bean powder (Table 1) with the L^* of mung bean flour decreased, whereas, the a^*, b^* and ΔE increased with the sprouting increasing.

The L^*, which represents brightness, is negatively correlated with ash content and it is affected by protein content and damaged starch content. The NMBF was brighter then sprouting mung bean flour, which was probably due to the content of ash decreased during germination. Additionally, the increased content of protein (Table 1) and destroyed starch may lead to the light down after sprouting (Ding et al. 2018). Furthermore, the harder-to-cook grains accession during sprouting might increase, which led the L* decrease (Parmar et al. 2017).

The a^* and b^* also showed a change with germination. The b* related with native pigment like uranidin, brown pigment and flavonoids, which increased after sprouting (Chandrasiri et al. 2016). The ΔE means the difference compared to standard white plate and the ΔE of mung bean flour decreased and then increased with the prolong of germination time and the turning point of 12 h germination suggested that the ΔE of 12 h sprouted mung bean flour took the smallest difference compared to standard whiteboard was. However, the difference in color index might be due to the degree of dispersion of the bean powder, the shape of the particles, etc. (Kaur and Singh 2005; Maninder et al. 2007).

Data presented in Table 1 show the bulk density of native and germination mung bean flour. Bulk density is a measure of heaviness of the flour, which is affected by surface properties of mung bean such as smooth, rough or wrinkled skin, the proportion of powder particle volume to the total powder volume as well as seed coat and fat characteristics (Ghavidel and Prakash 2006; Chinma et al. 2015). The bulk density of mung bean flour decreased after sprouting and the SMBF-72 exhibited the lowest value (Table 1), indicating its poor dispersibility, which may because the little destroy of silty, the large particle size and the high density of the flour after sprouting, and thus showed low heaviness of powders. Ghavidel and Prakash

(2006) argued that the flour with low bulk density has good dispersibility so that it can be used as a raw material for weaning and supplements.

Pasting characteristics

The pasting curves of flour from mung bean germinated for the varied duration is presented in Fig. 1 and the results are shown in Table 2. The general RVA curve shapes of mung bean flour at different sprouted time were quite similar with the trend of first increased, then reduced and to be gentle at last (Fig. 1). The pasting characteristics parameters like the peak, trough, final and setback viscosity, peat time and pasting temperature of the sprouting mung bean flour increased with the increase of germination time, while, the breakdown viscosity increased with the increase of germination time from 12 to 36 h and then decreased (Table 2). The similar trend or the pasting characteristics were also observed for 8, 24 and 36 h germinated rice flour (Ding et al. 2018).

The peak viscosity provides a measure of the thickening power of the starch (Sanz et al. 2016). The reduction in peak viscosity of sprouted mung bean flour might be due to the degradation of starch by activating endogenous enzyme like α-amylase, which converted starch into smaller molecules and reduction of swelling index of starch caused by germination (Ghumman et al. 2016a; Ding et al. 2018). The final viscosity is attributed to the content of starch and the aggregation of its molecules. Ghumman et al. (2016a) also found that the final viscosity of lentil and horsegram decreased after germination, which indicated their ability to form a viscous paste.

The breakdown viscosity is the disintegrated degree of the swollen granules during continuous heating and shearing (Singh et al. 2014), and the flour is easy to degrade with an increase in breakdown. The low breakdown of germinated flour indicated its high resistance to

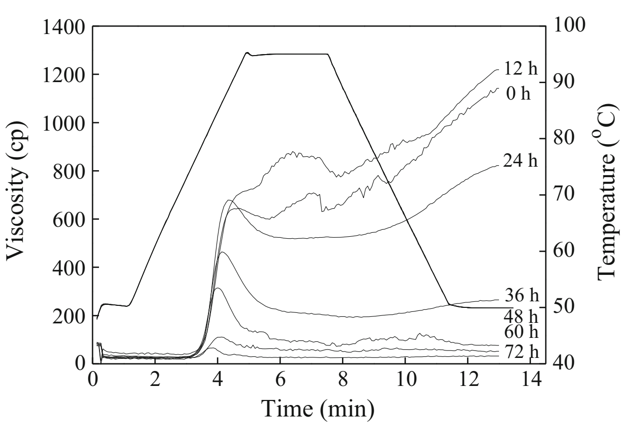

Fig. 1 Pasting properties of mung bean flour with different germination time at 0, 12, 24, 36, 48, 60 and 72 h, respectively

Table 2 Physiochemical and functional properties of mung bean flour before and after sprouting

Samples	Pasting parameters							Functional properties (g/g)			
	PV (cp)	TV (cp)	BD (cp)	FV (cp)	SB (cp)	PT (min)	GT (°C)	WAI	WSI	OAC	WRC
NMBF	703 ± 6^{b}	606 ± 34^{b}	97 ± 29^{c}	1129 ± 18^{b}	523 ± 16^{a}	6.967 ± 0.047^{a}	80.70 ± 0.05^{a}	3.736 ± 0.015^{a}	0.259 ± 0.003^{ab}	1.638 ± 0.043^{d}	2.354 ± 0.045^{d}
SMBF-12	859 ± 30^{a}	746 ± 40^{a}	113 ± 9^{c}	1201 ± 25^{a}	455 ± 14^{b}	6.500 ± 0.141^{b}	81.08 ± 0.67^{a}	4.072 ± 0.052^{ab}	0.236 ± 0.019^{a}	1.792 ± 0.061^{c}	2.479 ± 0.089^{d}
SMBF-24	674 ± 7^{c}	514 ± 6^{c}	160 ± 1^{b}	825 ± 4^{c}	311 ± 9^{c}	4.367 ± 0.047^{c}	79.93 ± 0.04^{b}	4.346 ± 0.031^{bc}	0.230 ± 0.003^{a}	1.958 ± 0.028^{a}	2.660 ± 0.027^{c}
SMBF-36	462 ± 3^{d}	198 ± 9^{d}	264 ± 11^{a}	265 ± 1^{d}	67 ± 9^{d}	4.167 ± 0.047^{d}	79.95 ± 0.00^{b}	4.388 ± 0.111^{bc}	0.229 ± 0.015^{a}	1.803 ± 0.021^{c}	2.856 ± 0.066^{b}
SMBF-48	316 ± 3^{e}	73 ± 1^{e}	243 ± 1^{a}	78 ± 3^{e}	5 ± 1^{e}	4.000 ± 0.000^{de}	79.08 ± 0.04^{c}	4.469 ± 0.057^{c}	0.239 ± 0.012^{a}	1.833 ± 0.014^{bc}	2.935 ± 0.058^{b}
SMBF-60	110 ± 2^{f}	45 ± 4^{e}	65 ± 2^{d}	50 ± 3^{ef}	5 ± 1^{e}	4.067 ± 0.094^{d}	0.00 + 0.00^{d}	4.552 ± 0.045^{c}	0.252 ± 0.005^{ab}	1.872 ± 0.010^{b}	3.170 ± 0.091^{a}
SMBF-72	66 ± 0^{g}	24 ± 0^{e}	42 ± 0^{d}	33 ± 1^{f}	9 ± 1^{e}	3.833 ± 0.047^{e}	0.00 + 0.00^{d}	4.620 ± 0.382^{c}	0.324 ± 0.074^{b}	1.953 ± 0.020^{a}	3.170 ± 0.130^{a}

[a] *PV* peak viscosity, *TV* trough viscosity, *BD* breakdown, *FV* final viscosity, *SB* setback, *PT* peak time, *GT* pasting temperature

[b] *WAI* water absorption index, *WSI* water solubility index, *OAC* oil absorption capacity, *WRC* water retention capacity

[c] All values with different superscripts within a column are significantly different ($p < 0.05$)

Table 3 The color parameters and cooking properties of noodles with wheat flour blends substituted by different proportion of sprouted mung bean flour

Content	Color parameters			Cooking properties		
	L^*	a^*	b^*	Best cooking time (min)	Water absorption rate (%)	Cooking loss (%)
0	74.61 ± 0.01^a	-2.323 ± 0.005^a	13.17 ± 0.031^a	5	77.85 ± 0.09^a	15.66 ± 0.04^c
10%	63.05 ± 0.02^b	0.901 ± 0.032^b	13.51 ± 0.028^b	5.5	69.42 ± 0.01^a	17.41 ± 0.03^{bc}
20%	57.17 ± 0.02^c	1.373 ± 0.024^c	18.25 ± 0.011^c	5.5	64.81 ± 0.06^a	22.10 ± 0.02^b
30%	53.40 ± 0.02^d	2.057 ± 0.008^d	18.30 ± 0.013^d	6	67.38 ± 0.02^a	29.92 ± 0.02^a

[a]0, 10%, 20% and 30% represent the noodles with wheat flour blends substituted by 0, 10%, 20% and 30% sprouted mung bean flour

[b]Values with different superscripts within a column are significantly different ($p < 0.05$)

degrade and great thermal stability. The setback of germination mung bean flour ranged from 5 to 455 cp (Table 3), which might be attributed to extensive degradation of starch (Ghumman et al. 2016a). Additionally, the lower setback after sprouting indicated the stronger the ability of the raw material processing glued and the lower degree of product aging. The flour is easy to aging, when setback is large. As a result, the flour is hard to aging after sprouting. The pasting temperature of flour decreased ranged from 81.08 to 79.08 °C after germination. The lower the passing temperature was, the easier the starch collapsed, swelled and gelatinized, the stronger the swelling and water absorption of simple after (Kumar et al. 2018). Sprouting destroyed and consumed the starch and thus the degraded starch resulted in a low tendency of aggregation of the gelatinized starch molecules during cooling and the final viscosity became lower with the sprouted time prolong. Additionally, the content of protein and fat influenced the pasting characteristics by effecting with starch.

Functional properties of native and germinated mung bean flour

The results of water absorption index (WAI) and water solubility index (WSI) of native and germinated mung bean flour are showed on Table 2. The WAI of NMBF was the lowest (373.6%) and it increased with the germination time extended from 12 h to 72 h (Table 2). The WAI is related to the macromolecular starch, protein and cellulose, the higher the WAI of the flour is, the better the hydrophilicity and the ability of gelatinization of the macromolecule are. An increase in WAI might be due to protein denaturation caused by heating, starch granule destruction and gelatinization and crude fiber water swelling (Milán-Carrillo et al. 2000), and Ghumman et al. (2016b) thought that proteins restrict starch swelling. Therefore, the hydrolysis and re-synthesis of starch and protein during sprouting may cause the WAI increased in this study.

With the increase of germination time, the WSI decreased first and then increased (Table 2). The WSI is related to the content of soluble matter in flour and its solubility, the higher the soluble substance content is, the better the solubility is, the higher the WSI is. In the study, protein that includes soluble protein with a tendency to increase first and then decrease (Table 1) influenced the WSI. Additionally, a higher water absorption, which may be related to the larger contact surface of the particles, provided greater exposure of hydroxyl groups (Adedeji et al. 2014).

Oil absorption capacity (OAC) that obtained from mung bean flour was significantly influenced by sprouting ($p < 0.05$), it showed the lowest (163.8%) in NMBF and increased after sprouting and became higher with extending germination time. Earlier studies also showed that the OAC of sorghum and brown rice flour increased as the germination time progressed (Chinma et al. 2015). The denaturation of protein molecule after sprouting resulted in higher surface availability of lipophilic proteins and these hydrophobic amino acids then with binds the hydrocarbon side chains of oil and led to enhancement the OAC (Elkhalifa and Bernhardt 2010). The flour with high OAC, which is important for nutrient and energy density in foods, can be used in food formulation where high OAC is essential, especially for infant feeding and young children as high lipid content it is important for nutrient and energy density in foods (Singh and Sharma 2017).

The water retention capacity (WRC) is defined as the amount of water that remains bound to the hydrated fibre after the application of a specific external force like centrifugation. Germination time had significantly ($p < 0.05$) affected the WRC of mung bean flour and the WRC enhanced with sprouted time prolong. Sattar et al. (2017) also found that the WAC of 24 h sprouted green gram, lentils and black gram flour increased compared with non-germination. An increase in WAC by germination could be attributed to the breakdown of polysaccharide and an increase in protein content, which probably increased the sites for interaction of water molecules (Elkhalifa and Bernhardt 2010).

Analysis of noodle qualities

Color of noodles

There are significant differences among the L^*, a^*, b^* of the noodles by adding different addition (0, 10%, 20% and 30%) of SMBF-48 into wheat flour and the L^* decreased but the a^* and b^* increased with the increase of sprouting mung bean flour substitution (Table 3). That meant, the more SMBF-48 added in, the darker noodles exhibited, which might be due to that the protein content and destroyed starch in noodles increased by the SMBF-48 substitution progressed. Additionally, the color of noodles changed from red to green and changed from yellow to blue on account of the decreased of the content of yellow pigment. Similar findings were reported by Choy et al. (2013), where the L* values for pea flour containing noodles decreased significantly as compared with control samples.

Micro structure of noodles

Noodles that added the germination mung bean flour show a phenomenon of gathering into groups, what's more, the phenomenon become more and more obvious with the addition of germination mung bean flour (Fig. 2b–d), whereas, a continuous spider web could be seen in whole wheat flour noodles (Fig. 2a). Dexter et al. (1979) showed that the starch granules on the surface of the noodles were severely deformed because of gelatinization and mixed together. By increasing substitution of germination mung bean flour, the content of protein and small molecule polysaccharides increased. Additionally, the content of starch decreased lead low gelatinization and shape changed, there was no fusion effect between each other and the outline of starch granules was clearly visible finally. It could be concluded that with the increase of the content of sprouting mung bean flour, the interaction between protein and starch in the noodles increased and the binding became closer.

Cooking character of noodles

The results of cooking quality parameters including cooking time, cooking loss and water absorption of noodles incorporated different proportion of germinated mung bean flour are shown in Table 3. In comparison with noodles made with only wheat flour, the incorporation of increasing levels of germination mung bean flour revealed longer cooking time (the disappearance of white core) (Table 3). It might be due to that the increase of addition of germination mung bean flour increased the content of protein and degraded starch, which competed with water, weakened combination with water and made the dough water absorption decreased. The water absorption showed significant negative correlation with protein content, which increased after adding more germination mung bean flour (Lu and Lin 2011).

The best cooking time increased with an increase in additive amount of SMBF-48 (Table 3). The high cooking time of 30% SMBF-48 might be due to a low rate of water absorption. Additionally, an increase in amylose content of the mixed powder leaded the gelatinization temperature of the mixed powder increased, as a result, the cooking time of the noodle was prolonged. The increased germination flour leaded to an increase in protein content and intermolecular force, which in turn leaded to an extension of the best cooking time.

Cooking loss of noodle increased with the increasing addition of SMBF-48 (Table 3). In the noodle cooking process, amylose, soluble saccharides and soluble protein would dissolve into the water, so cooking water became cloudy and thick (Lin et al. 2010). The increasing sprouting mung bean enhanced the content of soluble protein and small molecule sugar, which may outflow after cooking,

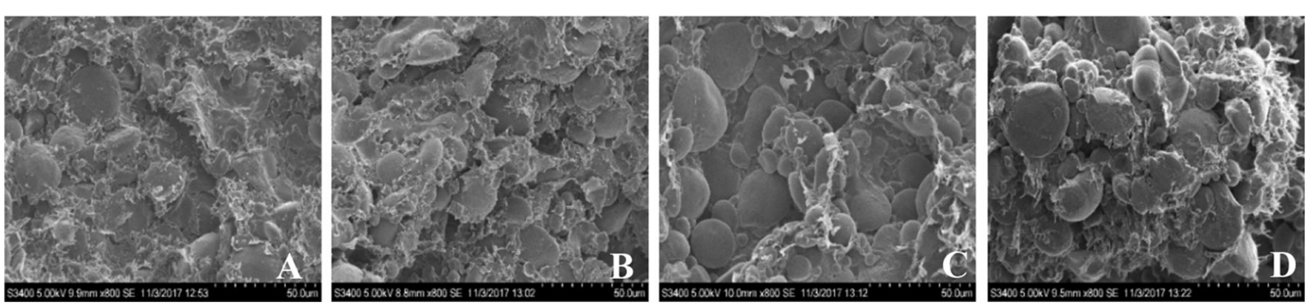

Fig. 2 Scanning electron micrographs (SEM) (× 800) of wheat flour noodles prepared with addition of 0% (**a**), 10% (**b**), 20% (**c**) and 30% (**d**) sprouting mung bean flour, respectively

Table 4 Textural properties of fresh and cooked noodles with wheat flour blends substituted by different proportion of sprouted mung bean flour

Samples	TPA							Shear		Stretch	
	Hardness (g)	Adhesiveness (g s)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience	Firmness (g)	WS (g.cm)	RE (g)	Extensibility (mm)
Fresh											
0	1630 ± 151^{b}	− 2.965 ± 1.253^{a}	0.347 ± 0.129^{a}	0.230 ± 0.012^{bc}	375 ± 75^{b}	133 ± 73^{ab}	0.243 ± 0.032^{a}	947 ± 96^{c}	56.90 ± 12.69^{c}	16.33 ± 2.13^{b}	− 6.367 ± 1.458^{b}
10%	1597 ± 146^{ab}	− 2.967 ± 0.536^{ab}	0.225 ± 0.021^{ab}	0.215 ± 0.028^{ab}	350 ± 112^{ab}	81 ± 33^{ab}	0.231 ± 0.039^{a}	1133 ± 78^{b}	78.76 ± 8.20^{b}	21.30 ± 3.15^{a}	− 5.716 ± 1.456^{b}
20%	1887 ± 181^{b}	− 5.699 ± 2.005^{a}	0.297 ± 0.030^{b}	0.258 ± 0.031^{c}	493 ± 127^{b}	148 ± 48^{b}	0.256 ± 0.033^{a}	1181 ± 56^{b}	87.67 ± 7.54^{b}	13.52 ± 2.90^{c}	− 2.781 ± 0.683^{a}
30%	2088 ± 209^{a}	− 8.754 ± 2.362^{b}	0.345 ± 0.068^{a}	0.283 ± 0.023^{a}	596 ± 139^{a}	211 ± 84^{a}	0.267 ± 0.023^{a}	1373 ± 106^{a}	111.8 ± 17.27^{a}	11.22 ± 0.97^{c}	− 2.11 ± 0.308^{a}
Cooked											
0	236 ± 20^{a}	− 7.340 ± 2.253^{ab}	0.993 ± 0.031^{a}	0.403 ± 0.023^{a}	95 ± 14^{a}	94 ± 12^{a}	0.180 ± 0.019^{a}	210 ± 14^{a}	35.57 ± 2.12^{a}	31.22 ± 4.56^{a}	− 8.523 ± 0.936^{c}
10%	201 ± 16^{ab}	− 8.046 ± 2.729^{b}	0.860 ± 0.118^{b}	0.282 ± 0.048^{b}	58 ± 22^{b}	51 ± 23^{b}	0.116 ± 0.012^{b}	201 ± 16^{a}	31.36 ± 2.16^{b}	16.59 ± 4.28^{b}	− 4.146 ± 1.613^{b}
20%	178 ± 21^{b}	− 4.514 ± 1.489^{a}	0.818 ± 0.142^{bc}	0.315 ± 0.039^{b}	57 ± 19^{b}	48 ± 22^{b}	0.102 ± 0.012^{b}	126 ± 21^{b}	21.55 ± 4.00^{c}	15.14 ± 4.76^{b}	− 3.176 ± 1.420^{b}
30%	243 ± 20^{a}	− 4.334 ± 1.173^{a}	0.713 ± 0.061^{c}	0.224 ± 0.008^{c}	54 ± 5^{b}	39 ± 6^{b}	0.075 ± 0.005^{c}	132 ± 15^{b}	18.39 ± 3.84^{c}	11.79 ± 4.57^{b}	− 1.653 ± 1.003^{a}

[a] 0, 10%, 20% and 30% represent the noodles of different addition of sprouting mung bean flour about 0, 10%, 20%, 30% into wheat flour

[b] WS and RE represent work of shear and resistance to extension, respectively

[c] Values with different superscripts within a column are significantly different ($p < 0.05$)

and as a result, cooking loss rate increased. Cooking loss rate showed a very significant negative correlation with protein content, which increased after adding more germination mung bean flour (Lu and Lin 2011).

Textural properties of fresh and cooked noodles

The effects of SMBF-48 substitution (0, 10%, 20% and 30%) on textural properties of fresh and cooked noodles are shown in Table 4. The TPA parameters of raw noodles including hardness, cohesiveness, gumminess, chewiness and resilience risen with the increasing of the addition of germination mung bean flour, whereas the adhesiveness and springiness of it decreased after adding germination mung bean flour (Table 4). Hardness, springiness, adhesiveness and chewiness were significantly and positively correlated with the protein content (Lu and Lin 2011). As a result, an increase in hardness, springiness, adhesiveness and chewiness of fresh noodles might be due to the increase of protein by rising germination mung bean flour (Table 1). The dough's gluten network structure could be strengthened by the cooperation among wheat flour protein and germination mung bean flour protein throng weak forces including H bonds and van der Waals interactions and other electrostatic interactions such as covalent bonds (Li et al. 2017). Whereas, a decrease in springiness, adhesiveness and chewiness of cooked noodles might because the denaturation of protein after cooking. The rising cooking loss (Table 3) in noodles indicated that the soluble protein lost and deformed, resulting in some changes in the texture of noodles.

Additionally, firmness, work of shear and extensibility significantly enhanced after adding SMBF-48, but resistance to extension reduced with addition enhanced (Table 4). Nevertheless, the boiling noodles did not show the same trend like raw noodles. It could been seen that the firmness, work of shear and resistance to extension decreased but extensibility decreased after cooking. Noodle has been found to be directly related to flour protein content, which specially impact stickiness and adhesiveness (Choy et al. 2013). Lu and Lin (2011) had shown that within a certain range, the breaking strength and stretching distance of cooked noodles and flour in the protein content was extremely significant positive correlation. The texture tester quantitatively measures the softness of the noodles, which helps to objectively evaluate the apparent state of the noodles, palatability and total score. What's more, the hardness and fracture energy measured by the texture analyzer could be used as the main representative indicators to reflect the viscoelastic and gluten properties of the noodles.

Conclusion

The germination had a significant impact on components, physiochemical and functional properties of mung bean flour. The content of protein and function properties like water absorption index, water solubility index, oil absorption capacity and water retention capacity improved, but the content of fat and ash as well as the pasting viscosity decreased with the increase of germination time. Moreover, the improved nutrition and functional properties of germination mung bean flour was successfully used to produce noodles. The addition of germinated mung bean flour at different levels into wheat flour had a significant effect on the functional properties and textural characteristics of cooked and uncooked noodles.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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