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EFFECT OF TRANSGLUTAMINASE ON QUALITY ATTRIBUTES OF NOODLE ENRICHED WITH GERMINATED MUNG BEAN FLOUR

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ABSTRACT
Germination is an effective process improving nutritional status of cereal and legume. This study evaluates the effect of germinated mung bean flour (GMF) (0-20%) on physical, chemical properties and cooking quality of egg noodles, as well as the impact of transglutaminase (TGase) on the physical properties and cooking quality of GMF noodles. Compared to raw mung bean flour, GMF showed higher total phenolic content, antioxidant activity, total-extractable ash, Ca, Fe, K, P and Zn content with lower phytic acid. As the GMF ratio increased, cooking loss values also increased. TGase developed cooking quality with decreasing cooking loss and improving firmness. Noodles made with 20% of GMF revealed the highest total ash, HCl-extractable ash, protein, phytic acid, antioxidant activity and total phenolic content. This study shows the potential of GMF (up to 15%) and TGase to produce noodles with high nutritive value and good consumer acceptability.
Keywords: Phytic acid, mung bean, transglutaminase, germination, mineral bioavailability

TRANSGLUTAMİNAZIN ÇİMLENDİRİLMİŞ MAŞ FASULYESİ UNU İLE ZENGİNLEŞTİRİLMİŞ ERİŞTENİN KALİTE ÖZELLİKLERİ ÜZERİNE ETKİSİ

ÖZ
Çimlendirme, tahıl ve baklagillerin besinsel değerini geliştiren etkili bir prosestir. Bu çalışmada, çimlendirilmiş maş fasulyesi ununun (ÇMU) (%0-20) yumurtalı eriştenin fiziksel ve kimyasal özellikleri ile pişme kalitesi üzerine etkisi ile birlikte, transglutaminazın (TG) ÇMU eriştelerinin fiziksel özellikleri ve pişme kalitesi üzerindeki etkisi değerlendirilmiştir. Ham maş fasulyesi unu ile karşılaştırıldığında, ÇMU düşük fitik asit ile daha yüksek toplam fenolik madde, antioksidan aktivite, toplam-ekstrakte edilebilir kül, Ca, Fe, K, P ve Zn içeriği göstermiştir. ÇMU oranı arttıkça, pişme kaybı değerleri de artmıştır. TG, pişme kaybını azaltıp sıkılığı artırarak pişme kalitesini geliştirmiştir. %20 ÇMU ile yapılan eriştede en yüksek toplam kül, HCl'de ekstrakte edilebilir kül, protein, fitik asit, antioksidan aktivite ve toplam fenolik madde miktarı belirlenmiştir. Bu çalışma, besin değeri yüksek ve tüketiciler tarafından kabul edilebilir erişte üretiminde ÇMU (%15'e kadar) ve TG'nin kullanım potansiyelini ortaya koymuştur.
Anahtar kelimeler: Fitik asit, maş fasulyesi, transglutaminaz, çimlendirme, mineral biyoyararlılığı

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INTRODUCTION

Mung bean (*Vigna radiate* L.) is a legume that is also called as green gram. It has been cultivated in worldwide (especially in Asia) for nearly 3500 years (Shi et al., 2016). In India, Thailand, China, Philippines, Bangladesh and Western countries, mung bean is commonly consumed as a food with a high nutritional value (Tang et al., 2014). The seed contains high levels of protein, carbohydrate, dietary fiber, phytochemicals, vitamins and minerals, with a low fat content. Moreover, the potential antioxidant, antimicrobial, anti-inflammatory and antitumor properties of mung bean are attribute to its polyphenols (Ganesan and Xu, 2018). On the other hand, mung bean includes antinutrients such as phytic acid, trypsin inhibitors, tannins and hemagglutinin (Lin and Li, 1997), which lead researchers to investigate methods that reduce the effect of such antinutrients in cereals and legumes. One of the most simple, inexpensive and effective methods that are used for this purpose is germination (Swieca and Gawlik-Dziki, 2015). While this method results in a decrease in the levels of starch, reducing sugars, indigestible oligosaccharides and antinutrients (phytic acid, tannins, etc.), it increases the enzyme activity, phytochemical content, antioxidant activity, mineral bioavailability, protein digestibility, free amino acids and vitamin C content of mung bean (Mubarak, 2005; Guo et al., 2012; Tang et al., 2014). Germinated mung bean has been reported to be used in different studies to produce end-products (bread, biscuit, weaning foods, etc.) with improved nutritional and functional properties (Imtiaz et al., 2011; Menon et al., 2015; Wijeratne et al., 2012).

Noodles are one of the wheat-based products that are widely consumed worldwide by all age groups. The main ingredients of noodles are refined wheat flour and water in many countries. Due to the milling process, refined wheat flour is poor in terms of essential nutrients such as dietary fiber, vitamins and minerals. Therefore, many researchers have investigated the effects of different cereals and legumes to improve the nutritional quality of noodles (Khetarpaul and Goyal, 2007; Pakhare et al., 2017). However, it has been reported that the use of high levels of cereals and legumes may cause losses on some technological and sensory quality of noodles due to the diluted gluten content (Ha and Park, 2011).

Transglutaminase (TGase) is an enzyme catalyzes the acyl-transfer reaction between lysine and glutamine residues of proteins, thereby forming covalent cross-links (Bauer et al., 2003). In general, TGase enzyme is used to improve cooking quality, physical, textural and sensory properties in noodles and pasta products. Many studies showed that legume proteins such as soy (Yeoh et al., 2014), pea (Takacs et al., 2007) and bean (Elobeid et al., 2014) are good substrates for the TGase reaction in noodle making. Bilgiçli and İbanoğlu (2015) found that addition of TGase enzyme remarkably decreased the cooking loss of noodle containing lupin flour or lupin bran. In addition, Sissons et al. (2010) revealed positive impacts on dough strength, firmness and stickiness of fiber-enriched spaghetti with addition of 0.5% of TGase. To the best of our knowledge, three studies (Slathia et al., 2016; Slathia et al., 2018; Liu et al., 2018) used germinated mung bean flour (GMF) in noodle formulation so far. This is one of the first reports to show the effect of TGase on the physical and sensory properties and cooking quality of germinated (96 h) mung bean noodles. In the present study, it is believed that TGase may improve the technological quality of noodles deteriorated due to diluted gluten content by the addition of GMF.

This study aimed to enrich the nutritional value of egg noodles with different ratios of GMF and evaluated the effect of TGase enzyme on the physical properties and cooking quality of noodles.

MATERIALS AND METHODS

Materials

Commercial wheat flour (0.64% ash and 10.58% protein, Hekimoğlu, Konya, Turkey), mung bean (*Vigna radiate* L.) seeds (Yayla, Mersin, Turkey), chicken egg (Keskinoğlu, Manisa, Turkey) and salt (Salina, Konya, Turkey) were purchased from a local market in Konya, Turkey. Microbial TGase (activity 100 U/g) was supplied from SternEnzym, Ahrensburg, Germany.

Methods

Germination of Mung Bean Seeds

Mung bean seeds were steeped in ethanol for one minute. Then, the seeds were soaked in distilled water (1:10, w/v) at 25 ± 2 °C for 12 h. The soaked seeds were placed between layers of cotton to allow germination for 96 h at 25 ± 2 °C in a dark place. Afterward, the germinated seeds were frozen for 12 h to stop the germination process. The frozen seeds were thawed at 25 ± 2 °C and dried in an oven (Nüve FN-500, Ankara, Turkey) at 50 °C for 20 h (Mubarak, 2005). The germinated mung bean seeds were ground using a laboratory mill (Sinbo SCM 2934, İstanbul, Turkey).

Noodle Preparation

Control noodle (without GMF) was prepared with 1000 g of refined wheat flour, 200 g of whole egg, 10 g of salt and distilled water. All ingredients were kneaded with water obtaining a homogeneous dough in the mixer (Hobart N50, Ontario, Canada) at the minimum speed (level 1). Following this, the dough was allowed to rest at 25 ± 2 °C for 20 min. At the end of the resting time, the dough pieces were sheeted and cut into long strips via a laboratory noodle machine (Shule, Jiangsu, China). Fresh noodles were cut into 0.6 x 4 cm (width x length) and were dried at 55 °C for 20 h in the drying oven (Bilgiçli, 2009). GMF noodles were prepared by replacing wheat flour with GMF at 5, 10, 15 and 20% ratios. TGase (0.5%) was added into the formulations to improve the physical properties and cooking quality of noodles which was decreased upon addition of GMF. The procedure employed is the same as the procedure applied for the control noodle production.

Chemical Analysis

AACC methods were used to determine the moisture (method 44-19), ash (method 08-01), fat (method 30-25) and protein (method 46-12) content of wheat flour, raw mung bean flour (RMF), GMF and noodle samples (AACC, 1990). The phytic acid content of samples was measured by a colorimetric method (Haug and Lantzsch, 1983). Phytic acid in the sample was extracted with 0.2 N HCl and precipitated with a solution of ammonium iron (III) sulfate. 0.5 ml of extract and 1 ml of a solution of ammonium iron (III) sulfate was pipetted out into a test tube. The test tubes were kept in the boiling water bath for 30 min following an ice bath for 15 min. Later 2 ml of 2,2'-bipyridine solution was put into the test tube. The absorbance (Abs) was measured at 519 nm by a UV/Visible spectrophotometer (Biochrom Libra S22, Cambridge, UK).

Antioxidant activity was analyzed by a free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Gyamfi et al., 1999; Beta et al., 2005). Sample (4 g) was extracted with 10 ml solvent (methanol:distilled water:HCl, 80:10:1, v:v:v) for 2 h. After this, the extracts were centrifuged at 3000 rpm for 10 min. The extract (0.1 ml) was reacted with 0.9 ml of 0.05 M Tris-HCl buffer at pH 7.4 and 2 ml of DPPH solution. Blank was prepared using 0.9 ml of Tris-HCl buffer and 2 ml of DPPH solution. The mixture was incubated at room temperature for 30 min and the Abs read at 517 nm against the blank. Percentage of inhibition was calculated as:

$$\text{Inhibition } \% = [(Abs_{blank} - Abs_{sample}) / Abs_{blank}] \times 100$$

Total phenolic content of samples was determined spectrophotometrically using Folin-Ciocalteu's reagent (Beta et al., 2005; Gao et al., 2002). The results were expressed as milligrams of gallic acid equivalents per gram (mg GAE/g) on dry weight basis using the calibration curve of gallic acid. The Abs was measured at 760 nm by the spectrophotometer.

Mineral content of the raw materials and noodles were determined by inductively coupled plasma atomic emission spectrometer (ICP-AES) (Varian, Vista Model, Zug, Switzerland) (Skujins, 1998). HCl-extractable mineral and HCl-extractable ash content in the samples were determined according to the method applied by Kumari et al. (2015). Briefly, for analysis, 1 g of sample was extracted with 50 ml of 0.03 N HCl in a shaker (Daihan WSB-30, Gangwon, South Korea) at 37 °C for 3 h. The mixture was filtered through an ashless filter paper. The filter paper and solid residue were analyzed according to AACC Method 08-01 for HCl-extractable ash content of samples (AACC, 1990). The clear filtrate was dried in the drying oven at 100 °C and digested in diacid mixture. HCl-extractable minerals were determined as described above.

Color

The color parameters (L^*, a^* and b^*) of the raw materials and noodle samples were measured using a colorimeter (Konica Minolta CR 400, Osaka, Japan). The instrument was calibrated with a white reference tile prior to the measurements. The color measurements were replicated three times for each sample.

Cooking Quality

The weight increase and volume increase parameters of noodle samples were determined according to the method employed by Özkaya et al. (2001). The weight increase was obtained by measuring the differences between weight values of dry and cooked noodles. The volume increase values of the dry and cooked samples were measured by the volume difference of water overflow when the samples were put into the water full graduated cylinders. The cooking loss was determined by the Approved Method 66-50 (AACC, 2010).

Firmness

The firmness of cooked noodles was measured using a texture analyzer (Stable Micro Systems TA-XT.Plus, Surrey, UK) with an A/LKB-F probe according to AACC Method 16-50.01 (AACC, 2010). The maximum compression force of the noodle was defined as firmness.

Sensory Analysis

The sensory evaluation of cooked noodles was carried out by 25 healthy and nonsmoker panelists aged from 20 to 45 years. Before sensory evaluation, noodle samples (1000 g) were cooked in 3000 ml distilled water for 18 min. At the end of this period, noodles were drained and served to the panelists. Taste, odor, appearance, mouthfeel and overall acceptability parameters of samples were evaluated using a 9-point hedonic scale (1: dislike extremely, 5: neither like nor dislike, 9: like extremely).

Statistical Analysis

All analyses were the average of triplicate measurements on the duplicate samples, and the results were expressed as mean ± standard deviation. Statistical analysis was conducted using JMP (SAS Institute Inc., Cary, NC, USA) software.

RESULTS AND DISCUSSION

The chemical properties and color values of wheat flour, RMF and GMF are presented in Table 1. The moisture content of wheat flour was higher than those of RMF and GMF. Total ash content of raw materials ranged between 0.64 and 4.49%. A significant (P <0.05) increase in the ash content of mung bean flour was obtained with the germination process. Similar results were acquired in HCl-extractable ash content of mung bean flours. It can be seen from Table 1 that the GMF showed an inferior fat content than those of wheat flour and RMF. The usage of fat during germination resulted the reduction in fat content of germinated mung bean. In addition, stored fat was used in catabolic reactions of the mung bean seeds during germination (Onimawo and Asugo, 2004). The germination significantly (P <0.05) increased protein content, and the highest protein result was obtained in GMF (27.56%) among raw materials. The higher protein and ash contents of GMF might have arisen from the germination process, since carbohydrate and fat are used as an energy source to trigger germination. The ash, fat and protein contents were similar to those found by Masood et al. (2014) in GMF. Moreover, the germination process provided a significant (P <0.05) decrease (88%) in the phytic acid content of mung bean flour. The reduction in phytic acid could be explained by an enhancement in the phytase enzyme activity during germination. Mubarak (2005) found that 72 h of germination resulted in a significant decrease (30.5%) in the phytic acid content of mung bean. Antioxidant activity and total phenolic content values of raw materials have varied in the range of 11.52 to

83.14% and 1.02 to 1.76 mg GAE/g, respectively. GMF revealed the highest antioxidant activity and total phenolic content. Similarly, Guo et al. (2012) reported that the germination process remarkably increased total phenolics, total flavonoids and total antioxidant activity of mung bean seeds.

Table 1. Chemical properties and color values of raw materials[1]

	Wheat flour	RMF[2]	GMF[3]
Moisture (%)	11.82±0.10[a]	10.24±0.06[b]	10.19±0.05[b]
Total ash (%)	0.64±0.03[c]	3.75±0.03[b]	4.49±0.06[a]
HCl-extractable ash (%)	0.41±0.04[c]	2.94±0.06[b]	3.95±0.07[a]
Fat (%)	1.14±0.03[a]	0.95±0.06[b]	0.75±0.04[c]
Protein (%)	10.58±0.04[c]	25.94±0.06[b]	27.56±0.08[a]
Phytic acid (mg/100 g)	174±1.41[c]	1644±8.30[a]	198±0.71[b]
Antioxidant activity (% inhibition)	11.52±0.14[c]	63.00±0.25[b]	83.14±0.19[a]
Total phenolic content (mg GAE/g)	1.53±0.01[b]	1.02±0.03[c]	1.76±0.06[a]
Total mineral (mg/100 g)			
Ca	25.93±0.25[c]	69.18±0.21[b]	85.35±0.35[a]
Fe	1.61±0.03[c]	3.72±0.01[b]	3.93±0.04[a]
K	242±5.71[c]	1341±10.47[b]	1494±11.91[a]
Mg	36.16±0.45[b]	170.30±3.82[a]	183.93±4.14[a]
Mn	0.62±0.03[b]	0.85±0.01[a]	0.97±0.04[a]
P	130±3.05[c]	571±4.81[b]	644±6.08[a]
Zn	1.23±0.04[c]	2.70±0.01[b]	3.20±0.03[a]
HCl-extractable mineral (mg/100 g)			
Ca	13.07±0.20[c]	44.87±0.44[b]	67.73±0.27[a]
Fe	0.98±0.04[b]	1.12±0.03[b]	1.97±0.06[a]
K	148±7.99[c]	996±12.54[b]	1197±15.91[a]
Mg	28.51±0.62[c]	109.78±5.13[b]	151.21±4.21[a]
Mn	0.41±0.04[c]	0.57±0.03[b]	0.85±0.01[a]
P	71±1.70[c]	259±4.10[b]	434±6.36[a]
Zn	0.85±0.01[c]	1.49±0.03[b]	2.50±0.03[a]
Color			
*L**	95.31±0.10[a]	82.66±0.14[b]	64.28±0.17[c]
*a**	-0.45±0.04[b]	-2.44±0.03[c]	2.20±0.07[a]
*b**	9.97±0.10[c]	13.59±0.13[b]	19.48±0.09[a]

[1] Means followed by the same letter within a row are not significantly ($P < 0.05$) different. Chemical properties except moisture are based on dry matter.
[2] RMF: Raw mung bean flour.
[3] GMF: Germinated mung bean flour.

Total and HCl-extractable mineral contents of raw materials are presented in Table 1. The highest total Ca, Fe, K, P and Zn results were observed in GMF, followed by RMF and wheat flour, respectively. Similar results were reported by El-Adawy et al. (2003) for Ca, Fe, K, Mg, Mn and P contents of GMF. Compared to RMF, GMF has about 51, 76, 20, 38, 49, 68 and 68% higher HCl-extractable Ca, Fe, K, Mg, Mn, P and Zn content, respectively. Wang et al. (2015) also observed an increase in endogenous phytase activity by 14.5-fold in mung beans compared to raw beans with germination. They also found that Fe and Zn bioavailability values of germinated beans were 2.4- and 3.0-fold higher than RMF. The degradation of phytic acid by the phytase enzyme may have increased mineral bioavailability (Porres et al. 2001).

Color L^*, a^* and b^* values of raw materials changed between 64.28 and 95.31, -2.44 and 2.20, and 9.97 and 19.48, respectively (Table 1). Compared to the values obtained from wheat flour and mung bean flours, GMF showed the lowest L^* value and the highest a^* and b^* values. These results are in great agreement with a recent study conducted by Liu et al. (2018) who reported a significant (P <0.05) decrease in L^* values along with an increase in a^* and b^* values of mung bean flour as a result of germination. Chandrasiri et al. (2016) reported that the color b^* related to native pigment such as uranidin, brown pigment and flavonoids, which increases during germination of mung bean.

The cooking properties and firmness values of noodles are demonstrated in Table 2. Weight increase values changed between 112 and 142%. The control noodle sample (without GMF) revealed a maximum level in weight increase. Compared to the control, noodles containing GMF exhibited lower weight increase values. Similar results were also obtained with regard to a volume increase in noodles. Noodle formulated with 15-20% of GMF caused the lowest level of volume increase. Cooking loss values of noodles have varied in the range of 4.92 to 9.54%. The noodles enriched with GMF resulted in significantly (P <0.05) higher cooking loss values than that of the control noodle. A replacement of legume protein with gluten, and hence deterioration of protein network might have caused such an increase in cooking loss (Torres et al., 2007). In addition, germination process itself enhances soluble protein and simple carbohydrates of mung bean, which in turn dissolve into water while cooking and hence lead to an increase in the cooking loss (Liu et al., 2018). Our results agree with those reported by Bilgiçli and İbanoğlu (2015). Addition of TGase enzyme decreased the values of weight increase, volume increase and cooking loss, which can be explained by the formation of cross-linking reaction catalyzed by TGase in the protein network. Cross-linked proteins can form a strong network and physical barrier to inhibit the water penetration into the noodle matrix and accordingly decrease the cooking loss level (Kim et al. 2014). Bilgiçli and İbanoğlu (2015) reported that addition of TGase (0.5%) in lupin flour noodle reduced cooking loss and water uptake values compared to control. Firmness values of noodle samples increased from 300 g (control sample) to 316 g for noodle containing 20% GMF, which might be caused by a higher protein content in the germinated bean flour than refined wheat flour (Del Nobile et al., 2005). The noodles supplemented with TGase enzyme displayed higher firmness values than that of noodles without TGase. Similar results were observed by Aalami and Leelavathi (2008) who reported that TGase increases firmness by cross-linking proteins of pasta. The interaction between GMF addition ratio and TGase supplementation is shown in Figure 1. Usage of TGase in GMF noodle production resulted in lower weight increase, volume increase and cooking loss values. However, firmness results of noodles supplemented with TGase are found greater than noodles prepared without TGase. In addition, it was observed that the volume increase, cooking loss and firmness results of both of noodles containing 20% GMF with and without TGase were close to each other.

As seen by the Table 2, there was a decrease in L^* values, and an increase in a^* values of noodle with an increasing ratio of GMF. The levels of free amino acids increase with germination due to proteolytic cleavage of proteins (Chau and Cheung, 1997). Free amino acids in GMF could cause to Maillard reactions that increase the redness in drying stage of noodle (Rosa-Sibakov et al., 2016). Noodle samples including 15 and 20% of GMF resulted in the highest b^* values. There was no significant (P <0.05) difference in L^* and b^* values between noodles supplemented with 0 and 0.5% TGase, on the other hand TGase reduced a^* values of samples. Rosa-Sibakov et al. (2016) observed a decrease in L^*, a^* and b^* values of faba bean flour pasta supplemented with TGase in comparison with additive-free faba bean pasta. However, the presence of TGase in fermented faba bean flour pasta did not result in a significant (P <0.05) difference in L^*, a^* and b^* values compared to control fermented faba bean pasta.

Table 2. Cooking properties, firmness and color values of germinated mung bean noodle samples[1]

Variance sources	n	Weight increase (%)	Volume increase (%)	Cooking loss (%)	Firmness (g)	*L**	*a**	*b**
GMF[2] ratio (%)								
0	4	142±1.76[a]	190±2.83[a]	4.92±0.11[d]	300±3.96[b]	75.47±0.24[a]	1.74±0.03[e]	22.38±0.08[c]
5	4	121±2.64[b]	154±1.06[b]	7.03±0.16[c]	259±2.50[d]	65.45±0.21[b]	2.13±0.01[d]	22.59±0.10[bc]
10	4	115±2.01[bc]	144±1.41[bc]	7.37±0.17[c]	277±1.62[c]	61.63±0.20[c]	2.88±0.04[c]	22.98±0.08[b]
15	4	112±1.78[c]	135±2.12[c]	8.63±0.23[b]	312±1.00[a]	56.09±0.16[d]	3.35±0.08[b]	23.45±0.13[a]
20	4	113±1.81[c]	135±0.71[c]	9.54±0.16[a]	316±2.51[a]	52.95±0.27[e]	3.67±0.06[a]	23.73±0.17[a]
TGase[3] dosage (%)								
0	10	125±2.00[a]	159±1.63[a]	7.87±0.16[a]	287±2.32[b]	62.78±0.22[a]	2.85±0.05[a]	22.95±0.11[a]
0.5	10	116±1.63[b]	144±1.84[b]	7.12±0.15[b]	300±3.08[a]	61.86±0.20[a]	2.66±0.04[b]	23.10±0.14[a]

[1] Means followed by the same letter within a column are not significantly (P <0.05) different. Duncan's multiple comparison test according to two ways analysis of variance. Values are the average of triplicate measurements on the duplicate samples.
[2] GMF: Germinated mung bean flour.
[3] TGase: Transglutaminase.

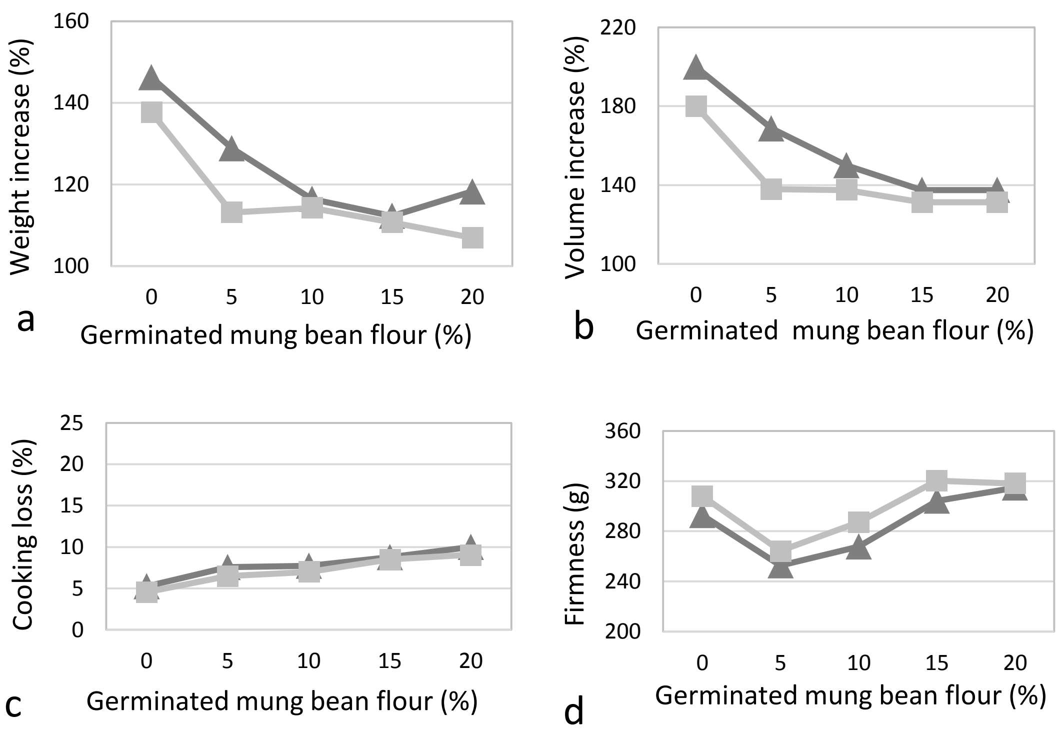

Figure 1. Weight increase (a), volume increase (b), cooking loss (c) and firmness (d) of noodle samples prepared with different ratios of germinated mung bean flour and TGase (▲: 0% TGase; ■: 0.5%TGase).

The chemical properties of noodles are given in Table 3. The moisture values of samples have varied in the range of 6.59 to 7.83%. Usage of 20% of GMF in noodle resulted in the highest total and HCl-extractable ash content. The fat content of noodles showed a decreasing trend with increasing levels of GMF, but the decrease was not significant (P >0.05). The replacement of 20% GMF increased the amount of protein content of noodles from 11.37 to 15.56%. Such increase could be due to the fact that the GMF contains more protein content than that of wheat flour (Table 1). Our results are in accordance with the findings of Imtiaz et al. (2011).

The phytic acid content of noodle samples changed between 127 and 178 mg/100 g (Table 3). The lowest and the highest phytic acid content was obtained in the control noodle (0% of GMF) and noodle containing 20% of GMF, respectively. The reason behind these results might be because of greater phytic acid content in legumes compared to refined wheat flour. Similar results were also acquired by Torres et al. (2007) where they showed a considerable increase in phytic acid content of pasta made with 90% of semolina and 10% of germinated pigeon pea flour in comparison to the pasta produced with 100% semolina.

Table 3. Chemical properties of germinated mung bean noodle samples[1]

GMF[2] ratio (%)	Moisture (%)	Total ash (%)	HCl-extractable ash (%)	Fat (%)	Protein (%)	Phytic acid (mg/100 g)	Antioxidant activity (% inhibition)	Total phenolic content (mg GAE/g)
0	6.59±0.07^{b}	1.76±0.01^{e}	1.43±0.03^{e}	1.73±0.36^{a}	11.37±0.08^{e}	127±2.19^{e}	13.53±0.24^{e}	0.87±0.01^{c}
5	6.93±0.05^{ab}	1.88±0.04^{d}	1.54±0.04^{d}	1.60±0.37^{a}	12.18±0.06^{d}	135±2.60^{d}	19.30±0.26^{d}	0.91±0.03^{bc}
10	7.31±0.11^{ab}	2.09±0.04^{c}	1.75±0.02^{c}	1.46±0.10^{a}	13.95±0.03^{c}	148±1.23^{c}	35.56±0.33^{c}	0.93±0.03^{b}
15	7.62±0.10^{a}	2.25±0.03^{b}	1.95±0.03^{b}	1.36±0.33^{a}	14.81±0.01^{b}	160±4.39^{b}	41.10±0.18^{b}	0.96±0.01^{b}
20	7.83±0.08^{a}	2.42±0.01^{a}	2.10±0.04^{a}	1.24±0.20^{a}	15.56±0.07^{a}	178±3.77^{a}	56.11±0.23^{a}	1.18±0.04^{a}

[1] Means followed by the same letter within a column are not significantly (P <0.05) different. Values are the average of triplicate measurements on the duplicate samples. Chemical properties except moisture are based on dry matter.
[2] GMF: Germinated mung bean flour.

The greatest antioxidant activity value (56.11%) was observed in noodle containing 20% of GMF (Table 3). This might be due to the presence of germinated flour. The germination process significantly (P <0.05) increased the antioxidant activity in mung bean sprouts than raw beans (Table 1). Total phenolic content of noodles ranged between 0.87 and 1.18 mg GAE/g. Utilization of 20% GMF in noodle formulation increased total phenolic content by about 36% compared to the control. Similar results were reported by Turco et al. (2016) for pasta enriched with faba bean flour.

Mineral content of noodle samples is shown in Table 4. Noodle enriched with 20% of GMF showed a significant (P <0.05) increase in Ca, Fe, K, Mg, Mn, P and Zn content by about 49, 42, 97, 69, 14, 65 and 31%, respectively, when compared to the control noodle. Our results are in great agreement with the findings reported by Torres et al. (2007) who observed an increase in Ca, K and Mg content of 10% germinated pigeon pea flour pasta compared to control semolina pasta.

Table 4. Mineral content (mg/100 g) of germinated mung bean noodle samples[1]

GMF[2] ratio (%)	Ca	Fe	K	Mg	Mn	P	Zn
0	33.58±0.41^{e}	1.94±0.01^{e}	310±7.11^{e}	46.02±0.35^{e}	0.59±0.03^{b}	158±4.29^{e}	1.26±0.01^{d}
5	37.63±0.25^{d}	2.18±0.03^{d}	379±8.84^{d}	52.61±0.18^{d}	0.62±0.03^{ab}	189±4.17^{d}	1.35±0.03^{c}
10	42.16±0.11^{c}	2.30±0.03^{c}	450±10.61^{c}	61.29±0.31^{c}	0.64±0.04^{ab}	210±2.23^{c}	1.41±0.03^{c}
15	46.54±0.16^{b}	2.46±0.01^{b}	531±7.91^{b}	68.42±0.37^{b}	0.65±0.01^{a}	230±3.05^{b}	1.50±0.04^{b}
20	50.10±0.23^{a}	2.75±0.04^{a}	612±10.13^{a}	77.71±0.23^{a}	0.67±0.06^{a}	261±5.81^{a}	1.65±0.03^{a}

[1] Means followed by the same letter within a column are not significantly (P <0.05) different. Values are the average of triplicate measurements on the duplicate samples, and are based on dry matter.
[2] GMF: Germinated mung bean flour.

The noodles containing TGase were subjected to sensory analysis because of their physical and technological superiority, and the results are presented in Table 5. Compared to the control sample, the addition of 10% of GMF improved the taste parameter of noodles. Noodles replaced with 5 and 10% of GMF instead of wheat flour displayed the greatest results regarding odor, appearance and overall acceptability properties, as also reported by Slathia et al. (2016), where noodles made with germinated (24 h) mung bean flour were more desirable to the panelists.

Table 5. Sensory properties of germinated mung bean noodles supplemented with TGase[1]

GMF[2] ratio (%)	Taste	Odor	Appearance	Mouthfeel	Overall acceptability
0	7.25±0.18[b]	7.50±0.21[b]	7.00±0.17[b]	6.75±0.14[c]	7.55±0.11[b]
5	7.75±0.14[b]	8.25±0.16[a]	8.60±0.10[a]	8.55±0.13[a]	8.65±0.13[a]
10	8.50±0.25[a]	8.50±0.11[a]	8.35±0.13[a]	7.75±0.17[b]	8.50±0.16[a]
15	7.35±0.16[b]	7.35±0.25[b]	7.30±0.14[b]	7.45±0.10[b]	7.25±0.17[b]
20	6.55±0.18[c]	7.10±0.23[b]	5.60±0.17[c]	4.75±0.13[d]	6.00±0.13[c]

[1] TGase: Transglutaminase.
[2] GMF: Germinated mung bean flour

CONCLUSIONS

This study aimed at investigating the effects of the addition of GMF with TGase on the egg noodle qualities. The germination of mung beans appears to be an effective process for enrichment of nutritional quality. Weight and volume increase values of noodles reduced by the addition of GMF and TGase compared to the control. Nonetheless, TGase supplementation significantly ($P < 0.05$) reduced a^* values than noodles without TGase. TGase improved the cooking loss and firmness values. Noodles containing 20% of GMF revealed the highest total ash, HCl-extractable ash, protein, phytic acid, antioxidant activity and total phenolic content. Usage of GMF in noodles remarkably increased Ca, Fe, K, Mg, P and Zn contents when compared to the control. Noodles containing 15% GMF with TGase demonstrated similar sensory properties to that of the control. GMF as high-nutritive value ingredient may use up to 15% in combination with TGase in noodle formulation to produce good acceptability and functional products.

CONFLICT OF INTEREST

There are no possible conflicts of interest between the authors.

AUTHOR CONTRIBUTION

NB designed the research project and supervised the article. EY performed experiments of the research and wrote the article. The authors read and approved the final version of the article.

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