Utilization of lentil, pea, and faba bean hulls in Turkish noodle production

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Abstract Turkish noodles (erişte) were substituted with green lentil (*Lens culinaris*), red lentil (*L. culinaris*), faba bean (*Vicia faba*), and pea (*Pisum sativum*) hulls at the level of 2.5, 5, and 10% and the effects of the substitution on proximate composition, mineral composition, colour, cooking properties, thiamine and riboflavin contents, texture and sensory properties of the noodles were investigated. Crude ash, dietary fibre, Ca and Mg contents of the noodles significantly increased with pulse hull substitution regardless of the hull type compared to control. Lightness or brightness (L^*) values of the noodles showed a general decreasing trend with increasing pulse hull substitution excluding pea hull. L^* value of the pea hull substituted noodles was higher than that of the control. Water absorption and swelling volume of the noodles remarkably increased with pea hull substitution. Thiamine and riboflavin contents of the control noodles and the noodles substituted with the noted hull types up to 10% were very close to each other. Noodles substituted with faba bean hull at the level of 10% showed the highest hardness, gumminess, and chewiness values. Pea hull substitution up to 10%

did not significantly affected the sensory (appearance, texture and overall acceptability) scores of the panellists.

Keywords Pulse hull · Noodle · Lentil · Pea · Faba bean

Introduction

The Food and Agriculture Organization of the United Nations has declared 2016 as the “International Year of Pulses” with the aim of increasing public awareness about nutritional benefits and uses of pulses as part of sustainable food production. Pulses are consumed worldwide by large number of people as staple food and they are excellent sources of protein, carbohydrates, dietary fibre, and a variety of micronutrients and phytochemicals (Singh 2017).

Dehulling is the most common and widely practiced operation in post-harvest handling of the pulses (Kanatt et al. 2011). For instance, dehulling of pulses is the third largest food processing industry in India after rice and wheat milling (Tiwari and Singh 2012). Pulses are dehulled in order to produce cotyledons (whole or splits) with good appearance, texture and cooking quality. The oldest and most common home-scale technique for dehulling pulses is to pound them in a mortar with a pestle, either after spreading the grains in the sun for a few hours, or after mixing them with a little water. Methods used for commercial scale dehulling are usually similar in principle, however differ in the use of techniques for better yield and operational efficiency (Tiwari et al. 2011).

Dehulling industry generates a large amount of bio-waste, which is reported to be about 20% of the total quantity processed (Kanatt et al. 2011). Pulse hulls, which are by-products of pulse processing, are promising sources

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of nutrients, including bioactive compounds that may be used for their favourable technological or beneficial nutraceutical properties (Tiwari et al. 2011). Tiwari and Singh (2012) indicated that incorporation of pea hulls to high-fibre wheat bread significantly increased water retention capacity without markedly affecting the mixing properties. Kanatt et al. (2011) reported that the extracts of some pulse hulls showed high phenolic content, high reducing power and excellent radical scavenging activity even at very low concentrations. Besides, pulse hulls are reported to have high phenolic (Oomah et al. 2011) and dietary fibre (Tosh and Yada 2010) contents and efficient antimicrobial activity (Kanatt et al. 2011).

In recent years, many efforts have been made to develop value-added applications using food by-products. The World Health Organization (WHO) and Food and Drug Administration (FDA) consider pasta a good vehicle for the addition of nutrients. Furthermore, pasta was one of the first foods for which the FDA permitted vitamin and iron enrichment in 1940s (Marconi and Carcea 2001). Pulse-fortified pasta offers consumers the possibility to improve the nutritional quality of their diet by providing enrichment in proteins, fibres, vitamins, minerals and amino acid complementarity (Tiwari and Singh 2012). Literature is available on pulse flour enriched bread, pasta, noodle, and bakery goods, however, available information related pulse hulls and the effects of their substitution is rather scarce.

Turkish noodle (erişte) is a traditional cereal product which is typically produced with soft or hard wheat flour, salt, and water as the major ingredients. Additional ingredients such as egg, milk, whey, and other cereal or legume flours can also be added to the formulation for nutritional enhancement. The manufacturing involves mixing the ingredients, sheeting of the dough, cutting of the dough sheet, and drying the resulting noodles (Demi et al. 2010). Fortification of noodles with healthy nutrients is an effective public health intervention, since noodles are consumed very frequently due to the ease of cooking and affordable cost. Noodle industry supplies 95 billion servings annually throughout the world (Gulia et al. 2014).

In the present study, it was aimed to investigate the potential use of pulse hulls in Turkish noodle (erişte) production and to determine the effects of pulse hull substitution on proximate composition, minerals, colour, cooking properties, B vitamins, texture and sensory properties of the noodles.

Materials and methods

Material

Green lentil (*Lens culinaris*), red lentil (*L. culinaris*), faba bean (*Vicia faba*), and pea (*Pisum sativum*) seeds and noodle ingredients were procured from local markets. Pulse seeds were steeped in hot water ($\sim 85^{\circ}\text{C}$) and iced water ($\sim 2^{\circ}\text{C}$) consecutively for 30 min each, and loosened hulls were peeled manually. The hulls were allowed to dry at room temperature for 48 h. Dry pulse hulls were milled using a micronizer (Restch GM 200, Haan, Germany) and sieved through a 100-mesh sieve before use.

Noodle preparation

Noodle ingredients were 1000 g of commercial refined wheat flour, 200 g of egg (20%), 50 g of salt (NaCl) (5%), and 100 g of milk (whole milk including 3.5% of fat) (10%). The hulls were substituted at the rate of 2.5% (25 g), 5% (50 g), and 10% (100 g) based on flour weight. Further levels of substitution caused unfavourable texture and sensory perceptions and therefore, were not evaluated. The amount of the tap water was 200 g (20%) for control samples and it was increased to 212, 225 and 250 g for noodles substituted with the pulse hulls at the level of 2.5, 5 and 10%, respectively. Firstly, commercial refined wheat flour and the hulls, then the other ingredients were mixed at low speed (level 1) for 1 and 10 min, respectively with a planetary mixer (Dirmak, IBT 22-VE, İzmir, Turkey). The whole content was further mixed at high speed (level 2) for 5 min to obtain a smooth dough. Afterwards, the dough was allowed to rest for 15 min and the dough sheets were obtained by passing small portions (~ 50 g) of dough through the reduction rolls of a noodle making machine (Imperia, Moncalieri, Italy). The sheets were allowed to rest for about 15–20 min and then were passed through cutting blades to form noodle strands which were 3 cm in length and 5 mm in width. Final noodle products were allowed to dry at room temperature for 2–3 days until the moisture content decreased below 12%.

Proximate analysis

Moisture, crude fat, crude protein, ash, soluble dietary fibre (SDF), insoluble dietary fibre (IDF) and total dietary fibre (TDF) contents of the noodles were determined by standard methods (Method No.: 44-15A, 30-10, 46-12, 08-01, 32-07, respectively) (AACC 2000). Dietary fibre analysis (enzymatic–gravimetric method) was carried out using Megazyme enzyme kits (Megazyme, Wicklow, Ireland). Phytate content was analysed spectrophotometrically using

the anion-exchange method (Method No.: 986.11) (AOAC 2000).

Mineral analysis

Finely ground 0.5 g of noodle sample was digested with 10 mL of nitric acid in a microwave digestion system at 200 °C for 20 min (Berghof SW-4, Eningen, Germany). The content was brought to 50 mL volume (after cooling to room temperature), filtered, and analysed with inductively coupled plasma-optical emission spectrometry (ICP-OES) (Perkin Elmer, Optima 8000, MA, USA). The instrument conditions were as follows: Pump speed: 30 rpm, plasma gas flow: 12 L min⁻¹, cooling gas (argon) flow: 1 L min⁻¹, and power: 1400 W. Analyses were replicated 3 times and the results were expressed as mg kg⁻¹.

Colour

Colour characteristics of finely ground uncooked noodles were measured with a colorimeter (Minolta, CR-400, Osaka, Japan). Lightness (L^*), redness ($+a^*$) or greenness ($-a^*$), yellowness ($+b^*$) or blueness ($-b^*$) were measured and total colour change (ΔE) was calculated according to the following formula:

$$\Delta E \text{ (Total colour change)} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

Cooking properties

Cooking properties of the noodles were measured using the same methods outlined by Yılmaz Tuncel et al. (2017).

Thiamine and riboflavin determination

Thiamine (B_1) and riboflavin (B_2) contents of the noodles were determined using the same extraction and chromatographic method outlined in our previous study (Tuncel et al. 2014).

Texture analysis

Texture profile analysis was carried out using a texture analyser (Brookfield, CT3-4500, Massachusetts, USA). Noodles were cooked for the predetermined optimum cooking time and allowed to cool at room temperature for 10 min. Then, 30 g of sample was weighed into a beaker and the noodles were compressed to a depth of 10 mm using the square probe (TA3/100). Trigger load was 100 g. Pre-test, test and return speeds were set to 1 mm s⁻¹.

Sensory analysis

Consumer acceptance test was conducted for each noodle type individually. Independent sessions were set at different days with different panellists. Noodles were served in plastic dishes, which were randomly coded with 3 digit numbers, immediately after cooking. Panellists were university staff and students and were instructed regarding the use of hedonic scale before the analyses. Noodles were evaluated for appearance, texture, and flavour on a 7-point hedonic scale (7 “excellent”, 6 “very good”, 5 “good”, 4 “fair”, 3 “poor”, 2 “very poor”, 1 “terrible”) according to Meilgaard et al. (1999). Additionally, panellists were asked to rank the samples according to their preference based on the overall acceptability. Therefore, smaller numbers refers to higher acceptability for the overall acceptability scores.

Statistical analysis

The noted properties of the noodles were evaluated with one-way ANOVA using Minitab (ver.17.0). Tukey’s test was used for multiple comparisons. Kruskal–Wallis test, which corresponds to the non-parametric version of ANOVA, was used solely for sensory analysis individually for each noodle type. When significant dose effects were observed, Dunn test was used for multiple comparison of the sensory results. All results were the average of at least three determinations and were expressed as mean $\pm$ standard error.

Results and discussion

Proximate composition

Moisture content of the noodles ranged between 10 and 11%. The effect of pulse hull substitution on crude fat content of the noodles found insignificant ($p > 0.05$). This was expected since crude fat content of the pulse hulls were between 0.15 and 0.91%. Additionally, it was reported that lipids in pulse grains are mainly found in embryo axis and either the cotyledon or seed coat (hull) contain only small amount of lipids (Tiwari and Singh 2012). Crude protein content of the noodles showed a significant decreasing trend as the level of the pulse hull substitution increased (with the exception of red lentil hull) ($p < 0.05$). Nevertheless, protein content of the noodles, which ranged between 11.10 and 11.84% (Table 1), was very close. The lowest ash content was found in control noodle. Ash content of noodles significantly increased with pulse hull substitution at the level of 5% or higher and it was doubled with the substitution of any type of pulse hull at the substitution level of 10% compared to control.

Table 1 Proximate composition of the noodles

Substitution material	Substitution dose (%)	Crude fat (d.w. %)	Crude protein (d.w. %)	Ash (d.w. %)	Soluble dietary fibre (%)	Insoluble dietary fibre (%)	Total dietary fibre (%)	Phytate (mg/g)
Control	0	2.61 ± 0.09	11.60 ± 0.10 ^{AB}	2.38 ± 0.38 ^C	0.83 ± 0.03 ^E	1.58 ± 0.04 ^D	2.41 ± 0.01 ^H	2.04 ± 0.04 ^C
Green lentil hull	2.5	3.21 ± 0.48	11.55 ± 0.02 ^{AB}	2.45 ± 0.20 ^C	2.03 ± 0.01 ^{CD}	5.83 ± 0.28 ^{BC}	7.86 ± 0.27 ^D	2.30 ± 0.05 ^{ABC}
	5.0	2.74 ± 0.37	11.30 ± 0.02 ^{BC}	2.79 ± 0.42 ^{BC}	1.38 ± 0.02 ^{DE}	6.68 ± 0.44 ^B	8.07 ± 0.46 ^D	2.30 ± 0.05 ^{ABC}
	10.0	2.18 ± 0.12	11.30 ± 0.05 ^{BC}	4.74 ± 0.20 ^A	1.86 ± 0.32 ^{DE}	6.44 ± 0.14 ^B	8.30 ± 0.46 ^D	2.24 ± 0.01 ^{ABC}
Red lentil hull	2.5	2.73 ± 0.01	11.84 ± 0.06 ^A	2.38 ± 0.16 ^C	2.13 ± 0.23 ^{CD}	1.60 ± 0.27 ^D	3.74 ± 0.26 ^{GH}	2.24 ± 0.16 ^{ABC}
	5.0	2.73 ± 0.06	11.76 ± 0.09 ^A	2.71 ± 0.20 ^{BC}	3.02 ± 0.18 ^{BC}	2.79 ± 0.21 ^D	5.81 ± 0.28 ^{EF}	2.41 ± 0.06 ^{AB}
	10.0	2.23 ± 0.06	11.83 ± 0.07 ^A	4.63 ± 0.03 ^A	3.32 ± 0.02 ^B	4.78 ± 0.44 ^C	8.11 ± 0.45 ^D	2.56 ± 0.03 ^A
Faba bean hull	2.5	2.87 ± 0.05	11.56 ± 0.02 ^{AB}	2.51 ± 0.03 ^C	2.32 ± 0.16 ^{BCD}	1.47 ± 0.27 ^D	3.79 ± 0.22 ^{GH}	2.23 ± 0.05 ^{ABC}
	5.0	2.55 ± 0.01	11.35 ± 0.07 ^{BC}	4.19 ± 0.44 ^{AB}	2.22 ± 0.23 ^{CD}	2.62 ± 0.16 ^D	4.84 ± 0.12 ^{FG}	2.25 ± 0.02 ^{ABC}
	10.0	2.47 ± 0.04	11.10 ± 0.05 ^C	4.46 ± 0.09 ^A	2.19 ± 0.28 ^{CD}	4.74 ± 0.36 ^C	6.93 ± 0.08 ^{DE}	2.28 ± 0.04 ^{ABC}
Pea hull	2.5	2.58 ± 0.10	11.71 ± 0.06 ^A	2.41 ± 0.36 ^C	5.92 ± 0.07 ^A	4.75 ± 0.36 ^C	10.68 ± 0.44 ^C	2.05 ± 0.02 ^{BC}
	5.0	2.71 ± 0.01	11.30 ± 0.05 ^{BC}	3.88 ± 0.47 ^{ABC}	6.68 ± 0.30 ^A	5.86 ± 0.02 ^{BC}	12.54 ± 0.32 ^B	2.08 ± 0.04 ^{BC}
	10.0	2.68 ± 0.17	11.14 ± 0.06 ^C	4.64 ± 0.15 ^A	6.71 ± 0.25 ^A	10.13 ± 0.19 ^A	16.84 ± 0.44 ^A	2.11 ± 0.06 ^{BC}
<i>p</i>		0.119	0.000	0.000	0.000	0.000	0.000	0.003

Means followed by different letters at the same column are significantly different by Tukey ($p < 0.05$)

TDF content of noodles substituted with any type of pulse hull was significantly higher than that of control noodles ($p < 0.05$). Singh et al. (2017) reported that both hull and cotyledon are fibre rich parts of pulse seeds and TDF content of different pulses (beans, chickpeas, lentils, and peas) ranged from 14 to 32% with SDF and IDF ranging from 0 to 9 and 10 to 28%, respectively. Fibre content of food products is important since it displays special functional properties. Fibre introduces swelling properties and thereby alters flour rheology and product behaviour owing to its ability of binding water and oil (Tiwari and Singh 2012). SDF contents of the noodles substituted with red lentil, faba bean, and pea hulls were higher than that of control noodles. However, SDF content of the noodles substituted with green lentil hull even at the level of 10% was not significantly different from control noodles which indicated that SDF content of green lentil hull was relatively lower among the pulse hulls used in this study (Table 1). Moreover, IDF contents of the noodles substituted with green lentil and pea hulls were higher than that of the control for all levels of substitution ($p < 0.05$). However, solely the substitution level of 10% lead to significantly higher IDF content compared to control for noodles substituted with red lentil and faba bean hulls ($p < 0.05$). The most dramatic variation in either SDF or IDF contents was observed in noodles that were substituted with pea hull. SDF and IDF contents of the noodles increased from 0.83 to 6.71% (eightfold) and from 1.58 to 10.13% (sixfold), respectively with the incorporation of pea hull at the level of 10%. Furthermore, the increase in IDF content of the noodles was higher than the increase in SDF content for any type of pulse hull substitution. Therefore, it can be suggested that pulse hulls comprise higher amounts of IDF compared to SDF. Similarly, Ramulu and Rao (1997) reported that dehulling of pulses namely chickpea, pigeon pea, green gram and lentil resulted in a significant decrease in IDF content, while only marginal decreases in SDF content. It was reported that SDF of pulses comprised of gums, pectins, fructans, inulins, and some hemicelluloses, whereas IDF of pulses composed of cellulose, some hemicelluloses, lignins, and arabinoxylan (Singh et al. 2017).

Phytate content of the noodles ranged between 2.04 and 2.56%. Pulse hull substitution, with the exception of red lentil hull, did not cause a significant change in phytate content of the noodles. Considering the notable increase in ash and fibre contents, variation in phytate content was relatively low. This result can be attributed to soaking and more likely to the location of phytate in pulses. It was reported that most of the phytate in pulses presented in cotyledons rather than hulls (Oomah et al. 2011). Additionally, soaking the pulse seeds in water (85 °C) for 30 min might have reduced the phytic acid content of the

pulses used in this study. Martín-Cabrejas et al. (2009) investigated the effects of soaking (at 20 °C for 16 h), cooking (30 min) and dehydration (at 75 °C for 6 h) on phytic acid content of lentil flours and found that phytic acid decreased 38, 40, and 44%, respectively compared to control as a result of the noted processes.

Mineral composition

Mineral composition of the pulse hull substituted noodles was shown on Table 2. A general increasing trend was observed in Ca and Mg contents of the noodles with pulse hull substitution regardless of the hull type. The highest relative increase (almost fivefold, compared to control) was observed in Ca content of the noodles which were substituted with red lentil hull at the level of 10% (Table 2). Substitution of other pulse hull types (at 10%) also provided at least threefold increase in Ca content compared to control. Moreover, substitution of pulse hulls at the level of 10% brought about an increase in Mg content of the noodles, ranging from 36 to 70%, depending on the hull type. Among pulse hull types, pea hull substitution provided the highest increase in Mg content of the noodles. These results suggest that pulse hulls are rich sources of Ca and Mg. However, although the effect of pulse hull substitution was significant on Fe, Na, K, P, and Zn contents of the noodles ($p < 0.05$), no consistent variation trend was observed with regard to the substitution level. Furthermore, the amount of the noted minerals in noodles substituted with the same type of pulse hull was not that distinct from each other. The inconsistent variation of these minerals can be attributed to the low levels of incorporation (max 10%) and lack of homogeneity of the distribution of the hulls in the noodle dough. During mixing, shear and tensile stresses disperse the water molecules into the flour, promoting the structure of the dough. With adequate quantities of water and mixing, some flour components such as pentosanes, soluble proteins and damaged starch are dissolved in the liquid phase, while insoluble hydrated proteins and starch globules distribute uniformly throughout the entire volume (Masi et al. 2001). However, pulse hulls are rough in texture which results in poor hydration and poor interaction with other molecules in the dough system. Therefore, distribution of the hulls in the entire dough might not be homogeneous enough despite their dimensions (< 100 mesh) and 15 min dough mixing process.

Difference in soil type and fertilizer applications affects the mineral composition of the pulses and therefore the mineral results cannot be generalized. Additionally, soaking of pulses might have a reducing effect on mineral contents of the hulls (Chitra et al. 1996). Nevertheless, it was observed that the highest Fe, Ca, P, and Zn contents were observed in noodles substituted with red lentil hull at

Table 2 Mineral composition of the noodles (mg/kg)

Substitution material	Dose (%)	Fe	Ca	Mg	Na	K	P	Zn
Control	0	42.22 ± 0.17 ^B	145.23 ± 3.38 ^L	122.95 ± 2.76 ^G	15,356.00 ± 35.80 ^D	1763.50 ± 28.90 ^F	1280.10 ± 4.91 ^F	7.70 ± 0.09 ^C
Green lentil hull	2.5	15.71 ± 0.13 ^J	164.60 ± 0.75 ^K	118.10 ± 0.86 ^G	14,105.00 ± 3.18 ^G	1586.90 ± 1.62 ^H	1138.90 ± 5.25 ^J	5.43 ± 0.09 ^H
	5.0	22.80 ± 0.21 ^G	374.60 ± 0.17 ^E	161.30 ± 0.05 ^D	17,078.00 ± 11.30 ^A	1911.80 ± 4.24 ^D	1383.40 ± 2.28 ^C	6.67 ± 0.07 ^F
Red lentil hull	10.0	17.49 ± 0.01 ^I	536.63 ± 2.92 ^B	167.00 ± 0.86 ^D	14,987.00 ± 49.90 ^E	1695.00 ± 4.42 ^G	1230.20 ± 0.20 ^H	6.80 ± 0.09 ^{EF}
	2.5	30.56 ± 0.08 ^C	317.10 ± 1.56 ^G	148.23 ± 0.20 ^E	15,621.00 ± 11.00 ^C	1891.20 ± 1.79 ^{DE}	1430.50 ± 2.14 ^B	11.72 ± 0.11 ^A
Faba bean hull	5.0	24.80 ± 0.01 ^F	379.63 ± 1.24 ^E	144.07 ± 0.49 ^{EF}	14,843.00 ± 1.45 ^E	1652.30 ± 8.40 ^G	1287.00 ± 3.09 ^F	7.25 ± 0.01 ^D
	10.0	45.38 ± 0.11 ^A	706.50 ± 0.34 ^A	193.00 ± 0.11 ^B	14,534.00 ± 26.30 ^F	1846.60 ± 11.00 ^E	1456.90 ± 2.57 ^A	11.54 ± 0.07 ^A
Pea hull	2.5	19.00 ± 0.11 ^H	249.97 ± 0.89 ^I	141.73 ± 0.08 ^{EF}	16,291.00 ± 32.30 ^B	1920.40 ± 8.66 ^D	1336.10 ± 4.88 ^D	8.27 ± 0.07 ^B
	5.0	13.21 ± 0.11 ^K	362.67 ± 2.63 ^F	167.20 ± 0.34 ^D	16,185.00 ± 1.73 ^B	2108.40 ± 3.46 ^C	1397.00 ± 1.56 ^C	7.11 ± 0.11 ^{DE}
Pea hull	10.0	15.63 ± 0.01 ^J	497.40 ± 2.60 ^C	188.37 ± 0.31 ^{BC}	15,335.00 ± 49.70 ^D	2166.60 ± 3.90 ^B	1257.90 ± 0.26 ^G	5.92 ± 0.06 ^G
	2.5	24.43 ± 0.01 ^F	228.67 ± 0.83 ^I	139.30 ± 0.23 ^F	14,045.00 ± 112.00 ^G	1859.60 ± 2.71 ^E	1278.40 ± 3.20 ^F	8.65 ± 0.06 ^B
Pea hull	5.0	27.09 ± 0.04 ^D	296.17 ± 1.36 ^H	182.80 ± 0.46 ^C	15,209.00 ± 2.89 ^D	2235.40 ± 1.91 ^A	1313.40 ± 1.96 ^E	8.37 ± 0.03 ^B
	10.0	26.36 ± 0.31 ^E	404.03 ± 0.49 ^D	208.90 ± 0.23 ^A	14,345.00 ± 0.01 ^F	2152.00 ± 3.44 ^{BC}	1174.80 ± 0.28 ^I	6.87 ± 0.01 ^{DEF}
<i>p</i>		0.000	0.000	0.000	0.000	0.000	0.000	0.000

Means followed by different letters at the same column are significantly different by Tukey ($p < 0.05$)

the level of 10% (Table 2). Therefore, it can be suggested that red lentil hulls are relatively rich in minerals among the hull types used in this study.

Colour characteristics

Colour is an important quality criteria that affects the sensory appeal and potential marketability of food products. Lightness or brightness (L^*) values of the noodles showed a general decreasing trend with increasing substitution dose regardless of the hull type (excluding pea hull). However, L^* value of the pea hull substituted noodles was higher than that of the control ($p < 0.05$). Redness ($+a^*$) was dominant in red lentil hull and faba bean hull substituted noodles, while greenness ($-a^*$) was dominant in control noodles and the noodles substituted with green lentil and pea hulls, as expected. Redness of the noodles substituted with any type of pulse hull (except for pea hull) increased with increasing substitution dose. Noodles substituted with green lentil hull at the level of 2.5% and with pea hull up to 10% were not significantly different from control noodles with regard to redness (a^*) ($p > 0.05$). The highest $+b^*$ value (yellowness) was observed in control noodles. Noodles substituted with all type of pulse hulls at any substitution level showed significantly lower $+b^*$ values compared to control ($p < 0.05$). ΔE , which explains the overall colour change, showed a general increasing trend with increasing pulse hull substitution level with the exception of pea hull. Furthermore, it was observed that the higher the level of pea hull substitution, the lower the ΔE . This result was attributed to the similarity of pea hull and refined wheat flour in colour (Table 3). L^* values were 51.21, 45.74, 52.38, and 76.69; a^* values were 2.74, 4.02, 7.69, and 0.47; and b^* values were 20.24, 16.49, 17.48, and 16.05 for green lentil, red lentil, faba bean, and pea hulls, respectively.

Chillo et al. (2010) incorporated mung bean, soya bean, red lentil, and chickpea flours to the semolina spaghetti at the level of 10% and found that the effect of incorporation was insignificant on L^* , a^* , b^* values when compared to control ($p > 0.05$). Adversely, all colour characteristics were significantly affected from pulse hull substitution in this study ($p < 0.05$). Therefore, it can be suggested that the form of the incorporated material (whole pulse flour or pulse hull) affects the colour characteristics in different ways. Moreover, incorporation of any pulse type at the same form (whole flour or hull) and the same level could lead different results due to the variation in pigment colour of the pulses.

Cooking properties

The optimum cooking time was 9 min for control noodles and it was 10, 11, and 12 min, respectively for the noodles substituted with the pulse hulls at the levels of 2.5, 5, and 10%. The lowest water absorption was observed in control noodles and it increased with increasing pulse hull substitution at varying degrees depending on the hull type. The increase in water absorption was attributed to strong water binding ability of fibres in an agreement with Kaur et al. (2012) who reported similar results for cereal bran enriched pasta. The highest water absorption and swelling volume values were observed in pea hull substituted noodles which also had the highest fibre content. Noodles that were substituted with pea hull at the level of 10% absorbed water almost 10% higher than that of the control noodles. Water absorption is closely related to noodle quality since insufficient water imbibition usually results in noodles with a hard and coarse texture, while excess water absorption produces too soft and sticky noodles (Lee et al. 2005). Among pulse hulls, green lentil hull and pea hull substitution resulted in noodles with higher swelling volume likewise water absorption (Table 3). Either for the water absorption or the swelling volume, the highest values were obtained by pea hull substitution at the level of 10%. Several studies have reported that addition of cereal brans also resulted in higher water absorption and swelling volume in noodles. Song et al. (2013) found that black wheat bran and purple red wheat bran significantly increased water absorption of the noodles even at the substitution level of 2% ($p < 0.05$). Furthermore, Chung et al. (2012) found an increase in water absorption of noodles which were substituted with germinated brown rice. Researchers attributed this increase to the diluted gluten content which reduces the tendency to form a continuous network and enables water to penetrate easier into the matrix (Chung et al. 2012).

Cooking loss is defined as the amount of solids that dissolve in water during cooking and therefore it may be an indicator of noodle structural integrity (Liu et al. 2012). Although the effect of pulse hull substitution was found statistically significant on cooking loss, no distinct variation was found between the cooking loss of the noodles with regard to pulse hull substitution (all means shared the same letter) (Table 3). Chillo et al. (2010) reported that incorporation of mung bean, soya bean, red lentil, and chickpea flours to the semolina spaghetti at the level of 10% had no significant effect on cooking loss. However, Kaur et al. (2012) reported an increase in cooking loss of pasta enriched with various cereal (wheat, rice, barley, and oat) brans.

Table 3 Colour characteristics and cooking properties of the noodles

Substitution material	Substitution dose (%)	L^*	a^*	b^*	ΔE	Water absorption (%)	Swelling volume (%)	Cooking loss (%)
Control	0	84.25 ± 1.14 ^{CDE}	−0.52 ± 0.07 ^F	17.19 ± 0.41 ^A	–	51.23 ± 0.68 ^F	16.27 ± 0.29 ^E	11.52 ± 0.52 ^{AB}
Green lentil hull	2.5	86.74 ± 0.26 ^{ABCD}	−0.51 ± 0.01 ^F	13.55 ± 0.20 ^{BCD}	2.55 ± 0.29 ^C	54.79 ± 0.15 ^{DE}	18.04 ± 0.29 ^{CDE}	14.61 ± 0.22 ^A
	5.0	83.73 ± 0.36 ^{DEF}	−0.06 ± 0.02 ^{DE}	14.20 ± 0.27 ^{BC}	2.50 ± 0.18 ^C	58.42 ± 0.09 ^{AB}	20.71 ± 0.01 ^{AB}	11.82 ± 1.50 ^{AB}
	10.0	79.96 ± 0.41 ^{FG}	0.21 ± 0.04 ^{CD}	14.33 ± 0.43 ^{BC}	5.81 ± 0.28 ^{BC}	58.15 ± 0.60 ^{AB}	19.52 ± 0.01 ^{BCD}	12.46 ± 0.58 ^{AB}
Red lentil hull	2.5	81.49 ± 0.84 ^{EFG}	0.47 ± 0.07 ^C	14.48 ± 0.50 ^B	4.44 ± 0.80 ^{BC}	54.56 ± 0.21 ^E	17.45 ± 0.29 ^{DE}	13.40 ± 0.68 ^{AB}
	5.0	78.75 ± 1.15 ^G	0.51 ± 0.08 ^C	12.39 ± 0.23 ^{DE}	5.49 ± 0.52 ^{BC}	54.42 ± 0.70 ^E	17.45 ± 0.88 ^{DE}	12.64 ± 0.45 ^{AB}
	10.0	71.30 ± 2.22 ^H	1.91 ± 0.18 ^A	13.49 ± 0.42 ^{BCD}	14.62 ± 2.12 ^A	57.78 ± 0.41 ^{BC}	19.82 ± 0.29 ^{BC}	14.42 ± 0.01 ^A
Faba bean hull	2.5	84.95 ± 0.13 ^{BCDE}	0.54 ± 0.05 ^C	13.16 ± 0.20 ^{BCDE}	2.82 ± 0.18 ^{BC}	54.38 ± 0.22 ^E	17.45 ± 0.29 ^{DE}	11.28 ± 0.41 ^{AB}
	5.0	83.50 ± 0.77 ^{DEF}	0.92 ± 0.06 ^B	12.58 ± 0.22 ^{DE}	4.18 ± 0.51 ^{BC}	56.55 ± 0.47 ^{BCDE}	18.93 ± 0.59 ^{BCD}	10.42 ± 0.20 ^B
	10.0	81.05 ± 0.33 ^{EFG}	1.59 ± 0.08 ^A	12.95 ± 0.26 ^{CDE}	5.64 ± 0.23 ^{BC}	55.11 ± 0.33 ^{CDE}	18.34 ± 0.01 ^{CDE}	12.31 ± 0.89 ^{AB}
Pea hull	2.5	90.05 ± 0.27 ^A	−0.40 ± 0.02 ^{EF}	11.72 ± 0.07 ^E	6.11 ± 0.20 ^B	55.98 ± 0.19 ^{BCDE}	19.23 ± 0.29 ^{BCD}	13.78 ± 0.32 ^{AB}
	5.0	88.86 ± 0.17 ^{AB}	−0.39 ± 0.02 ^{EF}	12.99 ± 0.20 ^{BCDE}	4.38 ± 0.24 ^{BC}	57.44 ± 0.23 ^{BCD}	20.11 ± 0.01 ^{BC}	14.26 ± 0.19 ^A
	10.0	88.17 ± 0.14 ^{ABC}	−0.39 ± 0.01 ^{EF}	13.57 ± 0.15 ^{BCD}	3.48 ± 0.20 ^{BC}	60.77 ± 1.02 ^A	22.48 ± 0.59 ^A	12.08 ± 0.31 ^{AB}
<i>p</i>		0.000	0.000	0.000	0.000	0.000	0.000	0.005

Means followed by different letters at the same column are significantly different by Tukey ($p < 0.05$)

B vitamins

Thiamine and riboflavin contents of the noodles were shown on Table 4. Pulse hull substitution significantly affected the content of the noted vitamins in noodles ($p < 0.05$). Nevertheless, the results were very close and thiamine and riboflavin contents of the noodles varied between 1.92–3.84 and 1.93–2.45 mg kg⁻¹, respectively. The highest thiamine content was observed in control noodles indicating that the pulse hulls were not rich sources of thiamine. Moreover, pea hull substituted noodles showed the lowest thiamine content. Thiamine content of the noodles substituted with pea hull at the level of 10% was 50% lower than that of the control noodles. Oppositely, the highest riboflavin content was observed in pea hull substituted noodles. Although the results were very close, noodles substituted with pea and faba bean hulls showed higher riboflavin levels compared to control at any substitution level. However, riboflavin content of the noodles substituted with green lentil and red lentil hulls even at the level of 10% was lower than that of the control noodles (Table 4). These results indicated that riboflavin contents of green lentil and red lentil hulls were not higher than the refined wheat flour.

Pulses are reported to be good sources of B vitamins namely thiamine, riboflavin, niacin, pyridoxamine, pyridoxal, and pyridoxine, and in general poor sources of vitamin A and C (Tiwari and Singh 2012). However, the amount of the noted vitamins in noodles substituted with the noted pulse hulls was rather low. These results may be related either to the location of the vitamins in pulse seed or the soaking procedures carried out before dehulling.

Prodanov et al. (2004) determined the effect of soaking (at room temperature for 9 h) on thiamine, riboflavin and niacin contents of lentil, faba bean and chickpea seeds and found that soaking resulted in 15, 7, and 6% decrease in thiamine content of faba bean, chickpea, and lentil, respectively. However, no significant change was observed in riboflavin contents of faba bean and chickpea seeds with regard to soaking treatment. The authors explained the vitamin losses due to soaking with the multiple effect of several factors such as hydration rate, chemical form of vitamin, relative solubility, and soaking medium (Prodanov et al. 2004).

Textural properties

Texture profile analysis (TPA) results were presented on Table 5. Texture of noodles is a complex characteristic that depends on many factors such as flour quality, water absorption, ingredients used like salt or alkaline reagents as well as processing parameters like sheeting, steaming, and dehydration method used (Gulia et al. 2014). The effect of pulse hull substitution was significant on hardness of the noodles ($p < 0.05$). Noodles substituted with faba bean hull at the level of 10% resulted in the highest hardness value. However, hardness of the noodles substituted with the other type of pulse hulls at any substitution level was not statistically different from control. Nevertheless, a general increasing trend was observed in hardness of the noodles with increasing pulse hull substitution level (especially at 10%). Similarly, Chillo et al. (2010) reported higher hardness values for spaghetti containing pulse flours ($p > 0.05$). Adhesiveness values of the noodles ranged between 0.89 and 7.76 mJ. Adhesiveness of the noodles

Table 4 Thiamine and riboflavin contents of the noodles (mg/kg)

Substitution material	Substitution dose (%)	Thiamine (B ₁)	Riboflavin (B ₂)
Control	0	3.84 ± 0.12 ^A	2.03 ± 0.02 ^{DEF}
Green lentil hull	2.5	3.22 ± 0.10 ^{AB}	2.19 ± 0.01 ^{CD}
	5.0	2.64 ± 0.30 ^{BC}	2.19 ± 0.05 ^{CD}
	10.0	2.80 ± 0.04 ^{ABC}	1.93 ± 0.01 ^F
	10.0	2.80 ± 0.04 ^{ABC}	1.93 ± 0.01 ^F
Red lentil hull	2.5	2.54 ± 0.31 ^{BC}	2.41 ± 0.06 ^{AB}
	5.0	2.63 ± 0.15 ^{BC}	2.12 ± 0.06 ^{CDEF}
	10.0	2.20 ± 0.12 ^{BC}	1.96 ± 0.01 ^{EF}
Faba bean hull	2.5	2.92 ± 0.23 ^{ABC}	2.14 ± 0.01 ^{CDE}
	5.0	2.86 ± 0.11 ^{ABC}	2.24 ± 0.01 ^{BC}
	10.0	2.23 ± 0.02 ^{BC}	2.11 ± 0.01 ^{CDEF}
Pea hull	2.5	2.68 ± 0.10 ^{BC}	2.40 ± 0.04 ^{AB}
	5.0	2.10 ± 0.26 ^C	2.45 ± 0.03 ^A
	10.0	1.92 ± 0.19 ^C	2.45 ± 0.01 ^A
<i>p</i>		0.000	0.000

Means followed by different letters at the same column are significantly different by Tukey ($p < 0.05$)

Table 5 Textural characteristics of the noodles

Substitution material	Substitution dose (%)	Hardness (g)	Adhesiveness (mJ)	Cohesiveness	Springiness (mm)	Gumminess (g)	Chewiness (mJ)
Control	0	441.25 ± 6.62 ^B	7.76 ± 0.30 ^A	0.72 ± 0.06 ^B	4.36 ± 0.38	318.40 ± 29.10 ^B	13.80 ± 2.10
Green lentil hull	2.5	400.40 ± 45.30 ^B	0.99 ± 0.22 ^C	0.55 ± 0.03 ^{BC}	4.17 ± 0.55	228.60 ± 39.60 ^B	9.96 ± 2.60
	5.0	411.00 ± 21.30 ^B	1.44 ± 0.30 ^C	0.51 ± 0.05 ^{BC}	3.50 ± 0.34	212.40 ± 25.10 ^B	7.54 ± 1.50
	10.0	617.90 ± 88.90 ^B	0.89 ± 0.08 ^C	0.55 ± 0.02 ^{BC}	4.03 ± 0.10	342.10 ± 51.70 ^{AB}	13.64 ± 2.31
	10.0	617.90 ± 88.90 ^B	0.89 ± 0.08 ^C	0.55 ± 0.02 ^{BC}	4.03 ± 0.10	342.10 ± 51.70 ^{AB}	13.64 ± 2.31
Red lentil hull	2.5	534.80 ± 47.10 ^B	5.14 ± 0.70 ^{AB}	0.59 ± 0.03 ^{BC}	3.90 ± 0.17	317.60 ± 38.40 ^B	12.09 ± 1.27
	5.0	414.40 ± 23.70 ^B	2.58 ± 0.79 ^{BC}	0.62 ± 0.07 ^{BC}	4.18 ± 0.27	259.30 ± 38.80 ^B	10.92 ± 2.11
	10.0	615.60 ± 98.60 ^B	1.69 ± 0.85 ^C	0.45 ± 0.10 ^C	4.29 ± 0.08	360.20 ± 61.90 ^{AB}	15.29 ± 2.85
Faba bean hull	2.5	576.10 ± 66.50 ^B	1.97 ± 0.38 ^C	0.53 ± 0.03 ^{BC}	4.42 ± 0.35	306.90 ± 38.70 ^B	13.50 ± 2.34
	5.0	608.80 ± 62.80 ^B	1.93 ± 0.28 ^C	0.58 ± 0.01 ^{BC}	4.65 ± 0.30	353.10 ± 33.60 ^{AB}	15.95 ± 1.35
	10.0	952.00 ± 101.00 ^A	2.00 ± 0.53 ^C	0.61 ± 0.04 ^{BC}	4.57 ± 0.14	586.20 ± 70.90 ^A	26.54 ± 3.90
Pea hull	2.5	416.30 ± 63.70 ^B	7.56 ± 0.55 ^A	1.01 ± 0.01 ^A	4.26 ± 0.28	421.00 ± 62.60 ^{AB}	20.83 ± 6.61
	5.0	518.00 ± 85.70 ^B	2.74 ± 1.09 ^{BC}	0.63 ± 0.06 ^{BC}	4.59 ± 0.54	343.70 ± 81.70 ^{AB}	23.51 ± 9.24
	10.0	585.00 ± 50.30 ^B	1.45 ± 0.32 ^C	0.52 ± 0.02 ^{BC}	3.10 ± 0.95	308.40 ± 31.60 ^B	11.78 ± 2.13
<i>p</i>		0.000	0.000	0.000	0.499	0.001	0.042

Means followed by different letters at the same column are significantly different by Tukey ($p < 0.05$)

substituted with pulse hulls at the level of 5% or higher was significantly lower than that of control noodles regardless of the hull type ($p < 0.05$). Additionally, adhesiveness of the red lentil hull and pea hull substituted noodles significantly decreased with increasing the level of substitution while, substitution level was insignificant on the adhesiveness of noodles that were substituted with green lentil and faba bean hulls (Table 5). Noodles substituted with green lentil and faba bean hulls showed relatively lower adhesiveness values (below 2) at any substitution level. Adversely, Chillo et al. (2010) reported that incorporation of mung bean, soy bean, lentil and chickpea flours into noodle recipe at the level of 10% did not significantly affect the adhesiveness of the semolina spaghetti. Indeed, lower adhesiveness is a desired quality criteria for noodles, since sticky noodles are not preferred by consumers.

Although the effect of pulse hull substitution found statistically significant ($p < 0.05$) on cohesiveness, the mean values ranged between 0.45 and 1.01 and the variations were not significant either practically or mathematically. The effect of pulse hull substitution was found insignificant on springiness ($p > 0.05$) which means that the elasticity of the noodles did not notably affected from the substitution of the hulls up to 10%. Gumminess of the noodles substituted with green lentil, red lentil, and faba bean hulls at the level of 10% was higher than that of the noodles substituted with the noted pulse hulls at lower levels. On the contrary, gumminess of the noodles substituted with pea hull decreased with increasing substitution level (Table 5). Although the effect of pulse hull substitution was found insignificant on chewiness ($p > 0.05$),

gumminess and chewiness values showed a similar variation trend. The highest and the lowest values either for gumminess or chewiness were observed in noodles substituted with faba bean hull and green lentil hull, respectively.

Sensory properties

Consumer acceptance test was carried out with volunteers between 19 and 48 years old, recruited among university staff and students and the results were presented on Table 6. Noodles substituted with each type of pulse hull were evaluated individually along with the control noodle prepared according to the same recipe.

Appearance scores of the pulse hull substituted noodles significantly decreased with increasing the level of substitution with the exception of pea hull substituted noodles ($p < 0.05$). The lowest appearance scores was observed at the substitution level of 10% for all hull types. However, panellists did not recognize or significantly affected from pea hull substitution up to 10% level with regard to appearance. This result may be attributed to the light and creamy colour of pea hull which makes it unrecognizable. Similarly, the effect of pea hull substitution on texture scores of the noodles was also insignificant ($p > 0.05$). Texture scores of the noodles substituted with green and red lentil hulls at the level of 2.5% was also not different from control noodles, while higher substitution levels lead to lower scores. Although the texture scores of faba bean substituted noodles were lower than that of the control noodles, there was no significant difference between the

Table 6 Results of the consumer acceptance test

Noodle type	Substitution dose (%)	Appearance	Texture	Flavour	Overall acceptance (rank)
Green lentil hull substituted (n = 64)	0	5.68 ^A	5.56 ^A	5.65 ^A	1.93 ^A
	2.5	5.20 ^B	5.46 ^A	5.43 ^A	2.23 ^A
	5.0	4.99 ^B	4.96 ^B	4.81 ^B	2.79 ^B
	10.0	4.21 ^C	4.62 ^B	4.64 ^B	3.03 ^B
	<i>p</i>	0.000	0.000	0.000	0.000
Red lentil hull substituted (n = 64)	0	5.59 ^A	5.40 ^{AB}	5.62 ^A	2.00 ^A
	2.5	5.12 ^B	5.56 ^A	5.53 ^B	2.09 ^A
	5.0	5.01 ^B	5.17 ^{BC}	5.12 ^B	2.56 ^B
	10.0	4.35 ^C	4.78 ^C	4.54 ^C	3.34 ^C
	<i>p</i>	0.000	0.004	0.000	0.000
Faba bean hull substituted (n = 64)	0	5.64 ^A	5.62 ^A	5.84 ^A	1.65 ^A
	2.5	5.03 ^B	4.70 ^B	4.85 ^B	2.40 ^B
	5.0	4.68 ^B	4.65 ^B	4.54 ^{BC}	2.60 ^B
	10.0	3.98 ^C	4.14 ^B	4.01 ^C	3.32 ^C
	<i>p</i>	0.000	0.000	0.000	0.000
Pea hull substituted (n = 66)	0	5.72	5.16	5.25 ^{AB}	2.54
	2.5	5.48	5.40	5.50 ^A	2.25
	5.0	5.51	5.15	4.97 ^B	2.65
	10.0	5.21	5.18	5.04 ^B	2.54
	<i>p</i>	0.157	0.333	0.033	0.237

Means followed by different letters at the same column (for each noodle type individually) are significantly different by Dunn's test ($p < 0.05$)

substitution levels of 2.5 and 10% with regard to textural acceptability. Among the evaluated noodle types, the lowest flavour score was observed in noodles substituted with faba bean hull at the level of 10%. Flavour scores of the noodles substituted with green lentil, red lentil and faba bean hulls showed a downward trend with increasing substitution level. However, no notable variation was observed in flavour scores of the noodles substituted with pea hull up to 10% (Table 6). Accordingly, the effect of pea hull substitution up to 10% was insignificant on the overall acceptability scores ($p > 0.05$). Besides, control noodles and the noodles substituted with 10% of pea hull got the same scores in terms of overall acceptability. Therefore, it was concluded that appearance or colour has a remarkable effect on the overall acceptability of the noodles.

Among the noodles substituted with green lentil, red lentil, and faba bean hulls, the most preferred noodle type was control noodle in each set of analysis. However, noodles substituted with pea hull at the level of 2.5% was the most preferred (rank 1) sample among pea hull substituted noodles. Increasing the substitution level from 5 to 10% significantly decreased the overall acceptability scores of the noodles substituted with red lentil and faba bean hulls, while this amount of increase in substitution level

had no significant effect on the acceptability of the noodles substituted with green lentil and pea hulls.

Conclusion

Among the pulse hulls evaluated in this study, pea hull came forward owing to its high dietary fibre content, water absorption capacity and swelling volume. Moreover, pea hull substituted noodles up to 10% were well accepted by the panellists in terms of sensorial attributes. Therefore, it was concluded that pea hull has a significant potential as a noodle ingredient.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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