

Development of Quality Characteristics of Pasta Enriched with Lupin (*Lupinus albus* L.) Flour and Resistant Starch Type 4

Lüpen (*Lupinus albus* L.) Unu ve Tip 4 Dirençli Nişasta ile Zenginleştirilmiş Makarnanın Kalite Özelliklerinin Geliştirilmesi

Elif YAVER^{1*}, Nermin BİLGİÇLİ²

Abstract

Lupin (*Lupinus albus* L.) is a leguminous seed with a good source of protein, dietary fiber, fat, and is an alternative to soybean. Resistant starch, a prebiotic dietary fiber, cannot be digested in the small intestine; can help prevent diabetes, some cancer types, obesity, intestinal diseases and cardiovascular diseases. In this study, 15% lupin flour (debittered by traditional method and ultrasound application) and 10% resistant starch type 4 (RS4) were used in pasta production to improve its nutritional quality. The effects of vital gluten and/or transglutaminase on color, cooking quality, thermal and sensory properties of pasta containing lupin flour and RS4 were investigated. Ultrasound application had no adverse impact on the color L^* , a^* , b^* , water uptake, cooking loss, thermal and sensory (color, taste, odor, appearance, stickiness and overall acceptability) properties of pasta samples compared to traditional lupin debittering method. Compared to 100% semolina pasta, addition of lupin flour and RS4 revealed a higher b^* value, cooking loss and gelatinization onset temperature, and lower volume increase, firmness and gelatinization enthalpy values in pasta. The use of additives (vital gluten, transglutaminase and vital gluten + transglutaminase) improved the volume increase, cooking loss and firmness values of pasta containing 15% lupin flour + 10% RS4. The lowest cooking loss values were obtained in 100% semolina pasta (4.62%) as well as pasta samples supplemented with vital gluten (4.82%) and vital gluten + transglutaminase (4.90%). The color, taste and odor scores of 15% lupin flour + 10% RS4 pasta samples prepared with additives were close to each other. The addition of vital gluten and vital gluten + transglutaminase presented similar overall acceptability scores to 100% semolina pasta ($P>0.05$).

Keywords: Lupin, Resistant starch type 4, Vital gluten, Transglutaminase, Pasta

^{1*} Elif Yaver, Department of Food Engineering, Engineering and Architecture Faculty, Necmettin Erbakan University, Köycegiz Campus, 42050, Konya, Turkey.

E-mail: elifyaver@hotmail.com  ORCID: 0000-0002-2651-9922

² Sorumlu Yazar/Corresponding Author: Nermin Bilgiçli, Department of Food Engineering, Engineering and Architecture Faculty, Necmettin Erbakan University, Köycegiz Campus, 42050, Konya, Turkey. E-mail: nerminbil2003@hotmail.com  ORCID: 0000-0001-5490-9824

Atif/Citation: Yaver E, Bilgiçli N. Development of Quality Characteristics of Pasta Enriched with Lupin (*Lupinus albus* L.) Flour and Resistant Starch Type 4. *Tekirdağ Ziraat Fakültesi Dergisi*, 18 (3), 557-568.

*Bu çalışma Doktora tezinden özetlenmiştir.

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Öz

Bir baklagil tanesi olan lüpen (*Lupinus albus* L.), iyi bir protein, diyet lifi, yağ kaynağı olmasıyla birlikte soya fasulyesi için bir alternatiftir. Prebiyotik bir diyet lifi olan dirençli nişasta, ince bağırsakta sindirilemez; diyabet, bazı kanser çeşitleri, obezite, bağırsak hastalıkları ve kardiyovasküler hastalıkların önlenmesine yardımcı olabilir. Bu çalışmada; besinsel özelliklerini geliştirmek için, makarna üretiminde %15 oranında lüpen unu (geleneksel yöntem ve ultrason uygulaması ile acılığı giderilmiş) ve %10 oranında tip 4 dirençli nişasta (DN4) kullanılmıştır. Vital gluten ve/veya transglutaminazın, lüpen unu ve DN4 içeren makarnanın renk, pişme kalitesi, termal ve duyuşal özellikleri üzerine etkileri araştırılmıştır. Ultrason uygulaması, geleneksel lüpen acılık giderme yöntemine göre makarna örneklerinin renk L^* , a^* , b^* , ağırlık artışı, pişme kaybı, termal ve duyuşal (renk, tat, koku, görünüş, yapışkanlık ve genel beğeni) özellikleri üzerinde olumsuz bir etki göstermemiştir. %100 irmik makarnası ile karşılaştırıldığında, lüpen unu ve DN4 ilavesi makarnada daha yüksek b^* değeri, pişme kaybı ve jelatinizasyon başlangıç sıcaklığı ile daha düşük hacim artışı, sıklık ve jelatinizasyon entalpisi değerleri ortaya koymuştur. Makarna formülasyonunda katkı maddelerinin (vital gluten, transglutaminaz ve vital gluten + transglutaminaz) kullanımı, %15 lüpen unu + %10 DN4 içeren makarnanın hacim artışı, pişme kaybı ve sıklık değerlerini iyileştirmiştir. En düşük pişme kaybı değerleri %100 irmik makarnası (%4.62) ile vital gluten (%4.82) ve vital gluten + transglutaminaz (%4.90) ile katılanmış makarna örneklerinde elde edilmiştir. Katkı maddeleri kullanılarak üretilen %15 lüpen unu + %10 DN4 makarna örneklerinin renk, tat ve koku puanları birbirine yakın bulunmuştur. Vital gluten ve vital gluten + transglutaminaz ilavesi, %100 irmik makarnasına benzer genel beğeni puanları sağlamıştır ($P>0.05$).

Anahtar Kelimeler: Lüpen, Tip 4 dirençli nişasta, Vital gluten, Transglutaminaz, Makarna

1. Introduction

Protein-energy malnutrition, which causes morphological changes in the brains of children and child mortality, is an important problem in most developing countries. Legumes are important foods to improve the nutritional quality of cereal-based products as a high protein and energy source in these countries (Temba et al., 2016). Lupin (*Lupinus albus* L.) is an ancient leguminous crop that is rich in protein, dietary fiber, fat, vitamins, minerals and phytochemicals (Uzun et al., 2007). Furthermore, the amount of antinutritional compounds such as lectins, trypsin inhibitors and haemagglutinins in lupin is lower than other legumes (Enneking and Wink, 2000). Consumption of lupin may provide many health benefits that are associated with obesity, diabetes, cholesterol and cardiovascular diseases (Prusinski, 2017).

Resistant starch (RS), known as a dietary fiber, cannot be digested in the small intestine within 120 min after consumption, but fermented by the large intestine microflora (Englyst et al., 1992). RS, like as a soluble fiber, has potential benefits on health by reducing serum cholesterol and triglycerides, increasing short-chain fatty acids and the crypt cell production level in the colon (Haralampu, 2000; Uran et al., 2021). Also, RS has a positive impact on color, functional and organoleptic properties of food products without markedly changing texture compared to traditional dietary fiber sources (Sajilata et al., 2006).

The weakening of gluten matrix in cereal-based products such as pasta due to addition of lupin flour and RS causes a reduction in the technological quality (Velioğlu et al., 2017). So, many additives such as vital gluten and transglutaminase can be used to improve cooking quality, textural and sensory properties of pasta enriched with lupin flour and RS. Gluten content/composition is more important than protein content in terms of pasta quality (Dexter and Matsuo, 1978). The use of vital wheat gluten in pasta enriched with non-wheat flours helps to develop of a strong gluten network, increases firmness and decreases cooking loss and stickiness in pasta (Wood, 2009). Transglutaminase catalyzes an acyl-transfer reaction in covalent bonds between proteins, resulting covalent cross-links between protein chains (Kuraishi et al., 2001). It was reported that addition of transglutaminase provided a strong protein network (Kim et al., 2014), decreased cooking loss and improved textural properties in pasta (Sissons et al., 2010).

To the best of our knowledge, this is the first study to determine the effect of vital gluten and transglutaminase on quality properties of ultrasound-treated lupin flour and RS enriched pasta. The aims of this study were to improve the nutritional quality of pasta with 15% debittered lupin flours + 10% resistant starch type 4 (RS4) and to investigate the effect of different additives (vital gluten, transglutaminase and vital gluten+transglutaminase) on the color, cooking quality, firmness, thermal and sensory properties of pasta containing lupin flour and RS4.

2. Materials and Methods

2.1. Materials

Durum wheat (*Triticum durum* L.) semolina (11.89% protein, 0.95% ash and 4.15% total dietary fiber) was supplied from Selva (Konya, Turkey). RS4 (phosphorylated cross-linked wheat starch, 91.03% RS and 93.12% total dietary fiber) was obtained from a commercial manufacturer in Konya (Turkey). Vital wheat gluten was supplied from Vatan Enzyme (İstanbul, Turkey), and microbial transglutaminase (activity 100 U g⁻¹) was procured from SternEnzym (Ahrensburg, Germany).

Debittered lupin flours [lupin flour debittered by traditional method (LFTM - 39.29% protein and 45.19% total dietary fiber) and lupin flour debittered by ultrasound application (LFUA - 40.21% protein and 44.32% total dietary fiber)] used in this study were obtained as described in the previous study of the authors (Yaver, 2021). Two different debittering processes including traditional method and ultrasound application were applied to bitter lupin seeds (*L. albus* L.). The bitter seeds were boiled in water (1:3, w/v) for 75 min. In traditional method, the seeds were soaked in water (1:10, w/v) for 144 h after boiling. In developed method with ultrasound, the boiled seeds were soaked in 25 °C water (1:10, w/v) for 60 h, and were sonicated for 25 min every 4 h during soaking. After debittering, the seeds (total alkaloid content < 0.02 g 100 g⁻¹) were dried in a hot-air oven (Nüve KD-200, Ankara, Turkey) at 50 °C and then were ground into whole flour (< 500 µm). After that, the flour samples were stabilized by dry roasting method at 160 °C for 30 min.

2.2. Methods

2.2.1. Pasta production

Pasta samples were produced using a pilot-scale pasta extruder (La Monferrina Dolly, Moncalieri, Italy) according to the method described by Brennan and Tudorica (2007). For preparation of pasta containing 100% semolina, semolina and distilled water (100:30, semolina:water, w/v) were mixed for 5 min. The mixture was extruded in the shape of penne rigate. The samples were dried in a pilot-scale drier (La Monferrina EC50, Moncalieri, Italy) at low temperature (maximum 58 °C) for 10 h 44 min.

The experimental design of pasta samples is demonstrated in *Table 1*. In additive-free enriched pasta samples, semolina was replaced with 15% LFTM/LFUA + 10% RS4. To produce pasta containing 15% lupin flour + 10% RS4 + additives, vital gluten (at the amount of the diluted gluten), transglutaminase (0.5%) or vital gluten+transglutaminase combination were supplemented into pasta formulations. The same pasta production procedure applied for 100% semolina pasta was also employed for these samples.

Table 1. Experimental design for pasta production

Lupin flour type	Additives
LFTM	100% semolina
	15% LFTM + 10% RS4
	15% LFTM + 10% RS4 + VG
	15% LFTM + 10% RS4 + TG
LFUA	100% semolina
	15% LFUA + 10% RS4
	15% LFUA + 10% RS4 + VG
	15% LFUA + 10% RS4 + TG
	15% LFUA + 10% RS4 + VG + TG

LFTM: Lupin flour debittered by traditional method; LFUA: Lupin flour debittered by ultrasound application; RS4: Resistant starch type 4; VG: Vital gluten; TG: Transglutaminase.

2.2.2. Color

The color L^* (lightness; 0 = black, 100 = white), a^* (redness/greenness; + = red, - = green) and b^* (yellowness/blueness; + = yellow, - = blue) parameters were measured using a colorimeter (Konica Minolta CR 400, Osaka, Japan) according to the method described by Francis (1998). All measurements were made in triplicate.

2.2.3. Cooking quality

The water uptake, volume increase and cooking loss values of cooked pasta samples were determined according to Oh et al. (1985) and Özkaya (2005). The pasta samples (20 g) were cooked in 250 ml boiling distilled water for optimum cooking time. The water uptake of samples was expressed by ratio between cooked and dry pasta weights. The volume increase was determined as the percentage difference in cooked and dry pasta volumes. For determination of cooking loss, cooking water was dried until constant weight and weighed. The cooking loss was expressed as a percentage of the dry pasta.

2.2.4. Firmness

The firmness values of cooked pasta samples were measured by a texture analyzer (Stable Micro Systems TA-XT.Plus, Surrey, UK) equipped with an A/LKB-F probe according to AACC method 66-50 (AACC, 2000). Test conditions were as follows: load cell 30 kg; test speed of 1.0 mm s⁻¹, post-test speed of 10 mm s⁻¹ and distance of 4.5 mm. The three cooked pasta strands were sheared at a 90° angle. The maximum compression force of the pasta was defined as firmness. Measurements were performed three times and average were reported.

2.2.5. Differential scanning calorimetry measurements

Differential scanning calorimetry (DSC) measurements were made with a TA DSC25 equipment (TA Instruments, Delaware, USA) according to the method described by Güler et al. (2002). Ground pasta samples were weighed (2.4-

2.7 mg) into DSC aluminum hermetic pans, and distilled water was added at 1:3 ratio (sample:water, w/v). The pans were allowed to equilibrate in a refrigerator for 4 h prior to analysis. An empty hermetic pan was used as a reference. The cell was heated at a rate of 10 °C min⁻¹ from 10 °C to 100 °C. The onset temperature (T_o), peak temperature (T_p) and enthalpy (ΔH) were evaluated using the TA Instruments analysis software program (TA Instruments, Delaware, USA).

2.2.6. Sensory analysis

For sensory analysis, pasta samples were cooked for optimum cooking time in boiling distilled water, drained and served to 12 panelists. Color, taste, odor, appearance, stickiness and overall acceptability parameters were evaluated using a 9-point scale (1: dislike extremely, 5: neither like nor dislike, 9: like extremely)(Epler et al., 1998).

2.2.7. Statistical analysis

The results were compared by two-way analysis of variance (ANOVA) using TARIST 4.01 (Ege University, İzmir, Turkey) software. Differences between the respective means were determined using Duncan's multiple comparison tests ($P < 0.05$). The results were expressed as mean \pm standard deviation (Düzgüneş et al., 1987).

3. Results and Discussion

The color L^* , a^* and b^* values of pasta samples are demonstrated in Table 2. The mean L^* , a^* and b^* values of pasta samples prepared with LFUA were found statistically similar to pasta samples prepared with LFTM ($P > 0.05$). When the results are compared in terms of additives, a decrease in the mean L^* value of pasta containing 15% LFTM/LFUA + 10% RS4 was found with the addition of vital gluten. This result may be attributed to creamy color of vital gluten. The mean a^* values of samples varied in the range of 0.27 and 2.46. The use of 15% lupin flour + 10% RS4 with/without additives in pasta formulation significantly ($P < 0.05$) increased a^* value compared to 100% semolina pasta. Bright yellow color is generally preferred by consumers in pasta. The addition of 15% lupin flour + 10% RS4 increased b^* value of pasta compared to 100% semolina pasta (Figure 1). This may be related to higher yellow pigment content in lupin flour than semolina (Jayasena and Nasar-Abbas, 2012). While addition of vital gluten decreased the mean b^* value of pasta containing 15% lupin flour + 10% RS4, addition of transglutaminase and vital gluten+transglutaminase had no significant ($P > 0.05$) effect on b^* value of pasta containing 15% lupin flour + 10% RS4 (Table 2). According to Sissons et al. (2010), this result may be related to the insufficient effect of transglutaminase on the pasta surface.

Table 2. Color values of pasta samples

Factor	n	L^*	a^*	b^*
Lupin flour type				
LFTM	10	57.77 \pm 1.37 ^a	1.98 \pm 0.97 ^a	30.33 \pm 0.92 ^a
LFUA	10	57.65 \pm 1.32 ^a	1.91 \pm 0.92 ^a	30.61 \pm 0.91 ^a
Additives				
100% semolina	4	57.68 \pm 0.30 ^b	0.27 \pm 0.01 ^b	29.62 \pm 0.20 ^b
15% lupin flour + 10% RS4	4	58.24 \pm 0.06 ^{ab}	2.27 \pm 0.04 ^a	30.97 \pm 0.28 ^a
15% lupin flour + 10% RS4 + VG	4	55.91 \pm 0.22 ^c	2.36 \pm 0.18 ^a	29.35 \pm 0.20 ^b
15% lupin flour + 10% RS4 + TG	4	59.54 \pm 0.38 ^a	2.46 \pm 0.10 ^a	31.27 \pm 0.11 ^a
15% lupin flour + 10% RS4 + VG + TG	4	57.18 \pm 0.15 ^{bc}	2.38 \pm 0.04 ^a	31.16 \pm 0.21 ^a

Means followed by the different letter within a column are significantly ($P < 0.05$) different. Duncan's multiple comparison test results according to lupin flour type and additives variance sources. Values are the average of triplicate measurements on the duplicate samples. n: number of samples analyzed; LFTM: Lupin flour debittered by traditional method; LFUA: Lupin flour debittered by ultrasound application; RS4: Resistant starch type 4; VG: Vital gluten; TG: Transglutaminase.

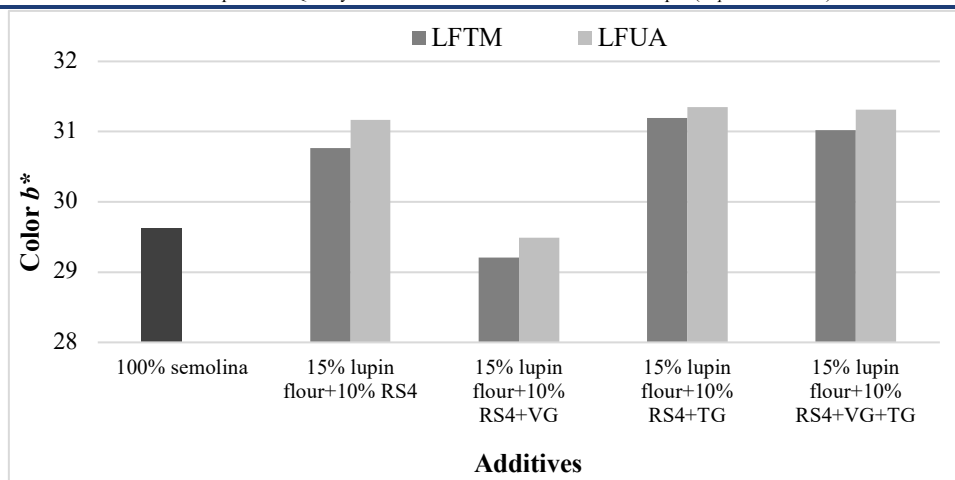


Figure 1. Color b* values of pasta samples

The water uptake, volume increase and cooking loss values of cooked pasta samples are given in Table 3. Lupin flour type (LFTM and LFUA) did not show a significant ($P>0.05$) difference in water uptake values of the samples. Compared to 100% semolina pasta, addition of 15% lupin flour + 10% RS4 significantly ($P<0.05$) decreased the mean water uptake value of pasta from 147.11% to 137.88%. This decrease may be related to disruption of gluten network due to addition of lupin flour and RS4. However, the mean water uptake values of pasta samples supplemented with vital gluten and vital gluten+transglutaminase were close to 100% semolina pasta. The water absorption of pasta during cooking is mainly related to starch gelatinization and water absorption of gluten (Delcour et al., 2000; Sozer and Kaya, 2003). Therefore, the increase in gluten ratio with the addition of vital gluten can be provided a higher water uptake values in the pasta (Majzooobi et al., 2011). Jyotsna et al. (2004) showed that addition of vital gluten increased water uptake value of vermicelli compared to control.

Table 3. Cooking properties and firmness values of pasta samples

Factor	n	Water uptake (%)	Volume increase (%)	Cooking loss (%)	Firmness (g)
Lupin flour type					
LFTM	10	144.06±4.60 ^a	210.14±4.37 ^a	5.22±0.68 ^a	1350±136.86 ^a
LFUA	10	143.93±3.84 ^a	207.63±4.09 ^b	5.26±0.64 ^a	1311±140.63 ^b
Additives					
100% semolina	4	147.11±1.04 ^a	214.71±2.04 ^a	4.62±0.06 ^c	1446±16.26 ^a
15% lupin flour + 10% RS4	4	137.88±1.07 ^c	203.56±1.97 ^d	6.18±0.02 ^a	1092±21.21 ^c
15% lupin flour + 10% RS4 + VG	4	147.84±2.02 ^a	210.78±1.98 ^b	4.82±0.05 ^c	1365±41.80 ^b
15% lupin flour + 10% RS4 + TG	4	141.81±0.77 ^{bc}	207.17±0.03 ^c	5.68±0.04 ^b	1376±44.55 ^b
15% lupin flour + 10% RS4 + VG + TG	4	145.31±0.21 ^{ab}	208.21±2.92 ^{bc}	4.90±0.04 ^c	1374±45.96 ^b

Means followed by the different letter within a column are significantly ($P<0.05$) different. Duncan's multiple comparison test results according to lupin flour type and additives variance sources. Values are the average of triplicate measurements on the duplicate samples. n: number of samples analyzed; LFTM: Lupin flour debittered by traditional method; LFUA: Lupin flour debittered by ultrasound application; RS4: Resistant starch type 4; VG: Vital gluten; TG: Transglutaminase.

As shown in Table 3, the mean volume increase value of pasta samples produced with LFUA (207.63%) was lower than the samples produced with LFTM (210.14%). It was reported that ultrasound may decrease the water holding capacity of proteins due to causing denaturation of the molecular structure of proteins and an increase of the hydrophobic surface of proteins (Resendiz-Vazquez et al., 2017). The decrease in volume increase may be attributed to the decrease in the water holding capacity of lupin proteins because of ultrasound application during debittering process. When the results are examined in terms of additives, all of additives increased the mean volume increase values of pasta compared to pasta containing 15% lupin flour + 10% RS4 without additives (Figure 2). In addition, the highest volume increase value was observed in 100% semolina pasta, followed by pasta

samples supplemented with vital gluten and vital gluten+transglutaminase (Table 3). This may be related to the strengthening of the gluten network because of the vital gluten addition.

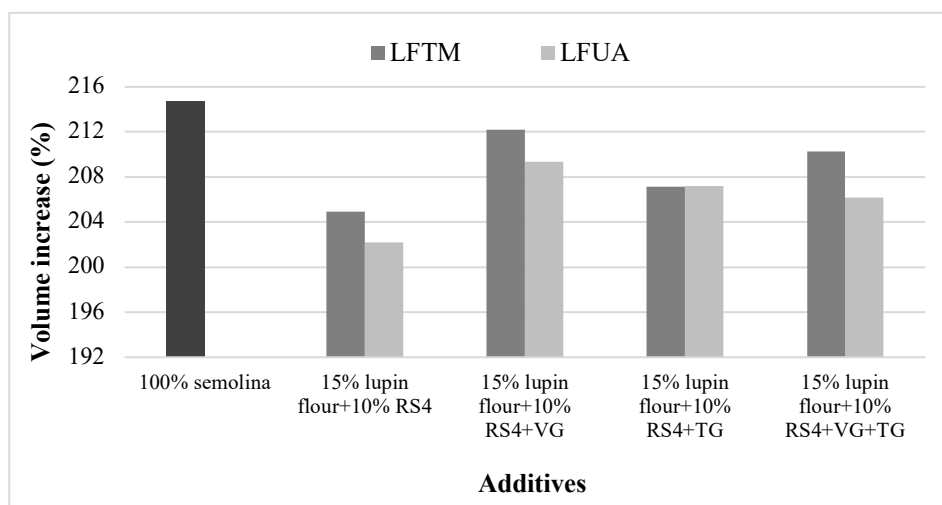


Figure 2. Volume increase values of pasta samples

The mean cooking loss values of pasta samples prepared with LFTM and LFUA were 5.22% and 5.26%, respectively (Table 3). Lupin flour type factor had no significant ($P>0.05$) effect on cooking loss of pasta samples. As seen in Figure 3, the highest cooking loss value was obtained in pasta containing 15% lupin flour + 10% RS4 without additives. This result may be attributed to disruption of protein-starch matrix due to addition of dietary-fiber rich lupin flour and RS4 (Petitot et al., 2010). The use of vital gluten and vital gluten+transglutaminase in pasta revealed statistically ($P>0.05$) similar cooking loss results to 100% semolina pasta (Table 3). This may be due to the decrease in leaching of soluble components into cooking water as a result of the formation of a strong gluten network by the addition of vital gluten. Jyotsna et al. (2004) reported that cooking loss of vermicelli reduced from 6.7% to 5.0% by vital gluten supplementation. On the other hand, the effect of transglutaminase on cooking loss of pasta may be attributed to the presence of cross-linked protein structures due to transglutaminase addition which reduces the leaching of starch granules into water (Kuraishi et al., 2001).

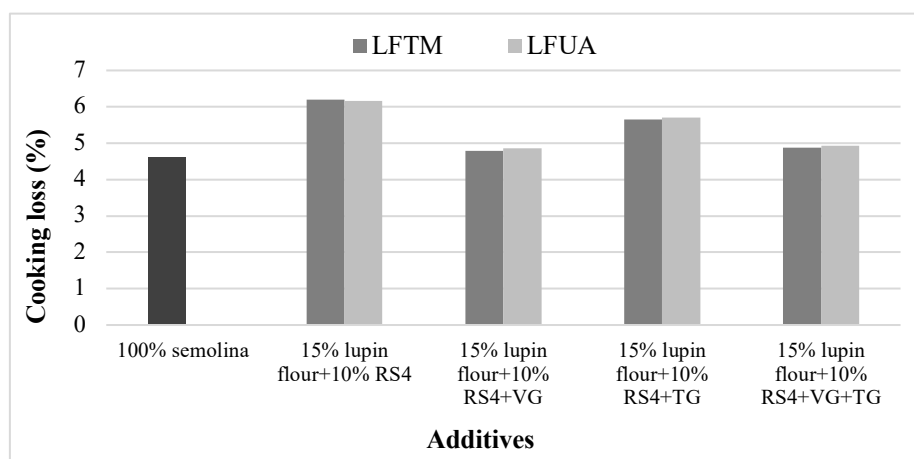


Figure 3. Cooking loss values of pasta samples

The mean firmness value of pasta containing LFTM was higher than pasta containing LFUA (Table 3). This may be due to the decrease in water absorption capacity because of changes in the molecular structure of proteins induced by ultrasound application (Resendiz-Vazquez et al., 2017). In terms of additives, use of 15% lupin flour + 10% RS4 without additives resulted in the lowest firmness value in pasta (Figure 4). This result may be due to

a weakening of the gluten network as a result of increasing dietary fiber content with the addition of lupin flour and RS4 (Petitot et al., 2010). While all additives increased the mean firmness value of pasta containing 15% lupin flour + 10% RS4, there was no significant ($P>0.05$) difference between pasta samples produced with additives in terms of firmness value (Table 3). The increase in firmness may be associated with the strengthening of the gluten network due to addition of vital gluten or transglutaminase. Sissons et al. (2010) reported that adding transglutaminase to pasta increased firmness value compared to control.

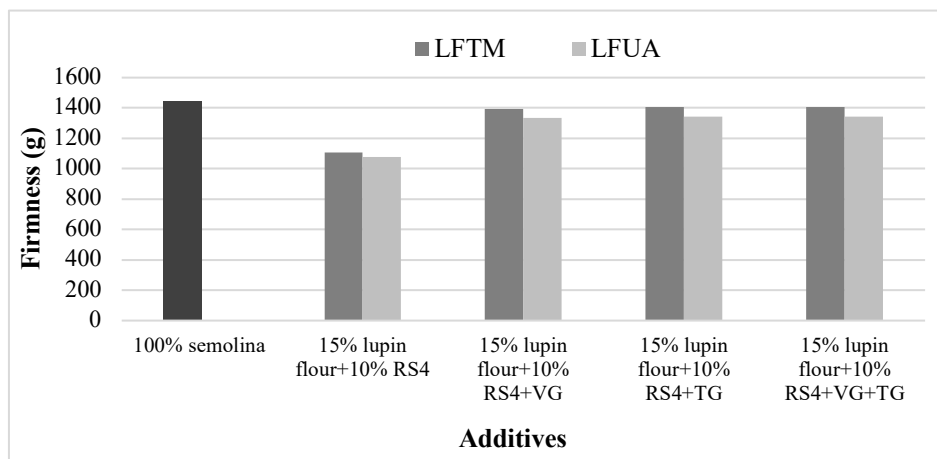


Figure 4. Firmness values of pasta samples

DSC measurements of pasta samples are given in Table 4. There was no statistically significant ($P>0.05$) difference between the mean T_o , T_p and ΔH values of pasta samples prepared with LFTM and LFUA. While the mean T_o value of pasta samples increased with the addition of 15% lupin flour + 10% RS4, the mean ΔH value decreased. These results may be associated with the alteration in starch structure and content due to the addition of lupin flour and RS4 (Tazart et al., 2019). In terms of additives, use of vital gluten, transglutaminase or vital gluten+transglutaminase did not show a significant ($P>0.05$) effect on the mean T_o and T_p values of pasta containing 15% lupin flour + 10% RS4. However, the mean ΔH value of pasta containing 15% lupin flour + 10% RS4 + vital gluten + transglutaminase (0.08 J g^{-1}) was lower than pasta containing 15% lupin flour + 10% RS4 (0.36 J g^{-1}). The decrease in ΔH value may be due to increase in protein content of pasta with the addition of vital gluten (Tazart et al., 2019). On the other hand, the effect of transglutaminase on ΔH value may be attributed to the formation of covalent cross-linked bonds between proteins (Lin et al., 2009). Our results are in agreement with Kim et al. (2014) who obtained a decrease in ΔH value of noodle due to addition of rice protein isolate and transglutaminase.

Table 4. DSC measurement values of pasta samples

Factor	n	T_o (°C)	T_p (°C)	ΔH (J g ⁻¹)
Lupin flour type				
LFTM	10	58.15±1.12 ^a	59.86±0.35 ^a	0.46±0.58 ^a
LFUA	10	58.10±1.02 ^a	59.97±0.26 ^a	0.49±0.63 ^a
Additives				
100% semolina	4	56.22±0.06 ^b	59.55±0.27 ^a	1.54±0.10 ^a
15% lupin flour + 10% RS4	4	58.68±0.23 ^a	60.16±0.03 ^a	0.36±0.06 ^b
15% lupin flour + 10% RS4 + VG	4	58.64±0.21 ^a	59.81±0.06 ^a	0.17±0.04 ^{bc}
15% lupin flour + 10% RS4 + TG	4	58.47±0.25 ^a	60.28±0.06 ^a	0.20±0.06 ^{bc}
15% lupin flour + 10% RS4 + VG + TG	4	58.61±0.08 ^a	59.78±0.08 ^a	0.08±0.02 ^c

Means followed by the different letter within a column are significantly ($P<0.05$) different. Duncan's multiple comparison test results according to lupin flour type and additives variance sources. Values are the average of triplicate measurements on the duplicate samples. n: number of samples analyzed; T_o : Gelatinization onset temperature; T_p : Gelatinization peak temperature; ΔH : Gelatinization enthalpy; LFTM: Lupin flour debittered by traditional method; LFUA: Lupin flour debittered by ultrasound application; RS4: Resistant starch type 4; VG: Vital gluten; TG: Transglutaminase.

Sensory analysis results of pasta samples containing LFTM and LFUA are demonstrated in Figure 5. In both pasta samples produced with LFTM and LFUA, color, taste and odor scores of pasta samples supplemented with additives were close to pasta containing 15% lupin flour + 10% RS4. The use of vital gluten and vital gluten+transglutaminase in pasta presented a higher appearance scores compared to pasta produced without additives. Whereas the addition of 15% lupin flour + 10% RS4 decreased stickiness and overall acceptability scores compared to 100% semolina pasta, pasta containing 15% lupin flour + 10% RS4 + vital gluten or vital gluten+transglutaminase had statistically ($P>0.05$) similar scores to 100% semolina pasta. Similarly, Majzooobi et al. (2011) reported that sensory analysis (color, taste, stickiness, hardness and overall acceptability) scores of pasta supplemented with vital gluten were higher than control pasta.

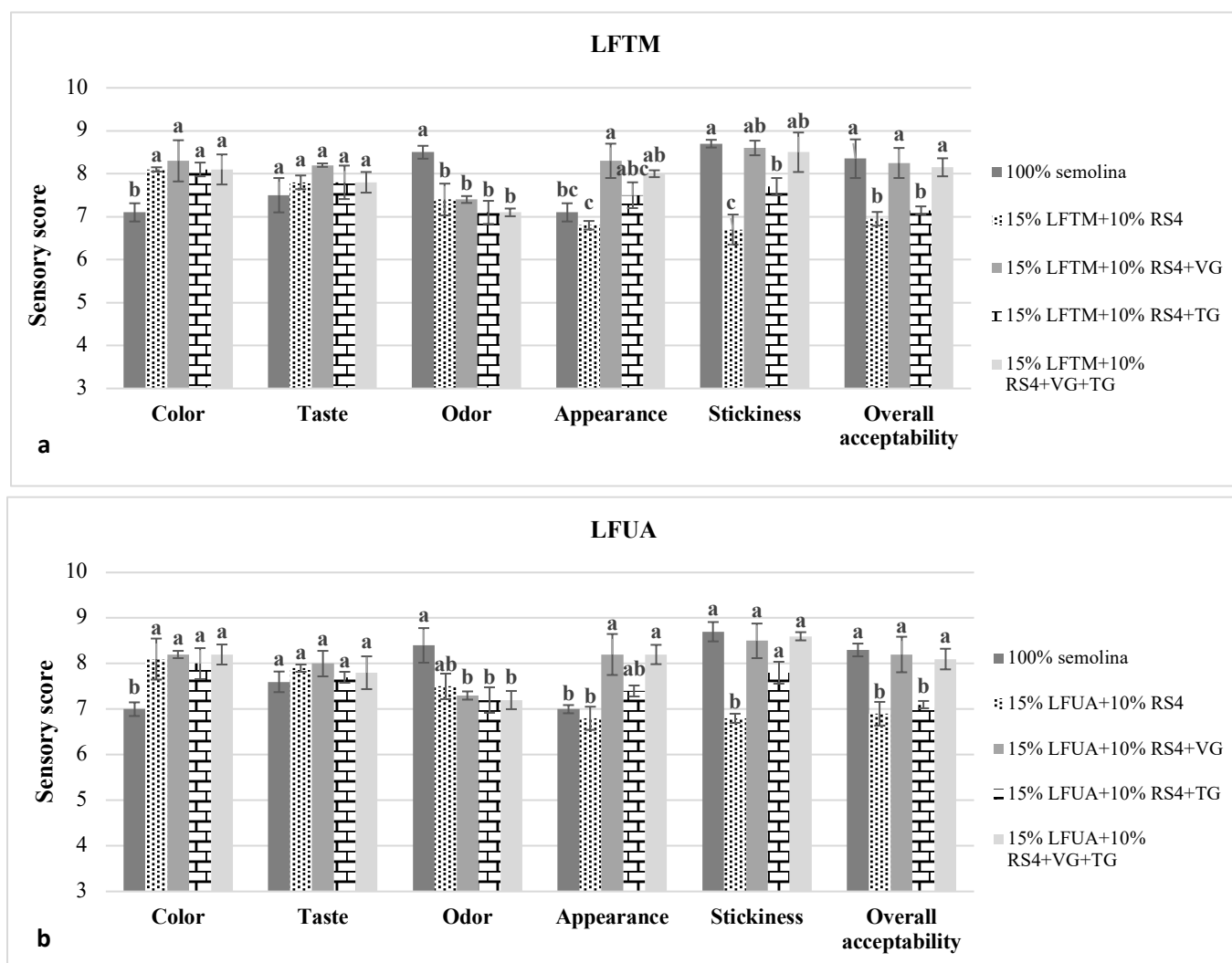


Figure 5. Sensory properties of pasta samples containing LFTM (a) and LFUA (b)

4. Conclusions

This study showed that the use of LFUA instead of LFTM in pasta production had no adverse effect on the color, water uptake, cooking loss, thermal and sensory properties of pasta. The addition of 15% lupin flour + 10% RS4 without additives increased b^* value of pasta, but caused a negative effect on the cooking properties, firmness, stickiness and overall acceptability of pasta. All additives (vital gluten, transglutaminase and vital gluten+transglutaminase) markedly improved volume increase, cooking loss, firmness and stickiness values of pasta containing 15% lupin flour + 10% RS4. In addition, among the additives, vital gluten was more effective on cooking properties of pasta. In both pasta samples containing LFTM and LFUA, overall acceptability scores of pasta produced with 100% semolina, 15% lupin flour + 10% RS4 + vital gluten/vital gluten+transglutaminase were statistically ($P>0.05$) similar to each other and higher than pasta containing 15% lupin flour + 10% RS4 without additives or with

transglutaminase. This study demonstrated that the combination of 15% lupin flour + 10% RS4 + vital gluten could be enhanced nutritional, technological and sensory quality of pasta.

Acknowledgment

This work was supported by The Scientific and Technological Research Council of Turkey (TUBITAK) (Project No: 119O071), Turkey. Elif Yaver is YÖK 100/2000 scholarship holder.

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