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The Quality Assessment of Starch Based Noodles Enriched with Acorn Flour, Cooking Characteristics, Physical, Chemical and Sensorial Properties

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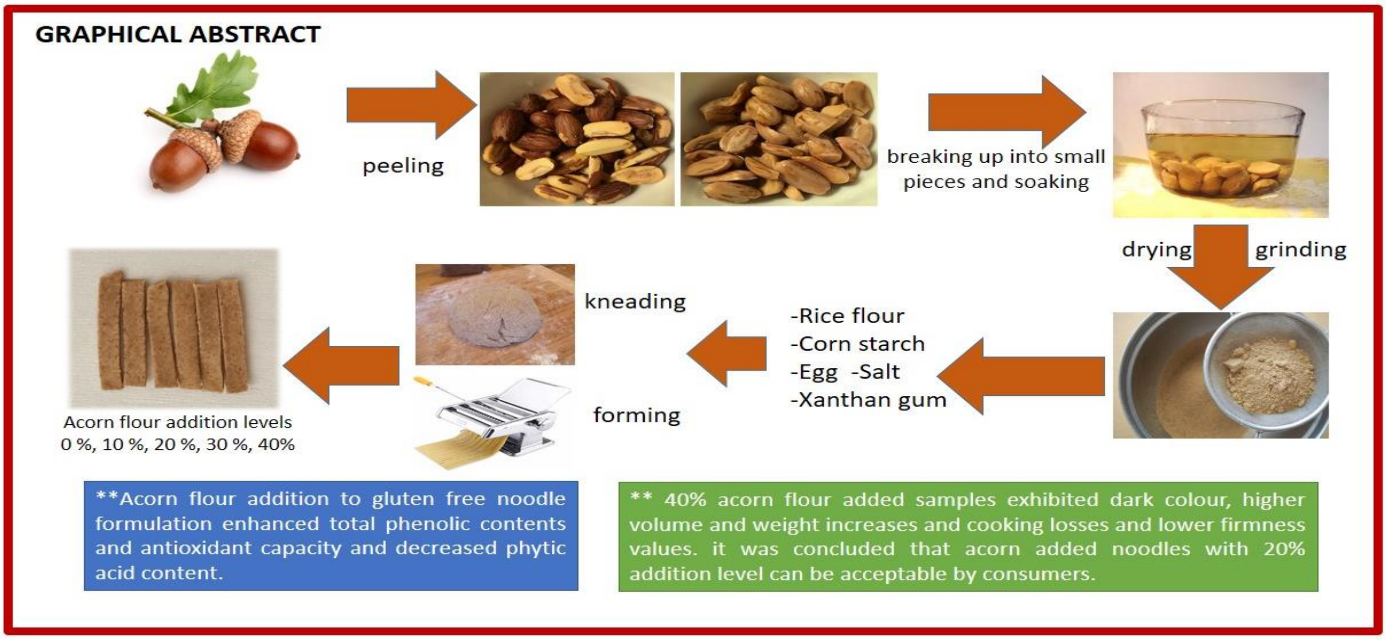
HIGHLIGHTS

- Acorn flour increased ash, protein and fat contents of gluten free noodles.
- The lower phytic acid values were observed with acorn flour addition.
- Total phenolic contents and antioxidant capacity significantly increased.
- Volume and weight increases and high cooking losses occurred.
- Acorn flour added samples gained lower sensory scores.

Abstract: In this research, acorn flour (AF) was used in starch based noodle production. It was replaced with gluten free mix at four different ratios (10, 20, 30 40%) for supplementation. The results indicated that AF utilization caused lower L* values and higher a* values and the total color difference reached 22.86. Especially, 30% and 40% addition of AF led to volume and weight increases and high cooking losses compared to control. Besides these samples exhibited lower firmness values. There were not a significant effect on optimum cooking time, swelling index, water solubility index and brix values. The utilization of AF at the level of 40% increased ash, protein and fat content from 0.89%, 5.64% and 2.64% to 1.14%, 7.70% and 6.83% respectively. The highest total phenolic contents and antioxidant capacity were detected in 40% AF added samples (17.55 and 5.77 fold). Also one of the remarkable results of the study were the lower phytic acid and phytate phosphorus contents with AF usage. The results changed between 184.39-27.54 mg/100g and 52.00-7.76 mg/100g respectively. An increment in water absorption and decrement in C3 and stability values revealed with usage of 30% and upper levels of AF in mixolab measurements. The parameters of sensory analysis evaluated, it was observed that AF addition occured negative effects and it was concluded that although improvement of nutritional composition of gluten free noodles with AF, it may be used maximum 20% as ratio.

Keywords: acorn; cooking properties; gluten free; noodle; quality.



INTRODUCTION

Gluten comprises mixture of gliadin and glutenin proteins in wheat and corresponds to 80% of total grain proteins [1]. It is responsible for structure-forming in bakery products especially extensibility, stretch resistance, mixing tolerance, gas holding capacity of doughs are provided with gluten. Also it encompasses starch granules and fibre components in the medium and it affects the appearance and crumb structure of many baked products [2]. Some individuals have gluten intolerance or allergenicity. When this intolerance or allergenicity progresses, it is called celiac disease which can be defined as antibody-mediated enteropathy. The patients present permanent intolerance to ingested gluten and it is pointed out by Fasano and Catasi [3] that the disease is most common food intolerance in the world [4]. The intolerance occurs against the gliadins (wheat), hordeins (barley), secalins (rye), and possibly avidins (oats) [5]. This disease leads to some deficiencies of various nutritional components intake. Unfortunately, the only available treatment is eliminating gluten in diet during life [6].

Pasta and noodle products which attract attention due to simple preparation, utilisation and storage can be a good prefer for improvement of structural and nutritional value of gluten free products [7] and for assessment of pasta and noodle quality, consumers mostly take the texture properties into consideration. High firmness, absence of stickiness and low cooking losses are desirable properties for pasta-type products. The lack of gluten which lead to discontinuous network affects these quality characteristics [8]. On the other hand gluten free pasta and noodle products display poor nutritional and sensorial profiles due to flour and/or starch from corn, rice, potato (or other tubers), gums, and emulsifiers are used as general ingredients in formulations [9]. Recently, for elimination of these deficiencies researchers have focused on alternative ingredients such as pseudo-cereals, legume flours and vegetable or fruits powders [8].

Acorn flour as one of the these alternative ingredients was used in formulation of some gluten free products. It (nuts of the oak) have been used in the cuisine of many nations, countries, and cultures for a long time and it's consumption has been in different forms such as raw, roasted or boiled or used to make oil, soup, porridge, cake, bread, ice cream and other desserts and coffee-like beverages or liqueurs [10]. For example, Korus and coauthors [11], Skendi and coauthors [12] and Beltrão Martins and coauthors [13] produced gluten free breads, Korus and coauthors [14], Torabi and coauthors [15] and Pasqualone and coauthors [16] produced gluten free biscuits and Masmoudi and coauthors [17] produced gluten free muffins with acorn flour in recent times. When the chemical composition of acorn is examined, it can exhibits differences depending on the species and starch, protein, fat contents ranged from 31.00, 2.75, 0.70% to 55.00, 8.44, 9.00% respectively [11]. Silva and coauthors [18] described the nutritional value of acorn flours from two different subspecies of Quercus using two different traditional methods (drying and roasting) and they reported that moisture content 5.40-22.05%, ash content 1.81-2.04%, protein content 4.32-5.00%, lipid content 8.44-13.86%, starch content 51.79-57.82% and fibre content 10.89-17.90%. The taste of acorn oil is comparable to olive oil because of high levels of unsaturated fatty acids mostly oleic and linoleic acids and it is also a good source of minerals and biologically active compounds. However, the amount of acorn tannins can be reduced with different thermal treatments [11]. It was expressed that acorn coffee, which is obtained by pulverizing the roasted acorn (*Q. robur, Q. cerris and Q. ithaburensis subsp. macrolepis*) after peeling, is used as a support that is good for the stomach. Furthermore, the antimicrobial activities of the different extracts of *Q. petraea ssp. iberica*'s acorn against two gram-positive, two gram-negative bacteria and three yeast-like fungi were investigated. Ethyl acetate extract showed the highest activity among all extracts. [19]. Sasani and coauthors [20] evaluated the effects of acorn added muffin consumption on appetite in patients with type 2 diabetes. They reported that hunger, desire to eat, and prospective to eat as some of the appetite parameters were significantly lower, and satiety and fullness were significantly higher, in the acorn muffin group. Gkountenoudi-Eskitzi and coauthors [21] used acorn (ACF) and chickpea (CPF) flour blend in gluten free breads and the results showed that *in vitro* enzymatic starch digestibility of the bread crumb decreased with increasing ACF and ACF-CPF added breads had lower *in vivo* glycemic index and load compared to control.

When considering only available treatment is eliminating gluten in diet during life for celiac disease, the importance of the alternative products is revealed. This study was investigated the usage potential of acorn flour in gluten free noodle production (with cooking characteristics and some selected physical, chemical, sensorial properties) and it is believed that the end product can be an alternative for some individuals who have gluten intolerance or allergenicity.

MATERIAL AND METHODS

Materials

Rice flour, corn starch, egg and salt used in gluten free noodle formulation were purchased from a local market in Karaman, Turkey. Xanthan gum was supplied by Vatan Gıda (Istanbul, Turkey). Acorns *(Quercus ithaburensis)* were collected at the maturity stage from Konya, Turkey in 2020 and were soaked (1:50 g/mL) for debittering after their shells and inner membranes were removed. Then they were dried, grounded and turned into flour with a grinder. The flour was stored in a refrigerator (4°C) until further using. Acorn flour had 4.40% moisture, 1.00% ash, 5.12% crude protein, 9.78% crude fat.

Preparation of noodle samples

The method reported by Levent [22] was used for gluten free noodle production and formulation of control sample was consist of 100 g rice flour:corn starch (50:50), 30 g whole egg, 3 g xanthan gum, 0.5 g salt and 40 ml water. Acorn flour was replaced with gluten free flour at 0, 10, 20, 30 and 40% levels (Fig. 1). All ingredients were mixed in a mixer (Kitchen Aid Artısan Series Mixer, USA) for 5 min and the obtained doughs were divided three pieces and rested for 15 min. Thickness of doughs were arranged with noodle machine (Vitalia Pasta Machine, İzmir, Turkey) to 2 mm. The sheeted doughs were cut as 6 mm stripes and 4.5 cm long pieces. Drying was performed at ambient conditions then the samples were packed in polyethylene plastic bags.

Color measurements

The color measurements (L^* (white; black), a^* (red; green) and b^* (yellow; blue) values) were obtained with a Hunter Lab Color QUEST II Minolta CR-400 (Minolta Camera, Co., Ltd., Osaka, Japan). The total color difference (ΔE^*) and the whiteness index (W) were calculated with Equation 1 and 2 respectively as specified in the study of Zarzycki and coauthors [23].

$$\Delta E^* = ((L_c - L_i)^2 + (a_c - a_i)^2 + (b_c - b_i)^2)^{1/2} \qquad Eq. (1).$$

$$W = 100 - ((100-L)^2 + a^2 + b^2)^{1/2} \qquad Eq. (2).$$

The L_c, a_c, and b_c show color values of the control sample, besides, L_i, a_i, and b_i references show color values of other samples.

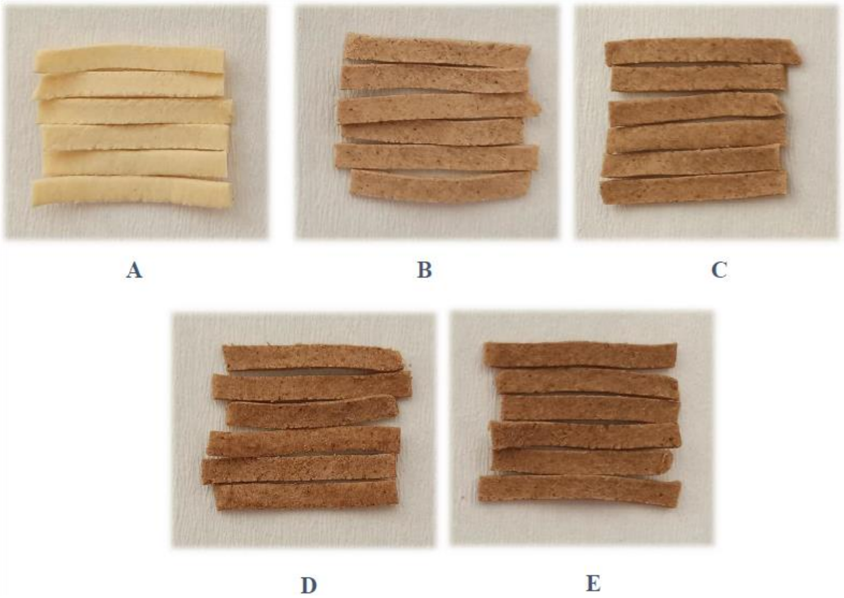


Figure 1. AF added gluten free noodle samples - (AF addition ratios; A:0% B:10% C:20% D:30% E:40%) (AF:Acorn flour)

Cooking characteristics and firmness

The WAI and WSI were carried out according to method of Ding and coauthors [24] with some modifications. 30 mL of distilled water was added to 2.5 g noodle sample, and the resulting suspension was kept in a shaking water bath (Memmert WB/OB 10, Germany) for 30 minutes and then centrifuged (Nuve NF 800R, Turkey) at 3000 g force at 25 ºC for 20 minutes. The liquid phase was taken into a tare-measured drying vessel and dried until it reached a constant weight, and the unit weight WSI was calculated. The WAI value was calculated by weighing the remaining gel portion in the tube. The water absorption index (WAI) was expressed per unit weight of dry solids. The water solubility index (WSI) was determined with dry solids weight in liquid phase and it was expressed as a percentage. The cooking loss (CL), optimal cooking time (OCT) and swelling index (SI) were carried out according to Gasparre, et. al. [25]. Noodles was evaluated as cooked when the white core disappeared after being pressed between two plastic plates during cooking and time was recorded as OCT. The cooking water was evaporated to constant weight (Nüve FN-500, Ankara, Turkey) and the solid remnant amount from cooking water was expressed as percentage for CL. For SI, cooked noodle samples were dried and the difference was expressed per unit weight. Brix degree was measured with a refractometer (Kem RA-600, Japan) in boiling water. On the other hand, for VI determination, raw and cooked samples were placed into a graduated cylinder with certain amount of water, the difference in the water level was measured and it was calculated according to the Equation 3. WI was specified according to the Equation 4 with measurement of weight difference before and after cooking [26].

VI (%)=100x(volume of cooked sample- volume of raw sample)/ volume of raw sample *Eq. (3).*

WI (%)=100x(weight of cooked sample- weight of raw sample)/ weight of raw sample Eq. (4).

Firmness values belonging to noodle samples were determined by TAXT Plus Texture Analyser (Stable Micro Systems, Surrey, UK) equipped with A/LKB-F probe using a 5 kg of load cell for the analysis. The fracture force values were expressed as g.

Chemical composition

The methods of AACC [27] were used for determination of moisture, ash, protein and fat contents (Method no: 44-19, 08-01, 46-12, 30-25 respectively). The moisture content was determined using the drying norm at 135 °C. For the determination of ash content, the samples were burned in a muffle furnace at 550 °C until light gray ash was obtained. Protein determination was made by the Kjeldahl method and a multiplication factor of 6.25 was used in the calculation. For fat determination, the samples were extracted with hexane using a soxhelet device and then the solvent was removed. The residue was dried and weighed until constant weight and the result was reported in %.

The extraction and following processes for determination of total phenolic content (TPC) and antioxidant activity were carried out as described by Wronkowska et. al [28] with some modifications. For the extraction of the samples, 1 g of sample was left to shake with 80% methanolic water (10 ml) for 1 hour. Afterwards, it was centrifuged at 5000 rpm for 15 minutes and the supernatant part was taken. To determine the TPC, 0.9 ml of distilled water was added to the 0.1 ml extract, then 1 ml of 10% diluted Folin-Ciocalteau reagent (Merck, Germany) and 2 ml of 10% sodium carbonate (Merck, Germany) solution were added and mixed. After incubation for 1 hour at room temperature, absorbance values were measured at 765 nm in a spectrophotometer (Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer; 115 VAC, US). Results are given in were expressed in mg of gallic acid equivalent (GAE) per 100g dry-weight basis.

2,2 diphenyl-1-picrylhydrazyl (DPPH) radical was used for the antioxidant activity determination of extracts. For antioxidant activity analysis, 0.25 ml of DPPH solution was added to 0.1 ml of the extract, and after 2 ml of 80% methanol solution was added, it was kept in the dark at room temperature for 20 minutes. Absorbance values were determined with a spectrophotometer (Shimadzu UV-1800 UV/Visible Scanning Spectrophotometer; 115 VAC, US) at 517 nm. The results were calculated according to the Equation 5.

$$\text{Antioxidant activity} = [\,(\text{Abs}_{blank} - \text{Abs}_{sample}) / \text{Abs}_{blank}\,] \times 100 \qquad \textit{Eq. (5).}$$

Phytic acid content was detected according to colorimetric method of Haugh and Lantzsch [29]. For that purpose, HCl was used for phytic acid extraction and Fe(III) solution was applied for precipitation. Then the measurement of remaining iron was performed spectrophotometrically. Phytate phosphorus value was multiplied by 3.546 factor to determine PA.

Mixing behaviours

Thermomechanical properties of doughs can be determined by Mixolab 2 (Chopin Technologies, Villeneuve-la-Garenne, France) and it is also reported that the obtained results can be commented for gluten free systems. For the analysis the standard ‘‘Chopin+’’ protocol was used. Amount of samples were determined according to the software calculation based on water absorption and moisture content and mixed with distilled water in the Mixolab bowel. The target torque was 1.1 ± 0.5 N and the stages composed of developing 30°C for 8 min, heating from 30 °C to 90 °C for 15 min, holding at 90°C for 7 min, cooling from 90 °C to 50 °C for 10 min, holding at 50°C for 5 min respectively. 80 rpm was applied as mixing speed [30].

Sensory evaluation

A laboratory panel was installed in an area far from the work area for the panellists unaffected by the preparation of samples. Noodle samples (100 g) were cooked with distilled water (500 ml) and salt (2.5 g) and then the drained and coded noodle samples were served with randomized order. A glass of water was on standby for mouth rinsing between assesment of noodle samples. The panellists evaluated samples using a 5-point hedonic scale (1=dislike extremely and 5=like extremely) for color, taste, odour, chewiness, stickiness and overall acceptability.

Statistical Analysis

The results were reported as mean ± standard deviation (SD). The assessment of differences obtained from results was made by One Way Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test using SPSS statistics software (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

Color properties

Color as one of the primary properties are taken into consideration by consumers when they are evaluating to a food product. Also, the decreament of brightness indicates a suggestion about darkening of the product [31]. The color attributes of noodle samples were showed in Table 1. Results showed that the all of color attributes were affected by AF additions at all levels. L^*, a^*, b^* and W values ranged from 91.81, 0.34, 13.31 to 84.35 to, 70.71, 4.75, 20.92 and 77.03, respectively. When AF addition levels were increased, L^* and W values regularly decreased. Besides this, a^* and b^* values increased as the AF addition level increased but there was no significant difference between b^* values of 30 and 40% AF added gluten free noodle samples. ΔE^* is usually defined as a trace level (0–0.5), slight (0.5–1.5), noticeable (1.5–3.0), appreciable (3.0–6.0), large (6.0–12.0), and obvious difference (>12.0) [23]. As it was seen, when AF substitution was higher than 10% level, an obvious color difference occured in starch based noodle samples. Beltrão Martins and coauthors [13] examined the ΔE^* values for bread crumbs color in their study using 0, 23 and 35% acorn flour. They reported that the ΔE^* of the bread crumbs increased with the increasing amount of acorn flour and the following results were obtained: *ΔE** (control - A23%) = 12.72; *ΔE** (control - A35%) = 21.22; *ΔE** (A23% - A35%) = 8.78. It is thought that the color characteristics of noodle products may be affected by the protein, ash and high pigment content of the used materials. AF has a light brown color compared to gluten free flour mix (rice flour and corn starch) and AF can be characterized by darker color properties. Similarly Park and coauthors [32] and Skendi and coauthors [12] reported that adding AF at different ratios to bread samples with or without gluten conduced to decrement of L^* values and increment of a^* and b^* values. Korus and coauthors [14] reported that the use of AF at increasing rates in gluten-free biscuits decreased the *L** value. The *L** value, which was 71.32 at the control, decreased to 43.14 in the samples with 60% AF additive, which is the highest addition rate.

Table 1. The color attributes of samples

Samples	*L**	*a**	*b**	W	*ΔE**
0% AF	91.81±0.19^{a}	0.34±0.14^{e}	13.31±0.21^{d}	84.35±0.19^{a}	-
10% AF	80.89±0.13^{b}	2.81±0.00^{d}	15.86±0.33^{c}	81.92±0.29^{b}	11.47±0.20^{d}
20% AF	77.80±0.73^{c}	3.48±0.16^{c}	17.84±0.25^{b}	80.06±0.25^{c}	15.05±0.79^{c}
30% AF	74.19±1.18^{d}	4.03±0.10^{b}	19.58±0.38^{a}	78.38±0.37^{d}	19.05±1.23^{b}
40% AF	70.71±0.15^{e}	4.75±0.08^{a}	20.92±0.45^{a}	77.03±0.43^{e}	22.86±0.31^{a}

AF: Acorn flour, Mean values showed by the different letters are significantly different ($p<0.05$). W:whiteness index

Cooking characteristics and firmness

Determination of eating quality of pasta and pasta-like products was related to some parameters such as good firmness, low stickiness and lower releasing of solids into the cooking water [33] and for evaluation of these properties, some indicators were improved. WI, VI, CL, OCT, SI, WAI, WSI and brix were evaluated in Table 2. Incorporation of AF at different ratios affected WI, VI, CL and WAI (p<0.05). However, OCT, SI, WSI and brix results were not affected by AF addition statistically. The highest values for WI, VI, CL and WAI were obtained from 40% AF added samples as 218.08, 262.50, 9.28 and 4.08 respectively. On the other hand, noodle samples without AF showed the lowest VI, CL and WAI values and this samples and 10% AF added samples showed not difference statistically for WI results. For WI, VI, CL and WAI, the lowest values were 185.56, 225.00, 4.29 and 3.16 respectively. Also, OCT, SI, WSI and brix results ranged between 17.60-18.80, 2.32-2.83, 6.40-8.08 and 0.18-0.30 respectively. Lucisano and coauthors [33] pointed out that behaviours of starch noodles commonly related to functional properties of starch as primary provider of structural network during processing with different heat applications. It was explained that water uptake depended on the weakness of starch granules and is related to the amount of starch damage. However, cooking properties could be affected by other fractions of AF besides starch. Molavi and coauthors [34] indicated that different amylase/amylopectin ratio of AF starch, amino acid composition of AF proteins which affects its interactions with other proteins such as egg proteins and oil contents of AF should be considered in the system. The results in this study revealed that AF added samples bound more water and contained more soluble materials. Bilgiçli [35] produced gluten free egg noodles with similar recipe and used buckwheat flour at various ratios (0, 20, 30%) and it was reported that noodles containing 30% buckwheat flour gave the highest weight and volume increase in all samples and cooking loss increased with buckwheat flour addition.

The mean firmness values were between 107.46 -142.33g (Fig. 2). The firmness values of gluten free noodles added 30 and 40% AF were significantly lower than the others (p < 0.05) and the control showed no significant change statistically (p > 0.05) with 10 and 20% addition levels. Yeyinli [36] determined that increment of ash content of pasta samples led to decrement of hardness values and there was a negative correlation. Serin [37] examined different gluten free pasta samples formulated with lentil flour, chickpea flour, quinoa flour and buckwheat flour and reported that compared to control, addition of these flours decreased hardness values.

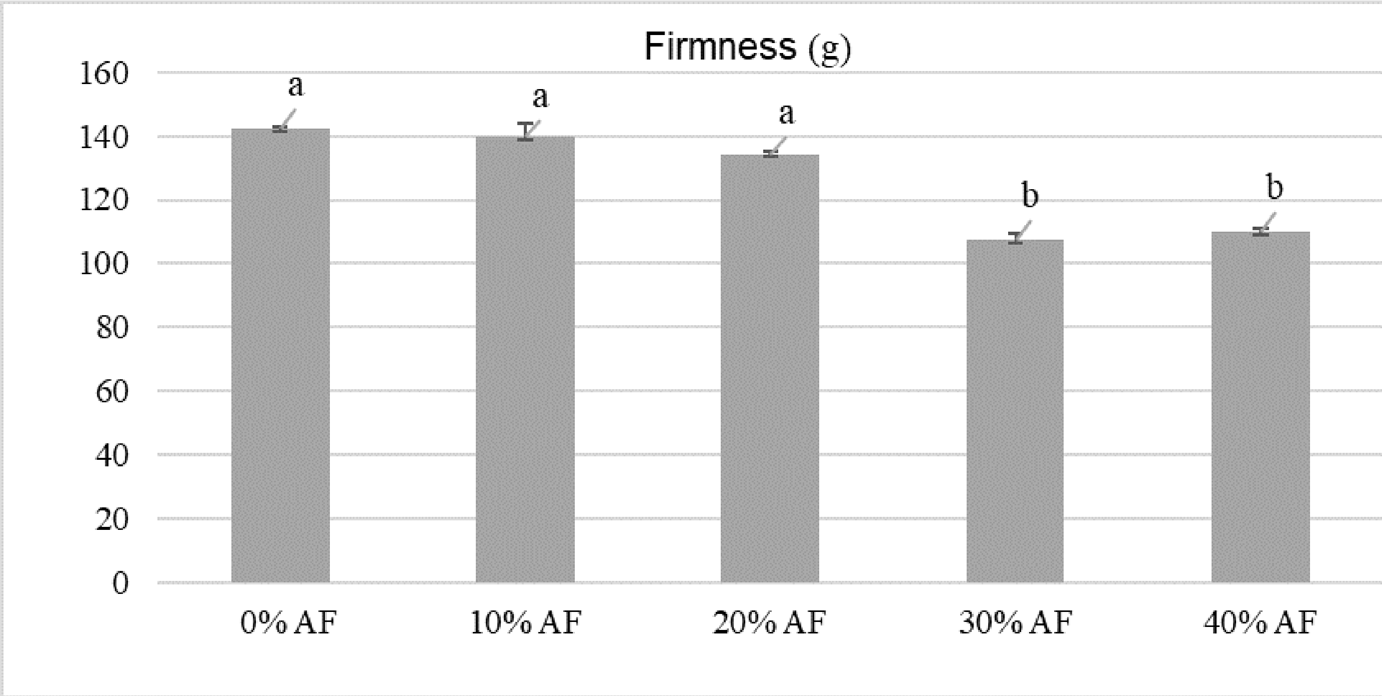


Figure 2. Firmness values of cooked AF added gluten free noodle samples (AF:Acorn flour)

Chemical composition

Gluten free products need to improvement of nutritional quality with alternative flours due to they are formulated with refined flour and/or starches [9]. In the current study, usage of AF generally changed chemical composition of starch based noodles (Table 3). Only moisture contents of samples were not influenced by the addition level of AF significantly and ranged between 6.24-6.73%. On the other hand, AF replacement resulted in an increase in ash, protein and fat contents. The extent of this increment was parallel with the replacement ratio and this state was expected due to chemical composition of AF (1.00% ash, 5.12% protein, 9.78% fat). While control sample had 0.89% ash, 5,64% protein and 2.64% fat contents, 40% AF added samples had 1.14% ash, 7.70% protein and 6.83% fat contents. Korus and coauthors [11] used 20, 40, 60%AF (9 g/kg ash, 54 g/kg protein, 52 g/kg fat) in gluten free bread production and reported that the increase in protein and fat contents of breads were 37-105% and 24-72% respectively. Besides ash, protein and fat content, similar trend was also observed for TPC and antioxidant capacity of samples as a result of AF addition. Both results exhibited significant increases and TPC and antioxidant capacity values ranged from 27.66 mg GAE/100g, 10.49% to 485.66 mg GAE/100g, 60.55% respectively. The high TPC and antioxidant capacity of AF (921.33 mg GAE/100g and 84.12% data not shown) reflected to gluten free noodles composition. Pasqualone et. al [16] studied AFs obtained from three different *Quercus* species and found that TPC were 691.10, 785.90 and 1017.40 mg GAE/100g and antioxidant activity by DPPH assay were 25.53, 33.06, 42.56 µmol TE/g and showed that TPC and antioxidant capacity of 60% AF added biscuits were 291.1 mg GAE/100g and 8.04 µmol TE/g while control biscuit had 28.19 mg GAE/100g and 0.55 µmol TE/g. On the other hand, as the PA and phytate phosphorus results examining, we observed that AF affected once again chemical composition positively. It is known that PA causes to mineral deficiency for essential minerals, such as calcium, iron and zinc and forms a complexes with proteins and lipids in addition to therapeutic effects [38]. PA and phytate phosphorus values of control were 184.39 and 52.00 mg/100g, respectively and they were determined as 27.54 and 7.76 mg/100g in 40% AF added noodles. PA and phytate phosphorus may be more investigated in further studies about AF fortification in gluten free products.

Table 2. Cooking properties of starch based noodles

Samples	Weight increase (WI) (%)	Volume increase (VI) (%)	Cooking loss (CL) (%)	Optimum cooking time (OCT) (min)	Swelling index (SI) (g/g)	Water absorbtion index (WAI) (g/g)	Water solubility index (WSI) (%)	Brix
0% AF	185.56±6.73[c]	225.00±0.00[c]	4.29±0.10[c]	18.80±0.36[a]	2.32±0.29[a]	3.16±0.11[b]	6.92±0.65[a]	0.18±0.04[a]
10% AF	191.42±5.07[c]	237.50±0.00[bc]	5.90±0.57[bc]	18.36±0.08[a]	2.42±0.04[a]	3.35±0.33[ab]	6.40±0.70[a]	0.20±0.00[a]
20% AF	200.20±0.00[bc]	243.75±8.84[abc]	7.60±0.27[ab]	18.74±0.62[a]	2.50±0.02[a]	3.55±0.19[ab]	7.44±0.88[a]	0.23±0.04[a]
30% AF	212.49±3.83[ab]	255.00±7.07[ab]	9.19±1.55[a]	17.91±0.58[a]	2.61±0.10[a]	3.59±0.05[ab]	7.51±0.98[a]	0.25±0.07[a]
40% AF	218.08±2.71[a]	262.50±3.54[a]	9.28±0.57[a]	17.60±0.63[a]	2.83±0.21[a]	4.08±0.12[a]	8.08±0.27[a]	0.30±0.00[a]

AF:Acorn flour, Mean values showed by the different letters are significantly different ($p<0.05$).

Table 3. Chemical composition of noodle samples[*]

	0%AF	10% AF	20% AF	30% AF	40% AF
Moisture (%)	6.73±0.01[a]	6.24±0.06[a]	6.35±0.24[a]	6.65±0.37[a]	6.68±0.13[a]
Ash (%)	0.89±0.01[c]	0.92±0.05[bc]	0.98±0.04[abc]	1.10±0.02[ab]	1.14±0.09[a]
Protein (%)	5.64±0.18[d]	6.11±0.06[cd]	6.73±0.12[bc]	7.34±0.25[ab]	7.70±0.23[a]
Fat (%)	2.64±0.08[d]	3.52±0.06 [cd]	4.47±0.65 [bc]	5.74±0.25 [ab]	6.83±0.16[a]
Total phenolic contents (mg/100g)	27.66±2.67[e]	115.03±3.35[d]	216.09±1.56[c]	352.00±3.46[b]	485.66±4.24[a]
Antioxidant capacity (%)	10.49±0.37[e]	28.08±0.62[d]	36.33±0.80[c]	49.76±1.05[b]	60.55±0.74[a]
Phytic acid (mg/100g)	184.39±3.25[a]	146.39±2.97[b]	99.49±1.68[c]	51.84±3.04[d]	27.54±2.62[e]
Phytate phosphorus (mg/100g)	52.00±0.92[a]	41.28±0.84[b]	28.05±0.47[c]	14.62±0.86[d]	7.76±0.74[e]

[*] On dry basis AF:Acorn flour, Mean values displayed with different letters in a row are significantly different ($p<0.05$).

Mixing behaviours

The thermo-mechanical properties of gluten free mixtures with AF were determined according to Mixolab parameters and summarized in Table 4. The water absorbtion (amount of water required for optimum dough consistency) was 59.90% for control and it increased to 62.00 and 63.35 with 30 and 40% AF levels respectively. Inclusion of AF at 30 and 40% levels affected the dough stability negatively. The values varied from 12.85 min to 7.26 for control and 40% AF included samples respectively. Torbica and coauthors [39] used buckwheat flour in gluten free formulations and they found that higher water absorption values and lower stability with increased buckwheat flour levels. C2 refers to protein network weakening and the C2 values were higher than others in samples without AF but there were not significantly different. Higher protein and cellulose content of AF can be caused these changes. C3 refers to starch gelatinization and it is maximum torque during the heating stage and 20% and upper levels of AF addition decreased C3 values. On the other hand, C4 indicates physical breakdown of gelatinized starch granules which is minimum torque during the heating stage and C5 refers to starch retrogradation and it was observed torque after cooling at 50 °C [39, 40]. The difference between C5 and C4 decreased with the increase of AF addition levels but there were no significant differences statistically. Zhang and coauthors [41] studied wheat/AF composite doughs and reported that the difference between C5 and C4 values showed no statistically significant difference between the different proportions of AF substitutions.

Table 4. Mixolab parameters of gluten free mixtures with and without acorn flour

Samples	Water absorption (%)	C2 (Nm)	C3 (Nm)	C5-C4 (Nm)	Stability (min)
0% AF	59.90±0.14^b	0.82±0.02^a	2.76±0.07^a	0.89±0.03^a	12.85±0.78^a
10% AF	59.50±0.71^b	0.76±0.00^a	2.75±0.00^a	0.86±0.10^a	11.00±0.79^a
20% AF	60.00±0.00^b	0.73±0.07^a	2.45±0.00^b	0.84±0.09^a	11.01±1.69^a
30% AF	62.00±0.00^a	0.75±0.03^a	2.43±0.07^b	0.81±0.08^a	8.75±0.68^b
40% AF	63.35±0.49^a	0.73±0.03^a	2.40±0.02^b	0.74±0.08^a	7.26±0.62^b

AF:Acorn flour, Mean values showed by the different letters are significantly different ($p<0.05$)

Sensory properties

Sensory properties of noodle samples was displayed in Figure 3. In the gluten free noodle samples, AF usage affected sensorial scores. In general, the scores disposed to reduction with the increased levels of AF. The control and 40% AF added samples received the highest and lowest scores respectively out of 5 points for color (4.94-3.10), taste (5.00-3.30), odour (5.00-3.90), chewiness (4.98-4.00), stickiness (4.98-3.90) and overall acceptability (5.00-3.15). Pasqualone et. al [16] used AF in biscuit production and stated that the enriched samples with AF gained lower color and sweet taste scores and higher bran-like odour scores. However, there were no significant differences statistically between the color and odour scores of 30 and 40% AF added noodles. On the other hand, stickiness scores of 10, 20 and 30% AF added samples were slightly lower than those of control and Zhang coauthors [41] observed similar results and they reported that it could be due to the significantly higher firmness values. Consequently, sensory scores of 10% AF added noodles were close to those of control and 40% AF added samples were the most unenviable samples among others in terms of overall acceptability.

CONCLUSION

It is fact that gluten free products need to be supplementation due to poor nutritional composition and structural challenges during production. For this reason, many studies about supplementation have been carried out. This study aimed to investigation of AF supplementation effects in gluten free noodle production. Results showed that an obvious color difference occurred in starch based noodle samples with 20% AF and upper addition levels. While L^* and W values decreased, $a^{*,}$ b^* and ΔE^* values increased. As cooking characteristic indicators, WI, VI, CL, OCT, SI, WAI, WSI and brix were evaluated. The highest WI, VI, CL and WAI values were observed in 40% AF added samples. However, OCT, SI, WSI and brix results ranged between 17.60-18.80, 2.32-2.83, 6.40-8.08 and 0.18-0.30 respectively and there were no significant difference statistically. That is to say, AF added samples bound more water and contained more soluble materials. The higher water absorption values were also obtained within Mixolab parameters and dough stability decreased. Besides, the firmness values of gluten free noodles added 30 and 40% AF were significantly lower than the others ($p < 0.05$). On the other hand, an improved nutritional value was determined with AF addition. While the ash, protein, fat contents, TPC and antioxidant capacity increased, PA and phytate phosphorus content decreased in AF included samples. But when the sensory results were viewed, 40% AF added samples were the most unenviable samples among others and it was concluded that AF should be used maximum 20% as ratio.

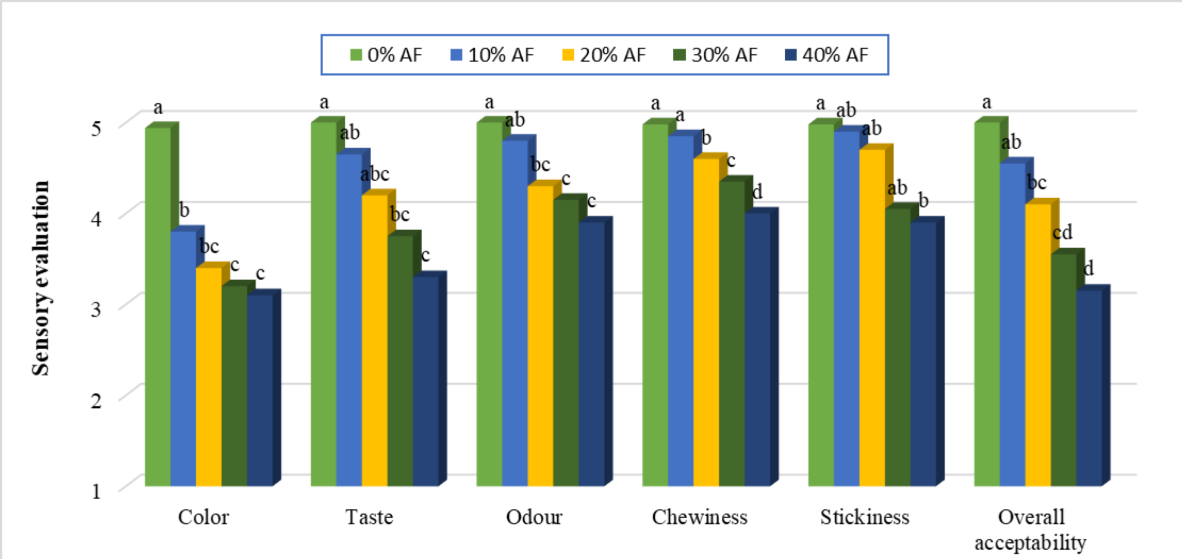


Figure 3. The sensory attributes of gluten free noodle samples (AF:Acorn flour)

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