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Effect of defatted almond flour on cooking, chemical and sensorial properties of gluten-free fresh pasta

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Summary The aim of this work was to analyse the influence of defatted almond flour on soya bean-based gluten-free pasta. Optimal cooking time of pasta varied between 2.0 and 3.5 min, while cooking loss ranged 6.1% and 19.7%. The total protein content of samples varied from 30.4% to 41.0% (dry basis, db) in cooked pasta. The total phenols content of cooked samples varied between 1.66 and 2.99 mg ellagic acid equivalent/g, while the antioxidant activity (DPPH•) ranged between 19.1% and 41.9%. The sensory test showed no significant differences between the formulated pasta samples among brightness (3.20–3.27), surface appearance (1.14–1.20), hardness (2.14–2.36) and elasticity (1.56–1.71). Pasta developed is an innovative product that improves nutritional and functional properties of gluten-free pasta compared to gluten-free and traditional wheat flour pasta available on market.

Keywords Almonds, gluten-free, pasta, soya beans.

Introduction

Coeliac disease is a digestive autoimmune disorder due to a permanent intolerance to gluten. This disease is related specifically to the composition of the storage proteins present in many common cereals such as wheat, rye, barley and oat, which are harmful for the sensitive consumers (Hill *et al.*, 2005). The increased prevalence of coeliac disease has led to a higher demand for gluten-free products. It is important to highlight that the gluten-forming proteins are essential for the production of a great variety of products, including pasta, which is generally made from durum wheat. A gluten replacement by compounds that mimic their viscoelastic properties and thus obtained acceptable quality products has been the major technological challenge. With this objective, starch of different origins and dairy and vegetables proteins have been used. Low amounts of emulsifiers, gums or hydrocolloids have also been added (Mariotti *et al.*, 2011). The inclusion of hydrocolloids such as guar gum, xanthan gum, locust bean gum, carrageenan and HPMC (Lutz & León, 2009) provides an option to replace gluten in pasta (Sozer, 2009). Pasta is a traditional food, widely accepted because of its nutritional and sensory qualities (Petitot *et al.*, 2009). Pasta is also recognised as a good vehicle to incorporate beneficial and healthy ingredients due to its ease of processing, low cost, long shelf-life (when dry) and quick preparation. Pasta was one of the first foods to be authorised by the Food and Drug Administration (FDA) for enrichment with vitamins and iron in 1949 and both, the World Health Organization (WHO) and the FDA consider pasta a good vehicle for the addition of nutrients (Pasqualone *et al.*, 2016).

The by-product from the almond oil obtaining process has high protein content, minerals, dietary fibre and substances with antioxidant capacity; it is still not widely used as food ingredient and can be turned into flour. Soy flour is a major source of protein regarding both the quantity and quality of them and has been used to produce pasta with high protein and high lysine content by adding up to 35% of it without adverse effect on flavour and texture (Shogren *et al.*, 2006). The relevance of using defatted almond flour (DAF) and soy flour (SF) to produce laminated fresh pasta lies in the fact that they provide higher nutritional benefits than wheat flour and the flours

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traditionally used for the production of gluten-free pasta (Baiano *et al.*, 2011; Torres *et al.*, 2017). The objective of this work was to analyse the influence of defatted almond flour (DAF) on gluten-free pasta evaluating cooking properties and chemical composition. A sensory test was conducted to compare the DAF gluten-free pasta with control wheat pasta and three commercial samples used as references.

Materials and methods

Raw materials

Solvent defatted almond flour (*Prunus amygdalus* L.), obtained from the residue of almond oil extraction (pilot scale helical screw press Komet brand driver, Model CA 59 G), with 67.8 protein, 7.8 ash, 12.5 moisture and 13.4 carbohydrates (values expressed as g/100 g flour). Commercial full-fat soya bean flour (Grandiet) with 22.1 oil, 42.1 proteins, 5.6 ash, 7.9 moisture and 22.3 carbohydrate (values expressed as g/100 g flour). Corn starch (Egran)(CS) containing 89.4 carbohydrate, 0.02 ash and 10.6 moisture (no protein and oil were detected) (values expressed as g/100 g sample). Commercial refined wheat flour with 12.2 protein, 4.4 ash, 11.9 moisture and 70.6 carbohydrates (values expressed as g/100 g flour). All analyses were performed in triplicate. Xanthan gum (food grade, 200 mesh, 91% purity Deosen Biochemical ORDS LTD, China), locust bean gum (Viscogum FA 180 mesh, 98% purity, System BioIndustries Maroc SA, Morocco).

Characterisation of flours

Total protein (AACC Method 13.01), moisture (AACC Method 44-15.02) and the ash (AACC Method 08-01.02) contents were determined according to the AACC International (AACC 2000). Oil content was determined by AOCS Official Method Am 5-04 (AOCS 2009). Carbohydrates were calculated as a difference between 100 and all other components.

Formulations

Fourteen different samples of laminated fresh pasta were prepared. The weight percentages of raw materials (DAF, SF and CS) used to prepare samples are reported in Table 1. The amount of hydrocolloid (H) (5% db, 2.5% of each) and salt (0.5% db) was kept constant in all formulations. A control sample was also prepared by replacing the gluten-free flours content (DFA, SF, CS) by commercial refined wheat flour (No. 15). Each formulation was prepared in triplicate. The dough contained about 30% of water. To have reference values, laminated fresh pasta commercialised in the city of Córdoba, Argentina were also tested: wheat pasta (Ottonello, No. 16) and gluten-free pastas (Zero Gluten and Dimax, No. 17 and No.18 respectively).

Fresh laminated pasta preparation

Flat pieces were produced as follows: the required amount of water was added on dry homogenised ingredients (flours, salt and mixture of gums) in a vessel. A mixer Howland HL-20 was used at speed 3 for 3 min. Dough buns were formed and left to stand for 10 min, covered with film. Finally, it was laminated up to 2 mm thickness and cut into 3 mm wide tagliarini type, that were allowed to rest 30 min before analyses.

Cooking properties evaluation

Laminated pasta (4 g) was broken into pieces of 5 cm and cooked in boiling distilled water (200 mL). Boiling was kept at this level for the entire cooking period. After cooking and draining, the samples were analysed. Each assay was performed in triplicate.

Optimal cooking time (OCT)

The 'al dente' point was determined by compressing the pasta strand between two glass slides in intervals

Table 1 Raw material content of pasta samples

	Fraction w/w			
Sample	**%DAF**	**%SF**	**%CS**	**%Moisture (raw pasta)[1]**
1	20	45	30	$30.35^{bc} \pm 1.20$
2	20	50	25	$30.47^{bcd} \pm 0.91$
3	25	40	30	$30.02^{bc} \pm 0.37$
4	25	45	25	$30.19^{bc} \pm 0.58$
5	30	35	30	$29.87^{bc} \pm 0.19$
6	30	40	25	$29.98^{bc} \pm 0.55$
7	35	30	30	$31.44^{cde} \pm 0.49$
8	35	35	25	$29.89^{bc} \pm 0.40$
9	40	25	30	$32.24^{def} \pm 2.28$
10	40	30	25	$32.18^{def} \pm 1.65$
11	45	20	30	$32.39^{ef} \pm 1.44$
12	45	25	25	$29.56^{ab} \pm 1.85$
13	50	15	30	$30.68^{bcde} \pm 1.17$
14	50	20	25	$33.25^{fg} \pm 1.50$
15 wheat control		wheat flour 95%		$34.55^{g} \pm 0.40$
16 wheat pasta				$29.88^{bc} \pm 0.47$
17 gluten-free pasta				$34.43^{g} \pm 0.20$
18 gluten-free pasta				$27.86^{a} \pm 0.51$

Values followed by a different letter are significantly different ($P < 0.05$); each value is mean ± standard deviation ($n = 3$).
DAF (defatted almond flour), SF (soya bean flour), CS (corn starch).
All the test samples and wheat control pasta contained 2.5% xanthan gum and 2.5% locust bean gum.

of 30 s. The optimal cooking point was reached when the white centre of ungelatinised starch had just disappeared according to AACC International.

Cooking loss (CL)

Cooking water collected from each sample was evaporated until constant weight in a hot air oven at 105 °C. The residue was weighted and reported as percentage of original sample according to AACC International.

Water absorption (WA)

Twelve and a half grams of pasta samples were cut into 5-cm-long pieces which were cooked in 200 mL boiling water until their optimal cooking time was reached, and afterwards, they were drained and rinsed with other 50 mL water at room temperature for 1 min. They were weighted after reaching room temperature. WA of drained pasta was determined as [(weight of cooked pasta − weight of uncooked pasta)/ weight of uncooked pasta] × 100.

Chemical analysis of pasta

Ground pasta samples, both raw and cooked (at OCT), were tested. Reference pasta samples and control wheat flour pasta sample, in the same conditions, were also tested.

Moisture

Moisture content was determined by drying at 130 °C for 2 h according to AACC International (AACC 2000).

Total protein content (TP)

The protein content was determined for both raw and cooked pastas according to methodology described in section 'Characterisation of flours' using a $N = 5.7$ conversion factor and expressed on dry weight basis.

Total phenols content (TPc)

Total phenols were extracted according to Fukuda *et al.* (2003) and quantified according to Siddhuraju *et al.* (2002). The TPc was expressed in mass equivalents of Ellagic Acid (EAE, mg g^{-1} sample) and expressed on dry weight basis.

Antioxidant activity (AA)

Antioxidant Activity was determined by using the stable radical DPPH • (1,1-diphenyl-2-picrylhydrazyl) AA towards DPPH was estimated by means of the following equation:

$$\text{AA}\ (\%) = \{1 - [(\text{Absorbance of control} - \text{Absorbance of test sample})/\text{Absorbance of control}]\} \times 100.$$

where AA(%) expresses the amount of the DPPH radical that remains in the medium after the antioxidants present in the extract are depleted (Braca *et al.* (2001)).

Sensory evaluation

Sensory profiling was performed by a semi-trained panel of forty eight individuals (twelve males and thirty six females) aged between 20 and 60 years according to IRAM, Standards 20002: 1995, 20010: 1997 and 20014: 1998. An instructive with the descriptor definitions of sensory attributes (Table 2) and warm-up intensity for each attribute was given to each judge. Five samples were presented to each judge at the same time as conventional pasta. The order of sample presentation was completely randomised among judges, identified with three arbitrary numbers. A registration form was given to each judge. Discontinuous bipolar 7-point scales were used, where zero represented the lowest intensity, and 7 represented the highest intensity of a particular attribute (Parvathy *et al*., 2016). Cooked pasta was presented in 250 mL sealed thermal plastic cups and served at room temperature within 1 h after cooking. Drinking water was provided for palate cleansing between each sample. To know the acceptability of the pasta, a ranking test (1 = most accepted sample and 5 = less accepted sample) was also performed with sixty regular pasta consumers.

Statistical analysis

Mean and standard deviations were calculated. The data were compared by the test of Fisher, with significant level at 0.05. For each physical and chemical parameters studied, a analysis of variance (ANOVA) was performed (INFOSTAT version 2011). A multivariate analysis was also performed (principal components) to establish partnerships between the formulations and the studied parameters.

Results and discussion

Cooking properties evaluation

During cooking, starch granules rapidly swell, tend to disperse and become partly soluble. At the same time, gluten proteins become completely insoluble and coagulate, creating a network, which contributes in the entrapment of starch and limits their swelling and subsequent leaching. Starch gelatinisation and protein coagulation are both competitive phenomena, occur at

Table 2 Definition of attributes and standard reference intensity used in descriptive analysis of gluten-free pasta

Attribute	Definition	Technique	Reference value
Brightness	The amount of light that is reflected by the object compared to the light incident on it.	Take one pasta strand and place it aligned to your sight, turn it slightly around so that light falls upon it and observe how much of it is reflected.	3.5
Surface appearance	Amount of spots on pasta surface.	Take one pasta strand and place it on the plate. Observe and count how many spots can be seen.	0.0
Hardness	Force required to compress and cut the spaghetti using the incisors.	Take one pasta strand at the time, place it between the incisors, bite evenly, evaluating the force required to compress and cut.	3.5
Chewiness	Time required to chew the pasta with the molars and reduce it to a suitable consistency for swallowing.	Take one pasta strand, place it between the molars and chew at constant speed. Count the times you chew to reduce it to state of being swallowed.	12 times = 3.5
Elasticity	Extent to which the pasta attains its original shape once it has been stretched with hands.	Take one pasta strand at the ends and extend it. Assess the degree to which the pasta attains its original length.	3.5

the same temperature and are influenced by water availability (Martínez, 2010; Sandhu *et al.*, 2015). In order to obtain gluten-free pasta, the added proteins and gums may partially act as substitutes for gluten to assure low cooking loss, even after prolonged cooking, high absorption and good final texture.

The optimal cooking time (OCT), cooking loss (CL) and water absorption (WA) of the samples are reported in Table 3. The average OCT was 3.0 min for all samples and varied from 2.0 to 3.5 min. Results showed that OCT was affected by the amount of DAF. The OCT of all DAF pasta samples was similar to the results of commercial gluten-free pasta (samples 17 and 18) and was significantly lower than wheat pasta (both the control wheat pasta (No. 15) and the commercial wheat sample (No. 16)) used as reference

Table 3 Cooking properties of pasta samples

	Fraction w/w					
Sample	%DAF	%SF	%CS	OCT (min)	CL (%)	WA (%)
1	20	45	30	$3.27^{ef} \pm 0.06$	$9.27^{fg} \pm 0.55$	$184^{ab} \pm 9$
2	20	50	25	$2.00^{a} \pm 0.00$	$7.85^{de} \pm 0.56$	$174^{a} \pm 8$
3	25	40	30	$2.21^{ab} \pm 0.02$	$7.64^{de} \pm 0.76$	$168^{a} \pm 4$
4	25	45	25	$2.43^{bc} \pm 0.04$	$6.09^{bc} \pm 0.27$	$169^{a} \pm 10$
5	30	35	30	$2.36^{c} \pm 0.05$	$8.32^{ef} \pm 0.35$	$181^{ab} \pm 9$
6	30	40	25	$3.30^{ef} \pm 0.00$	$9.20^{fg} \pm 0.22$	$187^{ab} \pm 12$
7	35	30	30	$3.17^{ef} \pm 0.03$	$9.97^{gh} \pm 0.35$	$190^{b} \pm 4$
8	35	35	25	$3.25^{ef} \pm 0.05$	$6.23^{bc} \pm 0.50$	$184^{ab} \pm 10$
9	40	25	30	$3.30^{ef} \pm 0.00$	$10.3^{ghi} \pm 0.60$	$214^{c} \pm 16$
10	40	30	25	$3.30^{ef} \pm 0.00$	$6.73^{cd} \pm 0.49$	$181^{ab} \pm 13$
11	45	20	30	$3.36^{fg} \pm 0.04$	$19.7^{i} \pm 1.92$	$199^{bc} \pm 1$
12	45	25	25	$3.43^{fg} \pm 0.05$	$10.8^{hi} \pm 0.66$	$199^{bc} \pm 9$
13	50	15	30	$3.50^{fg} \pm 0.00$	$13.3^{j} \pm 0.40$	$175^{a} \pm 9$
14	50	20	25	$3.50^{fg} \pm 0.00$	$18.3^{k} \pm 1.26$	$205^{bc} \pm 1$
15 wheat control	wheat flour 95%			$6.27^{i} \pm 0.03$	$5.46^{b} \pm 0.45$	$216^{c} \pm 15$
16 wheat pasta				$8.17^{j} \pm 0.15$	$9.64^{gh} \pm 0.48$	$234^{d} \pm 8$
17 gluten-free pasta				$4.23^{h} \pm 0.03$	$3.94^{a} \pm 0.35$	$171^{a} \pm 3$
18 gluten-free pasta				$3.68^{g} \pm 0.28$	$11.4^{i} \pm 0.57$	$224^{cd} \pm 9$

Values followed by a different letter are significantly different ($P < 0.05$); each value is mean ± standard deviation ($n = 3$).
DAF (defatted almond flour), SF (soya bean flour), CS (corn starch).
OCT (Optimal cooking time), CL(cooking lost), WA (water absorption).

(Table 3). Similar results were reported by Chillo *et al.* (2007), who found that the absence of gluten network in the amaranths flour spaghetti influenced the optimum cooking time; and by Gallegos-Infante *et al.* (2010) in spaghetti with common bean flour (3.2 to 4.8 min)..CL showed an average of 10.0% and varied from 6.1% to 19.7%. According to Hoseney (1999), CL for good-quality pasta should be lower than 12% and, except samples No. 11, 13 and 14, DAF pasta samples presented CL values lower than 12%. This fact is in concordance with Padalino *et al.* (2013) who observed that ingluten-free spaghetti enriched with vegetable flour, the absence of the continuity of the protein-starch network seems to facilitate the water diffusion through the spaghetti matrix during cooking, reducing the time that water needs to reach the spaghetti centre and increasing the quantity of solids going into water. Baiano *et al.* (2011) observed that the substitution of increasing amounts of SF was able to increase the OCT due to the fact that the soy protein is hydrophilic and it gels at cooking temperature, which protects and prevents the starch to absorb water to gelatinise.. WA varied between 168% and 214% for DAF pasta with an average value of 186%. This shows that water absorbed by the starch and proteins during cooking was similar in all tested samples regardless of the weight percentages of raw materials. Similar behaviour was reported by Padalino *et al.* (2013) and Gallegos-Infante *et al.* (2010), in gluten-free spaghetti enriched with yellow pepper and spaghetti with common bean flour respectively. Wheat flour samples, both control (15) and reference (16), showed a similar value of WA that some DAF formulations. OCT and WA showed values in accordance with the appropriate ranges for pastas.

Pasta samples No. 11, 13 and 14 were not considered for chemical analysis due to the high values of CL, according to the criteria set out by Hoseney (1999).

Chemical analysis

After 30 min resting at room temperature, moisture contents of the raw pasta samples varied from 29.0% to 33.0% (wet basis, Table 1). These values were lower than the limit set by FAC (Food Argentine Code, 2010) at 35.0% (wet basis), corroborating that the final product moisture content was adequate.

Total protein (TP)

The total protein contents (TP) are shown in Table 4. TP of DAF raw and cooked pasta varied between 33.3% and 42.1% (db) and 30.4% and 41.0% (db) respectively. These values were in average three and five times higher than the total protein content of reference (No. 16, 17 and 18) and control (No. 15) samples (5.9% to 13.0% in raw pasta and 2.8%–12.7% in cooked pasta). The total protein content of experimental samples rose with the increase of DAF content. Differences between raw and cooked pasta total protein content may be due to the leaching of soluble proteins into boiling water. Protein enhancement in spaghettis with amaranths, quinoa, broad bean and chick pea (15.4%); banana flour (9.4%); common bean flour (16.7%); and rice and defatted soy flour (12.3%),

Table 4 Chemical properties (on dry basis) of raw and cooked pastas

	TP, %		TPc (mg EAE g^{-1} sample)		AA %	
Sample	Raw	Cooked	Raw	Cooked	Raw	Cooked
1	$33.3^{c} \pm 1.3$	$30.4^{c} \pm 0.1$	$2.13^{i} \pm 0.16$	$2.65^{ef} \pm 0.11$	$65.3^{l} \pm 1.1$	$42.0^{k} \pm 0.5$
2	$33.8^{c} \pm 0.9$	$31.7^{c} \pm 1.4$	$1.13^{cd} \pm 0.09$	$2.27^{cd} \pm 0.16$	$57.3^{k} \pm 0.3$	$39.0^{j} \pm 1.2$
3	$33.7^{c} \pm 0.6$	$31.0^{c} \pm 0.9$	$1.16^{cd} \pm 0.04$	$2.11^{c} \pm 0.23$	$44.9^{j} \pm 2.8$	$36.4^{i} \pm 0.7$
4	$38.0^{de} \pm 0.8$	$34.9^{de} \pm 0.4$	$1.76^{h} \pm 0.11$	$2.48^{def} \pm 0.05$	$41.7^{hi} \pm 0.3$	$27.7^{f} \pm 0.4$
5	$36.1^{cd} \pm 1.6$	$34.8^{de} \pm 0.4$	$1.08^{c} \pm 0.06$	$1.70^{b} \pm 0.10$	$34.0^{f} \pm 0.1$	$32.7^{h} \pm 1.3$
6	$35.9^{cd} \pm 1.3$	$34.1^{d} \pm 0.2$	$1.38^{ef} \pm 0.15$	$2.24^{cd} \pm 0.17$	$23.1^{d} \pm 0.0$	$21.9^{e} \pm 0.9$
7	$33.8^{c} \pm 0.1$	$31.4^{c} \pm 1.0$	$1.83^{h} \pm 0.05$	$1.66^{b} \pm 0.16$	$21.5^{d} \pm 0.4$	$19.1^{d} \pm 0.2$
8	$37.6^{de} \pm 0.5$	$36.4^{e} \pm 1.6$	$1.52^{fg} \pm 0.06$	$2.36^{cde} \pm 0.17$	$40.3^{gh} \pm 0.9$	$37.2^{ij} \pm 0.4$
9	$38.3^{de} \pm 3.0$	$36.1^{e} \pm 1.1$	$1.27^{de} \pm 0.08$	$2.99^{g} \pm 0.16$	$43.1^{ij} \pm 1.3$	$34.2^{h} \pm 0.8$
10	$40.3^{e} \pm 2.8$	$38.9^{f} \pm 1.1$	$2.06^{i} \pm 0.02$	$2.13^{c} \pm 0.06$	$39.0^{g} \pm 1.6$	$30.3^{g} \pm 1.7$
12	$42.1^{e} \pm 0.2$	$41.0^{g} \pm 1.3$	$1.55^{g} \pm 0.06$	$2.70^{fg} \pm 0.21$	$31.7^{e} \pm 0.4$	$29.2^{fg} \pm 1.3$
15 wheat control	$12.8^{b} \pm 2.2$	$11.4^{b} \pm 0.3$	$0.26^{a} \pm 0.02$	$0.74^{a} \pm 0.06$	$2.3^{a} \pm 0.2$	$1.3^{a} \pm 0.1$
16 wheat pasta	$13.0^{b} \pm 0.2$	$12.6^{b} \pm 0.5$	$0.40^{a} \pm 0.01$	$0.86^{a} \pm 0.05$	$11.4^{c} \pm 0.9$	$10.5^{c} \pm 0.2$
17 gluten-free pasta	$5.9^{a} \pm 0.1$	$2.8^{a} \pm 0.1$	$0.68^{b} \pm 0.02$	$0.93^{a} \pm 0.10$	$8.2^{b} \pm 0.4$	$6.8^{b} \pm 0.2$
18 gluten-free pasta	$12.9^{b} \pm 0.1$	$12.7^{b} \pm 0.3$	$0.68^{b} \pm 0.03$	$0.89^{a} \pm 0.06$	$9.2^{bc} \pm 0.7$	$8.1^{b} \pm 0.01$

Values followed by a different letter are significantly different ($P < 0.05$); each value is mean ± standard deviation ($n = 3$).
TP (Total Protein), TPc (total polyphenol content, AA (antioxidant activity).

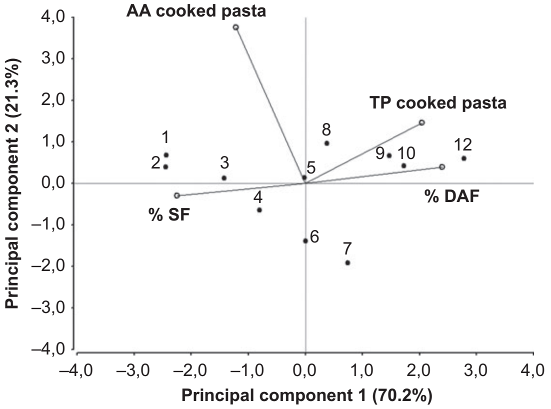

Figure 1 Principal components analysis of chemical parameters evaluated.

respectively, has been reported (Chillo *et al.* (2008); Ovando-Martinez *et al.* (2009); Gallegos-Infante *et al.* (2010)). Nevertheless, these values were much lower than the level obtained in the present study indicating the high nutritional advantage of the product for coeliac patients. Total phenols content (TPc) is reported in Table 4. As expected, the DAF raw and cooked pasta showed significantly higher total phenols contents than reference and control samples ($P < 0.05$). Values varied between 1.08 and 2.13 mg EAE g^{-1} and from 1.66 to 2.99 mg EAE g^{-1} in raw and cooked samples respectively. TPc in commercial reference samples (No. 16, 17 and 18) ranged between 0.40 and 0.68 mg EAE g^{-1} and from 0.86 to 0.93 mg EAE g^{-1} in uncooked and cooked pasta respectively, whereas raw and cooked control wheat flour pasta TPc were 0.26 mg EAE g^{-1} and 0.74 mg EAE g^{-1} respectively. Cooked pasta showed higher TPc values than the uncooked formulations. These results were similar to those obtained by Fares & Menga (2012) who studied the effect of cooking on the amount of phenols in durum wheat pastas to which chickpea flour was added. The fact that at higher temperatures higher TPc were observed is in concordance with Gallegos-Infante *et al.* (2010) and Torres *et al.* (2017) and references therein. They attribute this to the cleavage of polyphenol polymers occurred, increasing the associated presence of simpler polyphenol molecules.

The antioxidant activity in DAF raw and cooked pasta varied between 21.5% and 65.3% and from 19.1% to 42.0% respectively (Table 4). There was significant reduction in DPPH radical scavenging activity ($P < 0.05$) between raw and cooked pastas. The raw and cooked reference (No. 16, 17 and 18) and control (No. 15) samples showed significant lower antioxidant activity ($P < 0.05$) than DAF pasta, varying between 2.3% and 11.4% and from 1.3% to 10.5% respectively. Biney Kuuku (2014) reported similar trends in uncooked products enriched with buckwheat flour. After cooking, experimental samples presented a significant reduction in DPPH radical scavenging activity as well. To select the adequate formulated pasta for sensory evaluation, principal component analysis was used (Fig. 1). Total protein (TP) content of cooked pasta, DAF and SF content and antioxidant activity (AA) were the variables considered in the multivariate analysis. The first two dimensions of the chart explained 91.5% of the variance between the formulations. The first dimension separated formulations with higher TP and DAF content from those with higher SF content; while the second dimension classified them regarding AA. In line with the objective of this work and the results obtained in relation to the impact of the incorporation of DAF in the technological properties of pasta and their nutritional value, samples with higher protein content (No. 9, 10 and 12) were selected for sensory evaluation.

Sensory evaluation

The sensory characteristics of cooked pasta determined by a semi-trained panel are reported in Table 5. Brightness, hardness, elasticity and chewiness are considered positive attributes, and on the other hand, the surface appearance is considered a negative one (Martínez, 2010). The results showed no significant differences among the DAF pasta samples regarding brightness, surface appearance, hardness and elasticity. The DAF pasta presented reduction in the elasticity values, ~54%, hardness and chewiness, in average of 37%, and

Table 5 Sensory properties of cooked pasta samples

Sensory attributes **Sample**	**Brightness**	**Surface appearance**	**Hardness**	**Chewiness**	**Elasticity**	**Ranking Test Score**
9	$3.20^{a} \pm 0.68$	$1.18^{c} \pm 0.36$	$2.36^{a} \pm 0.68$	$2.44^{b} \pm 0.62$	$1.71^{a} \pm 0.57$	4 (203 points)
10	$3.27^{a} \pm 0.53$	$1.14^{c} \pm 0.34$	$2.25^{a} \pm 0.64$	$2.16^{a} \pm 0.65$	$1.56^{a} \pm 0.48$	3 (177 points)
12	$3.27^{a} \pm 0.61$	$1.20^{c} \pm 0.37$	$2.14^{a} \pm 0.57$	$2.07^{a} \pm 0.55$	$1.61^{a} \pm 0.46$	5 (219 points)
15 wheat control	$3.45^{a} \pm 0.64$	$0.44^{b} \pm 0.17$	$3.57^{b} \pm 0.64$	$3.50^{c} \pm 0.53$	$3.51^{b} \pm 0.73$	2 (161 points)
18 gluten-free pasta	$4.05^{b} \pm 0.95$	$0.00^{a} \pm 0.00$	$3.50^{b} \pm 0.89$	$3.59^{c} \pm 0.75$	$3.62^{b} \pm 0.85$	1 (140 points)

Values followed by a different letter are significantly different ($P < 0.05$); each value is mean ± standard deviation ($n = 48$).
Ranking test score: 1 (most accepted sample) and 5 (less accepted sample), $n = 60$.

brightness, ~9%, compared with gluten-free reference sample and wheat control sample. Wood (2009) informed similar trends in hardness in cooked chickpea-fortified spaghetti. Surface appearance presented higher intensity values than commercial gluten-free pasta (No. 18) and wheat control pasta (No. 15), due to the presence of the brown kernel skin of DAF It is important to highlight that remarks made by the panellists as observations in the registration forms while evaluating the attributes, suggested a preference for formulation number 10 (40% DAF, 30% SF and 25% CS). This fact was in concordance with the results obtained in the ranking test (Table 5) that showed that the formulation 10 was the most preferred after the gluten-free (18) and wheat control samples (15).

Conclusion

DAF pasta developed in this work showed technological properties in the range of those measured for commercial products.

It was possible to improve the protein content, total phenols content and antioxidant profile of gluten-free pasta based on incorporating DAF in formulations.

To further explain antioxidant losses experienced during cooking, even though the total phenols content increases, the polyphenol structure changes need to be properly investigated. Finally, it is possible to assert that, on the whole, pasta enriched with defatted almond flour improved nutritional and functional properties and demonstrated good quality in all the parameters evaluated.

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