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Utilization of a partially-deoiled chia flour to improve the nutritional and antioxidant properties of wheat pasta

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Keywords: pasta, chia, antioxidants, FRAP,DPPH, antioxidant capacity

Abstract

Pasta is a popular staple food. Today, there is a trend to consume less processed foods. Products fortification with certain properties, such as antioxidant potential and dietary fiber, represents an added value. Chia is an ancient grain, that contains exceptional proportions of polyunsaturated fatty acids (ω-3/ω-6). After oil extraction, a residue, termed partially-deoiled chia flour (PDCF), high in protein content, dietary fiber, and phenolic compounds, remains as a by-product. The main goal of this work was to evaluate the nutritional and technological quality of pasta supplemented with PDCF at different proportions (2.5%, 5% and 10%). Parameters such as texture, color, microstructure, protein and fiber content, polyphenol content and antioxidant activity (FRAP and DPPH) were analyzed. A sensory evaluation has been also performed. Our results demonstrate that the addition of PDCF improves the antioxidant capacity with respect to a non-supplemented pasta (0% PDCF). The acceptance of pasta by semi-trained judges was also good. As a concluding remark, the study confirms the feasibility to introduce this food product, and also lead us to consider a profitable application of a by-product of the chia oil extraction process.

Keywords: pasta, chia, antioxidants, FRAP,DPPH, antioxidant capacity

1. Introduction

Pasta is a popular staple processed food all over the world. It is manufactured with wheat semolina and flour as the primary ingredient. Its high content of complex carbohydrates makes it a valuable source of energy in human nutrition. Conventional pasta is usually high in starch but low in dietary fiber, minerals, vitamins, and bioactive compounds (Boroski et al., 2011). Fortification, defined as the addition of one or more components for the purpose of correcting and/or enhancing a biological activity of newly designed food products, has been proposed as a strategy to improve the nutritional quality of traditional cereal-based products (Swieca, Seczyk, Gawlik-Dziki, & Dziki, 2014). Many ingredients have been applied in pursue of this goal for pasta products, such as buckwheat (Biney & Beta, 2014), sorghum flour (Khan, Yousif, Johnson, & Gamlath., 2013), algae wakame (Prabhasankar et al. 2009), oregano and carrot leaves (Boroski et al., 2011), amaranth leaves (Borneo & Aguirre, 2008), pea flour (Padalino et al., 2014), and parsley leaves (Seczyk, Swieca, Gawlik-Dziki, Luty, Czyz, 2016). These studies have demonstrated the feasibility of pasta fortification, although some changes in the pasta technological quality and consumer acceptability do occur.

Chia (*Salvia hispanica* L.), belonging to the Lamiaceae plant family, was a very important food for Mesoamericans in pre-Columbian times and it has been cultivated in Central America since those times (Sandoval-Oliveros & Paredes-Lopez, 2013) .This crop has been successfully introduced and developed in Argentina, mostly in the northern part of the country, where it has been turned into a very important economic activity (Martínez et al., 2012). Chia seeds are one of the best natural sources of poly-unsaturated fatty acid (PUFA) α-linolenic [ALA; 18:3 (n-3)] showing a highly beneficial proportion of ω-3/ω-6 (Menga et al., 2017). The oil content of these seeds is around 30% and the protein content is between 19-27% (Menga et al., 2017) with a very good balance of essential aminoacids, especially methionine and cysteine. Additionally, the dietary fiber content is significant ranging 34-50%, higher than the described for flax seeds (Sandoval-Oliveros & Paredes-Lopez, 2013). Chia seeds also contain antioxidants compounds most of them derivatives of caffeic acid, such as rosmarinic acid, danshensu, and its glycosides (Oliveira-Alves et al., 2017), but also some flavonoids such as quercetin and kaempferol have been reported (Capitani, Spotorno, Nolasco, & Tomas, 2012). Antioxidant activity is among the most widely studied properties in foods. Many authors suggest that it is involved in protection against oxidative damage of cells and tissues, playing an important role in the prevention of numerous diseases related with the oxidation stress, such as cancer, diabetes and cardiovascular problems (Dias, Alves, Casal, Oliveira, & Silva, 2017). Generally, the antioxidant capacity is attributed to the phenolic compounds, which are common constituents of edible plants (Kwee, 2016). After oil is extracted from chia seeds, a fiber-rich, protein-rich, and polyphenol-rich fraction remains as a by-product. This fraction, the partially-deoiled chia flour (PDCF) could be used to naturally improve the nutritional profile and the antioxidant capacity of traditional cereal-based products such as pasta. Thus, the aim of this study was to evaluate the feasibility of utilization of chia meal in the production of pasta with an improved nutritional profile and increased antioxidant capacity.

2. Materials and Methods

2.1. Materials

Commercial wheat flour (*Triticum aestivum*) was obtained from Molino San José, José Minetti & CIA Ltda. (Córdoba-Argentina). Chia seeds (*Salvia hispanica* L.) were obtained in a local market. All chemicals reagents were of analytical grade, acquired from Sigma Aldrich (Switzerland).

2.2. Deoiling of chia seeds to obtain partially-deoiled chia flour (PDCF)

PDCF was obtained according to the process: chia seeds were hydrated to 9.5% moisture, packed in air-tight bags, and stored for 48 h. The bags were shaken regularly to homogenize de sample moisture. Hydrated chia seeds were conditioned to 60°C and pressed using a screw press Komet (Model CA 59 G, IBG Monforts, Germany). Screw speed was 20 rpm. A 5 mm of restriction die was used. The meal obtained after oil extraction was subsequently ground with a coffee mill and passed through a 0.25 mm sieve. This milled fraction represents the PDCF.

2.3. PDCF composition

PDCF was analyzed for oil content (method 30-25; AACC, 2000), fatty acid profile (method Ce1b 89; AOCS, 1991), total protein (method 46-13; AACC, 2000), and ash (method 08-01; AACC, 2000).

2.4. Pasta manufacture

A small-scale standardized laboratory procedure was used for pasta manufacture. Pasta was prepared with different concentrations of PDCF (0, 2.5, 5.0, and 10%, respectively, weight flour basis). For each formulation pasta flour, water, and salt (50 g, 22.5 g, and 1.0 g, respectively) were mixed in a Hobart bench top mixer (Hobart Inc., Troy, OH, USA) until the dough had an adequate consistency for lamination. Dough was divided by hand in appropriate size and was laminated using a pasta home scale size lamination machine (Drago, Inc., China) using a 3-step procedure: hand lamination, up to approximately 10-mm thickness; roll lamination, up to a 5-mm thickness; and final roll lamination to a 2-mm thickness (final pasta thickness). Laminated pasta sheets were cut using a cutting roll (2-mm wide) obtaining the pasta strings (2 x 2 x 200 mm). Pasta strings were suspended in wooden sticks on a wooden rack. Pasta was dried using a two stage process: pre-drying at 30°C for 30 minutes (with forced air circulation) and 24 h at 30°C in a closed chamber (relative humidity 70%). Dried pasta was stored in airtight bags at room temperature.

2.5. Technological quality of pasta

2.5.1. Cooking quality determination

Cooking quality of pasta was evaluated using official methods of the American Association of Cereal Chemists (method 16-50; AACC, 2000). Optimum cooking time (OCT), weight gain (WG), and cooking loss (CL) were evaluated.

2.5.2. Texture and color

Texture of uncooked and cooked pasta was analyzed using an INSTRON Texturometer (Model 3342, Norwood, MA, USA) equipped with a 500 N cell. Raw pasta was evaluated by the three-point bending test (AACC, 2000). Firmness (hardness) and adhesiveness of cooked pasta were evaluated using Application Study Ref N002/P35 (Stable Micro System, Surrey, UK). An AP/35 cylinder probe was used and force was measured in compression mode at fixed 50% strain. Color of raw and cooked pasta was determined using a colorimeter (CM spectrophotometer KONICA MINOLTA Sensing, INC), which defines each color from three coordinates in the CIE Lab color space: L* (luminosity), a* (red-green) and b* (yellow-blue).

2.5.3. Microstructural evaluation

The microstructural characteristics of the surface and inner (cross-section) of raw and cooked pasta were determined using an Olympus LEXT OLS4000 3D confocal laser scanning microscope (CLSM). The confocal microscope allowed to observe the samples in three dimensions for detection of marks, cracks and to evaluate the microstructural characteristics of samples.

2.5.4. Sensory evaluation

Pasta samples were evaluated by panelists at time zero and after 10 months of storage (air-tight bags at room temperature). Before evaluation, pasta was cooked (at OCT), strained, rinsed, and cooled in water at 20°C. Samples were evaluated for the degree of liking for color, taste, aroma, texture (mouth feeling in order to evaluate firmness), and overall liking. Before testing all participants were asked for possible food allergies to wheat or chia. Thirty-five healthy adults (semi-trained judges) participated in the study. All participants had consumed pasta before. Rating were collected using a 9-hedonic scale where 1= extremely dislike and 9= extremely like. The mid-point of the scale (5) = neither like nor dislike. Participants were asked to complete paper ballots.

2.6. Nutritional evaluation of pasta

Protein content was determined by the official method 46-13 of the AACC (2000). TDF was quantified by using a Total Dietary Fiber Assay Kit (number K-TDFR-100) from Megazyme Inc. based on AACC method 32-05.01 (AACC, 2000) and AOAC Method 985.29 (AOAC, 2016). Ash content was determined by the official method 08-01 of the AACC (2000). Fatty acids were determined following the official method Ce1b 89 of the AOAC (2016).

2.7. Antioxidant properties of pasta

2.7.1. Extraction of phenolic compounds

Dry pasta samples were ground in a coffee grinder for extraction. In parallel, another batch of pasta samples were cooked in ultra-pure water at their respective OCT. Afterwards, cooked pasta was lyophilized and ground. Five grams of uncooked pasta or lyophilized cooked pasta powder were extracted with 20 mL of a mixture acetone/water (4:1), for 1h at room temperature in darkness. The supernatant was removed and filtered through a cellulose filter. This procedure was repeated twice. Finally, supernatants were pooled, evaporated to dryness at 50°C under reduced pressure, and reconstituted with 5 mL of HPLC grade methanol. Samples were prepared in duplicate and stored at -80°C until analysis.

2.7.2. Total polyphenol content

Total polyphenol content (TPC) of extracts was measured by the Folin-Ciocalteu method (Orthofer & Lamuela-Raventos, 1999) according to the following procedure: 20 µL of extract were mixed with 1.68 mL of ultrapure-water and 100 µL of methanol. Then, 100 µL of the Folin-Ciocalteu reagent were added and stirred (vortex). After exactly 1 min, 300 µL of aqueous sodium carbonate (20%) were added, stirred (vortex), and allowed to stand 120 min at room temperature in the dark. Then, the absorbance was read at 750 nm. TPC was calculated by linear regression using gallic acid as standard. Results are expressed in mg of gallic acid equivalents (GAE) per 100 g of pasta. All samples were analyzed in duplicate.

2.7.3. Determination of antioxidant capacity

Antioxidant capacity was measured by two chemical methods: the ferric reducing ability of plasma assay (FRAP), to evaluate the reducing power, and the DPPH assay to assess the antiradical capacity. FRAP assay (Benzie & Strain, 1996) was performed as follows. Briefly, the fresh working solution was prepared by mixing acetate buffer pH 3.6, a 10 mM TPTZ solution in 40 mM HCl, and a 20 mM $FeCl_3.6H_2O$ solution (10:1:1, respectively). Twenty micro liters of sample were added to 3 mL of FRAP solution and 80 µL of methanol. The mixtures were incubated in the dark for 15 min, and absorbance measured at 593 nm. Results are expressed in mmol Trolox Eq./100 g of pasta. DPPH assay (Brand-Williams, Cuvelier, & Berset, 1995) was performed using a working solution of DPPH in methanol at a concentration of 24 mg/L. Three milliliters of the solution were added to 30 µL of sample and 70 µL of methanol. Mixtures were incubated in the dark for 15 min, and absorbance measured at 515 nm. Trolox was used as standard to calculate a linear regression. Results are expressed in mmol Trolox Eq./100 g of pasta. All samples were analyzed in duplicate.

2.8. Statistical analyses

ANOVA was performed to evaluate the differences between samples. In the case of significance ($p < 0.05$), a DGC (Di Rienzo, Guzmán, & Casanoves, 2002) comparison test was performed to reveal paired differences between means. The test was performed using InfoStat Software (InfoStat, Córdoba, Argentina)

3. Results and discussion.

3.1. Characterization of the PDCF

The characterization of the PDCF is reported in Table 1. Results show that the PDCF is an ingredient material with high content of protein, fiber, and minerals when compared to wheat flour. Also, the PDCF has a high content of omega-3 fatty acids and a higher ω-3/ ω-6 proportion than wheat flour. According to many authors a diet with ω-3/ ω-6 ratios above 1.0 are better for human health (Simopoulous, Leaf, & Salem, 2000). Overall, the PDCF obtained in this study represents a potential food ingredient to improve the nutritional value and antioxidant capacity of pasta products.

3.2. Effects of PDCF on the technological quality of pasta

One of the main issues in food formulation with novel food materials is the possible adverse effect on the quality of the product. The effects of PDCF on raw pasta and on cooked pasta were evaluated.

3.2.1. Effects on texture and color of uncooked pasta

Table 2 shows the effect of adding PDCF on raw pasta quality, considering color and breaking force as the main characteristics of uncooked pasta. Color is the first quality parameter that a consumer evaluates at the moment of buying a pasta product. A bright yellow color is the most preferred. The breaking force (BF) is an indication of the strength of pasta and how the product will withstand storage and manipulation. Regarding the color, our results show that the addition of increasing concentrations of PDCF decreases both the L* parameter (whiteness) and the overall color grade. This implies that pasta with PDCF are darker, with a more brownish hue than the control sample. Although this brownish appearance of pasta could cause some concern for consumers not habituated to consume whole-grain products, the current tendency towards "healthier" foods may represent an opportunity to introduce this type of pasta. The breaking force (BF) is defined as the force at which a spaghetti strand breaks (fractures) under compression (Mariotti, Lametti, Cappa, Rasmussen, & Lucisano, 2011). The addition of PDCF decreased BF at a significant level (Table 2), implying that pasta with PDCF are weaker than control pasta. Probably, by using a different drying procedure this weakness can be overcomed. The increase in the strength of the protein network in pasta as the result of high temperature drying is well known (Zweifel, Handschin, Escher, Conde-Petit, 2003).

3.2.2. Effects on texture, color and cooking quality of cooked pasta

As with uncooked pasta, the addition of PDCF decreased the whiteness (L*) of the cooked pasta when compared with the control (0% PDCF). The a* parameter increased, while the b* parameter decreased (Table 2). Also, the color score decreased with the increase of the PDCF in the pasta formulation. These parameters indicate that pasta became darker with increased proportions of PDCF.

With regard to cooking quality we found that firmness and adhesiveness, two very important textural characteristics of pasta quality, were not statistically different between pasta with or without PDCF (Table 2). Optimum cooking time (OCT) decreased as the PDCF content is increased in the formulation, allowing less preparation times of pasta with

PDCF in comparison to control. Cooking loss (CL) decreased while the weight gain (WG) did not change as a result of including PDCF. The fact that PDCF is a material with higher water absorption (Iglesias & Haros, 2013) could explain the lower cooking times for pasta with higher proportions of PDCF.

3.2.3. Effects of PDCF on pasta microstructure

Confocal laser scanning microscopy (CLSM) was used to evaluate the effect of PDCF addition on the microstructure of pasta. Figure 1 shows microphotographs of the surface and of a cross-section of dry pasta and cooked pasta strands. Control pasta (0% PDCF) and pasta with 5% PDCF were evaluated.

The microphotography of the surface of raw pasta (Figure 1a) shows the presence of intact starch granules as well as small bodies of presumable proteins. The surface of the dry pasta control sample is homogeneous while pasta with PDCF (5%) has a more heterogeneous surface, with "clumps" of material inserted between the starch granules (Figure 1e). Also, it can be noted that the surface of pasta with 5% PDCF is more porous. This open structure and the presence of pores may be responsible for faster water uptake, a plausible explanation for the observed lower cooking times of pasta with PDCF. The images of the cross-section of the raw pasta also show some differences between control and 5% PDCF pasta. Cross section of control pasta (Figure 1b) seems to be more compact and shows a matrix of presumably proteins surrounding starch granules, in accordance with the observations of other authors (Gull, Prasad, & Kumar, 2016). While pasta with 5% PDCF (Figure 1f) is similar but the structure is less homogeneous than that of the control. Other authors have also observed similar effects on pasta microstructure when adding other ingredients such as lentil seeds (Wojtowicz & Moscicki, 2014).

Regarding the microstructure of cooked pasta, microphotographs of the surface show that there are not visible starch granules or protein bodies (Figures 1c and 1g). The surface of cooked pasta with 5% PDCF seems to be covered by a film-like homogeneous structure. Such a structure can also be observed on the cross-section of the pasta strand looking as a matrix that engulfs starch granules (Figure 1h). Similar microstructural matrices were observed by Wojtowicz & Moscicki (2014) when adding white bean flour.

3.2.4 Sensory evaluation

Table 3 shows the results on the sensory evaluation of cooked pasta samples. Preference scores for color, appearance, taste, smell, and firmness were obtained at time zero and after 10 months of storage (airtight bags, room temperature). In general, all sensory characteristics were evaluated above the center point of the scale (5 = neither like nor dislike), indicating that pasta samples with PDCF were not disliked. However, all characteristics were evaluated with scores below of those of the pasta control. Preferences based on smell were not statistically different due to the inclusion of PDCF implying that PDCF did not impart negative smelling characteristics. This is an obvious advantage over other materials that may be used for the same purpose as chia such as flaxseeds or fish oil. The taste and firmness of 10% PDCF pasta were significantly different from the rest. However, 2.5 and 5% PDCF samples were statistically similar to the control. Color preference was affected by the inclusion of PDCF in the formulation. Samples with PDCF were (as a group) different from the control.

The sensory evaluation performed after 10 months (Table 3) of storage did not show significant differences regarding color, appearance, taste or smell preferences among samples with or without PDCF. Only firmness preference was negatively impacted when pasta contained PDCF. These results show that although pasta with PDCF is less preferred than traditional pasta there are not significant alterations in the sensorial characteristics of pasta with PDCF. Moreover, the general acceptance of the supplemented product seems to be better after 10 months storage. It is possible to conceive that with a good communication effort about the benefits of pasta with PDCF consumers will choose the product.

3.3. Nutritional quality

The results of nutritional evaluation of pasta show that total dietary fiber (TDF) and omega-3 content of pasta increased significantly with higher proportions of PDCF (Table 4). In fact, 10% PDCF pasta demonstrates an increase of around 300% of TDF compared with control. The ratio ω-3/ω-6 fatty acids also increased significantly from 0 to 2.14, constituting a product with a better PUFA balance as stated by Simopolous et al. (2000). With respect to the protein and mineral content, although both parameters increased as the level of PDCF augmented in the formulation, no statistical differences were observed except in the case of ash content of 10% PDCF pasta.

3.4. Total phenolic content (TPC) and antioxidant capacity of pasta

The results of TPC analysis show that the addition of PDCF increased the total phenolic content when compared to the control pasta (Figure 2a). In the case of raw pasta, the level of phenolic compounds is linearly increased along with higher PDCF content. Nevertheless, considering that pasta is consumed after cooking, the key result is represented by the increase of TPC of boiled PDCF-containing pasta compared with control boiled pasta. Regarding the antioxidant capacity measured by DPPH and FRAP, the tendency is the same for raw and cooked pasta showing an increase of activity directly correlated with the higher PDCF content (Figure 2b and 2c). Our results are consistent with previous studies of pasta fortified phenolic-rich materials, such as algae wakame (Prabhasankar et al., 2009) or buckwheat (Biney & Beta, 2014), in which positive relationships between TPC, antioxidant capacity and the proportion of added materials, have been observed. Altogether, these studies support the improvement of the antioxidant properties of plain wheat pasta through the use of ingredients of natural origin, obtaining a product with a beneficial added value for human health.

On the other hand, it is interesting to analyze the effects of cooking process. Whereas TPC is increased in control and 2.5% PDCF pasta after boiling, TPC of 5% PDCF pasta was not affected, while for 10% PDCF pasta a slight decrease is observed. FRAP assay also denotes that in control pasta and 2.5% PDCF a release of phenolic components is occurring, but not for 5% and 10% PDCF pasta. In the case of DPPH, the only significant difference is between 10% PDCF pasta, for which boiled pasta shows even less activity than raw pasta. In this regard, Fares, Platani, Baiano, & Menga (2010) have concluded that the cooking process enhance the antioxidant properties of plain wheat pasta (measured by chemical methods), which could be explained by the release of some phenolic acids from wheat caused by high temperatures. From our results, it is noticeable that the higher increase between raw and cooked pasta is observed for control and 2.5% PDCF pasta. This suggests that phenolic compounds released in the boiling process are most probably components from wheat, and not those provided by chia flour. Then it is plausible to think that chia compounds responsible of its antioxidant properties are not strongly affected by boiling.

4. Conclusions

The results of this work lead us to conclude that the addition of PDCF to wheat pasta allows an evident improvement of several nutritional properties compared with non-supplemented pasta. We have demonstrated a noticeable increase of total dietary fiber, ω-3/ω-6 ratio, total phenolic content and antioxidant capacity. This represents a promising use of a by-product generated after chia oil extraction process, proposing PDCF as an ingredient in the manufacture of fortified wheat pasta. A good communication campaign exposing the beneficial properties and pro-health characteristics of the supplemented product could be surely an adequate way to encourage consumers to choose it.

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Figure 1. Confocal laser scanning microscopy (CLSM) of pasta with and without PDCF. (a) surface of 0% PDCF raw pasta; (b) cross-section of 0% PDCF raw pasta; (c) surface of 0% PDCF cooked pasta; (d) cross-section of 0% PDCF cooked pasta; (e) surface of 5% PDCF raw pasta; (f) cross-section of 5% PDCF raw pasta; (g) surface of 5% PDCF cooked pasta; (h) cross-section of 5% PDCF cooked pasta.

Figure 2. Total phenolic content (a) and antioxidant capacity by DPPH (b) and FRAP (c) of pasta made with different levels of PDCF. Bars are the mean ± SD of 4 values. Different letters indicate significant difference in DGC test ($p < 0.05$).

Table 1. Characterization of partially-deoiled chia flour (PDCF)

	PDCF	**Wheat Flour**
Moisture (%)	11.80 ± 0.08	12.00 ± 0.15
Protein (%, d.b.)	27.70 ± 0.18	9.71 ± 0.18
Lipids (%, d.b.)	7.06 ± 0.28	1.08 ± 0.10
Ash (%, d.b.)	5.62 ± 0.15	0.58 ± 0.02
Total Dietary Fiber (%, d.b.)	59.73 ± 7.75	3.40 ± 1.75
Total Polyphenols (mg GAE/100 g)	221.20 ± 5.49	N/A
FRAP (mmol Trolox Eq./100 g)	0.70 ± 0.03	N/A
DPPH (mmol Trolox Eq./100 g)	0.47 ± 0.02	N/A
ω-3 (18:3) (mg/100g)	6850±50	4.8*
ω-6 (18:2) (mg/100g)	2160±50	232*
ω-3/ω-6 ratio	3.17	0.02

PDCF= ´partially deoiled chia flour; N/A not available; d.b.: dry basis;
*Data from SELFNutritionData (2017); GAE: gallic acid equivalent

Table 2. Color, texture, and cooking characteristics of pasta samples[a]

UNCOOKED PASTA					
PDCF (%)	**L***	**a***	**b***	**Color Grade[1]**	**Breaking Force (N)**
0.0[b]	68.84±3.01a	1.04±0.14a	16.08±0.15a	5.05	3.87±0.07a
2.5	66.09±0.78a	1.35±0.29b	14.43±1.42b	4.75	2.86±0.62b
5.0	63.50±2.34b	1.38±0.08b	12.99±0.54c	4.47	2.25±0.11b
10.0	61.81±5.07b	1.52±0.09b	11.07±0.88d	4.20	2.25±0.53b

COOKED PASTA									
PDCF (%)	**L***	**a***	**b***	**Color Grade**	**Firmness (N)**	**Adhesiveness (mJ)**	**OCT (min)**	**CL (%)**	**WG (%)**
0.0[b]	74.45±1.64a	0.57±0.36a	13.03±3.15a	5.03	7.42±1.06a	0.29±0.05a	14.15±0.20a	13.61±1.27a	162.23±3.90a
2.5	68.01±1.05b	1.76±1.21b	12.87±4.83a	4.69	8.40±0.12a	0.25±0.02a	13.15±0.20b	11.77±1.26b	159.35±5.86a
5.0	64.48±3.56c	1.68±2.62c	11.84±4.12b	4.41	6.73±0.59a	0.24±0.02a	13.00±0.20b	10.22±1.42b	156.76±8.56a
10.0	60.24±0.31d	2.70±3.80d	9.70±0.10c	3.98	7.42±0.64a	0.27±0.03a	12.00±0.20c	10.43±0.50b	161.73±6.88a

[a]Values with the same letter are not significantly different ($p > 0.05$) according to the DGC test; PDCF= ´partially deoiled chia flour; [b]The 0.0 %PDCF sample corresponds to a 100% wheat flour pasta; color Grade = (L* + b* x 2) / 20; OCT: optimum cooking time; CL: cooking loss; WG: water gain;

Table 3. Sensory evaluation of cooked pasta made with different levels of PDCF at 0 and after 10 months of storage[a]

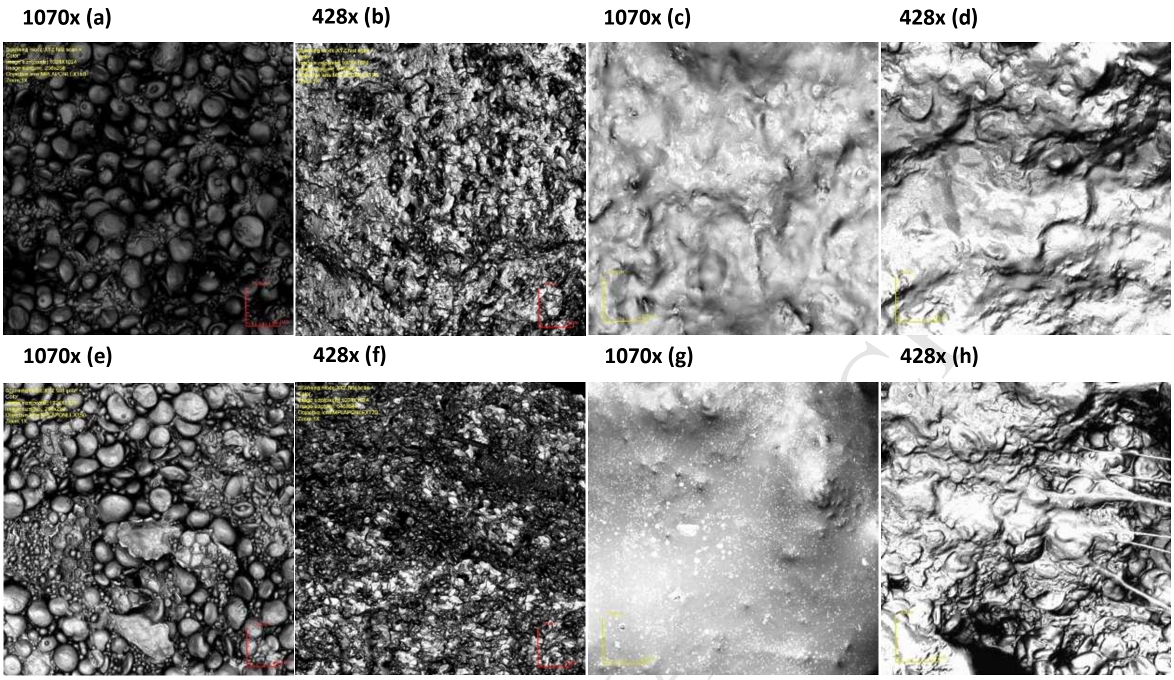
PDCF (%)	Color	Appearance	Taste	Smell	Firmness
	0 months of storage				
0.0[b]	6.95±1.05a	6.85±1.14a	6.50±1.00a	5.55±1.10a	7.30±1.45a
2.5	5.30±1.03b	5.40±1.35b	6.50±0.75a	5.65±1.10a	6.60±1.23a
5.0	5.10±0.97b	5.35±1.18b	6.50±0.91a	5.75±1.19a	6.60±1.23a
10.0	4.65±1.50b	4.70±1.56b	5.40±0.95b	5.20±1.70a	5.80±1.88b
	10 months of storage				
0.0[b]	6.60±1.75a	6.80±1.36a	6.50±1.41a	6.53±1.50a	7.18±1.39a
2.5	6.15±1.39a	6.35±1.39a	6.30±1.24a	6.10±1.39a	6.18±1.57b
5.0	6.03±1.61a	6.03±1.72a	6.15±1.48a	6.40±1.37a	6.05±1.81b
10.0	6.08±1.95a	5.90±1.85a	6.13±1.70a	6.00±1.38a	6.10±1.78b

[a]Values with the same letter are not significantly different ($p > 0.05$) according to the DGC test; PDCF= ´partially deoiled chia flour; [b]The 0.0 %PDCF sample corresponds to a 100% wheat flour pasta

1 Table 4. Nutritional analysis of manufactured pasta[a]

	PDCF[b]			
	0%	**2.5%**	**5%**	**10%**
Protein (%, d.b.)	11.04 ± 0.03a	11.28 ± 0.12a	11.72 ± 0.18a	12.66 ± 0.14a
Total Dietary Fiber (%, d.b.)	2.86 ± 0.19a	4.53 ± 0.12b	4.89 ± 0.05b	9.08 ± 0.63c
Moisture (%)	10.45 ± 0.33a	10.74 ± 0.06a	10.65 ± 0.11a	10.42 ± 0.19a
Ash (%) (d.b.)	2.18 ± 0.00a	2.25 ± 0.01a	2.37 ± 0.07a	2.48 ± 0.02b
ω-3 (18:3) (g/100 g)	0.00± 0.00a	0.06± 0.01a	0.11± 0.01a	0.30± 0.01a
ω-6 (18:2) (g/100g)	0.02± 0.00a	0.05± 0.00a	0.07± 0.02a	0.14± 0.01a
ω-3/ω-6 ratio	0.00± 0.00a	1.20± 0.01b	1.57± 0.01c	2.14± 0.02d

2 [a]Values with the same letter are not significantly different ($p > 0.05$) according to the DGC
3 test; [b]PDCF= partially deoiled chia flour; The 0.0 %PDCF sample corresponds to a 100%
4 wheat flour pasta; ω-3 : omega 3 fatty acids, ω-6 : omega- 6 fatty acids;
5
6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1070x (g)
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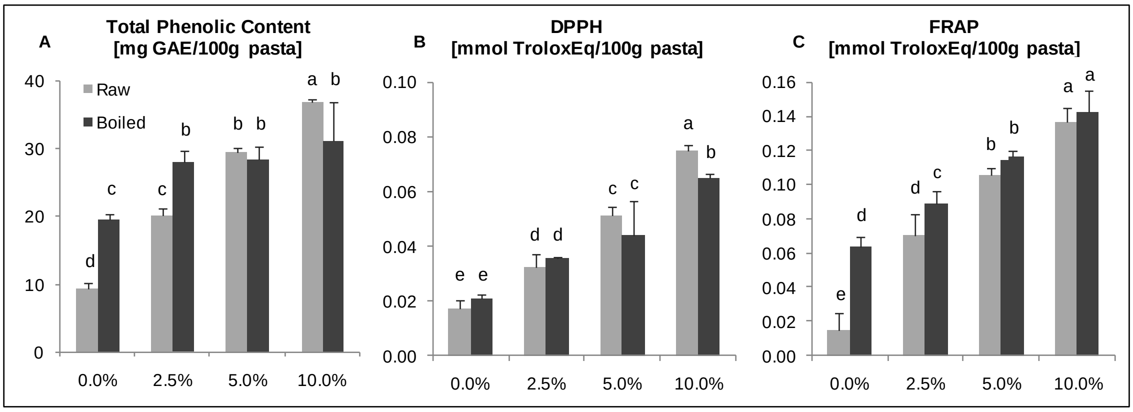
A
Total Phenolic Content
[mg GAE/100g pasta]
Raw
Boiled
0.0%
2.5%
5.0%
10.0%
B
DPPH
[mmol TroloxEq/100g pasta]
C
FRAP
[mmol TroloxEq/100g pasta]

Highlights

- A feasible use of a by-product from chia oil extraction (PDCF) is proposed.
- PDCF is rich in protein, dietary fiber and phenolic compounds.
- It can be used as an ingredient to improve the nutritional quality of wheat pasta.
- Supplemented pasta showed better antioxidant capacity.
- The technological properties and the acceptance by consumers were evaluated.