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Application of parsley leaf powder as functional ingredient in fortified wheat pasta: nutraceutical, physical and organoleptic characteristics

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Abstract. The aim of the study was to evaluate certain selected properties of durum wheat pasta fortified with parsley leaf powder. Various levels of parsley leaf powder (2.5, 5.0, 7.5, and 10.0%) were incorporated in order to develop fortified pasta and their effects on nutraceutical properties (total phenolic content, antioxidant activity), cooking quality (optimum cooking time, water absorption capacity, cooking loss), texture (hardness, adhesiveness, extensibility at break, elongation at break), colour and organoleptic attributes were assessed. The results showed that the amount of phenolic compounds increased significantly in the fortified pasta with the increase in the fortification level. Furthermore, the increase in the levels of these bioactive compounds in fortified pasta improved its antiradical ability and its reducing power. Moreover, the addition of parsley leaf powder to the pasta significantly reduced its optimum cooking time, hardness, extensibility at break, elongation at break, lightness and yellowness. In contrast, the incorporation of parsley leaf powder in the pasta significantly increased its water absorption capacity, cooking loss, adhesiveness and greenness. All of the fortified pasta received acceptable scores in overall acceptability. Approximately 93% of the data variance may be explained by the first two principal components and significant correlations were noted between different properties of the pasta. Parsley leaf powder can successfully be used (up to 5.0%) in nutritionally valuable pasta formulations.

Keywords: parsley leaf, pasta, nutraceutical properties, cooking quality, texture

INTRODUCTION

Pasta is one of the most widely consumed food products in the world due to its low cost, ease of preparation and long shelf life. At present, the increase in consumer demand for healthy natural foods is leading to the diversification of pasta products (Mercier *et al*., 2016).

Pasta is commonly produced from durum wheat semolina as this is considered to be the most suitable raw material for pasta-making (Petitot *et al*., 2010). Such pasta is rich in starch but poor in vitamins, minerals, dietary fibre and phenolic compounds (Jalgaonkar *et al*., 2018). However, pasta is an excellent product for the addition of nutrients, as non-traditional ingredients can be incorporated into their formulation with no apparent loss in pasta quality (Petitot *et al*., 2010). As a result, substantial efforts have been made to develop fortified pasta. Ingredients considered for pasta fortification include plant-based flours (*e.g.* cereals, pseudo-cereals, legumes, and dietary fibres), animal-based supplements (*e.g.* egg white powder and fish oils), protein concentrates and isolates, nutraceuticals and herbal products, microalgae, and agro-industrial by-products (Krishnan and Prabhasankar, 2012; Li *et al*., 2014; Mercier *et al*., 2016; Lisiecka *et al*., 2019; Bianchi *et al*., 2021). The fortification process aims to compensate for nutritional deficiencies (*e.g.* low contents of threonine and lysine) or to provide additional sources of fibre, minerals, bioactive components or antioxidants (Mercier *et al*., 2016).

Parsley (*Petroselinum crispum* Mill.) is a popular culinary herb which is widely consumed due to its specific aroma and taste. Parsley originates from the Mediterranean region,

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but it is cultivated all over the world at the present time, its dried and/or fresh leaves are largely used as a condiment, garnish and flavouring food additive (Díaz-Maroto *et al*., 2002; Zhang *et al*., 2006). Parsley is employed in traditional and folklore medicine for the treatment of various diseases. In pharmacological research, it has been discovered that the bioactive compounds of this plant exhibit a wide range of activities - including antioxidant, cytoprotective, gastroprotective, hepatoprotective, brain protective, spasmolytic, analgesic, diuretic, estrogenic, immunosuppressant, laxative, hypotensive, anti-diabetic, anti-platelet, antibacterial and antifungal activity (Farzaei *et al*., 2013).

The objective of the study was to evaluate the nutraceutical properties, cooking quality, texture and organoleptic attributes of durum wheat pasta fortified with various levels of parsley leaf powder (PLP).

MATERIALS AND METHODS

Durum wheat semolina (DWS) was purchased from a local store (Constantine, Algeria) and sieved to obtain semolina with a granulation below 0.5 mm. Parsley (*Petroselinum crispum* Mill.) leaves, purchased from a local market (Constantine, Algeria), were first cleaned by washing and rinsing with tap water, and then dried at 40°C in a fluid bed dryer Retsch TG 200 (Retsch, Haan, Germany) until a constant weight was achieved. The dried leaves (6% residual moisture) were subsequently ground using a knife mill (Philips 2102, Drachten, Netherlands) and sieved to produce PLP with a particle size of below 0.5 mm. This PLP was stored in hermetically sealed plastic bags. The proximate composition of semolina and dried parsley was tested according to AACC (1995) methods as follows: protein AACC 46-10, fat AACC 30-10, ash AACC 08-01, and fibre according to AOAC 993.21 (AOAC, 2000).

The control pasta was prepared by hydrating DWS with distilled water up to 40% moisture content and kneaded (Kenwood KM 300, Havant, UK) until a homogeneous dough was obtained. This dough was left to stand for 5 min and then sheeted by passing it between the two rollers of the pasta machine Marcato Ampia 150 several times (Campodarsego, Italy). The obtained dough sheets were cut using the same pasta machine used to produce fettuccine-type pasta with a 1 mm thickness, 6.5 mm width, and 150 mm length. The pasta was dried at 25°C for 48 h (moisture content below 12%) and then stored in hermetically sealed plastic bags.

The fortified pasta was prepared as described for the control pasta with three modifications: (1) DWS was replaced in the recipe with the incorporation of PLP in the amounts of 2.5, 5.0, 7.5, and 10.0% (w/w), (2) DWS and PLP were blended for 5 min before hydration, and (3) the hydration level of the dough was increased gradually up to 52.5%. The fortified pasta was then shaped and dried as it was for the control pasta.

The pasta was cooked at the optimum cooking time, drained and then cooled down at room temperature. It was frozen at –20°C and lyophilized (Christ Alpha 1-4, Osterode am Harz, Germany). The lyophilized cooked pasta was ground and sieved to pass through a 0.5 mm sieve. The samples were kept in darkness at –20°C. Approximately 1 g of sample was extracted with 20 mL of 75% acetone (Chaalal *et al*., 2013). The mixture was stirred for 30 min, centrifuged at 1700×g for 5 min (Sigma 3-30K, Osterode am Harz, Germany) and paper filtered. The filtrates (extracts) were used for the assessment of total phenolic content and antioxidant activities.

Total phenolic content (TPC) was determined in duplicate as described by Singleton and Rossi (1965) by mixing 150 µL of extract with 750 µL of Folin-Ciocalteu reagent and 600 µL of sodium carbonate (7.5%). After a 30 min reaction in a dark place at room temperature, the absorbance was measured at a wavelength of 750 nm with a UV spectrophotometer UV-1800 (Shimadzu, Kyoto, Japan). The TPC was expressed by gallic acid equivalent (GAE) in mg 100 g^{-1} of dry weight (dw).

The method described by Brand-Williams *et al*. (1995) with a minor modification was used to measure the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity of the samples. In brief, the extract (0.1 mL) was added to DPPH solution (1 mL, 60 µM), and after 30 min of incubation, the absorbance was measured at 517 nm. The results were expressed by ascorbic acid equivalents (AAE) in mg 100 g^{-1} dw. The tests were performed in duplicate.

The Ferric-reducing antioxidant power (FRAP) of the samples was evaluated in duplicate according to the method described by Chaalal *et al*. (2013). A mixture containing 1 mL of extract, 1 mL of phosphate buffer (200 mM, pH 6.6) and 1 mL of potassium ferricyanide (1%) was prepared and incubated at 50°C for 20 min. After the addition of 1 mL of 10% trichloroacetic acid, the obtained mixture was centrifuged for 10 min at 1700×g, then an aliquot of the supernatant (1 mL) was mixed with distilled water (1 mL) and 0.2 mL of ferric chloride (0.1%). After 10 min of incubation, the absorbance was measured at 700 nm. FRAP was expressed by AAE in mg 100 g^{-1} dw.

In order to determine the optimum cooking time (OCT), 10 g of pasta was cooked in 200 mL of boiling distilled water. Every 30 s during cooking, a pasta strand was sampled and immediately squeezed between two transparent glass plates. The OCT corresponded to the time at which the dry core of the pasta disappeared, according to 66-50.01 AACC method (2011). The tests were performed in duplicate.

The water absorption capacity (WAC) was determined twice by cooking the dry pasta in boiling distilled water (10 g 200 mL^{-1}) to OCT. The cooked pasta was then rinsed, drained for 5 min and weighed. The weight increase of the pasta during cooking was calculated and divided by the weight of the dry pasta in order to calculate the WAC (%) (Bouasla *et al*., 2017).

The cooking loss (CL), which is the amount of solids lost to the cooking water, was determined in duplicate by evaporating water from pasta cooking and rinsing to obtain a constant weight in an air oven (Memmert, Schwabach, Germany) at 105°C. The weight of the obtained residue was divided by the weight of dry pasta to calculate the cooking loss (%) (Bouasla *et al*., 2017).

The textural properties of the dry and cooked pasta samples were determined in duplicate using a Zwick Roell BDO-FB0.5TH (Zwick GmbH & Co., Ulm, Germany) instrument according to the protocols of testXpert®13.3 software (Zwick GmbH & Co. KG, Ulm, Germany). The hardness (N) of a single dry pasta strip was found through the determination of the maximum cutting force by using a Warner-Bratzler cutting knife operating at a speed of 100 mm min^{-1}. The cooked pasta (50 g) was double compressed up to 50% with a test speed of 100 mm min^{-1} and the resulting adhesiveness (mJ) was the energy required to remove the working plate from the pasta surface after compression, this was evaluated using an Ottawa Texture Measuring System Cell. The extensibility at break (ExB, mm) and the elongation at break (EB, %) of the cooked single pasta strips were determined using a Kieffer Extensibility Rig in tension mode with a test speed of 100 mm min^{-1}.

The colour profile was measured in five replications for dry and cooked pasta using an NR20XE colorimeter (Shenzhen, China) with the CIE-Lab colour scale. All three CIE-Lab coordinates (L^*, a^* and b^*) were determined. Herein, L^* values measure lightness (0 black to 100 white); a^* values indicate greenness when negative and redness when positive; b^* values indicate blueness when negative and yellowness when positive. The total colour difference (ΔE) was calculated using the following Eq. (Wójtowicz *et al*., 2013):

$$\Delta E = \sqrt{\left(L^*_{sample} - L^*_{control}\right)^2 + \left(a^*_{sample} - a^*_{control}\right)^2 + \left(b^*_{sample} - b^*_{control}\right)}$$

As regards the organoleptic evaluation, each pasta sample was cooked for its corresponding OCT, drained and then kept in warm conditions until evaluation. The cooked pasta samples were served in a random order to a panel of 20 panellists who evaluated each sample separately using a 5-point scale – where 1 and 5 represented a poor and good appreciation, respectively. The following organoleptic attributes were assessed: appearance, stickiness, colour, taste and flavour. The overall acceptability was also evaluated by the same panel using a 9-point hedonic scale – where 1 = extremely dislike and 9 = extremely like. Pasta samples with a mean score above 5 were considered to be acceptable (Bouasla *et al*., 2017).

Data were subjected to a one-way analysis of variance (ANOVA) followed by the Fisher's least significant difference (LSD) *post hoc* test in order to compare means at the 0.05 significance level by using Statistica 10.0 software (StatSoft, Inc., Tulsa, USA). Additionally, Pearsons' correlation coefficients and the principal component analysis (PCA) were performed using Statistica 13.3 software (StatSoft, Inc., Tulsa, USA).

RESULTS AND DISCUSSION

The proximate composition of the raw materials was as follows: semolina – 12.68% protein, 1.35% fat, 0.91% ash and 5.40% fibre, PLP – 26.6% protein, 5.5% fat, 8.63% ash and 26.7% fibre. Based on the chemical composition of ingredients used, increasing the amount of PLP in the recipe had the effect of increasing the protein and fibre content in the pasta product originating from the dry parsley leaf, which makes the pasta more nutritionally valuable when it has a higher PLP content.

The TPC and antioxidant activity of the control sample and pasta fortified with different amounts of PLP are shown in Table 1. As expected, increasing PLP in the pasta recipe brought about a significant positive effect on its phenolics content and antioxidant activities. Wheat pasta has the lowest TPC and antioxidant activity, this was also confirmed by the results presented in previous studies (Sęczyk *et al*., 2016; Biernacka *et al*., 2017; Michalak-Majewska *et al*., 2020). In our study, the TPC of the fortified pasta ranged from 60.06 mg GAE 100 g^{-1} dw for pasta with the addition of 2.5% PLP, to 83.01 mg GAE 100 g^{-1} dw for pasta with the addition of 10.0% PLP. In the study of Sęczyk *et al*. (2016), the addition of 4% PLP to durum wheat pasta resulted in a 179% increase in TPC. The same authors reported that phenolic compounds from fortified pasta were characterized by a high *in vitro* bioaccessibility. With respect to the control, the fortification of pasta with PLP at different levels (1-4%) increased the TPC by 18-71% (Sęczyk *et al*., 2015).

Table 1. TPC and antioxidant activities of the control and fortified pasta

PLP content (%)	TPC (mg GAE 100 g^{-1} dw)	DPPH-radical scavenging activity (mg AAE 100 g^{-1} dw)	FRAP (mg AAE 100 g^{-1} dw)
0	54.87±0.16^a	6.36±0.14^a	20.37±1.24^a
2.5	60.06±0.27^b	8.27±0.10^b	26.91±0.74^b
5.0	68.22±0.10^c	10.19±0.12^c	50.29±0.91^c
7.5	74.19±0.05^d	12.30±0.04^d	53.50±0.11^d
10.0	83.01±0.13^e	13.75±0.17^e	87.20±1.68^e

Values are means ± SD (n=2). Values with different superscripted letters within a column are significantly different ($p<0.05$). PLP: parsley leaf powder; TPC – total phenolic content; DPPH – 1,1-diphenyl-2-picrylhydrazyl; FRAP – ferric-reducing antioxidant power; GAE – gallic acid equivalent; AAE – ascorbic acid equivalent; dw – dry weight.

In our work, the ability to scavenge DPPH radicals increased significantly with the increase in PLP. A similar tendency in the ability of fortified pasta to reduce Fe^{3+} ion concentration was noted. In fact, a significant positive correlation between DPPH and FRAP was indicated (r = 0.95). Nielsen *et al*. (1999) demonstrated that apigenin was the main compound responsible for the antioxidant activity of parsley leaf.

As reported in previous studies, the addition of phenolic-rich ingredients to wheat pasta had a positive effect on the phenolic content and/or antioxidant activity (Boroski *et al*., 2011; Sęczyk *et al*., 2016; Lisiecka *et al*., 2019). It should be noted that several factors may affect the antioxidant potential of fortified pasta, such as the supplement type, the conditions applied during pasta processing, and the various interactions between the phenolic compounds and pasta components (proteins and starch) (Ozdal *et al*., 2013). The antioxidant potential of foods may be created by various factors as phenolic-protein, phenolic-phenolic and phenolic-starch interactions (Sęczyk *et al*., 2015). It has been concluded that proteins significantly decrease the antioxidant capacity in general, but there are some controversial results which might be due to the differences in the analytical techniques used to measure the antioxidant capacity or total phenolic/flavonoid contents. Moreover, as a result of protein-phenolic interactions, there are changes in the total phenolic or flavonoid contents, the contents of individual phenolic compounds, as well as in the in-vitro and in-vivo bioavailability of phenolic compounds, thus, changes in the antioxidant activities may be noted (Ozdal *et al*., 2013).

The OCT of the control pasta was 5.5 min (Table 2). This time decreased significantly with the increase in PLP addition. Pasta fortified with PLP at 7.5 and 10.0% had the shortest OCT. A shorter cooking time may be related to the addition of PLP as this could induce changes in pasta composition and microstructure (Mercier *et al*., 2016). Moreover, the amount of water required to gelatinize the starch may be decreased with enrichment by diluting the pasta starch content. The incorporation of PLP reduces the amount of durum wheat semolina and therefore decreases the glutenin fraction which has a higher molecular weight and longer hydration time (Vernaza *et al*., 2012). The physical disruption of the gluten matrix by fibre-rich fractions of PLP, as confirmed by proximate composition, and provided a path of water penetration into the pasta containing nontraditional ingredients which resulted in a shorter OCT (Petitot*et al*., 2010; Jalgaonkar *et al*., 2018).

Table 2. Cooking quality of the control and PLP enriched pasta

PLP content (%)	Optimum cooking time (min)	Water absorption capacity (%)	Cooking loss (%)
0	5.5±0.01^{c}	201.50±0.71^{a}	4.3±0.21^{a}
2.5	5.0±0.01^{bc}	203.75±0.21^{b}	5.2±0.14^{b}
5.0	4.5±0.01^{b}	206.60±0.14^{c}	7.4±0.14^{c}
7.5	4.0±0.01^{a}	210.48±0.27^{d}	10.7±0.28^{d}
10.0	3.5±0.01^{a}	211.32±0.40^{d}	11.2±0.28^{d}

Values are means ± SD (n=2). Values with different superscripted letters within a column are significantly different ($p<0.05$). PLP – parsley leaf powder.

The absorption of water during cooking determines the texture of the cooked pasta (Sissons *et al*., 2012). Adding PLP caused a significant increase in the WAC of the fortified pasta as compared to the control pasta, and the WAC ranged from 201.50% for the control pasta to 211.32% for pasta with 10.0% PLP. This increase in WAC in pasta fortified with PLP may be due to the presence of dietary fibre in the PLP, as confirmed by proximate composition, which has a high water absorption potential (Sivam *et al*., 2010) and therefore results in a higher WAC. Furthermore, pasta with a level of enrichment of less than 15% and dried at less than 60°C tends to absorb higher amounts of water during cooking (Mercier *et al*., 2016) which is the case in our study. These processing conditions may facilitate the penetration of water and the swelling of starch and also increase water absorption during cooking despite starch dilution. Additionally, in semolina pasta, the appropriate cooked weight is about three times the dry weight (Sissons *et al*., 2012). This effect was observed in the control pasta and pasta fortified with 2.5 and 5.0% PLP.

The cooking loss is considered to be an important factor for pasta cooking quality (Mercier *et al*., 2016). In our study, CL increased significantly with increasing PLP levels and varied from 4.3% for the control pasta to 11.2% for pasta with 10.0% PLP, due to the replacement of the glutenin and gliadin fractions of protein originating from semolina. Similar tendencies have been reported for pasta fortified with oregano and carrot leaf (Boroski *et al*., 2011) and also for pasta fortified with *Cistus incanus* (Lisiecka *et al*., 2019). This effect resulted from the fact that the gluten strength was diluted by the incorporation of non-gluten material that weakened the pasta structure. This leads to more solids being leached from the pasta during the cooking process (Petitot *et al*., 2010; Mercier *et al*., 2016). Moreover, the drying conditions applied in the present study could lead to the formation of micro-cracks that may be responsible for the high dry matter losses during cooking. For good quality pasta, the CL should be lower than 7-8% (Sissons *et al*., 2012). With regard to this limit, the control pasta and pasta fortified with 2.5 and 5.0% PLP may be ranked as good quality pasta. By contrast, the addition of 7.5 and 10.0% PLP triggers a higher degree of solids leaching during cooking (CL > 10%), but the pasta strands still maintained their proper shape.

The textural properties of the pasta play an important role in determining the final degree of acceptability to the consumer. The results of the dry pasta hardness tests and cooked pasta adhesiveness and extensibility features are presented in Table 3. The fortification of the pasta with PLP significantly decreased the hardness of the dry pasta (r = –0.97), but also the ExB (r = –0.95) and EB (r = –0.91) of the fortified cooked pasta. Similar findings were reported

Table 3. Textural properties of the control and PLP fortified pasta

PLP content (%)	Hardness (N)	Adhesiveness (mJ)	Extensibility at break (mm)	Elongation at break (%)
0	7.11±0.02^{d}	0.36±0.05^{a}	10.85±0.75^{d}	40.65±2.65^{c}
2.5	6.66±0.15^{c}	0.56±0.20^{a}	7.65±0.05^{c}	23.3±2.00^{b}
5.0	5.38±0.14^{b}	2.80±0.46^{b}	6.55±0.45^{bc}	19.7±1.50^{b}
7.5	5.09±0.01^{b}	4.50±0.17^{c}	5.70±0.10^{ab}	16.85±0.15^{b}
10.0	3.71±0.13^{a}	5.86±0.15^{d}	4.55±0.35^{a}	10.00±1.60^{a}

Explanations as in Table 2.

for durum wheat pasta fortified with different fibre-rich ingredients, such as carob fibre (Biernacka *et al*., 2017), mango peel powder (Jalgaonkar *et al*., 2018) and moringa leaf powder (Jalgaonkar *et al*., 2018; Simonato *et al*., 2021).

Pasta texture depends to a great extent on the presence of a tough protein network (Jalgaonkar *et al*., 2018). The reduction in the hardness of the dry pasta, and the extensibility and elongation of cooked pasta with the addition of PLP may be due to the substitution of gluten by non-gluten ingredients causing a reduction in gluten strength and elasticity (Krishnan and Prabhasankar, 2010), and therefore the fortified pasta has a weaker and less elastic structure. During cooking, gluten absorbs water and starch undergoes gelatinization and hence its texture becomes softer. This weakening effect can also be explained by the higher fibre content in pasta fortified with PLP, as confirmed by its proximate composition, as the high affinity for water of the fibres probably reduced the amount of water available for the development of a gluten network. Furthermore, the incorporation of fibre fractions may have reduced the amount of starch necessary for the formation of a dough. This resulted in the disturbance of the protein matrix, which led to the development of a less hard and less extensible pasta (Biernacka *et al.*, 2019; Jalgaonkar *et al.*, 2018). In addition, inside the pasta strand of the fortified samples, as a result of fibre incorporation as well as drying conditions, the pasta structure may have been weakened by the formation of cracks or discontinuities (Bouasla *et al*., 2017).

The control pasta was characterized by its robust structure. This is confirmed by the highest hardness results of the dry product, the lowest cooking loss and the greatest extensibility and elongation at break after cooking. In fact, the hardness of the dry pasta and CL were negatively correlated (r = –0.93). Negative correlations were also observed between CL and ExB (r = –0.84) and also between CL and EB (r = –0.78). By contrast, an increase in the adhesiveness of pasta was noted as the percentage of PLP increased (r = 0.96). This increase in adhesiveness may be due to the higher fibre content and also to proteins replacing wheat semolina with non-gluten components. When considering that pasta consists of starch granules embedded in a gluten network, a reduction in the glutenous fractions of the protein content could increase water penetration and starch swelling during cooking, thereby leading to a more intensive leaching of the amylose molecules from the fortified pasta and increasing pasta adhesiveness (Mercier *et al*., 2016; Bouasla *et al*., 2017). These results are in agreement with the cooking quality which shows that fortified pasta samples exhibited higher CL and WAC, as compared to the control pasta. In fact, adhesiveness was positively correlated with CL (r = 0.99) and WAC (r = 0.98).

Pasta colour is an essential attribute for the evaluation of pasta quality (Petitot *et al*., 2010) and it also affects the tendency of the consumer to purchase the product (Lisiecka *et al*., 2019) because the possibility exists for the assessment of this property directly at the time of purchase. The addition of PLP to DWS pasta resulted in a significant colour change in the fortified samples (Fig. 1). The results of instrumental colour measurements (Table 4) showed that the lightness (L^*) of the pasta samples decreased significantly with the increase in PLP levels (r = –0.97), thereby indicating that the fortified pasta had become darker, as the recipe was changed by the incorporation of PLP. Dry parsley leaf was characterized by an L^* value of 48.69, it was much darker than durum wheat semolina (L^* 91.87). Previous studies reported similar trends concerning pasta fortified with carrot (Carini *et al*., 2010), grape marc powder (Sant'Anna *et al*., 2014) and *Cistus incanus* L. leaves (Lisiecka *et al*., 2019). Moreover, the a^* values decreased significantly with the increase in PLP incorporation in the pasta recipe (r = 0.84), thereby indicating that the colour of the fortified samples shifted towards green. This was expected, since PLP is characterized by its green colour (a^* value was –7.75) due to the presence of chlorophyll pigments. This fact may explain the decrease in the colour coordinate values. Similarly, the fortification of pasta with PLP significantly decreased the yellowness (r = –0.55) of the dry pasta.

After cooking, all of the pasta samples fortified with PLP were significantly darker (lower L^* values), less green (lower negative a^* values for pasta fortified with 5.0% and 7.5% PLP) and less yellow (lower positive b^* values) than

Table 4. Colour profile of the control and PLP fortified pasta

PLP content (%)	L^*	a^*	b^*	ΔE
	Dry pasta			
0	86.79±0.12^{e}	3.31±0.04^{d}	21.92±0.11^{d}	ref
2.5	84.31±0.86^{d}	–2.26±0.07^{c}	18.98±0.39^{b}	6.77
5.0	77.20±0.73^{c}	–3.81±0.21^{a}	18.95±0.16^{b}	12.31
7.5	67.46±1.52^{b}	–3.33±0.12^{b}	19.95±0.95^{c}	20.54
10.0	60.47±1.93^{a}	–3.79±0.36^{a}	17.82±0.29^{a}	27.57
	Cooked pasta			
0	77.35±0.64^{e}	1.99±0.07^{d}	25.23±0.56^{e}	ref
2.5	64.74±0.35^{d}	–2.19±0.12^{c}	16.80±0.52^{d}	16.06
5.0	61.90±0.75^{c}	–2.57±0.12^{b}	11.77±0.04^{b}	21.29
7.5	49.65±0.71^{b}	–3.80±0.10^{a}	12.99±0.13^{c}	31.19
10.0	43.84±0.37^{a}	–3.72±0.05^{a}	10.80±0.12^{e}	37.29

L^* – lightness; a^* – greenness (negative value) and redness (positive value); b^* – yellowness (positive value) and blueness (negative value); ΔE – total colour difference. Other explanations as in Table 2.

Fig. 1. Control pasta and pasta fortified with various levels of parsley leaf powder (PLP): a) – uncooked pasta, b) – cooked pasta at OCT.

uncooked pasta. The reduction in the degree of greenness and yellowness after the cooking of the fortified pasta samples may be due to thermal degradation and/or the leaching of pigments (Sant'Anna *et al*., 2014; Mercier *et al*., 2016).

For both dry and cooked pasta, the total colour difference (ΔE) between the control pasta and pasta with PLP increased with the increase in PLP levels. Higher values of ΔE were recorded for the cooked samples (ranging from 16.06 to 37.29). These samples showed a more intensive colour change after cooking, as compared to the control pasta. The total colour difference may be visually detected by an experienced observer when ΔE is higher than 3.5 (Mokrzycki and Tatol, 2011) and higher than 5 for an inexperienced observer (Tazrart *et al*., 2016). Thus, the results indicated that pasta fortified with PLP deviated from the control pasta and that significant differences may be visible to the naked eye.

Table 5 shows the organoleptic attributes and overall acceptability of the cooked pasta. All of the pasta samples received acceptable scores (scores higher than 5) in terms of overall acceptability. The control pasta without PLP had a neutral taste and flavour, and the results were similar in the homogenous groups for each organoleptic characteristic, except in the case of the appearance and colour due to the darkening of the pasta with the addition of over 7.5% PLP. Pasta fortified with 2.5% PLP received the highest score (6.5) and pasta fortified with 10.0% PLP received the lowest score (5.7), although the difference was not significant ($p>0.05$). The overall acceptability was closely and positively correlated with flavour ($r=0.93$). The control pasta and the pasta which had low amounts of PLP added to it (2.5 and 5.0%) received acceptable scores for appearance and colour (>3). The appearance was closely and positively correlated with the colour ($r=0.97$) and negatively correlated with CL ($r=-0.92$) and adhesiveness ($r=-0.87$). In contrast, the pasta with high amounts of PLP (7.5 and 10.0%) received unsatisfactory scores (<3) probably because of the intensive dark green colour.

With regard to stickiness, the panelists attributed unsatisfactory scores to the pasta enriched with the highest level of PLP. In fact, these pasta products had the highest values of CL and adhesiveness. The leaching of amylose during cooking leads to an unsuitable sticky texture (Mercier *et al*., 2016). Overall, the panellists responsible for the organoleptic evaluation attributed acceptable scores to all of the pasta products with regard to taste and flavour. Palatability and consumer preference should, therefore, not be adversely affected by the addition of healthy ingredients. Indeed, fortified foods can be both delicious and healthy (Krishnan and Prabhasankar, 2012).

In terms of the PCA results, approximately 93% of the variance in the pasta results was explained by the first two principal components: PC1 (77.43%) and PC2 (15.95%). PC1 was closely and negatively correlated with the OCT, appearance, colour, stickiness, L^*, a^* and b^* of both the

Table 5. Results of organoleptic evaluation and the overall acceptability of the control and PLP fortified pasta

PLP content (%)	Appearance[1]	Stickiness[1]	Colour[1]	Taste[1]	Flavour[1]	Overall acceptability[2]
0	3.65±1.14^{b}	2.90±1.48^{a}	3.50±1.24^{b}	3.30±1.17^{ab}	3.05±1.15^{a}	5.75±1.89^{a}
2.5	3.60±0.88^{b}	2.80±1.11^{a}	3.60±0.82^{b}	3.65±0.93^{b}	3.60±0.75^{a}	6.50±1.50^{a}
5.0	3.55±0.94^{b}	2.70±1.08^{a}	3.70±0.80^{b}	2.95±0.69^{a}	3.60±0.75^{a}	6.25±1.48^{a}
7.5	2.60±1.05^{a}	2.60±1.10^{a}	2.55±1.00^{a}	3.15±1.39^{ab}	3.25±0.97^{a}	6.10±1.65^{a}
10.0	2.25±1.33^{a}	2.65±1.31^{a}	2.45±1.05^{a}	3.05±1.23^{ab}	3.30±1.23^{a}	5.70±1.95^{a}

[1] – organoleptic features in 5-points scale; [2] – acceptability in 9-points hedonic scale. Other explanations as in Table 2.

uncooked and cooked pasta, hardness, extensibility at break and elongation at break. In addition, the first component PC1 was positively correlated with TPC, antioxidant activity by DPPH and FRAP, WAC, CL and adhesiveness, while PC2 was closely and positively correlated with flavour and overall acceptability (Fig. 2a). Placing the pasta in the space of the examined components (Fig. 2b) showed an increase in the differences between the samples as the addition of parsley increased in the recipe. However, minor differences were noted between pasta with 2.5 and 5.0%, and between 7.5 and 10.0% PLP additions, as compared to the control sample. This result is clearly visible in Fig. 2b by the location of the samples in the components space. In general, it can be concluded that the first component with a value of 77.43% describes the system variability well and indicates the effect of the plant additive content.

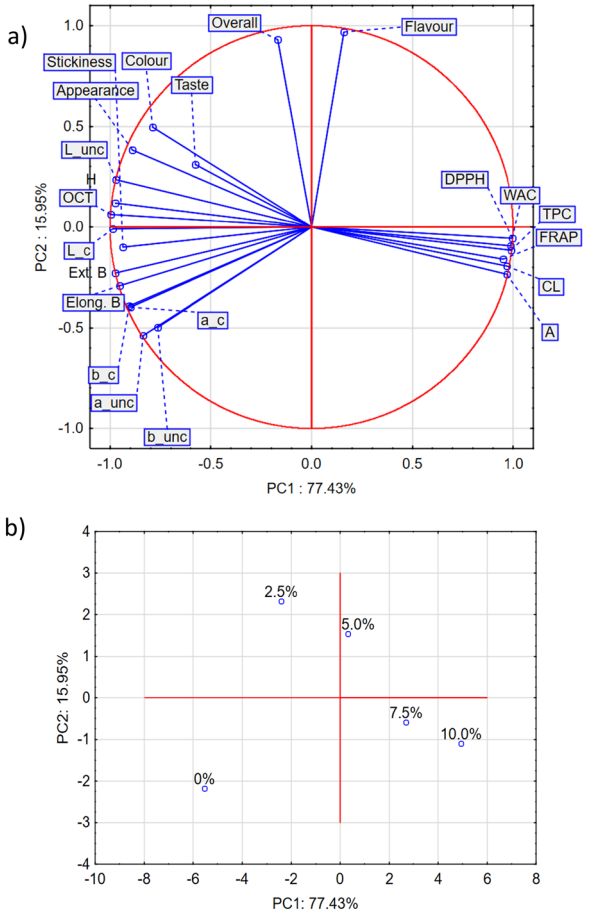

Fig. 2. Analysis of the principal components (PCA) of pasta features (a) and the objects placement of pasta with various PLP contents (b) in space of first two major components: PC1 – first component, PC2 – second component, 0-10% – content of PLP, TPC – total phenolic content, DPPH, FRAP – antioxidant activity against DPPH and FRAP radicals, OTC – optimal cooking time, WAC – water absorption capacity, CL – cooking loss, L_unc – lightness uncooked, a_unc – redness-greenness balance uncooked, b_unc – yellowness-blueness balance uncooked, L_c – lightness cooked, a_c – redness-greenness balance cooked, b_c – yellowness-blueness balance cooked, H – hardness, Ext B – extensibility at break, Elong B – elongation at break, A – acceptability.

CONCLUSIONS

1. The fortification of the pasta with powdered parsley leaf leads to an increase in total phenolic content and antioxidant activity.

2. Pasta fortified with parsley leaf powder up to a concentration of 5.0% was found to be a successful compromise between improving the nutritional characteristics and providing favourable physical, as well organoleptic qualities.

3. Pasta supplemented with parsley leaf powder could therefore be an attractive and healthy alternative to common pasta.

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