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Physicochemical, texture and sensorial evaluation of pasta enriched with chickpea flour and protein isolate

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ABSTRACT

Pasta is healthy, cheap, versatile, and convenient as a carrier of bioactive components. The present work focused on increasing the nutritional quality of pasta via chickpea flour and protein isolate in addition to monitoring the influences of this fortification on the physicochemical, texture and sensory attributes of functional pasta. Eight fortified pasta products were prepared of durum semolina wheat with partial replacements of 2.5, 5, 7.5 and 10% of chickpea flour (CF)/or chickpea protein isolate (PI). Cooking quality, moisture content, swelling index, starch content, in-vitro protein digestibility, texture and sensory properties were evaluated. CF and PI fortifications decreased optimum cooking time (Min. 5 min) and starch content (Min. 62%) with overall increases in cooking losses (Max. 5.79%), swelling index (SI) (Max. 31.69%), hardness (Max. 22.13 g), cohesiveness (Max. 1.13), springiness (Max. 1.11 cm), gumminess (Max. 21.34 N) and doubled the chewiness (Max. 21.36 g cm^{-1}). The impact of pasta enrichment on its in-vitro protein digestibility against control (91.89%) was varied where CF substitution resulted increased protein digestibility (Max. 95.57%), while counter results have been announced by PI that significantly decreased pasta protein digestibility to (48.55%). Absorbed water was increased along with CF or PI substitutions resulting in higher moisture cooked pasta (Max. 68.83%). Panelists' opinion summed the upraised differences positively affecting chickpea fortified pasta sensory attributes to gain high acceptance scores. Enrichment the nutritional quality of pasta by fortification with chickpea flour and protein isolate can be recommended supported by enhancements in rheological and sensorial properties.

1. Introduction

Pasta, is known to be the Italian style extruded foods, namely spaghetti and lasagna, which originated from the Italian word for "dough". The world pasta production amounts to approximately 14 million tons in 2014 (Nilusha et al., 2019). Unfortunately, the quality of pasta protein is low because of the limitations in the amounts of essential amino acids. Proteins are fundamental macronutrients in the human diet as their primary function is to provide amino acids required for growth and maintenance (Laleg et al., 2019). Many studies that targeted the improvement pasta quality focused on replacing the gluten network in pasta by additives and texturizing ingredients like protein isolates and components that increase the nutritional value or exert a beneficial effect on health (Duda et al., 2019; Linares-García et al., 2019). Several authors, with a view to enhancing the nutritional value of pasta, have attempted fortification of pasta by partially or totally adding/replacing durum wheat with various sources such as legume flours, dietary fibers and protein isolate (Brennan and Tudorica, 2008; Cedola et al., 2020; Gopalakrishnan et al., 2011; Kowalczewski et al., 2015; Sandhu et al., 2015) The extent of protein coagulation and starch gelatinization, and consequently, the overall cooking quality of the final pasta product, is greatly affected by the native properties of protein quantity and quality. Nutraceutical is defined as "food or parts of food that provide medical or health benefits, including the prevention and/or treatment of disease" (DeFelice, 1995). Nutraceutical may range from isolated nutrients, herbal products and processed products such as pasta. The positive effects of legume proteins on human health are beyond classical nutritional properties due to the high protein content. A growing interest in the development and production of vegetable-based protein functional foods are due to their easy preparation, richness in good-quality proteins, and appreciation by consumers (Osorio-Díaz et al., 2008).

Chickpea is the third most important pulse crop in the world in terms of total production, which is mostly grown in semi-arid regions such as North Africa and Southern Europe. Chickpea is a valuable source of protein, carbohydrate, fiber and many essential vitamins and

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minerals (Arefian et al., 2014). Durum wheat (*Triticum durum*) is the hardest among wheat varieties when milled produces a coarse particle known as semolina, which is ideal for making pasta because of its hardness, intense yellow color, and nutty taste with good cooking quality (Marti et al., 2013; Ogawa and Adachi, 2017).

The present study is an attempt to develop innovative functional pasta with high nutritional value by fortification with chickpea flour or chickpea protein isolate in escalating concentrations and assess the effect of fortification on physicochemical, texture and sensory attributes of fortified pasta targeting consumer acceptance for convenient food industry application.

2. Materials and methods

2.1. Raw materials

Organic chickpea flour (*Cicer arietinum* L.) http://www.theplantlist.org/tpl/record/ild-4318 (Aka Besan Chickpea Flour, ACO, Australia) (25% protein, 4.5% fat and 9.7% moisture) and durum wheat semolina (Carbohydrates: 72.83 g, protein: 12.68 g, fat: 1.05 g, dietary fiber: 3.9 g, potassium: 4 DV%, 186 mg and iron: 9 DV%, 1.23 mg) were obtained from the local market of Christchurch, New Zealand.

Chickpea protein isolate (PI) was prepared according to (Alsohaimy et al., 2007; Chang et al., 2011). The defatted chickpea flour (by Folch method), was suspended in deionized distilled water (1:20 w/v)/pH ranged from 3 to 12, stirring for 1 h for maximum solubilization, followed by centrifugation at 6000 x*g*/30 min/20 °C. The supernatant was acidified to pH from 1 to 6 to facilitate protein precipitation and then centrifuged at 10,000×*g*/45 min/4 °C.

2.2. Fortified pasta preparation

Control pasta containing 100% durum wheat semolina was manufactured using a pasta machine fitted with 2.25 mm spaghetti die (Firmar S.P.A. Villa Verucchino (RN), Italy; model: MPF15N235 M). In addition, durum wheat semolina was substituted with the chickpea flour (CF) or chickpea protein isolate (PI) in different percentages as follow: 2.50%, 5.00%, 7.50% and 10.00%. Different fortified pasta mixing formulations are shown in Table 1. Samples were mixed in order to ensure uniform blending of the chickpea flour and protein isolate fortifies durum wheat flour. Pasta batches (500 g) were mixed with 30% of tap water (41 °C) for 20 min using the pasta maker according to the manufacturing guidelines (The U.S. Department of Agriculture (USDA), 2015). After 20 min, the resulting dough was extruded through 2.25 mm spaghetti diameter opening. Pasta samples of 50 g were sealed in plastic bags and frozen at -18° C for further analysis. Prior analysis, pasta was defrosted for 15 min at room temperature (Tudorica et al., 2002).

Table 1
Fortified pasta formulations.

Sample	Ingredients (g/100 g)		
	Durum wheat semolina	CF[a]	PI[a]
Control	100	0	0
P1 (CF 2.5)	97.50	2.50	0
P2 (CF 5)	95.00	5.00	0
P3 (CF 7.5)	92.50	7.50	0
P4 (CF 10)	90.00	10.00	0
P5 (PI 2.5)	97.50	0	2.50
P6 (PI 5)	95.00	0	5.00
P7 (PI 7.5)	92.50	0	7.50
P8 (PI 10)	90.00	0	10.00

[a] CF, Chickpea flour; PI, Chickpea protein isolate.

2.3. Cooking quality of fortified pasta

2.3.1. Optimum cooking time (OCT)

Spaghetti strands (20 g) were cut in an equal length of 100 mm and cooked in 300 ml of boiling water. During cooking, the optimal cooking time was evaluated every 30 s by observing the time of disappearance of the white core of spaghetti, by squeezing it between two transparent glass slides according to the (AACC Approved Methods of Analysis, Method 66-50, 2000). The time at which the white core completely disappeared was taken as the optimum cooking time (OCT).

2.3.2. Cooking loss (CL)

The amount of solid substance lost in the cooking water was determined according to the (AACC Approved Methods of Analysis, Method 66-50, 2000). Ten grams of spaghetti was cooked in 300 ml of boiling water at OCT. Rinsed with 100 ml of cold water, trained for 30 s to determine the cooking loss of the pasta. The cooking water was collected in an aluminum vessel, placed in an air oven at 105 °C to evaporate the water until a constant weight was reached. The residue was weighted and reported as a percentage of starting materials. The analysis was carried out in triplicate.

2.3.3. Moisture content of cooked pasta

Moisture content of fortified cooked pasta products was determined according to (AOAC, 1990).

2.3.4. Swelling index (SI)

The swelling index of cooked pasta was determined as previously described by (Cleary and Brennan, 2006). Ten grams of spaghetti was cooked at OCT in 300 ml boiling water and rinsed with 100 ml cold water. The diameter of spaghetti strands was determined before and after cooking and the swelling index was determined according to the following equation:

$$SI = \left(\frac{D2-D1}{D1}\right) \times 100$$

where: SI: Swilling Index, D1: Diameter before cooking, D2: Diameter after cooking.

2.4. Starch content

Total starch content was determined in order to evaluate starch content of the highest present of fortification of both CF and PI (T4 and T8) comparing to control pasta. This was held via the Megazyme Total Starch Assay Procedure Kit (Megazyme, 2017). One hundred grams of dried milled sample accurately weighed into glass test tube (16 × 120 mm). Then, 0.2 ml of aqueous ethanol (80% v/v) was added to the wet sample and aid dispersion. The tubes were stirred on a vortex mixer; 3 ml of thermostable α-amylase was added and incubated in a boiling water bath for 6 min with stirring vigorously after 2, 4, and 6 min. The tubes were transferred into 50 °C water bath, and 0.1 ml of the amyloglucosidase (330 U on starch) was added. Again, the tubes were stirred on a vortex mixer, incubated at 50 °C for 30 min. The content of the test tubes was transferred into 100 ml volumetric flask (with a funnel to assist transfer and the volumes were completed with distilled water to 100 ml) and mixed well. Ten milliliter of the mixture was centrifuged at 3000 rpm for 10 min at 20 °C, and then clear pure filtrates were used for the assay. A volume of 100ul of the diluted solutions transferred to glass test tubes (16 × 100 mm) and 3 ml of Glucose oxidase plus peroxidase reagent (GOPOD) was added to each tube, including the D-Glucose controls and reagent blanks. All tubes were incubated at 50 °C for 20 min. The absorbance at 510 nm was noted. Calculations were carried out using the Megazyme Mega-Calc™ (Megazyme, 2017).

$$Starch\% = \Delta A\, x \frac{F}{W} x\, FV\, x\, 0.9$$

where: ΔA: absorbance (reaction) read against the reagent blank, F: 100 (μg of D-glucose) absorbance for 100 μg of glucose (conversion from absorbance to μg), FV: final volume, W: the weight in milligrams of the flour analyzed.

2.5. In-vitro protein digestibility

In-vitro protein digestibility was carried out for chickpea fortified pasta by the multi-enzymes method of (Bodwell et al., 1980; Carbonaro et al., 1997). Porcine pancreatic trypsin (type IX, 15310 units/mg protein), bovine pancreatic chymotrypsin (type II, 48 units/mg of solid), porcine intestinal peptidase (P-7500, 115 units/g of solid) and bacterial protease (type XIV, 4.4 units/mg of solid) (Sigma-Aldrich, Germany) were used for the enzymatic digestion. One milliliter of the three-enzyme mix water solution (1.58 mg of trypsin, 3.65 mg of chymotrypsin and 0.45 mg of peptidase) was added to 63.8 mg of sample in 10 ml of distilled water equilibrated at 37 °C and adjusted pH of 8.0 (with 1 N NaOH). The digestion was allowed to proceed for 10 min at 37 °C before the addition of 1 ml (1.48 mg) of protease solution. The digestion was allowed to continue for 9 min at 55 °C. The pH value was monitored after a further 1 min at 37 °C and used to estimate the in-vitro protein digestibility according to the following equation:

$$Y = 234.84 - 22.56X$$

where: Y: is the in-vitro digestibility of protein %, X: is the pH of the suspension after 20 min digestion. The experiment was carried out in triplicates.

2.6. Texture profile analysis (TPA) of pasta

Twenty grams of pasta was cooked on the optimal cooking time as determined previously in 2 L of boiling water containing 5 g of NaCl. Pasta was rinsed with 100 ml of distilled water, allowed to equilibrate at room temperature for 10 min in plastic containers before texture analysis. The texture analyzer (TA/TX-plus; Stable Micro system, Surrey, UK) was equipped with a 5 kg load cell. Exponent 32.6.0.2.0 software was used for recording data. All texture measurements were carried out in ten replicates. TPA parameters, hardness (g) (the peak force that occurs during the first compression), cohesiveness (calculated as the ratio of A_2/A_1, where A_1: area under the peak of first bite and A_2: area under the peak of the second bite), springiness (cm) (distance$_2$ (T_2)/distance$_1$ (T_1), where T_1: the distance between the beginning and the highest point of the first bite and T_2: the distance between the beginning and the highest point of the second bite), gumminess (N) (hardness × cohesiveness) and chewiness (g cm) (hardness × cohesiveness × springiness), were calculated from the force-time curve (Bourne, 2002). The instrument was equipped with a P36 cylinder probe, with default settings of 2 mm/s pre-test speed, test speed, and post-test speed, 75% strain, trigger type, 10 g - auto, and 200 pps (points per second) data acquisition. Two stripes of pasta were tested at a time. Pasta hardness was determined using the AACC (16–50) Standard method using a Light Knife Blade probe. Default settings were used: 0.17 mm/s test speed, 10 mm/s post-test speed, 4.5 mm distance, trigger type - button, and 400 pps data acquisition. 5 stripes of pasta were placed under the blade perpendicularly (Bagdi et al., 2014).

2.7. Sensory evaluation

Fifteen panelists, (9 men and 6 women, aged between 27 and 51 years), conducted sensory evaluation on cooked pasta samples at Wine, Food and Biosciences Department, Faculty of Agricultural and Life Sciences, Lincoln University, Christchurch, New Zealand. Pasta products were cooked at optimum cooking time OCT conditions, in boiling water without the addition of salt, drained and placed in warm conditions until testing. Panelists were instructed to evaluate the pasta products with respect to their degree of acceptance, according to (Torres et al., 2007). Panelists evaluated pasta products sensory parameters; mouth feel, flavor, odor, color, texture.

2.8. Statistical analysis

Data were expressed as means ± standard deviations (SD) by multiple comparisons one-way analysis of variance (ANOVA) using Duncan test, IBM SPSS Statistics 23 software program where probability ($p < 0.05$) considered statistically significant.

3. Results and discussion

3.1. Cooking quality of fortified pasta

Dried pasta is typically consumed after rehydration by cooking to recover its properties. Therefore, it is important to understand the processes occurring during the rehydration of dried pasta, which is a complicated mass transport process governed by several migration mechanisms of water into the pores (Ogawa and Adachi, 2017). Cooking quality parameters of chickpea, fortified pasta was exhibited in (Table 2).

3.1.1. Optimum cooking time of pasta

The optimum cooking time (OCT) of chickpea flour and protein isolate fortified pasta results are exhibited in Table 2. The results showed that cooking time was decreased along with increasing of chickpea flour and protein isolate concentrations compared to control. The optimum cooking time of control was 6.30 min, while the optimum cooking time of chickpea flour fortified pasta was 6:00, 6:00, 5:30 and 5:30 min for 2.5, 5, 7.5 and 10% CF respectively. While the optimum cooking time of protein isolate, fortified pasta was 5:30, 5:30, 5:00 and 5:00 min for 2.5, 5, 7.5 and 10% PI, respectively. On the other hand, the optimum cooking time of 10% chickpea protein isolate pasta P8 (5:00 min) was <10% chickpea flour pasta P4 (5:30 min), and both showed to be less than control pasta (6:30 min). From the obtained results, it is clear that the substitution of the semolina wheat flour with chickpea flour and chickpea protein isolate caused the elevation of pasta protein that subsequently decreased the optimum cooking time. These results are agreement with (Padalino et al., 2014), who reported the same pattern with chickpea flour fortified spaghetti. The resulted decrease of cooking times may be relied on to the increased rate of water penetration to the core of pasta in the absence of continuity in the protein-starch network that could facilitate the water diffusion through the pasta matrix, resulting reduced time for the water to reach the center during cooking, as claimed by (Padalino et al., 2014). This water penetration may be due to the physical disruption of the gluten matrix by the chickpea particles which provided a path of water absorption into the whole wheat spaghetti strand (Kaur et al., 2012).

3.1.2. Cooking loss

The cooking loss of chickpea fortified pasta was illustrated in (Table 2). Solubility of nutrients leads to their losses, water absorbance by pasta during cooking, whereby cause the mass fractions of the nutrients to decrease (Filip and Vidrih, 2015). According to (AACC Approved Methods of Analysis, Method 66-50, 2000), all the cooking loss obtained values are within the acceptable limits since the solid loss in cooking water should not exceed 9%. The cooking loss showed significant gradual decrease along with increased CF concentrations to reach a minimum value of 3.88% with P4 (CF 10) product to become less than control (4.64%). In contrast, in the case of protein isolate supplemented pasta that cooking loss gradually increased as a function of the PI

Table 2
Cooking quality parameters of chickpea fortified pasta.

Pasta	OCT (min)	CL (%)	Moisture (%)	D_1 (mm)	D_2 (mm)	$D_2 - D_1$ (mm)	SI (%)
Control	6.30 ± 0.40^{a}	4.64 ± 0.26^{c}	66.48 ± 1.32^{de}	2.10 ± 0.09^{a}	2.51 ± 0.05^{b}	0.41^{b}	19.52^{i}
P1 (2.5%CF)	6.00 ± 0.51^{a}	5.79 ± 0.14^{a}	68.23 ± 0.36^{b}	2.14 ± 0.06^{a}	2.61 ± 0.03^{ab}	0.47^{ab}	21.96^{h}
P2 (5%CF)	6.00 ± 0.40^{a}	5.43 ± 0.33^{b}	67.31 ± 0.28^{c}	2.08 ± 0.23^{a}	2.59 ± 0.02^{ab}	0.51^{ab}	24.51^{f}
P3 (7.5%CF)	5.30 ± 0.41^{b}	5.32 ± 0.42^{b}	66.21 ± 0.93^{e}	2.12 ± 0.26^{a}	2.62 ± 0.03^{ab}	0.50^{ab}	23.59^{g}
P4 (10%CF)	5.30 ± 0.52^{b}	3.88 ± 1.17^{d}	68.83 ± 1.22^{a}	2.23 ± 0.03^{a}	2.82 ± 0.05^{ab}	0.59^{ab}	26.46^{e}
P5 (2.5%PI)	5.30 ± 0.00^{b}	3.91 ± 1.14^{d}	67.07 ± 0.81^{c}	2.19 ± 0.05^{a}	2.77 ± 0.10^{ab}	0.58^{ab}	26.48^{d}
P6 (5%PI)	5.30 ± 0.15^{b}	3.37 ± 1.11^{e}	56.87 ± 0.48^{g}	2.26 ± 0.13^{a}	2.89 ± 0.08^{ab}	0.63^{ab}	27.87^{c}
P7 (7.5%PI)	5.00 ± 0.17^{b}	4.08 ± 0.35^{d}	65.26 ± 1.22^{f}	2.24 ± 0.02^{a}	2.95 ± 0.03^{a}	0.71^{a}	31.69^{a}
P8 (10%PI)	5.00 ± 0.38^{b}	5.31 ± 0.17^{b}	66.57 ± 0.42^{d}	2.31 ± 0.06^{a}	2.98 ± 0.05^{a}	0.67^{a}	29.00^{b}

Values are the means of triplicates ±SD
^{a,b}Mean in the same column followed by different superscript letters differ significantly ($p < 0.05$).
OCT, Optimum Cooing Time; CL, Cooking Loss; D_1, Diameter of row pasta; D_2, Diameter of cooked pasta; SI, Swelling Index.
CF, Chickpea flour; PI, Chickpea protein isolate.

percentage to reach a maximum value of 5.31 ± 0.17 with 10% PI fortified pasta, P8 (PI 10) to exceed control. These results are in agreement with (Gallegos-Infante et al., 2010) who reported the same pattern with common bean fortified spaghetti. These results could be concluded to protein-starch network where, increased protein content was reported to negatively affect the gluten development and weaken the structure, facilitating more solid loss (Arora et al., 2018). Taking into account starch content results (Fig. 1), the higher starch content of P4 (CF 10) (63.4%) against 62% of P8 (PI 10) may work adversely to reduce that effect. Formation of starch-protein new arrangements was reported due to different protein and carbohydrate ratios in formulations (Monteiro et al., 2016). Fortification of pasta with chickpea and quinoa flour was reported to decrease the cooking time, increase the cooking lose and also affect the firmness and cohesiveness (Petitot et al., 2010).

3.1.3. Moisture content and swelling index (SI)

The moisture content and swilling index were illustrated within cooking quality of chickpea fortified pasta (Table 2). Similar moisture content values were recorded for cooked legume enriched pasta (Howard et al., 2011). Chickpea CF and PI fortified cooked pasta showed significant increases in moisture content accompanied by the supplementation with chickpea flour/protein isolate comparing to control. On the other hand, the differences between cooked and row diameters of fortified pasta fluctuated between a minimum of 0.47 and a maximum of 0.71 mm in pasta products, P1 (CF 2.5) and P7 (PI 7.5) respectively, against 0.41 mm in the cooked control sample. The upraised results were supported with swelling index values that exhibited the same pattern. Comparing to control, the swelling index (SI) values were significantly increased when chickpea flour or protein isolate was added and showed directly proportional relation with increased concentration. Obtained results could be interpreted referring to the water absorption behavior of chickpea protein, where legume proteins were reported to have high water absorption capacities (Alsohaimy et al., 2007). These results agreed with (Kaur et al., 2013), who also stated that fine particle size subsequently increases the water uptake and volume expansion of pasta, that leads to greater hydration capacity.

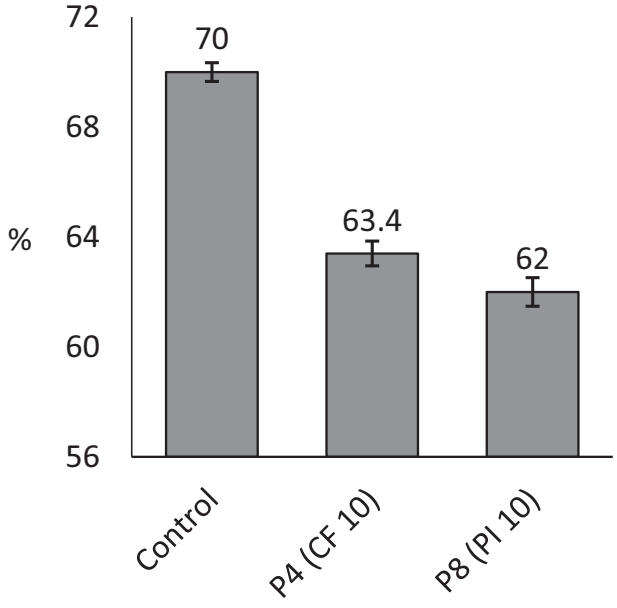

Fig. 1. Starch content of highest concentrations of chickpea flour (CF) and chickpea protein isolate (PI) fortified pasta (CF 10 and PI 10) - Data represented are the means of duplicates ±SD.

3.2. Starch content

Starch granules are embedded in the structural network of gluten in pasta, so in order to relate the quality of fortified pasta products, starch content was assessed for the highest substitution concentrations that presented in P4 (CF 10) and P8 (PI 10) against control sample (Fig. 1). Results clearly marked the significant decrease in starch content comparing to control because of the substitution of CF and PI instead of the semolina flour in fortified products. The starch content values were 63.4 and 62% for P4 (CF 10) and P8 (PI 10), respectively, against 70% starch content of the control. These differences reflected on cooking quality, texture profile and sensory evaluation of resulted fortified pasta. Water migration in the spaghetti was reported to be affected by starch gelatinization, water diffusion, and gluten matrix relaxation (Ogawa and Adachi, 2017).

3.3. In-vitro protein digestibility

Fig. 2 exhibited in-vitro protein digestibility of chickpea flour (CF) and protein isolate (PI) and fortified pasta. Except for (CF 10), chickpea flour, either individual or when used in pasta fortification, showed significantly higher protein digestibility than protein isolates with different percentages in fortified pasta. A similar observation was recorded by Pakhare et al. (2018), who stated that substitution with plant flour contributed to increase digestibility coefficient. On comparing to control pasta, the protein digestibility of CF fortified pasta was increased along with increased CF concentrations until (CF 7.5), and then decreased at (CF 10). Concerning PI fortified pasta comparing to control, the percentage of digestibility showed differences (89.26, 88.55 and 88.50) for (PI 2.5), (PI 5) and (PI 7.5) respectively, especially (PI 10) that showed a remarkable decrease. Laleg et al. (2016), stated that higher protein concentrations could result in a higher covalently linked protein network

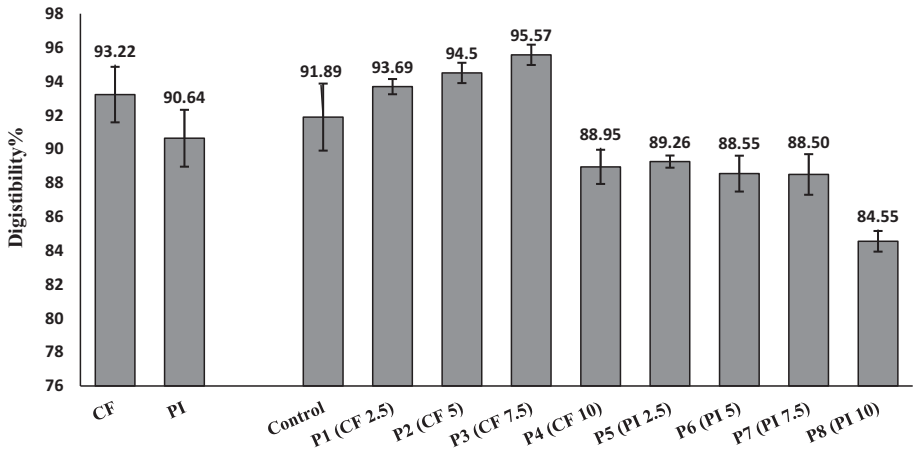

Fig. 2. In vitro protein digestibility of chickpea flour (CF), chickpea protein isolate (PI) and fortified pasta - Data represented are the mean of duplicates ±SD.

that subsequently reduced the degree of protein hydrolysis. This could explain the (CF 10) and PI obtained results.

3.4. Texture profile analysis (TPA) of spaghetti

Table 3 illustrated Texture Profile Analysis (TPA) of cooked pasta represented in hardness, cohesiveness, springiness (also named elasticity), gumminess and chewiness parameters. A significant increase was recorded comparing control pasta and both CF and PI fortified pasta in all TPA parameters. Additionally, similar patterns were exhibited in both CF and PI fortified pasta, where hardness continued in elevation in accordance with increased CF and PI substitution concentrations. These results could be ascribed to the strength of the gluten network of fortified pasta as a main factor that governed their hardness (Ogawa and Adachi, 2017). Gumminess and chewiness subsequently followed the hardness pattern to show increasing values along with CF and PI increased concentrations. This pattern may be related to the higher cooking loss values (Table 2) as explained by (Flores-Silva et al., 2015). Cohesiveness and springiness values did not record any significant differences between all chickpea fortified pasta formulations (CF or PI) except when they were compared to control. However, cohesiveness and springiness parameters indicated how the sample holds together upon cooking, which interpreted the higher values recorded for the chickpea fortified pasta than the control sample (Kosović et al., 2016).

3.5. Sensory evaluation

Sensory evaluation of pasta fortified with chickpea flour (CF) and chickpea protein isolate (PI) was carried out comparing to control. Despite that pasta fortified with chickpea flour and protein isolate, sensory parameters showed to be comparable to control, but P8 (PI 10%) and P4 (CF 10%) showed to be more preferred to panelists (Fig. 3A, B). These results could be connected to the decreased starch content pronounced in both treatments (Fig. 1) that reflected on better cooking quality and texture that consequently positively affected the organoleptic properties. The high acceptability of pasta fortification with chickpea protein isolate or flour might be due to of high protein content. The findings in the present study are in agreement with what was previously reported by (Bhatt et al., 2015).

4. Conclusion

Pasta products enriched with chickpea flour and protein isolate up to 10%, exhibited good cooking quality with decreased optimum cooking time. On the contrary, the fortification increased cooking losses, moisture and swelling index (SI) due to the chickpea particles that increased penetration and water uptake leading to greater hydration capacity. Furthermore, different protein substitutions formed starch-protein new arrangements that enhanced TPA values, hardness, cohesiveness, springiness, gumminess and chewiness, and succeeded to gain higher acceptance in sensory evaluation. Bottom line is that chickpea flour and protein isolate can be recommended for application in the pasta fortification targeting high nutritional value and high quality functional pasta products with enhanced physicochemical, texture and sensory attributes. This might encourage the adaptation of the large-scale production for manufacturing the protein rich pasta on an industrial scale to be available in the market for consumers.

Table 3
Texture Profile Analysis (TPA) of chickpea fortified cooked pasta.

Pasta	Hardness (g)	Cohesiveness	Springiness (cm)	Gumminess (N)	Chewiness (g cm)
Control	9.00 ± 1.15^{g}	0.79 ± 0.64^{a}	0.76 ± 0.54^{a}	7.13 ± 5.20^{g}	10.00 ± 4.92^{f}
P1 (2.5%CF)	12.60 ± 2.37^{f}	1.06 ± 0.53^{a}	1.02 ± 0.32^{a}	13.60 ± 4.72^{f}	11.6 ± 4.19^{e}
P2 (5%CF)	20.75 ± 3.99^{bc}	1.09 ± 0.27^{a}	1.07 ± 0.28^{a}	19.37 ± 4.54^{d}	20.33 ± 3.27^{cd}
P3 (7.5%CF)	21.00 ± 3.70^{b}	1.06 ± 0.18^{a}	1.01 ± 0.16^{a}	20.01 ± 3.45^{c}	20.68 ± 2.73^{bc}
P4 (10%CF)	22.13 ± 3.64^{a}	0.96 ± 0.19^{a}	0.99 ± 0.12^{a}	20.85 ± 2.96^{b}	21.36 ± 3.87^{a}
P5 (2.5%PI)	18.88 ± 1.81^{e}	1.13 ± 0.51^{a}	1.08 ± 0.42^{a}	18.14 ± 4.10^{e}	20.26 ± 0.72^{d}
P6 (5%PI)	19.00 ± 1.07^{e}	1.11 ± 0.21^{a}	1.11 ± 0.24^{a}	21.00 ± 4.28^{ab}	20.40 ± 1.09^{cd}
P7 (7.5%PI)	20.00 ± 1.06^{d}	1.02 ± 0.20^{a}	1.01 ± 0.19^{a}	21.33 ± 3.24^{a}	20.50 ± 3.08^{bcd}
P8 (10%PI)	20.63 ± 2.07^{c}	1.05 ± 0.33^{a}	1.03 ± 0.27^{a}	21.34 ± 5.77^{a}	20.83 ± 2.21^{b}

Values are the means of ten replicates ±SD
^{a,b}Mean in the same column followed by different superscript letters differ significantly ($p < 0.05$).
CF = Chickpea flour; PI = Chickpea protein isolate; N = Newton.

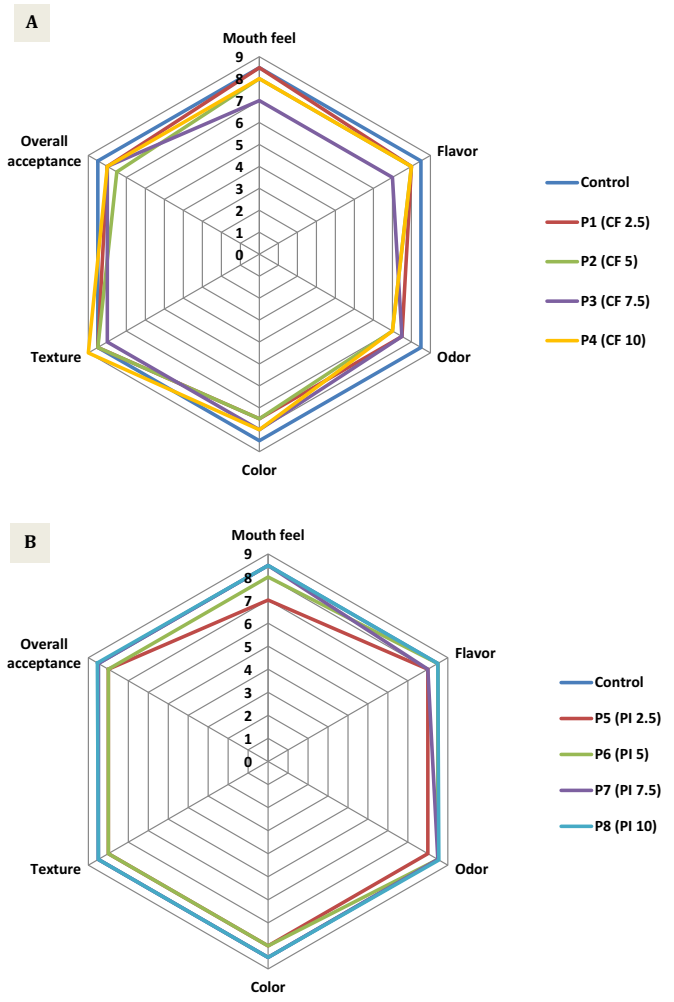

Fig. 3. Sensory evaluation of chickpea fortified pasta with different concentrations A: Sensory evaluation of chickpea flour fortified pasta (CF); B: Sensory evaluations of chickpea protein isolate fortified pasta (PI).

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Authors' contribution

Sobhy A. El-Sohaimy, Suggested the main idea of the research work, carried out all experimental work in the lab, made an experimental design and research plan of the paper, manipulating the received data, Reviewed the draft of the manuscript and interpreted the data, Finishing the manuscript in final format, Formatting the manuscript according to the journal format. **Amira M.G. Darwish**, Prepared the draft of the manuscript and participated in statistical analysis and revision of the manuscript. **Margareta Brennan**, Participated in the starch analysis. **Charles Brennan**, Participating in the experimental design and the main idea of the research work, supervising the experimental work in the lab.

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