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BIOTECHNOLOGY

The Effect of Lentil and Chickpea Flour incorporation on Pasta Quality

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ABSTRACT. The incorporation of legume flours in cereal-based products, such as pasta, is gaining the attention of food technologists and industries. This trend is also gaining popularity among consumers due to legumes' exceptional nutritional profiles. The aim of the present work was to study the effect of durum wheat semolina enrichment using chickpea and lentil flours on the physicochemical, enzymatic, rheological and sensorial characteristics of produced pasta, with substitution ratios ranging from 5% to 30%. The obtained results showed that pasta prepared with mixed flours had reduced water content of about 9.17 ± 0.01% and 7.2 ± 0.06%, respectively at a 30% replacement rate with lentil and chickpea flours. Moreover, the highest dose of lentil increased protein content of the mixture to reach 15.09 ± 0.4%. As chickpea and lentil flours are gluten free, incorporating them into recipes reduced the overall gluten content. The replacement with chickpea flour reduced the firmness of produced pasta compared to semolina-based pasta. Also, pasta produced with low legume dose recipes showed a better cooking quality profile, with limited cooking losses, low water absorption, and good firmness. Analyses performed on enriched samples showed that the most appropriate doses of legume flours for pasta production in terms of technological, rheological and sensorial properties were 15% and 10%, respectively for chickpea and lentil flours.

Keywords: Semolina; legumes; flour; pasta; quality.

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Introduction

Pasta is a highly popular food in the Mediterranean diet due to its taste, simplicity of preparation and reasonable price (Di Marco et al., 2021), making it a key cereal product. In (2022), the amount of pasta consumption per person varied significantly in the world. Italy claimed the top position with an annual average pasta consumption of 23 kilograms per person, while Tunisia closely followed with 17 kilograms per person (Bimbo et al., 2024).

Pasta products are prepared using durum wheat and are generally cooked for a few minutes to completely gelatinize the starch (Wojtowicz & Moscicki, 2014). Various studies report the use of non-durum wheat ingredients to improve functional properties of pasta like legumes known for their excellent nutritional composition and potential health benefits (Rebello et al., 2014) associated with a reduced risk of chronic diseases (obesity, diabetes type 2, hypertension, cancer and cardiovascular disease), mainly in the Mediterranean population (Arnoldi et al., 2015). In fact, peas, lentils, field pea, faba bean, or chickpea flours high in protein, have been used in pasta formulations because they are shown to be healthier than cereal, due to their richness in nutrients, reduced glycemic index (GI) and prevention of cardiovascular diseases of conventional pasta (Wojtowicz & Moscicki, 2014; Saget et al., 2020).

In this regard, the supplementation of semolina with legume flours for pasta production enhances the contents in proteins, dietary fiber, vitamins, minerals, essential amino acids, notably fatty acids and other bioactive compounds including phytosterols (Chillo et al., 2008; Tazrart et al., 2015; Bayomy & Alamri, 2022). Besides the nutritional benefits, legumes possess various sensorial and functional merits including water and oil absorption, foaming, emulsification and gelation capacities leading to interesting technological properties of final products (Du et al., 2014). These characteristics encourage the incorporation of legume flours and their derivatives, such as extracts, aquafaba, brans, and textured proteins in the manufacturing of food products. Moreover, the incorporation of lentil (*Lens culinaris medik.*) flour into bakery products has captured the interest of researchers due to its unique nutritional composition mainly its richness in proteins and essential amino acids and growing conditions. In fact, lentils require less water and can tolerate drought stress better than other crops (Bayomy & Alamri, 2022). On the other hand, chickpeas (*Cicer arietinum* L.) belonging to the Leguminosae family are widely used in food products for their flavour, nutritional profile, high protein content with high levels of lysine, low lipid content, and accessible iron and calcium (Bayomy & Alamri, 2022).

This study aimed to select the optimal lentil and chickpea flour rates to incorporate into the durum wheat semolina in order to improve pasta quality and to investigate the impact of these enrichments on nutritional profile, rheological and cooking properties and sensorial characteristics.

Materials and methods

Materials

Commercial durum wheat semolina (*Triticum durum*), commonly used for pasta production, was provided from an industrial mill (SMT, Tunisia). Tunisian yellow lentils (*Lens culinaris*) and chickpea (*Cicer arietinum*) were obtained from the National Institute of Agronomic Research of Tunisia (INRAT). The legume grains were manually cleaned to remove foreign matter and ground into flour using a laboratory mill (Retsch PM 100). Legume flours were then used to prepare two batches of enriched wheat semolina as summarized in Figure 1. Each batch was divided into different samples with different legume ratios (5, 10, 15, 20, 25 and 30 g 100 g^{-1} of wheat semolina mass). These concentrations were selected based on findings of preliminary analyses as well as the literature (Padalino et al., 2014; Wood et al., 2009; Zhao et al., 2005). The control sample was prepared with 100% of wheat semolina.

All chemical reagents used in the experimental analysis were of analytical grade.

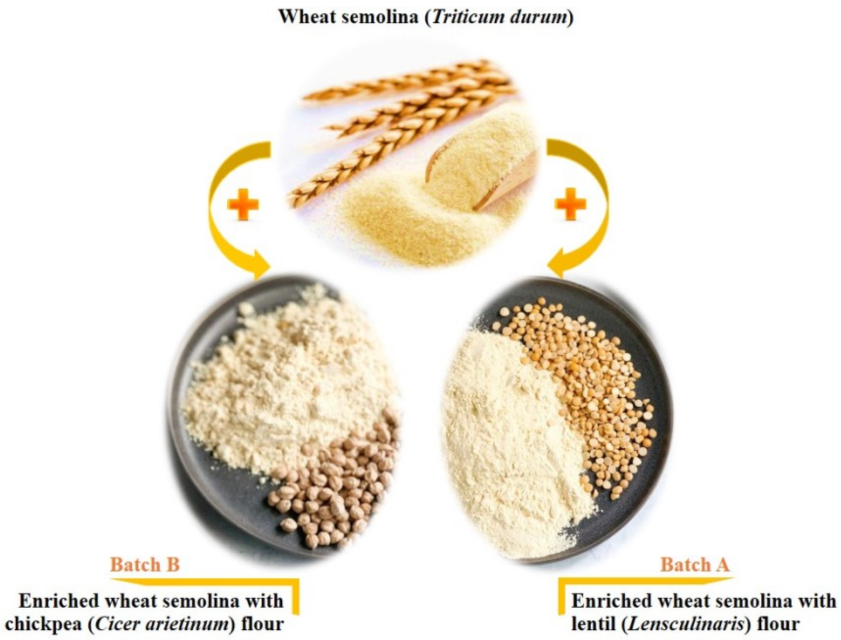

Figure 1. Preparation of wheat semolina enriched with different legume flours.

Characterization of enriched semolina

Granularity analysis

The particle size of ground wheat semolina and legume flours was evaluated according to the method of Boudalia et al. (2016) with slight modifications, using electrical sieving (ASTM International - Standards World-wide (2006)). First, they were homogenized (using a rotative mixer) in order to obtain representative samples. Then, 100 g of each sample were sieved at 180 rpm for 7 min. The distribution of the semolina depended on the diameter of the sieve (450 µm, 400 µm, 355 µm, 200 µm and 160 µm). When the sifting was completed, the rejected fraction from each sieve was weighed by adding it to the previous fraction. Only the extract from the last sieve was weighed separately. Results were expressed as a percentage of the original sample weight.

Proximate composition

The moisture, ash and protein contents of the raw materials (durum wheat semolina, lentil and chickpea flours) and enriched semolina samples were determined according to the Association of Official Agricultural Chemists methods (AOAC, 2005). Ash was measured by incinerating samples in a muffle furnace at 550°C for 3 h and protein content was investigated using the Kjeldahl method and a conversion factor of 5.7.

Wet and dry gluten yields

The wet and dry gluten yields of different samples were determined according to the American Association of Cereal Chemists method (American Association of Cereal Chemists [AACC], 2005). First, gluten was extracted from the prepared dough using a 2% sodium chloride solution, which was added at a proportion of 60% of the sample weight. The dough was then washed under a stream of running water until most of the starch was removed and the wash water became transparent.

The obtained viscoelastic mass was wet gluten and was calculated by the (Equation 1) given below:

$$\text{Wet gluten yield} = (\text{weight of wet gluten obtained} / \text{weight of sample}) \times 100 \quad (1)$$

The dry gluten yield was determined by drying wet gluten in a drying oven for 24 h and calculated according to the (Equation 2) given below:

$$\text{Dry gluten yield} = (\text{weight of dry gluten obtained} / \text{weight of sample}) \times 100 \quad (2)$$

Determination of α-amylase activity

The α-amylase activity of different samples was determined by the approved method using a Falling Number apparatus as described by [AACC] (2005). This assay involves the immersion of a suspension in a boiling water bath, leading to its rapid gelatinization. After that, the liquefaction of the starch by α-amylase was measured. The falling number, representing the required time to fall a set distance, was recorded. The results were expressed in time as seconds.

Color parameters analysis

The color of raw materials and legume- flour-enriched semolina samples was measured with a colorimeter (Chroma-meter Minolta, CR 300, Tokyo, Japan) using the space color CIE Lab system. The values of lightness (L*), greenness/redness (a*) and blueness/yellowness (b*) were recorded (Boulares et al., 2024).

Determination of damaged starch content

The content of damaged starch was determined according to the [AACC] (2005) method. This method determines the percentage of starch granules in samples that is susceptible to hydrolysis by α -amylase. The percentage of starch damage is defined as g starch subject to enzymatic hydrolysis per 100 g sample on a 14% moisture basis.

Manufacture of legume-enriched pasta

The pasta was produced in a long-cut form (tagliatelle) as described by Teterycz et al. (2020) with slight modifications. The pasta-making process involves three main steps: (1) First, the dough was prepared by mixing durum semolina, legume flours and water for 15 min. The formed dough was, then, left to rest for 10 min; (2). Then, a sheeting step was carried out with a KitchenAid Pasta Roller and Cutter Set Attachment (5KSMPRA–859704001031, France) to obtain uniform 7 mm wide and 15 cm long tagliatelle samples; (3) Finally, dough sheets were dried in a stream of warm air (70°C) for 2 h to reach a constant weight. The dried pasta formulations were cooled to room temperature and stored in polyethylene bags for further evaluation. A tagliatelle sample without legume flours was made and used as control.

Evaluation of cooked enriched pasta quality

Cooking characteristics

The cooking parameters including optimal cooking time, water absorption during cooking, and cooking loss, were performed on cooked tagliatelle to optimum cooking time as described by Bayomy and Alamri (2022).

Optimal cooking time was determined by boiling the tagliatelle strands (10 g, 15 cm length) in 300 mL distilled water, removing the pasta samples every 30 seconds and squashing it between two glass plates until the white central core of the samples disappeared.

Water absorption was determined by calculating the weight difference before and after cooking the product using the (Equation 3) given below:

$$\text{Water absorption (\%)} = [(W_c - W_r) / W_r] \times 100 \quad (3)$$

Where W_c is weight of cooked pasta (g), W_r is weight of raw pasta (g)

Cooking loss was determined by measuring the total solid loss in the cooking water after evaporation in an air oven at 100°C following (Equation 4) below:

$$\text{Cooking loss (\%)} = W_0 / W_1 \times 100 \quad (4)$$

Where W_0 is dry matter loss after oven drying (g) and W_1 is dry weight of uncooked pasta (g).

Firmness analysis

The firmness of pasta samples was evaluated as described by Teterycz et al. (2020) with slight modifications. The peak force (firmness) required to cut a cooked single tagliatelle strand was measured in five replicates using a TAXT2i Texture Analyzer (Stable Micro Sys tems, Godalming, UK). Pasta samples were cut using a cutting knife (3 mm thick) working with the head speed of 1.66 mm s^{-1}. The average value of force (N) required for cutting the product was determined.

Sensory evaluation

Based on texture results, only 3 formulations of each legume-flour semolina blends (10%, 15% and 20%) were chosen and subjected to descriptive sensory evaluation. Enriched pasta samples were cooked in distilled water to optimum cooking time as described above and served in coded white plates to 20 qualified panelists. Tagliatelle samples were evaluated for appearance, color, taste, aftertaste, flavor, texture (mouthfeel), and overall acceptability on a 6-point scale (0 low intensity, 5 high intensity) (ISO 13299, 2016; Boulares et al., 2024).

Statistical analysis

All analyses were conducted in triplicate and data were reported as mean ± standard deviation (SD). The obtained data were analyzed using one-way analysis of variance (ANOVA) and the mean comparisons were carried out using Tukey's test at a 5% level of significance by the statistical software package SPSS Statistics, version 22.0 (SPSS Inc., Chicago, IL, USA).

Results and discussion

Characterization of raw materials and enriched blends

Particle size of raw materials

Based on obtained results shown in Table 1, legume flours were characterized by a greater quantity of fine particles. In fact, chickpea flour is divided into two classes: those with a diameter between 200 and 355 µm and those with a diameter less than 160 µm. Lentil flour was mainly made up of particles with a diameter less than 160 µm. This result was in line with that of Odabbas and Cakmak (2021) who reported that the particle diameter of yellow lentil flour was about 102.39 µm. It was shown that the average particle size changes significantly as a function of successive dry sieving (Anuntagool et al., 2023).

Table 1. Granularity (%) of durum wheat semolina and legume flours.

Fraction	Particle size (%)		
	Durum wheat semolina	Chickpea flour	Lentil flour
Ø < 450 µm	0.5 ± 0.02 ^{a}	7.78 ± 0.2^c	1 ± 0.05^b
355 < Ø < 450 µm	21 ± 1.06^b	29.75 ± 1.5^c	9.25 ± 0.3^a
200 < Ø < 355 µm	65.5 ± 2.0^c	38.25 ± 1.6^b	33.85 ± 1.5^a
Ø < 160 µm	9.5 ± 0.5^a	58.5 ± 1.8^b	64 ± 2.1^c

Values are expressed as means ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples.

On the other hand, the particle size distribution carried out to check the coarseness or the fineness of samples showed that semolina used for pasta preparation retained on 450, 355, 200 and 160 µm sieves was 0.5 ± 0.02%, 21 ± 1%, 65.5 ± 2% and 9.5 ± 0.5%, respectively.

The fine particles of legume flour can absorb water more quickly than the semolina particles, which can result in heterogeneous dough. According to Patil et al. (2020), the particle size and shape of flour has a particular impact on rigidity property because they could affect hydration capacity, pasting viscosity, and gel strength.

Proximate composition of raw materials and legume-enriched semolina

It is important to highlight that the concentrations to be incorporated into durum wheat semolina were selected based on obtained results of preliminary analyses and those reported previously by Zhao et al. (2005), Wood et al. (2009) and Padalino et al. (2014). In fact, it has been shown that the addition of legume flours over 20% and 30% affected the rheological and sensorial properties and reduced overall acceptability.

The chemical compositions of the raw materials (durum wheat semolina, legume flours) as well as prepared blends are shown in Table 2.

Durum wheat semolina presented the highest ($p < 0.05$) moisture content (9.97 ± 0.03%) followed by lentil (9.2 ± 0.04%) and chickpea (8 ± 0.06%). Boucheham et al. (2019) reported higher moisture content for semolina (16.41%) and chickpea flour (12.22%). Moreover, it was observed that the water content of the blends decreased significantly ($p < 0.05$) with the increase of the legume flour enrichment rate. This finding was in accordance with those noted by Gliguem et al. (2022). These results remained within the safety limits of around 12-13% (Boudalia et al., 2016) and met the Tunisian standard (51.01.1983) which recommends moisture content of 14.5% as a maximum value to be suitable for storage and to present no risk of deterioration with a stability in the manufacturing process (Boudalia et al., 2016).

The main nutritional component of studied legume flours is protein contributing to nutritional, sensorial and rheological food product properties. Its content was significantly higher ($p < 0.05$) in chickpea flour (20.73 ± 0.02%) and lentil flour (22.45 ± 0.01%) compared to that of durum wheat semolina (11.9 ± 0.02%). This result was in agreement with those reported by Kumar and Pandey (2020) and Jarpa-Parra (2018) who showed the richness of these legume flours in proteins ,which encourages their use for enrichment Moreover, the protein content increased significantly ($p < 0.05$) in wheat-legume blends with the increase of the legume flour incorporation rate, reaching the highest values of about 14.54 ± 0.3% and 15.09 ± 0.4% when incorporating 30% of chickpea and lentil flours, respectively. Similar results were observed Gliguem et al. (2022) and Bayomy and Alamri (2022), who reported that the enrichment of semolina with legume flours could provide high nutritional value for final products. In fact, wheat proteins had deficiencies in lysine, tryptophan, and threonine; thus, the enrichment of pasta with legume flours leads to a richness in essential amino acids, especially lysine, phenylalanine, valine, threonine, methionine and tryptophan.

As shown in Table 2, ash contents of both lentil (2.88 ± 0.01%) and chickpea (2.36 ± 0.03%) flours were significantly higher ($p < 0.05$) than that of the wheat semolina (0.83 ± 0.02%). Ash content of semolina increased significantly to reach 1.56 ± 0.02% in blend enriched with 30% chickpea flour. In fact, lentil-wheat semolina and chickpea-wheat semolina blends presented high ash contents when compared to control, which is due to the significantly higher initial ash contents of legume flours. These results strongly agree with the studies of Gliguem et al. (2022) and Bayomy and Alamri (2022). Also, all ash contents remained higher than the recommended limit (⩽ 0.80%) as reported by Boudalia et al. (2016), confirming the richness of produced blends in nutrient compounds mainly minerals. According to these results, the incorporation of legume flours improved the nutritional value of the obtained blends compared to the control wheat durum semolina significantly. As reported by Ramirez-Ojeda et al. (2018), legumes are rich in minerals which are beneficial for the human body and health. Moreover, it was proved that legumes contain significant amounts of peptides and phytochemicals (Moreno-Valdespino et al., 2020).

Concerning wet gluten content, this content decreased significantly ($p < 0.05$) in enriched legume-semolina blends with the increase of replacement legume flour rates Table 2.

A similar trend in gluten values was reported by Bakare et al. (2016). Besides, the dry gluten contents followed the same tendency. In fact, this decrease is attributed to the gluten-free nature of chickpea and lentil flours. The addition of non-gluten flours during pasta production could dilute the gluten network of the semolina and weaken the overall structure of the final product which negatively affect the viscoelastic, culinary and technological properties of pasta (Feillet, 2000; Petitot et al. 2010).

The values of damaged starch representing the amount of starch quickly susceptible to α-amylase hydrolysis (Bresciani et al., 2021) showed that the lowest value was found in the durum wheat semolina. The amount of damaged starch followed the order wheat semolina (9.2 ± 0.2%) < chickpea flour (22.9 ± 0.4%) <

lentil flour (29 ± 0.4%). These results disagree with those found by Bresciani et al. (2021) that reported lower values. This finding was attributed to the mechanical damage due to the milling process that modified the physical and structural organization of starch granules.

The main factor responsible for the increase in damaged starch content was an increase in the proportion of the fine fraction in the flour. In fact, fine fractions contained higher damaged starch contents than coarse fractions.

All the samples were within the range specified by the French standard (Association Française de Normalisation AFNOR, 2006) (Table 2).

Table 2. Chemical characteristics of raw materials and enriched blends with different rates of chickpea or lentil flours.

Samples	Moisture (%)	Ash (%)	Protein (%)	Wet Gluten (%)	Dry Gluten (%)	Damaged Starch (%)
			Raw materials			
Durum wheat semolina	9.97 ± 0.03^{m}	0.83 ± 0.02^{a}	11.90 ± 0.02^{a}	26.86 ± 0.08^{m}	10.12 ± 0.04^{o}	9.20 ± 0.2^{a}
Chickpea flour	8.00 ± 0.06^{c}	2.36 ± 0.03^{k}	20.73 ± 0.02^{p}	ND	ND	22.90 ± 0. 4^{n}
Lentil flour	9.20 ± 0.04^{l}	2.88 ± 0.01^{l}	22.45 ± 0.01^{o}	ND	ND	29.00 ± 0.4^{p}
			Composite blends			
			Chickpea-enriched semolina			
C5	9.10 ± 0.03^{k}	1.01 ± 0.01^{c}	12.46 ± 0.02^{bc}	26.80 ± 0.08^{l}	8.90 ± 0.01^{l}	10.60 ± 0.02^{c}
C10	8.90 ± 0.05^{k}	1.11 ± 0.02^{e}	12.98 ± 0.03^{d}	26.57 ± 0.06^{k}	8.87 ± 0.03^{kl}	10.80 ± 0.02^{c}
C15	8.34 ± 0.02^{g}	1.17 ± 0.05^{ef}	13.42 ± 0.04^{f}	21.53 ± 0.04 ^{h}	8.74 ± 0.02^{j}	12.10 ± 0.02^{e}
C20	8.12 ± 0.02^{f}	1.29 ± 0.03^{g}	14.09 ± 0.1^{ef}	18.40 ± 0.02^{d}	7.93 ± 0.01^{e}	15.10 ± 0.1^{i}
C25	8.06 ± 0.01^{d}	1.45 ± 0.01^{h}	14.10 ± 0.2^{j}	15.79 ± 0.03^{b}	7.45 ± 0.02^{c}	15.40 ± 0.2^{j}
C30	7.20 ± 0.06^{a}	1.56 ± 0.02^{j}	14.54 ± 0.3^{l}	12.42 ± 0.01^{a}	5.49 ± 0.01^{a}	16.60 ± 0.4
			Lentil-enriched semolina			
L5	9.17 ± 0.01^{l}	1.01 ± 0.12^{b}	12.45 ± 0.01^{b}	25.95 ± 0.05^{j}	9.61 ± 0.03^{n}	9.80 ± 0.1^{b}
L10	8.55 ± 0.06^{i}	1.07 ± 0.05^{d}	12.98 ± 0.06^{de}	25.33 ± 0.04^{i}	9.10 ± 0.03^{m}	10.60 ± 0.03^{cd}
L15	8.55 ± 0.03^{hi}	1.08 ± 0,01^{c}	13.51 ± 0.02^{i}	20.25 ± 0.02 ^{g}	8.60 ± 0.01^{i}	14.10 ± 0.3^{f}
L20	8.36 ± 0.02^{g}	1.23 ± 0.02^{f}	14.03 ± 0. 1^{k}	19.75 ± 0.03^{f}	8.09 ± 0.02^{f}	14.40 ± 0.4 ^{g}
L25	8.09 ± 0.04^{e}	1.25 ± 0.04^{gi}	14.65 ± 0. 3^{m}	19.30 ± 0.02^{e}	7.59 ± 0.01^{d}	16.00 ± 0.2^{k}
L30	7.79 ± 0.03^{b}	1.28 ± 0.03^{i}	15.09 ± 0.4^{n}	17.51 ± 0.01^{c}	7.08 ± 0.01^{b}	17.80 ± 0.3^{m}

C (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of chickpea flour; L (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of lentil flour; Values are expressed as mean ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples; ND: Not Detected.

Color parameters of raw materials and legume-enriched semolina

In the present study, it was shown from the obtained color parameters (L*, a*, b*) (Table 3) that the replacement of wheat semolina using legume flours affects significantly ($p < 0.05$) the color of all analyzed enriched blends compared to the control. In fact, durum wheat semolina was yellow, as previously reported by Boudalia et al. (2016). However, the initial lightness L* value (87.31 ± 0.08) decreased with the increase of legume flours replacement rates to reach values of about 80.3 ± 0.02 and 84.6 ± 0.04, respectively when incorporating 30% of chickpea and lentil flour. This result was in agreement with that conducted by Teterycz et al. (2020) who noted that the lightness (L*) of all semolina samples supplemented with green pea, red lentil and grass pea flours decreased as the legume flours rates increased. The darker color of the chickpea- or lentil-wheat semolina flour composite blends may be assigned to the higher content of ash and the initial specific color of the legume flour (Teterycz et al., 2020).

Besides, a* values increased with chickpea flour proportion increase reaching a value of -0.18 ± 0.02 at a rate of 30%, confirming that the blend was becoming less green and browner. Also, chickpea flour showed the highest yellow index (b*) at the rate of 30%, with a value of 26 ± 0.04%, compared to the initial value of wheat semolina (18.55 ± 0.1%) and lentil flour (16.35 ± 0.03%). As expected, this parameter decreased with the increase of legume flours replacement.

Table 3. Color parameters of raw materials and enriched blends with different rates of chickpea or lentil flours.

	Color parameter		
Samples	L*	a*	b*
	Raw materials		
Durum wheat semolina	87.31 ± 0.08^{k}	-4.11 ± 0.01^{a}	18.55 ± 0.1^{h}
Chickpea flour	80.3 ± 0.01^{a}	+0.12 ± 0.01^{o}	26.00 ± 0.05^{m}
Lentil flour	83.69 ± 0.03^{c}	-2.72 ± 0.01^{i}	15.20 ± 0.07^{a}

Composite blends			
Chickpea-enriched semolina			
C5	86.17 ± 0.05^{h}	-2.84 ± 0.021^{h}	20.45 ± 0.02^{i}
C10	85.40 ± 0.05^{g}	-2.02 ± 0.01^{j}	21.28 ± 0.03^{j}
C15	83.85 ± 0.02^{e}	-1.50 ± 0.04^{k}	22.73 ± 0,02^{i}
C20	83.75 ± 0.04^{d}	-1.39 ± 0.03^{l}	23.30 ± 0.01^{k}
C25	82.62 ± 0.03^{b}	-0.89 ± 0.05^{m}	24.16 ± 0.02^{l}
C30	80.30 ± 0.02^{a}	-0.18 ± 0,02^{n}	26.00 ± 0.04^{m}
Lentil-enriched semolina			
L5	87.23 ± 0.08^{j}	-4.00 ± 0.01^{b}	17.64 ± 0.02^{g}
L10	87.84 ± 0.08^{l}	-3.83 ± 0.02^{c}	17.59 ± 0.03^{f}
L15	86.94 ± 0.05^{i}	-3.79 ± 0.03^{d}	17.44 ± 0.01^{e}
L20	86.12 ± 0.06 ^{h}	-3.63 ± 0.04^{e}	17.34 ± 0.02^{d}
L25	85.31 ± 0.05^{f}	-3.39 ± 0.01^{f}	16.62 ± 0.04^{c}
L30	84.60 ± 0.04^{d}	-3.03 ± 0.07^{g}	16.35 ± 0.03^{b}

C (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of chickpea flour; L (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of lentil flour; Values are expressed as means ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples.

Enzymatic properties of raw materials and legume-enriched semolina

Falling number values represent the activity of α-amylase enzyme in durum wheat semolina and legume flours. These values increased as a function of the increase of legumes flours substitution rates (Figure 2). In fact, the low initial semolina falling number value 262 ± 1.6 s increased significantly to reach respective values of 351 ± 2.4 s and 251 ± 1.4 s when replacing semolina with 30% of chickpea or lentil flour in the blend. Previous studies (Bakare et al., 2016) also reported the increase of falling number values after the incorporation of breadfruit flour, in the wheat flour-based blends. This increase was attributed to the extent of liquefaction and diastatic activity of the starches in the blends which decreased with the increase of the proportion of the legume flour (Bakare et al., 2016). The obtained values seem to comply with the plant's internal standard, but the improvement is still insufficient for wheat semolina and lentil blends, given that the target falling number for pasta production must be greater than 300 s according to ISO 3093 (2009). In fact, blends having high falling number corresponding to a very limited amylase activity are usually more suitable for pasta than for bread-making (Szydlowska-Tutaj et al., 2021). Besides, the decrease in the falling number leads to an increase in the activity of amylolytic enzymes leading to starch breakdown and consequently the increase in cooking losses and pasta stickiness (Szydlowska-Tutaj et al., 2021).

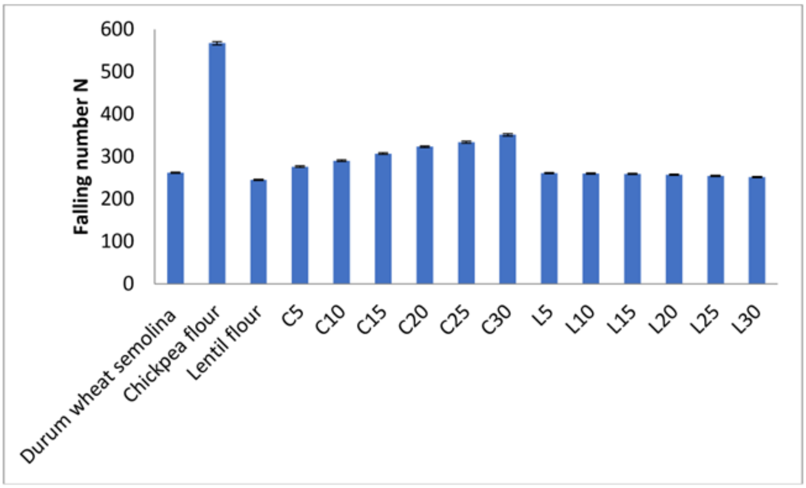

Figure 2. Falling number of raw materials and enriched blends with different rates of chickpea or lentil flours. C (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of chickpea flour; L (5-30): Produced blends by substituting durum wheat semolina with different proportions (5%, 10%, 15%, 20%, 25% and 30%) of lentil flour; Values are expressed as means ± standard deviation for three replicates.

Evaluation of legume-enriched pasta quality

Color parameters of legume-enriched pasta

From the consumer's point of view, color is a very important parameter of the quality of food products (Fratianni et al., 2005). The results of the effect of substituting wheat semolina with legume flours on the color parameters of precooked pasta are shown in Table 4. This replacement significantly affected ($p < 0.05$) the color parameters (L*, a*, b*) of all analyzed pasta samples.

The initial Lightness (L*) value (68.35 ± 0.02) of precooked pasta made with 100% durum wheat semolina, decreased significantly with the increase of legume flour replacement rates, to reach values of about 60.27 ± 0.02 and 57.2 ± 0.04, respectively with 25% of chickpea and lentil flours proportions. This decrease of enriched pasta Lightness is in perfect agreement with other studies when preparing fortified products with legumes such as chickpea, green pea, yellow pea, split pea, faba bean and lentils, as well as pseudo-cereals like quinoa (Petitot et al., 2010). In fact, Zhao et al. (2005) and Wood (2009) showed that the darker color of the legume-supplemented pasta may be attributed to the higher content of ash in prepared blends and the specific color of the legume flours.

Besides, a* values increased in all precooked pasta samples with the increase of legume flour replacement rates. The parameter a* reached values of about +3.7 ± 0.02 and 2.32 ± 0.02 when incorporating 25% of chickpea flour or lentil flour, respectively. These results confirmed that the pasta becomes browner with the replacement with legume flours.

Also, pasta made with wheat durum semolina incorporated with 25% of chickpea flour showed the highest yellow index (b*) (26.53 ± 0.02) when compared to wheat durum semolina (17.54 ± 0.03) and enriched pasta with 25% of lentil flour (15.3 ± 0.02). It was observed that b* values of precooked pasta prepared using blends containing legume flours increased with the replacement rate increase. Petitot et al. (2010) and Zhao et al. (2005) reported that the fortification of pasta with various legume flours mainly chickpea flour decreased the L* value and increased yellow color leading to the most appreciated product by consumers according to Oyeyinka et al. (2020). The increase in yellowness in chickpea- enriched pasta can be attributed to the natural pigments of the durum wheat like carotenoid and xanthophyll. In fact, the variability in their amounts depends on the botanical origin, growing conditions, distribution in grain, and technology processes (Fratianni et al., 2005).

Table 4. Color parameters of control and enriched pasta using legume flours.

Sample	Color parameters		
	L*	a*	b*
Control pasta	68.35 ± 0.02 ^{h}	-1.08 ± 0.02^{a}	17.54 ± 0.03^{e}
	Chickpea-enriched pasta		
PC5	66.90 ± 0.03^{f,g}	+0.35 ± 0.01^{d}	18.75 ± 0.01^{f}
PC10	65.29 ± 0.01^{e}	+3.01 ± 0.04^{i}	18.83 ± 0.02 ^{g}
PC15	63.65 ± 0.02^{c}	+3.06 ± 0.03^{j}	23.88 ± 0.04 ^{h}
PC20	62.20 ± 0.04^{c}	+3.60 ± 0.04^{k}	25.88 ± 0.01^{i}
PC25	60.27 ± 0.02^{b}	+3.70 ± 0.02^{l}	26.53 ± 0.02^{j}
	Lentil-enriched pasta		
PL5	67.00 ± 0.01 ^{g}	-0.76 ± 0.01^{f}	17.70 ± 0.03^{e}
PL10	66.15 ± 0.04^{f}	+0.10 ± 0.02^{c}	16.79 ± 0.02^{d}
PL15	64.22 ± 0.05^{d}	+0.70 ± 0.03^{e}	16.62 ± 0.01^{c}
PL20	60.86 ± 0.031^{c}	+2.00 ± 0.04 ^{g}	15.70 ± 0.01^{b}
PL25	57.20 ± 0.04^{a}	+2.32 ± 0.02 ^{h}	15.30 ± 0.02^{a}

PC (5-25): Enriched pasta with 5 to 25% chickpea flour; PL (5-25): Enriched pasta with 5 to 25% lentil flour; Values are reported as means ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples.

Cooking quality of legume-enriched pasta

According to the ISO 7304-1 (2016) standard, the optimum cooking time is equal to the minimum cooking time plus one minute. In this study, results (Table 5) met the recommendation of this standard. Pasta prepared pasta with different ratios of chickpea or lentil flours showed significant changes ($p < 0.05$) in the cooking characteristics compared to the control. The control registered the shortest cooking time (10 ± 0.2 min), which increased for enriched pasta to reach maximum cooking times of about 13 ± 0.2 min and 13.2 ± 0.3 min for samples enriched with chickpea or lentil flour at a rate of 25%, respectively. This finding was partially in line with those found by Kore et al. (2022) reporting cooking times of about 10.5 min 10.0 min, respectively for control and pasta enriched with chickpea flour at a rate of 15%.

The compactness of pasta and the higher gelatinization temperature of durum wheat starch can explain these results (Ahmad et al., 2018). Therefore, differences in the rate of water penetration to the core of the pasta due to the absence of continuity in the protein-starch network were suggested to influence cooking time (Oyeyinka et al., 2020). These results were in disagreement with those of Bayomy and Alamri (2022) and

Petitot et al. (2010), who reported that the addition of legume flours resulted in a decrease in cooking time. The recorded cooking times, in this study, were higher than values (5.30-6.00 min) reported for pasta enriched with chickpea flour and protein isolate (El-Sohaimy et al., 2020), and less than values (10-11.15 min) reported for semolina spaghetti enriched with pea flours (Padalino et al., 2014). This variability can be referred to the properties of used legume flours.

Concerning the cooking losses of control and enriched pasta, this parameter indicates the quality of pasta and components bounding inside products during cooking or during hot water hydration for precooked products.

Results illustrated in Table 5 showed that cooking loss was significantly ($p < 0.05$) affected by the addition of chickpea or lentil flour. Indeed, the control registered a value of 4.85 ± 0.2%, which increased with increasing the proportion of chickpea or lentil flours to reach respective values of 8.32% ± 0.02 and 7.78% ± 0.02 when using the highest ratios (25%). It was noted that the cooking losses were higher for pasta after replacement with chickpea flour without exceeding a value of 10% of pasta suggesting good final legume-based pasta quality as described by Wojtowicz and Moscicki (2014). These findings are in agreement with those of Bayomy and Alamri (2022) and Zhao et al. (2005) who reported an increase in cooking losses for lentils and chickpea-based pasta with values ranging from 5.05 to 7.35%, which was attributed to the reduced gluten content in legume flours. Besides, they reported that the cooking loss could be related to amylose leaching and solubilization of some salt-soluble proteins as well as the dilution of the gluten which forms a matrix holding the starch in the pasta together (Kore et al., 2022). In fact, this reduction weakens the gluten network, decreasing its ability to hold into soluble materials, as explained by Wood (2009).

Moreover, increased water uptake during cooking is crucial for quality control of pasta products. According to Gulia et al. (2014), high-quality pasta should absorb at least twice its weight after boiling. Obtained results showed that enriched pasta with chickpea flour exhibited the highest swelling index values ranging from 224.93 ± 0.02 g 100 g^{-1} to 260.26 ± 0.02 g 100 g^{-1} when compared to those of lentil flour enriched pasta (Table 5). It should be noted that the fixation of water by the starch grains is made possible by the weakening of the hydrogen bonds linking the chains of amylose and amylopectin (Gulia et al., 2014).

Table 5. Cooking parameters and physicochemical characteristics of control and enriched pasta using legume flours.

	Optimal cooking time (min)	Cooking losses (g 100 g^{-1})	Firmness (N)	Swelling index (g 100 g^{-1})
Control pasta	10 ± 0.2^{a}	4.85 ± 0.2^{a}	16 ± 0.1^{gh}	221.35 ± 0.2^{a}
		Chickpea-enriched pasta		
PC 5	11 ± 0. 3^{b}	5.45 ± 0.3^{d}	16.33 ± 0.3^{i}	224.93 ± 0.02^{c}
PC 10	11.5 ± 0.1^{c}	6.13 ± 0.1^{e}	16 ± 0.2 ^{g}	229.23 ± 0.2^{e}
PC 15	12 ± 0.4^{d}	7.01 ± 0.2 ^{g}	15 ± 0.1 ^{ef}	243.16 ± 0.1^{fg}
PC 20	12.3 ± 0. 1^{e}	7.29 ± 0.01 ^{h}	14.76 ± 0.04^{d}	251.77 ± 0.03 ^{h}
PC 25	13 ± 0.2^{gh}	8.32 ± 0.02 ^{g}	9 ± 0.2^{a}	260.26 ± 0.02^{j}
		Lentil-enriched pasta		
PL 5	11.5 ± 0.3^{cd}	5.37 ± 0.02^{b}	16.67 ± 0.02^{k}	221.83 ± 0.1^{b}
PL 10	12 ± 0.1^{d}	5.43 ± 0.01^{c}	16.5 ± 0.01^{j}	226 ± 0.2^{d}
PL 15	12.4 ± 0.2^{ef}	6.94 ± 0.03^{f}	15 ± 0.3^{de}	243 ± 0.3^{f}
PL 20	13 ± 0.1 ^{g}	7.35 ± 0.04 ^{g}	14.33 ± 0.2^{c}	245.66 ± 0.2 ^{g}
PL 25	13.2 ± 0.3^{e}	7.78 ± 0.02^{i}	11 ± 0.4^{b}	256.5 ± 0.1^{i}

PC (5-25): Enriched pasta with 5% to 25% chickpea flour; PL (5-25): Enriched pasta with 5% to 25% lentil flour; Values are reported as means ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples.

Finally, these values do not seem to agree with the work of Feillet et al. (2000), who reported that swelling values of cooked pasta at the optimal cooking time varying between 160 g 100 g^{-1} and 180 g 100 g^{-1} is in accordance with the ISO 7304-1 (2016).

Texture is a major concern for consumers, with firm, non-sticky pasta being generally accepted. In fact, firmness represents the force required to cut a defined amount of pasta while stickiness is the maximum peak force to separate the probe from the sample's surface upon retraction (Kore et al., 2022). As shown in Table 5, control durum wheat semolina pasta had a firmness of 16 ± 0.1 N. This parameter was inversely proportional to the amount of incorporated legume flours. The highest firmness value (16.67 ± 0.02 N) was recorded in the pasta sample prepared with 5% of lentil flour. However, the lowest value (9 ± 0.2 N) was observed for pasta containing 25% of chickpea flour. This finding was partially in line with that of Kore et al. (2022) who reported the highest firmness value for 15% chickpea flour added pasta. The decrease of this parameter can be explained by the increase of cooking loss and the changes in optimal cooking time, in water absorption and swelling index, as well as changes in textural properties such as firmness, elasticity and stickiness (Wang et al., 2021). Furthermore, color and taste of legumes enriched pasta may be affected.

Sensory evaluation of legume-enriched pasta

A very important factor in determining food quality is the balance between its nutritional, technological and sensorial properties in order to ensure consumer acceptance. Therefore, consumer evaluation is very important before a product is put on the market.

The sensory evaluation of control and prepared pasta by substituting a percentage of the wheat semolina with chickpea or lentil flours are presented in Table 6.

Table 6. Sensory evaluation of control and enriched pasta with legume flours.

Criteria	Appearance	Color	Odor	Taste	Aftertaste	Texture	Overall Acceptability
Control	3.92 ± 0.02^{f}	3.75 ± 0.01^{e}	3.37 ± 0.02^{cd}	3.12 ± 0.1^{bc}	3.11 ± 0.1^{c}	3.9 ± 0.1^{f}	3.05 ± 0.03^{d}
Chickpea-enriched pasta							
PC10	3.58 ± 0.02^{e}	3.82 ± 0.04^{f}	3.62 ± 0.03^{f}	3.33 ± 0.2^{d}	3.15 ± 0.2^{c}	3.4 ± 0.2^{e}	3.51 ± 0.02^{f}
PC15	3.34 ± 0.02^{d}	4.04 ± 0.03^{g}	3.89 ± 0.01^{g}	3.51 ± 0.2^{e}	3.53 ± 0.3^{d}	3.32 ± 0.01^{d}	3.98 ± 0.01^{g}
PC20	3.14 ± 0.02^{c}	2.76 ± 0.02^{b}	3.12 ± 0.02^{b}	2.95 ± 0.02^{b}	2.95 ± 0.5^{b}	3.09 ± 0.04^{b}	2.7 ± 0.2^{b}
Lentil-enriched pasta							
PL10	3.33 ± 0.02^{d}	3.25 ± 0.01^{d}	3.51 ± 0.02^{e}	3.26 ± 0.02^{cd}	3.11 ± 0.3^{c}	3.3 ± 0.02^{d}	3.45 ± 0.02^{e}
PL15	2.9 ± 0.01^{b}	3 ± 0.03^{c}	3.3 ± 0.1^{c}	3.09 ± 0.01^{bc}	3.08 ± 0.3^{c}	3.15 ± 0.01^{c}	2.89 ± 0.01^{c}
PL20	2.81 ± 0.02^{a}	2.73 ± 0.01^{a}	3.05 ± 0.03^{a}	2.65 ± 0.02^{a}	2.56 ± 0.2^{a}	2.9 ± 0.1^{a}	2.19 ± 0.02^{a}

PC (10-20): Enriched pasta with 10% to 20% chickpea flour; PL (10-20): Enriched pasta with 10% to 20% lentil flour; Values are reported as means ± standard deviation for three replicates. Column with different lower-case letters indicates significant differences ($p < 0.05$) between samples.

Pasta prepared by replacement of wheat semolina with 15% of chickpea flour received the highest scores in terms of taste, aftertaste, color, odor and overall acceptance. However, the texture and appearance of enriched pasta decreased significantly with increasing the chickpea flour rate and the highest scores were obtained for control pasta made with 100% wheat durum semolina. Regarding the pasta samples produced by substituting wheat semolina with different rates of lentil flour (10% to 20%), pasta prepared with the lowest proportion (10%) showed the highest scores in terms of the main descriptors.

Moreover, color plays an important role in the quality attributes of durum wheat, attracting consumers' attention and influencing the development of the pasta market. A bright yellow color is often associated with high-quality pasta, especially pasta made from durum wheat, as it indicates the presence of carotenoids, a natural pigment that helps improve the visual appeal and nutritional value of the product. In this study, the pasta enriched with 15% chickpea (PC15) had the highest color value (4.04), indicating a higher acceptability compared to the control sample (3.75). This increase in terms of preference can be attributed to PC15 sample's richer yellow hue, which is more in line with consumers' expectations of high-quality pasta. Since a bright yellow color is often associated with superior pasta quality, this result suggests that the addition of chickpea flour at this concentration has a positive impact on the product's visual appeal.

This replacement of wheat semolina using legume flours had a significant ($p < 0.05$) effect on the overall acceptability of the prepared cooked pasta. Also, the results showed that the panelists significantly ($p < 0.05$) preferred replacing wheat semolina with chickpea over lentil flour at low rates. These results strongly agree with those reported by Bayomi and Alamri (2022) who explained the lower consumer acceptance of pasta enriched with lentil flour due to its coarse texture, unpleasant mouthfeel, and unpleasant flavor. Similarly, fortified pasta with up to 10–15% of chickpea flour was generally more preferred (Petitot et al., 2010).

Conclusion

In this study, the effect of durum wheat semolina enrichment using lentil or chickpea flours was studied on prepared blends as well as on legumes-based pasta quality. The results showed that the addition of legume flours improved the nutritional value of enriched blends in term of proteins and ash contents when compared to raw materials. Moreover, cooked pasta quality was directly related to the type and rate of legume flours in the blend. In fact, cooking time increased as a function of legume flours increase in the blends. Also, cooking losses were found to be greater for enriched pasta with chickpea or lentil flours but they remained under the acceptability limit, thus confirming the good quality of enriched pasta. This enrichment reduced the firmness of produced pasta compared to control. Concerning the sensorial properties, chickpea-based pasta using 15%

of replacement was the most preferred by panelists in terms of taste, aftertaste, color, odor and overall acceptability followed by produced pasta using 10% of lentil flour in the blend, showing that several key aspects must be considered to translate these findings into industrial-scale production taking into account consumer attitudes and preferences. Finally, the final price of enriched pasta seems to be slightly higher than that of control, mainly due to the cost of the raw materials and additional processing. However, this product shall provide a healthier alternative for consumers.

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