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Research Article

Legume Flour Enrichment of Cereal Products: Effects on Consumer Perception and Physical Quality

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Abstract

Legume flour enrichment can enhance the nutritional value of many cereal products, in line with the current dietary recommendations of the World Health Organization. The aim of this study based on a survey of 105 consumers was firstly to investigate the perception and acceptance of Tunisian consumers with regard to including legumes in their diet, but also to be innovative in their consumption habits. Secondly, among the legumes listed in the survey, chickpeas and lentils were selected by the respondents and were added in different proportions to supplement bread and cake formulations. Moisture content, protein and ash of common wheat and legume flours and of the legume-enriched products were determined and compared to those of the control products. Crust and crumb color measurements were run on in final products. Sensory evaluations were also performed through a hedonic test and a linear scale test. The results showed that legume flour enrichment of bread and cake was a viable alternative and that consumers were aware of the fact that legumes are a source of dietary minerals and proteins. The challenge of including high percentages of legumes (between 20% and 40%) was met in this study with no major technological and organoleptic impairment.

Keywords: Cereal Products; Consumer Perception; Legumes; Physical Quality; Wheat Substitution

Introduction

The World Health Organization (WHO) increasingly encourages the inclusion of legumes in diets and their incorporation in food products to offset the decline in their production and consumption, while limiting massive worldwide soft wheat imports. The Mediterranean diet is highly based on legume consumption. Moreover, legumes represent a strategic food resource because of their highly nutritional quality and role in food system sustainability.

Cereals and legumes are major food components in human nutrition as they are a key source of calories and protein for a large proportion of the world population. Moreover, for economic and social reasons, people living in many countries in Africa and the Mediterranean Basin are still dependent on legumes in their diet. Indeed, crops contribute to reducing malnutrition in vulnerable social groups in some of these countries as they are important affordable nutritional foods [1,2].

Interest in vegetarian diets is currently growing. According to Dauchet and Jung (2019), epidemiological studies conducted on specific vegetarian populations, mostly including well-informed vegetarians, have revealed a reduced risk of obesity, mortality and vascular disease among vegetarians. Moreover, consumers are being encouraged to increase the proportion of plant protein in their diets to enhance food system sustainability [3]. The novel approaches adopted for this purpose generally involve the development of plant protein-rich foods that are acceptable to consumers [3] and modifying dishes and desserts to have proportionately more plant-based ingredients and fewer animal-based ingredients [4]. In this context, the increased use of legumes is also a rising trend in industrialized countries. The inclusion of legumes in the daily diet has several beneficial physiological effects in controlling and preventing obesity and various metabolic diseases such as diabetes mellitus, coronary heart disease and colon cancer [5,6]. Lately, trends toward healthy eating, functional foods development and ethnic and ethic eating all over the word, led to an important substitution of animal proteins by legumes in various food products. Composite cereal-legume foods are certainly beneficial due to the valuable nutritional and potential health benefits associated with their complementarity [7,8] but also for the beneficial effect encountered through this association in the traditional cultivation techniques. Indeed, as the protein content of legumes is twice as high as that of cereals, legumes represent an economically and environmentally sustainable protein source. They also could be a food alternative for consumers presenting with protein deficiency, which is considered to be the most common form of malnutrition in developing countries [9]. Legumes are also an excellent reservoir of dietary fiber and complex carbohydrates, with a concomitant low glycemic index (GI) [5]. Moreover, their low starch bioavailability and high resistant starch content may improve the nutritional value of many cereal products, which has been the focus of several studies on the use of wheat-legume flour blends in cakes, bread and pasta, etc. [10-21].

In addition, the dietary fiber composition of legumes is linked to therapeutic virtues, thereby promoting their daily consumption. Indeed, the effects of legume consumption on cholesterol levels, diabetes and the growth of intestinal microbiota have been highlighted and described in the literature [22].

As for Mediterranean countries, several types of legumes (e.g. chickpeas and lentils) are traditionally produced and consumed as a staple in many traditional Tunisian foods. Chickpeas and lentils are mostly consumed in several savoury dishes and preparations (soups, salads, etc.). However, they are also ground to make flours used to prepare different traditional sweets and snacks. Whether included in sweet or savoury dishes, chickpea and lentil consumption in Tunisia is related to local culinary habits. In North Africa, including Tunisia, legumes are traditionally one of the most widely cultivated vegetables. However, legume kernel production has declined drastically in several countries, especially over the last 10 years, and legumes are currently disappearing from crop rotation systems. Innovative development strategies should therefore be adopted to promote their cultivation, consumption and processing. In Mediterranean countries, cereal products such as bread, pasta or cake, are an integral part of local diets and legumes are still widely consumed. However, food products containing cereal-legume blends are not yet available on the Tunisian market, as is also the case in several other countries in the Mediterranean Basin. The possibility of reintroducing legume consumption in local diets through such products should hence be assessed.

The aim of this paper was to highlight new uses of two legume kernels, i.e. chickpeas and lentils, in mixed high added value cereal products (bread and cake) to provide arguments in favour of promoting the reintroduction of legumes in local agricultural policies. This study first aimed to investigate Tunisian consumer behavior, perception and acceptance in relation to legume-enriched bread and cake consumption. Identified legumes (chickpeas and lentils) were incorporated in these cereal matrices combined with common wheat flour to formulate mixed bread and cake products. Hence, the second objective was to verify the effectiveness of several legume flour percentages used in bread and cake preparation through physical and sensorial analysis. To the best of our knowledge, no previous research studies have involved such a combined socioeconomic and technological approach to investigate the impacts of legume flour enrichment of cereal products.

Materials and Methods

Materials

Local Tunisian chickpea (*Cicer arietinum* L.) and lentil (*Lens culinaris*) kernels were provided by Tunisian farmers. Legume flours were obtained after grinding legume kernels in a modern industrial mill (LEIFHEIT, Germany) until they could pass through a 300 µm mesh screen. Commercial wheat flours (for bread and cake making) were obtained from an industrial mill (Tunis, Tunisia). The other bread and cake making ingredients were purchased from a local supermarket (Tunis, Tunisia).

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

Methods

Consumer perception test

The perception and acceptance of Tunisian consumers with regard to directly or indirectly consuming legumes was assessed through a pilot study based on a consumer test survey that was conducted in a large supermarket in Tunis (Tunisia). This pilot study was carried out with 105 consumers who were randomly selected. Questionnaires were used to collect consumer profile data, legume consumption profile and acceptance and buying decisions on bread and cake with legume-enriched formulations. The collected data were processed and statistically analyzed using SPSS 22.0 software.

Legume flour enrichment of cereal products

According to the assessment of the results of the consumer perception test, the formulation of cereal products enriched with legume flours was based on two different legumes: chickpeas and lentils. These legumes were included in mixed cereal matrices along with common wheat to make innovative and nutritional added value bread and cake products. Legume flours were substituted for wheat flour in bread formulations at two rates, i.e. 20 and 40%. Two other levels of legume flours (25 and 50%) were substituted for wheat flour in cake formulations. Note that these high legume flour enrichment rates were one of the challenges of this study. The product formulations are described below.

Bread

Three blends were prepared by mixing wheat flour with legume flours at the respective proportions of 100:0, 80:20 and 60:40 (wheat/chickpea or lentil flours, w/w) using a mixer (Sammic, France). The bread making formula was: 400 g flour (with 20% and 40% legume flour enrichment rates), 0.2 g bread improver (wheat gluten), 8 g dried yeast, 225 ml water and 6 g salt. All the baking steps were conducted in a bread machine (600 W, Kenwood BM230, Japan). The ambient temperature during the operations was about 22-23°C. The total kneading time was 35 min. The total fermentation period was 90 min. The baking time was 65 min. The total bread preparation time was 3 h. Each baking test was conducted in triplicate. The bread characteristics were determined after a 2 h cooling period.

Cake

Five cake formulas were tested: one control (100% wheat flour), two cake formulas with wheat flour blended with 25 and 50% chickpea flour and two cake formulas with 25 and 50% lentil flour. The basic cake formula was described in Gómez, Oliete [10]. For cake preparation, the dry ingredients (flour, sugar, powder milk, baking powder) were mixed and then the liquid ingredients (egg, water, oil) were added. The blends were mixed for 5 min at speed 6 using a mixer with a spiral blade (Sammic, France). The cake batters obtained were placed in metallic pans previously tare weighed and coated with sunflower oil and a thin layer of wheat flour. They were then baked in an electric oven for 30 min at 185°C. Each baking test was conducted in triplicate. The cake characteristics were determined after 2 h cooling.

Physicochemical analysis

The composition of legume and wheat flours was determined according to AACC [23] methods for moisture (method 44-15A), protein (method 46-13) and ash (method 08-01) assessment. All analyzed sample measurements were conducted in triplicate. The physicochemical properties of legume flour-enriched products were determined and compared to those of the control products. Moisture, protein and ash levels of the cereal products were analyzed as above.

Color measurements

The tristimulus color parameters L* (lightness (100) to blackness (0)), a* (redness (+ve) to greenness (-ve)) and b* (yellowness (+ve) to blueness (-ve)) of the baked bread and cake samples were evaluated and compared to those of the control products with a colorimeter (Konica Minolta CR-410, Japan) using the space color CIE Lab system. For bread (n = 3) and cake (n = 5) samples, both the color of crust and crumb of legume flour-enriched products were measured.

Sensory evaluation

- **Hedonic test**: Forty untrained panelists (40 persons; 50% men and 50% women) were asked about their preference and acceptability of bread and cake products [24].
- **Intensity scoring test**: The bread and cake sensorial characteristics were evaluated following their cooling to room temperature for 3 h. Sensory evaluation using a quantitative descriptive analysis was performed on cake by 17 trained panelists and for bread by 15 trained panelists [25]. Sensory testing was done on the bread and cake crumb. The appearance, color, odor, taste, texture and overall acceptance of bread and cake samples were scored according to a 9-point non-structured horizontal scale (1 = extremely dislike to 9 = extremely like). The distance from the undesirable end of the scale was measured for each sample and the samples with a high scale were preferred.

Statistical analysis

Physicochemical analyses were conducted in triplicate and data were reported as mean ± standard deviation (SD). An analysis of variance (ANOVA) was performed and the mean comparisons were carried out using Tukey's test at 95% confidence level. Statistical analysis was performed using the SPSS Statistics, 22.0 statistical software package.

Results and Discussion

Consumer perception on legume consumption and cereal products enriched with legume flours

The questionnaire used in this study concerned both legumes and two cereal products, bread and cake, formulated or not with legume flours. The respondents' characteristics are reported in table 1. The majority of the consumers were women. Two significant age groups emerged between 21-30 years and over 55 years. More than half of the respondents had a 5-year university degree, followed by those with a 3-year university degree (35.2%). Among the respondents, 54.3% were senior executives or senior managers and a quarter of them were students.

96.2% of the consumers consumed legumes according to the profile in table 2. More than 60% of them consumed legumes throughout the year and 36% of them especially during winter. This consumption pattern could be related to the Tunisian dishes [26] typically prepared during the winter. A majority of the respondents (61%) ate legumes 2-3 times a week, especially at lunch (41%), but also at other times of the day (38%). Tunisians actually consume legumes, to almost an equal extent, in sweet or salty dishes. This high consumption rate may reflect consumer awareness of the nutritional benefits and virtues of legumes (75.2%). Finally, among the legumes listed, i.e. chickpeas, lentils, faba beans, broad beans and peas, the respondents much preferred chickpeas (73.8%) and lentils (63.1%), which are the legumes most used in traditional culinary preparations in Tunisia.

Characteristics	Data (%)
Gender	
Female	78.1
Male	21.9
Age	
20 or less	6.7
21 - 30	36.2
31 - 40	5.7
41 - 55	20.0
Over 55	31.4
Education	
Middle and High school	6.7
University degree (Bachelor's)	35.2
University degree (Master's and PhD)	58.1
Occupation	
Student	27.6
Senior executive/manager	54.3
Government employee	9.5
Worker	1.9
Unemployed	6.7

Table 1: Characteristics of the respondents.

Hence, despite current changes in the dietary habits of Tunisians [27], these results are encouraging and support the enrichment of cereal products with legumes flour for daily consumption.

105 people answered the questionnaire concerning the frequency of eating standard bread and cake made only with wheat flour (Table 3). All of them consumed bread and 73.3% of them consumed it daily. However, a minority of respondents (5.8%) nev-

Characteristics	Data (%)
Season of highest legume consumption	
Winter	36
Summer	1
Always	63
Consumption frequency	
Every day	14.3
2-3 times/week	61
Depends on the occasion	21
Never	3.8
Time of consumption	
Lunch	41
Dinner	21
Other	38
Consumption form	
Sweet dishes	70.7
Savory dishes	68.3
Awareness of the benefits of legumes	
Yes	75.2
No	24.8
Legume preference	
Chickpeas	73.8
Lentils	63.1
Faba beans	8.7
Broad beans	39.8
Peas	54.4

Table 2: Legume consumption profile.

er consumed cake while 57.7% consumed it occasionally. Regarding respondents' legume flour-enriched bread and cake product acceptance and buying decisions (Table 3), most respondents accepted the idea of new bread or cake products supplemented with legume flour and agreed to buy them.

The consumer survey results showed that mixed matrices were approved by consumers (Table 3) which is encouraging in terms of the development of plant-based foods with consumer appeal. Furthermore, this process involves better understanding the trade-off between consumer preferences and health/environmental benefits [3]. Hence, the health benefits and nutritional added value of legume-enrichment of cereal formulas fully justified the second part of this research. Bread and cake the two selected legume-wheat blend products were assessed to determine the physicochemical composition of the raw materials and the final products. Their physical properties were also evaluated.

Characteristics	Products/Data (%)	
	Bread	Cake
Frequency of eating standard wheat products		
Daily	73.3	15.4
2-3 times/week	21	21.2
Depends on the occasion	5.7	57.7
Never	0	5.8
Acceptance of legume-enriched bread and cake		
Acceptance	87.5	68.0
Non-acceptance	12.5	32.0
Decisions on buying legume-enriched bread and cake		
Buy	68.3	71.2
Not sure	26.9	26.9
Not buy	4.8	1.9

Table 3: Standard wheat bread and cake eating frequency and acceptance, and decisions on buying legume-enriched bread and cake.

Raw material physicochemical characteristics

The proximate compositions of the raw materials (wheat and legume flours and blends) are shown in table 4. Wheat flour had a significantly higher water content compared to legume flour (approximately + 5%). The moisture content of the blends thus decreased significantly and proportionally with the increase in the legume flour enrichment rate.

Both lentil and chickpea flour ash contents were fourfold higher than the raw wheat ash contents, i.e. 02.69 ± 0.01%, 02.86 ± 0.05% and 0.71 ± 0.01%, respectively. Bojnanska, Frančáková [11] obtained similar results (2.39 ± 0.04% for chickpea flour, 2.30 ± 0.20% for lentil flour and 0.57% for wheat flour). The significant increase in the raw material ash contents in the blends was expected. Depending on the wheat flour category (bread or cake flour) and the enrichment percentage, chickpea-wheat blends tended to have higher ash values compared to the lentil-wheat blends due to the significantly higher initial chickpea flour ash content ($p < 0.05$). Ash is an indicator of the food mineral content and legumes are reported to be rich in minerals [28] essential for the human body and health.

Remarkably, legume flours had a significantly higher protein content, i.e. 24.58 ± 0.25% for lentil flour and 21.17 ± 0.34 for chickpea flour, compared to that of wheat flour (12.06 **± 0.05%)**. These findings were in agreement with those of [5] for lentil flour (23-32%) and chickpea flour (15.5-28.2%). Protein content increased in wheat-legume blends as legume enrichment increased. The same trends were noted by other authors with regard to the proximate composition of wheat-chickpea and wheat-lentil flour blends [10,12,29-31]. From a nutritional standpoint, both chickpeas and lentils have high interesting protein contents, as is the case for all legumes overall, while legumes are also an excellent source of peptides and phytochemicals, which are present in significant amounts [6]. According to the results in table 4, with such protein content, largely higher than in cereals, legumes represent a source of protein of comparable quality to those of animal origin while more affordable. However, nutritional and technological improvement of legume proteins is needed to modify their structure and function, as recommended by Gharibzahedi and Smith [32].

Raw materials	Enrichment level (%)	Moisture content	Ash	Protein
Lentil flour	100	$10.02^{A} \pm 0.06$	$02.69^{A} \pm 0.01$	$24.58^{A} \pm 0.25$
Chickpea flour	100	$08.19^{B} \pm 0.07$	$02.86^{B} \pm 0.05$	$21.17^{B} \pm 0.34$
Bread wheat flour	0	$14.40^{Ca} \pm 0.10$	$0.71^{Ca} \pm 0.01$	$12.06^{Ca} \pm 0.05$
Lentil-bread wheat flour blend	20	$14.36^{a} \pm 0.05$	$0.97^{b} \pm 0.01$	$14.33^{b} \pm 0.06$
	40	$12.97^{b} \pm 0.06$	$1.29^{c} \pm 0.03$	$15.59^{c} \pm 0.05$
Chickpea-bread wheat flour blend	20	$13.67^{c} \pm 0.06$	$1.08^{d} \pm 0.02$	$13.70^{d} \pm 0.04$
	40	$12.91^{b} \pm 0.04$	$1.31^{c} \pm 0.02$	$14.63^{e} \pm 0.05$
Cake wheat flour	0	$14.00^{Da} \pm 0.02$	$0.50^{Da} \pm 0.01$	$09.60^{Da} \pm 0.18$
Lentil-cake wheat flour blend	25	$12.53^{b} \pm 0.09$	$1.08^{b} \pm 0.03$	$12.95^{b} \pm 0.15$
	50	$11.63^{c} \pm 0.24$	$1.61^{c} \pm 0.01$	$16.13^{c} \pm 0.16$
Chickpea-cake wheat flour blend	25	$12.27^{b} \pm 0.15$	$1.12^{b} \pm 0.01$	$12.08^{d} \pm 0.13$
	50	$10.91^{d} \pm 0.01$	$1.73^{d} \pm 0.02$	$15.09^{e} \pm 0.21$

Table 4: Physicochemical characteristics (g/100 g sample) of legume flours, wheat flours and blends (chickpea-wheat or lentil-wheat flour, w/w).

Means within columns followed by different capital letters (per raw material category: wheat or legume flours) and different lowercase letters (legume flour enrichment level per cereal product category) are significantly different ($p \le 0.05$).

Cereal product composition

The chemical characteristics of legume-enriched wheat products are shown in table 5. The bread moisture content decreased as the level of chickpea and lentil flour enrichment increased. This result was expected given the lower water content of legume flours compared to common wheat flour. It would be expected that mixed breads would therefore be less soft than the control one (100% wheat flour). Conversely, the water content in cake samples increased with the increasing enrichment rate. The moisture content increase in the cake formula could possibly be explained by three hypotheses: i) the high water holding capacity of proteins in mixed flours and cake samples due to their higher protein content compared to wheat flour bread; ii) the use of some ingredients that may further increase the water content of the blend, e.g. eggs and milk, and iii) the water retention and functional properties of oil, eggs, sugar and milk and thus to the simultaneous presence of hydrocolloids, humectants and emulsifiers. Besides, legumes flour enrichment significantly improved the nutritional composition of the formulated cereal products (Table 5). Compared to the control, the enriched formulas boosted consumer protein and mineral intake levels ($p < 0.05$) as the legume flour enrichment rate increased. These results are in agreement with those of Santos, Fratelli [18] for bread. Legume-enriched bread and cake products would thus confer major health benefits for consumers. This result was expected according to the raw flour blend compositions reported in table 4. These interesting protein and ash contents could likely play a major role in improving the protein and mineral nutrition of Tunisians consuming such enriched/mixed food products. The nutritional value reflected by the bread composition could be more directly linked to the flour mixture used since no other ingredients were added as was also the case for the cake samples.

Cereal Product	Enrichment level (%)	Moisture content	Ash	Protein
Bread	0 (control)	28.20[a] ± 0.09	0.99[a] ± 0.02	11.30[a] ± 0.09
	20 (lentil)	27.50[b] ± 0.06	1.22[b] ± 0.03	12.57[b] ± 0.12
	40 (lentil)	25.61[c] ± 0.10	1.38[c] ± 0.01	14.70[c] ± 0.10
	20 (chickpea)	27.16[d] ± 0.08	1.52[d] ± 0.04	12.26[d] ± 0.15
	40 (chickpea)	24.98[e] ± 0.11	1.94[e] ± 0.03	13.59[e] ± 0.09
Cake	0 (control)	22.92[a] ± 0.14	0.84[a] ± 0.04	07.29[a] ± 0.16
	25 (lentil)	24.04[b] ± 0.13	1.27[b] ± 0.05	08.68[b] ± 0.18
	50 (lentil)	25.09[c] ± 0.12	1.71[c] ± 0.08	11.35[c] ± 0.15
	25 (chickpea)	23.29[d] ± 0.09	1.41[b] ± 0.03	08.48[b] ± 0.12
	50 (chickpea)	23.93[b] ± 0.10	1.97[d] ± 0.04	11.28[c] ± 0.13

Table 5: Composition of bread and cake with different percentages of legume flour supplementation in wheat flour products (g per 100 g of product).

Means within columns (legume flour enrichment level per cereal product category) followed by different letters are significantly different ($p \leq 0.05$).

Physical quality of cereal products

Color of cereal products

The crumb and crust color attributes of the bread and cake samples are reported in table 6. The darkness (low L* values) of the crust of breads supplemented with chickpea and lentil flours and the significant increase in a* values were the most noteworthy effects of wheat flour legume enrichment. Except for the 20% chickpea-supplemented bread for which L* value was equal to that of the control, the darker crust color of the supplemented breads could be attributed to two factors: (1) the darker initial color of chickpea and lentils flours related to their pigment contents); (2) the increase in the Maillard reaction during the baking process due to the higher protein and lysine contents in legume flours than in wheat flour [30,33-35]. In fact, chickpeas and lentils contain high levels of lysine residues that promote enzymatic or non-enzymatic browning reactions[13,30,36], as well as high amounts of phenolic compounds and flavonoids compared to white wheat flour [36].

The decrease in the L* values was consistent with the increase in the a* values (Table 6), which were proportional to the legume enrichment rates in the wheat-legume flour breads. In addition, this behavior was more pronounced in the crust of the lentil-enriched bread because of its protein richness compared to the chickpea-enriched bread (Table 5). The highest crust b* values (Table 6) were recorded for chickpea-enriched breads followed by the control bread, whereas lentil-enriched breads had the lowest b* values ($p < 0.01$). The marked increase in yellowness in chickpea-enriched breads may have been due to the yellow pigment of the chickpea flour used. A comparison of these results with the a* values seemed to confirm that the yellowness hue diminished as the redness hue increased.

The bread color attribute results (Table 6) were in good agreement with those reported by Yamsaengsung, Schoenlechner [37] when studying the effects of chickpea flour supplementation on the crust color of white (and whole) wheat bread. They demonstrated that chickpea flour incorporation increased the darkness (lower L* value) and yellowness of white bread.

The L* and b* color parameters of the bread crumb showed trends similar to those of the bread crust. However, crust exposure to higher temperature resulted in a darker color. Considering the quantity and kind of legume flour used, the darker bread crumb color may have been due to a third more revealing factor in the crumb, which is directly linked to the increased fiber content [38-40] in legume flours. In fact, since legumes and their derivate flours are rich in dietary fiber, the latter would be more concentrated in the dense crumb of the bread rather than in its crust.

The crumb a* values of legume-enriched breads were all positive and the redness hue was greater for lentil-enriched breads than for chickpea-enriched breads. This result was expected due to the more intense brown color of the lentil flour. In contrast, the crumb a* value of the control bread was negative, indicating the presence of some green coloration.

Color analysis of cake samples indicated the same trends as those noted for bread, except for the crust a* and crumb b* values. Overall, the variation in the three color parameters L*, a* and b* was dependent on the enrichment rate and the kind of legume flour used. No significant difference on the cake crust a* values ($p < 0.05$) was recorded between control and chickpea supplemented cakes which is not the case of those with lentil. This may be attributed to the kind of pigments in the raw materials, such as the redness in lentil flour. Moreover, higher crust a* values were recorded for cake than for bread. This could be explained by the Maillard and sugar caramelization reactions taking place during baking, which are responsible for the final crust color [41]. These reactions were more accentuated due to the added sugar in the cake formulas. As also noted in bread, the highest cake crumb b* values were recorded for both chickpea supplemented samples followed by the control, whose b* value was equal to that of the 25% lentil-enriched cake. Moreover, cake was found to have a more yellowish crumb than bread.

The difference between cake and bread crumbs could be explained, according to de la Hera, Ruiz-París [12], by differences in the ingredients and in color of the control product crumb which, in the case of cake (b* = 21.11), was more yellowish than bread (b* = 17.28). Finally, changes in intensity values but not in hue were recorded when comparing the bread and cake samples. These differences may have been due to several factors, including differences in the composition of both cereal products and in the process conditions.

Cereal Product	Enrichment level (%)	Crust			Crumb		
		L*	a*	b*	L*	a*	b*
Bread	0 (control)	$61.34^a \pm 0.06$	$1.81^a \pm 0.06$	$29.01^a \pm 0.16$	$68.23^a \pm 0.10$	$-1.71^a \pm 0.03$	$17.28^a \pm 0.16$
	20 (lentil)	$56.35^b \pm 0.13$	$8.88^b \pm 0.15$	$23.68^b \pm 0.01$	$56.56^b \pm 0.12$	$1.58^b \pm 0.15$	$14.73^b \pm 0.03$
	40 (lentil)	$48.67^c \pm 0.03$	$13.41^c \pm 0.06$	$28.69^c \pm 0.18$	$49.15^c \pm 0.24$	$2.42^c \pm 0.04$	$13.74^c \pm 0.09$
	20 (chickpea)	$61.24^a \pm 0.15$	$6.90^d \pm 0.06$	$32.66^d \pm 0.03$	$67.95^a \pm 0.14$	$0.11^d \pm 0.08$	$20.48^d \pm 0.23$
	40 (chickpea)	$56.74^d \pm 0.01$	$11.70^e \pm 0.06$	$30.81^e \pm 0.05$	$64.75^d \pm 0.03$	$1.25^e \pm 0.07$	$23.97^e \pm 0.02$
Cake	0 (control)	$53.64^a \pm 0.22$	$12.75^a \pm 0.17$	$30.03^a \pm 0.18$	$78.77^a \pm 0.18$	$-1.23^a \pm 0.08$	$21.11^a \pm 0.19$
	25 (lentil)	$45.16^b \pm 0.19$	$15.21^b \pm 0.21$	$25.48^b \pm 0.16$	$65.50^b \pm 0.19$	$1.59^b \pm 0.04$	$20.98^a \pm 0.19$
	50 (lentil)	$42.99^c \pm 0.17$	$15.08^b \pm 0.16$	$20.98^c \pm 0.20$	$66.35^c \pm 0.14$	$2.45^c \pm 0.12$	$18.40^b \pm 0.20$
	25 (chickpea)	$49.49^d \pm 0.23$	$12.93^a \pm 0.19$	$27.09^d \pm 0.16$	$73.01^d \pm 0.18$	$0.15^d \pm 0.09$	$27.06^c \pm 0.22$
	50 (chickpea)	$47.82^e \pm 0.18$	$13.02^a \pm 0.22$	$23.63^e \pm 0.19$	$71.93^e \pm 0.16$	$0.69^e \pm 0.08$	$26.98^c \pm 0.20$

Table 6: Color values of cereal products when substituting wheat flour with legume flours**.**

Means within columns (legume flour levels per cereal product category) followed by different letters are significantly different ($p \leq 0.05$).

Sensory quality of cereal products

The sensory attribute scores obtained by the intensity scoring test, for the appearance, the color, the odor, the taste, the texture, and the overall acceptability, as well as scores of the hedonic test of bread and cake samples were evaluated and the results are given in table 7. The organoleptic quality attributes of bread and cake products were greatly affected by the addition of chickpea and lentil flours. As shown in table 7, there was an overall improvement in the sensory judgement scores when comparing the control products and those containing legume flours and this trend was more clearcut for cake.

For bread, wheat-legume flour blends and the increase in their enrichment rates caused a significant decrease in the sensory judgement scores for the appearance, odor and taste as compared with the control. These results may be explained by the Tunisian panellists eating habits due to their predominant consumption of white bread. Meanwhile, higher color, texture and overall acceptability scores were recorded for the same supplemented breads compared to the control. Overall, consumers sought a darker crumb color because it reflected that the product was natural and authentic, with a high nutritional value. The results of the descriptive test conducted on bread were consistent with those of the hedonic test (Table 7), especially for the overall organoleptic acceptability. The supplemented breads remained acceptable to consumers and their quality levels were generally higher than those of the white bread. The highest hedonic scores were assigned to breads with 20% lentil enrichment, followed by 40% chickpea enrichment, and then 40% lentil enrichment (35, 21 and 18%, respectively). Hence, legume flour enrichment positively affected the sensory characteristics of bread despite the high enrichment levels.

Concerning cake, table 7 shows that, compared to the control, there was a significant improvement in legume-enhanced cakes with respect to all of the characteristic judgement scores (appearance, color, odor, taste and overall acceptability), except for texture which presented a slight score decrease. This may be explained by changes in the internal structure of cakes which would be caused by an increase in fiber content [38], as well as in ash and protein contents (Tables 4 and 5), which could lead to an increase in the hardness and the compactness of the cake crumb. The intensity scoring test results were in agreement with those of the hedonic test (Table 7), and the corresponding hedonic scores of cake formulas were generally in line with the assessments of the trained panelists. Compared to the control, a major improvement in the hedonic scores of the legume-enriched cakes was recorded and the highest scores were attributed to lentil-enriched cakes, with levels of 25% and 50% and respective corresponding hedonic scores of 35% and 26%. In both cakes formulated with chickpea flour, the 50% enrichment rate significantly improved the cake acceptance, with a score of 24%, while the addition of 25% chickpea flour led to a 10% score. This could be explained by the eating habits of Tunisians who consume sweet products and traditional dishes, including cakes based on chickpea, lentil or sorghum flours. The control cake exhibited the lowest hedonic score (i.e. 5%), indicating that the sensory quality of legume-enriched cakes was better that of the current commercially available product.

Cereal Product	Intensity scoring test attributes							Hedonic test
	Enrichment level (%)	Appearance	Color	Odor	Taste	Texture	Overall acceptance	Hedonic score
Bread	0 (control)	7.86^{a}	1.65^{a}	7.47^{a}	8.04^{a}	1.79^{a}	3.90^{a}	15%
	20 (lentil)	4.08^{b}	5.86^{b}	5.29^{b}	5.47^{b}	5.72^{b}	5.88^{b}	35%
	40 (lentil)	2.50^{c}	8.94^{c}	2.09^{c}	2.05^{c}	7.84^{c}	4.72^{c}	18%
	20 (chickpea)	2.59^{c}	3.93^{d}	5.36^{b}	4.64^{d}	3.09^{d}	3.78^{a}	11%
	40 (chickpea)	2.87^{c}	7.88^{e}	4.08^{d}	3.06^{e}	7.26^{c}	5.19^{bc}	21%
Cake	0 (control)	4.15^{a}	2.38^{a}	2.92^{a}	2.05^{a}	5.95^{a}	4.93^{a}	5%
	25 (lentil)	7.78^{b}	7.32^{b}	7.54^{b}	7.37^{b}	5.81^{a}	6.90^{b}	35%
	50 (lentil)	7.65^{b}	7.66^{b}	7.74^{b}	8.17^{c}	4.94^{c}	6.46^{b}	26%
	25 (chickpea)	6.49^{c}	4.50^{c}	6.03^{c}	6.15^{d}	5.44^{b}	6.28^{b}	10%
	50 (chickpea)	7.67^{b}	7.10^{b}	7.26^{b}	7.82^{bc}	5.52^{b}	6.73^{b}	24%

Table 7: Sensory attributes for intensity scoring and hedonic tests of cereal products based on legume-wheat flour blends. Means within columns (legume flour levels per cereal product category) followed by different letters are significantly different ($p \leq 0.05$).

Conclusion

This pilot study revealed that legumes are still consumed in Tunisia which is one of the Mediterranean countries. It also highlighted that composite wheat-legume products such as bread and cake enriched with chickpea or lentil flours were accepted by Tunisian respondents. Most of the respondents claimed that they would accept and buy these products. The supplemented mixed products enhanced both basic nutritional and physical properties of the final products. The sensorial analysis results revealed that legume flour enrichment of bread and cake formulas improved the organoleptic quality characteristics of these cereal enriched products when compared with the standard wheat products. This was confirmed by the highest hedonic scores obtained for the supplemented formulas compared to the controls. These results were very promising as they constitute a key factor in the consumer's buying decision of enriched wheat products and give an alternative to excessive uses of wheat flour in bakery making process.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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