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Original article

Nutritional and technological assessment of durum wheat-faba bean enriched flours, and sensory quality of developed composite bread

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ABSTRACT

Faba beans are acknowledged as a good source of proteins, minerals, fibers, vitamins and antioxidants. A blending study was undertaken in order to prepare naturally bread from enriched flours with added nutritional value, mainly in terms of Iron and proteins. Enriched flours were prepared with varied levels (25, 30, 35 and 40%) of whole faba bean flour to assess the effects of this substitution on their nutritional and technological properties. Then, whole durum wheat bread (regular) and enriched bread at 40% substitution level (composite bread) were prepared and subjected to sensory evaluation. The substitution level of composite bread was selected on the basis of Iron and proteins contents and technological results of the flour blends. Nutritionally, except for moisture, fibers, fat, zinc and sodium values, significant ($p < 0.05$) increases were showed in ash, proteins, minerals, total phenolic compounds, condensed tannins, total flavonoids and anti-radical activity values. Technologically, significant ($p < 0.05$) decreases were recorded for lightness and whiteness index. The gluten strength value revealed a significant ($p < 0.05$) decrease as whole faba bean flour was added. On the sensory level, the level of substitution (40%) chosen for the manufacture of composite bread resulted in acceptable bread by consumers. Moreover, composite bread was most preferred in aroma as it imparts a feeling of satiety. The observed nutritional improvements could be useful for malnourished people, including those having Iron and proteins deficiencies. Technologically, the observed changes didn't present limitations since composite bread was accepted by consumers even at 40% substitution level. Besides, the slight preference of composite bread aroma might encourage its consumption by consumers. Also, its promotion of satiety is important for gluten sensitivity sufferers. Our results suggested that 40% is the appropriate ratio to increase, at the same time, Iron and proteins contents of enriched flours as well as their overall nutritional quality. Also it was possible to produce natural composite bread at this level (40%) while maintaining adequate technological and sensory quality.

1. Introduction

Wheat remains one of the principal cereal crops in the world and ranks third in terms of production after sugarcane and maize and before rice (FAO, 2018). Starch is its principal component and accounts for 65–75% of the final dry weight of grains (Valková et al., 2019; Li et al., 2016). Thereby, wheat contributes to up to 50% of caloric intake in the Western world and up to 90% in developing countries (Wang et al., 2015); and to food security of 35% of the world population (Polat et al., 2016). Bread is one of the most ubiquitous foods and it is basic in many countries; it is mostly wheat-based. The average global consumption of bread ranges from 59 to 70 kg per year per capita (Carocho et al., 2020).

However, the malnutrition continues to represent a real threat to more than one-third of the population worldwide, of which 59 million are children from Africa (Gillespie and Van Den Bold, 2017; WHO, 2017). Indeed, nearly one billion people have chronic insufficient intake of proteins, of which 165 million children less

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than five years old were stunted (FAO, 2013). In addition, micronutrient malnutrition is one of the greatest global health challenges (WHO, 2020a); impacting more than 2 billion people globally (WHO, 2016) and at least half of the population in developing countries (Goudia and Hash, 2015). Iron deficiency is the most prevalent; with more than 1.2 billion affected individuals with anemia and probably more than double without anemia (WHO, 2020b; Camaschella, 2019), most of them reside in low- and middle-income countries (Mantadakis, 2020). In fact, Iron deficiency anemia affects negatively human health and socio-economic wellbeing of millions of people (Baltussen et al., 2004).

Nutritional status of Moroccan population is characterized by malnutrition (undernourishment or obesity), particularly among the rural households (Aboussaleh et al., 2009). The prevalence of Iron deficiency is high in Morocco (Aboussaleh et al., 2011). According to Achouri et al., (2015) study, Iron deficiency has been recognized as a serious health problem in Morocco, mainly among pregnant women, infants and young children (Chhabra et al., 2012; Dillon, 2000).

Previous studies revealed that food fortification has been adopted by food processors since the mid-twentieth century to increase nutritional value and prohibit or correct nutritional deficiencies (Boen et al., 2007); it consists of incorporating essential nutrients and micronutrients in food (Mbaeyi and Onweluzo, 2010). Legume seeds constitute a source of proteins, fibers, minerals, B-group vitamins, bioactive compounds and antioxidants (Boen et al., 2007; Augustin and Klein, 1989). Faba beans are widely cultivated and extensively grown almost all over the world (Chillo et al., 2008), and take a part of traditional diets globally in Mediterranean countries, particularly Morocco, India, China, Middle Eastern and South American countries (Luo et al., 2013; Crépon et al., 2010; Borowska et al., 2003; Hedley, 2000).

Faba bean flour might be a suitable supplement of wheat-based products to enhance their nutritional value. The high consumption of wheat flour by the Moroccan population (366 g/person/day) (Aguenaou, 2012), makes wheat flour a good choice as a fortification vehicle; bread durum wheat-based is the unchallenged food of Moroccan culture, especially adopted by rural households.

Recently, Bouhlal et al. (2019) have obtained interesting results of wheat-lentil fortified flours. Likewise, for baking purpose in order to obtain faba bean supplemented bread with good nutritional quality, mainly in terms of Iron and proteins contents, the current study was carried out. It aims to assess the adding value on nutritional and technological properties of whole durum wheat flour naturally fortified using four ratios of whole faba bean flour. Afterwards, whole durum wheat bread and composite bread selected on the basis of Iron, proteins and technological properties of flour mixtures were prepared and subjected to sensory evaluation.

2. Material and methods

2.1. Raw material

The whole durum wheat (Triticum durum) of variety ''LOUIZA'' and the whole faba bean (Vicia faba L. var. minor) of variety ''ALFIA 321'' were milled into fine flour of uniform particle size using UDY Cyclone and mini Hammer mill respectively, equipped with a 1-mm and 0.5 sieves and were used into the experiment trial. Durum wheat was substituted for four ratios of 25, 30, 35 and 40% of faba bean flour. Nutritional parameters were evaluated for each composite compared to sole flour of whole durum wheat and whole faba bean in three replications.

2.2. Evaluation of the nutritional attributes

Whole durum wheat flour (WF), whole faba bean flour (FF) and enriched flours (EF) samples were analyzed for physico-chemical composition. Moisture (MS), crude ash (CA), crude proteins (CP), crude fiber (CFb) and crude fat (CF) were measured following American Association of Cereal Chemists (AACC) approved Methods (AACC, 2000). Total carbohydrate (TC) were determined by difference, by subtracting the measured moisture, ash, proteins and fat from 100% (Arab et al., 2010; AOAC, 2005), and energy value (EV) was calculated using the Atwater conversion factors, where EV = [9 × CF (%) + 4 × CP (%) + 4 × TC (%)] (Osborne and Voogt, 1978). Mineral composition was determined on dry matter (d.m) basis through extraction from the samples by dry ashing method (Chapman and Pratt, 1982). Iron (Fe), zinc (Zn), copper (Cu), calcium (Ca) and magnesium (Mg) were measured by atomic absorption spectrophotometry (AOAC, 1990). Sodium (Na) and potassium (K) contents were estimated using flame photometry (BWB XP) (AOAC, 2005), and phosphorus (P) was measured by ammonium molybdate method (Osborne and Voogt, 1978) using spectrophotometric methods (Khalil and Manan, 1990). Total phenolic compounds (TPC) were measured spectrophotometrically according to the Folin Ciocalteu method, using gallic acid as a standard (Singleton et al., 1999) and expressed as mg gallic acid equivalents/g extract (mg GAE/g extract). Condensed tannins (CT) were measured using the modified vanillin–HCl in methanol method (Julkunen-titto, 1985) and expressed as mg catechin equivalents/g extract (mg CE/g extract). Total flavonoids (TF) were measured (Zhishen et al., 1999) and expressed as mg quercetin equivalents/g extract (mg QE/g extract), and anti-radical activity (ARA) was measured using the widely accepted method: DPPH (2, 2-diphenyl-1 picrylhydrazyl) radical-scavenging activity (Mansouri et al., 2005). Chemicals were purchased from Panreac Química (Spain, Barcelona), LobaChemie (Mumbai, India) and from Sigma-Aldrich (l'Isle d'Abeau, France).

2.3. Assessment of the technological quality

2.3.1. Color measurement

Color index was evaluated using a calibrated Minolta Color Reader CR 400 (NF ISO 11664-4, 2008). Determined parameters were L* (0 black and 100 white), a* (greenness and redness) and b* (blueness and yellowness) as defined by CIE (International Commission on Illumination), from which whiteness index (WI) was calculated according to Angioloni and Collar (2012).

$$BI = \sqrt{(100 - \left[(100 - L)^2 + a^2 + b^2\right])}$$

2.3.2. Gluten strength assessment by the SDS sedimentation test

Gluten strength was estimated using SDS Sedimentation Test according to the Moroccan Standard 08.1.217 (AACC, 1984). This test is based on reading the volume of deposit formed following a series of shaking and swelling of the fixed proteinsunder well-defined conditions, using 6.3 g of ground durum wheat flour, in a solution based on 3% Sodium Dodecyl Sulfate (SDS) and 1.3 N lactic acid in the presence of bromophenol blue.

2.4. Baking test

2.4.1. Recipe used for Moroccan bread dough preparation

The samples were baked using the straight dough method; regular bread was used as control. For each test the following ingredients were maintained constantly:

- WF – 1000 g;

- Compressed yeast – 3% reported to WF;
- Salt – 1.5% reported to WF;

2.4.2. Technological process

Ingredients were mixed in a Kenwood mixer (10–12 min/28 °C); then the dough was bulk-fermented in bowls (40–60 min/30 °C), divided into 3 equal parts (for each substitution level) and shaped into round balls. The dough was molded and covered with a damp cloth, proofed (20–30 min at 30 °C) once again and backed (30–40 min at 200–220 °C).

2.5. Consumer sensory analysis (Acceptance and preference Testing)

Composite bread and regular bread were subjected to sensory assessment for determination of consumer acceptance and preference. 100 untrained sensory panelists were randomly selected among urban and rural households who are conversant with durum wheat bread. The panelists were instructed to evaluate the quality attributes of the bread samples: texture, aroma, taste, color and overall acceptability on a nine-point Hedonic scale where 9 = Like extremely and 1 = Dislike extremely (Adeyeye, 2018).

2.6. Statistical analysis

Analysis of variance (ANOVA) was used as the statistical method to determine significant differences. The means of data were compared using Tukey's test and were expressed by mean ± standard deviation. Student's *t* test (*t* test) was then used for sensory evaluation. The statistical significance was defined as P (p-value) ≤ 0.05.

3. Results and discussion

3.1. Effect of faba bean flour addition on physico-chemical composition of enriched flours

Compared to WF, FF showed 20.3% more of MS, 40.6% more of CA, 82.3% more of CP, 129.6% more of CFb, 40.5% less of CF, 15% less of TC and 4% less of EV (Table 1). The incorporation of increasing percentage of FF in the EF progressively increased MS, CA, CP, and CFb contents. While, CF, TC and EV decreased.

It can be inferred from the results that FF are more nutritious than WF. This is a good indication, as the overall objective of this study is to overcome malnutrition. WF substitution with FF has not significantly ($p < 0.05$) increased MS, which could enhance the EF shelf life. The significant ($p < 0.05$) increase (up to 11.17%) showed in CA until 40% substitution level might be due to an increase in mineral constituents (Ezeama, 2007). Since micronutrients deficiencies are the most common worldwide, this result could be important. The significant ($p < 0.05$) increase (up to 45%) showed in CP at all substitution levels is certainly attributed to their higher presence in faba beans. Since many people have chronic insufficient intake of proteins worldwide, this improvement in CP value might be beneficial. The not significant ($p < 0.05$) increase in CFb value could be attributed to their high presence in whole durum wheat as the fiber is mainly located in the pericarp of wheat, whereas the not significant ($p < 0.05$) decrease in CF might be explained by the low differences obtained in CF between WF and FF. The significant ($p < 0.05$) decrease (up to 7.49%) in TC value could be in favor of a dietetic product intended to prevent overweight, diabetes and risk for heart disease. The significant ($p < 0.05$) decrease (up to 2.34%) showed in EV until 30% substitution level might be the result of TC decrease.

MS and CA findings nearly matched those obtained by Torbica and Miroslav (2011) for WF and by Hacıseferoğulları et al. (2003) for FF. CP values were close to Giménez et al. (2012) results for WF and close to Kanamori et al. (1982) results for FF. CFb and CF values were slightly in accordance with those found by Mohie et al. (2011) for WF and by Hacıseferoğulları et al. (2003) for FF. TC and EV were consistent with USDA (2019) findings for WF as for faba beans. Wheat-legumes mixtures have been studied in many researches. Except for CF, our results were in the same trends with Ndife et al. (2011) data, who studied the nutritional and sensory quality of functional breads produced from whole wheat and soya bean flour blends.

3.2. Effect of faba bean flour addition on mineral contents of enriched flours

Compared to WF, FF revealed 79.2%, 12.9%, 126.3%, 50.2%, 28.8%, 70.2%, 53.9% and 34.7% more of Fe, Zn, Cu, Ca, Mg, K, Na and P respectively (Table 2). With increasing the amount of FF in the EF components, Fe, Zn, Cu, Ca, Mg, K, Na and P increased.

From the obtained results, FF seem to have higher mineral composition compared to WF. Since micronutrient deficiencies have been recognized as a real health problem over the world, FF could be useful in fortifying EF with minerals. With increased level of FF into WF components, the significant ($p < 0.05$) increase (up to 47.94%) in Fe value showed until 40% suggests that substitution at this level might be adopted to develop a bakery product with a high Fe content serving to prevent Fe deficiencies. The not significant ($p < 0.05$) variation in Zn value could be due to its high presence in whole durum wheat. The significant ($p < 0.05$) increase (up to 92.72%) in Cu value showed until 35% substitution level could have added nutritive value to our final product; this might interest people having Cu deficiency. Ca is an important mineral in the human's body, it is essential for the growth and maintenance of bones and teeth. However, many people still suffering from Ca deficiency. So, the significant ($p < 0.05$) increase (up to 38.42%) in Ca concentration after FF addition on EF is an important result. The significant ($p < 0.05$) increase (up to 23.22%) in Mg value showed until 35% substitution level could be in favor of people having Mg deficiency. The significant ($p < 0.05$) increase (up to 16.96%) in K content might be useful for people suffering from K

Table 1
Physicochemical characteristics of whole durum wheat flour, whole faba bean flour and their mixtures (g.100 g^{-1} DM).

Flour ratios		Parameters						
WF	FF	MS	CA	CP	CFb	CF	TC	EV
100%	0%	9.54 ± 0.40	1.97 ± 0.08	11.40 ± 0.16	3.48 ± 0.28	1.80 ± 0.20	75.32 ± 0.81	363.00 ± 1.00
75%	25%	9.87 ± 0.63^{NS}	2.03 ± 0.08^{NS}	14.00 ± 0.10^{*}	3.60 ± 0.50^{NS}	1.40 ± 0.20^{NS}	72.70 ± 0.64^{*}	359.38 ± 3.60^{NS}
70%	30%	10.48 ± 0.12^{NS}	2.09 ± 0.02^{NS}	15.07 ± 0.45^{*}	4.20 ± 0.96^{NS}	1.33 ± 0.41^{NS}	71.03 ± 0.69^{*}	356.41 ± 2.41^{*}
65%	35%	10.50 ± 0.26^{NS}	2.11 ± 0.01^{NS}	15.77 ± 0.50^{*}	4.39 ± 0.50^{NS}	1.33 ± 0.30^{NS}	70.30 ± 0.79^{*}	356.27 ± 1.88^{*}
60%	40%	10.53 ± 0.12^{NS}	2.19 ± 0.02^{*}	16.53 ± 0.30^{*}	4.60 ± 0.74^{NS}	1.08 ± 0.07^{NS}	69.68 ± 0.26^{*}	354.49 ± 0.87^{*}
0%	100%	11.48 ± 0.40^{*}	2.77 ± 0.10^{*}	20.73 ± 0.26^{*}	8.00 ± 0.32^{*}	1.07 ± 0.30^{NS}	64.00 ± 0.24^{*}	348.38 ± 3.02^{*}

WF: whole durum wheat flour; FF: whole faba bean flour; MS: moisture; CA: crude ash; CP: crude proteins; CFb: crude fibers; CF: crude fat; TC: total carbohydrates; EV: energy value (kcal.100 g^{-1} in dry weight). NS: not significant ($p < 0.05$) and *: significant ($p < 0.05$) according to Tukey's test.

Table 2
Mineral compositionof whole durum wheat flour, whole faba bean flour and their blends (mg.100 g^{-1} DM).

Flour ratios		Parameters							
WF	FF	Fe	Zn	Cu	Ca	Mg	K	Na	P
100%	0%	3.90 ± 0.10	4.80 ± 0.28	1.10 ± 0.22	41.12 ± 2.69	141.50 ± 4.42	385.33 ± 6.11	17.33 ± 6.11	122.83 ± 2.81
75%	25%	4.60 ± 0.23^{NS}	4.89 ± 0.40^{NS}	1.44 ± 0.11^{NS}	50.15 ± 2.70*	149.41 ± 6.78^{NS}	390.67 ± 6.11^{NS}	18.67 ± 6.11^{NS}	132.90 ± 1.64*
70%	30%	5.04 ± 0.03^{NS}	4.96 ± 0.18^{NS}	1.46 ± 0.11^{NS}	52.28 ± 1.34*	151.92 ± 4.47^{NS}	424.00 ± 4.00*	20.00 ± 4.00^{NS}	138.40 ± 1.45*
65%	35%	5.10 ± 0.30^{NS}	5.07 ± 0.23^{NS}	1.57 ± 0.11*	55.40 ± 1.61*	174.27 ± 4.47*	426.67 ± 6.11*	21.33 ± 6.11^{NS}	144.67 ± 2.07*
60%	40%	5.77 ± 0.90*	5.21 ± 0.18^{NS}	2.12 ± 0.11*	56.92 ± 1.70*	174.37 ± 4.48*	450.67 ± 6.11*	24.00 ± 4.00^{NS}	150.31 ± 2.59*
0%	100%	6.99 ± 0.58*	5.42 ± 0.30^{NS}	2.49 ± 0.22*	61.76 ± 1.39*	182.26 ± 6.90*	656.00 ± 4.00*	26.67 ± 6.11^{NS}	165.40 ± 1.64*

WF: whole durum wheat flour; FF: whole faba bean flour. NS: not significant ($p < 0.05$) and *: significant ($p < 0.05$) according to Tukey's test.

disorders, which are widespread worldwide. Na variation in mixtures wasn't significant ($p < 0.05$). Given the health risks of salt, this result is favorable. The significant ($p < 0.05$) increase (up to 22.38%) in P concentration is certainly due to its higher presence in FF compared to WF.

Fe data closely matched those obtained by Hussein et al. (2018) for WF and by Khalil (2001) for FF. Zn value was different than that found by Ficco et al. (2009) for wheat and different from Udayasekhara and Deosthale (1983) finding for FF. Cu concentration was slightly close to Hussein et al. (2018) result for WF, as it matched with that obtained by Khalil (2001) for FF. Ca content was in agreement with Hussein et al. (2018) finding for WF and with Hacıseferoğulları et al. (2003) for FF. Mg value was slightly close to Rachoń et al. (2015) result for WF, as it matched with that obtained by Aranda et al. (2004) for FF. K concentration was compared to Flagella (2006) finding for WF, as it matched with Khalil (2001) finding for FF. Na value was different compared to Ficco et al. (2009) result for wheat and different than Udayasekhara and Deosthale (1983) finding for FF. P data was consistent with Hussein et al. (2018) result for WF, while it was different than Torbica and Miroslav (2011) result for FF. Macro minerals values also confirmed Petitot et al. (2010) findings. The obtained minerals values were in well line with AwadElkareem and Al-Shammari, 2015 results, who stated that the lowest values of Fe, Ca, Mg, K, Na and P contents were found in biscuit wheat flour compared to lentil flour. Compared to WF, EF data were in the same trends with Nwachukwu et al. (2017) findings, who nutritionally enriched wheat bread using various plant proteins. Indeed, minerals rate in WF genetically depends on the cultivar and are environmentally determined by soil, climate and management practices (Razzaque, 2011).

3.3. Effect of faba bean flour addition on total phenolic compounds condensed tannins, total flavonoids content and antiradical activity of enriched flours

Compared to WF, FF showed 500%, 3900%, 69.6% and 500% more of TPC, CT, TF and ARA respectively (Table 3). With raising the amount of FF in EF, TPC, CT, TF and ARA increased.

Compared to WF, FF sound to be richer in antioxidants. With FF addition to WF components, the significant ($p < 0.05$) increases seen in TPC (up to 137.26%), CT (up to 56%), TF (up to 1666.67%) and ARA (up to 42.76%) are certainly due to the high antioxidant activity of polyphenols, which consumption decreases the risk to have degenerative diseases resulting from oxidative stress (D'Archivio et al., 2007). They also aid to prevent ulcer, diabetes, cancer and osteoporosis (Scalbert et al., 2005; Shi et al., 2005). In fact, polyphenols content reveals a vast variability in several legumes and depends on the source of legume seeds and the region of cultivation (Amarowicz and Pegg, 2008). As they are influenced by growing stage and genetic factors Boukhanouf et al., 2016; Abu-Reidah et al., 2014; Chaieb et al., 2011; Oomah et al., 2011; Yao et al., 2011; Kaufman et al., 2007).

TPC data nearly matched those obtained by Biney and Beta (2014) for WF and by Valente et al. (2019) and Boudjou et al. (2013) for FF extracts. TF, CT and ARA values were in well line with those obtained by Hamli et al. (2017) for WF and by Boudjou et al. (2013) for FF. Generally, TPC and ARA results were in the same trends with Anton et al. (2008) findings, who studied the influence of added bean flour on some physical and nutritional properties of wheat flour tortillas.

3.4. Effect of faba bean flour addition on color properties of enriched flours

Color is an important quality trait of durum wheat flour and products, which measurement interest is generally commercial. WF showed higher yellowness (b*), lightness (L*) and whiteness index (WI*) compared to FF. While higher redness (a*) was recorded for FF (Table 4). Thus, with increasing concentration of FF, b*, L* and WI* values progressively decreased, while a* increased.

The low increase in a* could be attributed to the predominance of pigment in whole faba bean hulls compared to whole durum wheat bran. The slight decrease in b* is certainly due to carotenoids reduction. While, the significant ($p < 0.05$) decreases seen in L* and WI* might be related to the increase in proteins content,

Table 3
Antiradical-activity (% DW), total phenolic compounds (mg GAE/g DW), condensed tannins (mg CE/g DW) and total flavonoids (mg QE/g DW) compositionof whole durum wheat flour, whole faba bean flour and their blends.

Flour ratios		Parameters			
WF	FF	TPC	CT	TF	ARA
100%	0%	0.51 ± 0.01	2.50 ± 0.02	0.03 ± 0.00	28.30 ± 0.50
75%	25%	0.94 ± 0.01*	2.70 ± 0.03*	0.37 ± 0.02*	33.68 ± 1.22*
70%	30%	1.17 ± 0.01*	3.01 ± 0.11*	0.42 ± 0.01*	35.62 ± 0.43*
65%	35%	1.19 ± 0.01*	3.58 ± 0.07*	0.48 ± 0.00*	37.54 ± 0.66*
60%	40%	1.21 ± 0.01*	3.90 ± 0.06*	0.53 ± 0.01*	40.40 ± 0.84*
0%	100%	3.06 ± 0.00*	4.24 ± 0.10*	1.20 ± 0.02*	63.50 ± 1.96*

WF: whole durum wheat flour; FF: whole faba bean flour; TPC: total phenolic compounds; CT: condensed tannins; TF: total flavonoids; ARA: antiradical-activity. NS: not significant ($p < 0.05$) and *: significant ($p < 0.05$) according to Tukey's test. Solvent used to prepare extracts: acetone/water.

Table 4
Color characteristics of whole durum wheat flour, whole faba bean flour and their blends.

Flour ratios		Parameters			
WF	FF	a*	b*	L*	WI*
100%	0%	−1.42 ± 0.01	16.50 ± 0.01	68.78 ± 0.35	64.66 ± 0.31
75%	25%	−1.36 ± 0.01^{NS}	16.46 ± 0.02^{NS}	63.38 ± 0.03*	59.82 ± 0.03*
70%	30%	−1.34 ± 0.01^{NS}	16.40 ± 0.01^{NS}	62.52 ± 0.41*	59.08 ± 0.38*
65%	35%	−1.34 ± 0.02^{NS}	16.37 ± 0.01^{NS}	60.03 ± 0.95*	56.80 ± 0.89*
60%	40%	−1.33 ± 0.03^{NS}	16.35 ± 0.03^{NS}	58.02 ± 0.68*	54.93 ± 0.61*
0%	100%	−0.22 ± 0.08*	15.14 ± 0.14*	46.48 ± 0.12*	44.38 ± 0.16*

WF: whole durum wheat flour; FF: whole faba bean flour; a*: redness; b*: yellowness; L*: lightness; WI*: whiteness index. NS: not significant ($p < 0.05$) and *: significant ($p < 0.05$) according to Tukey's test.

as it could be due to the dark color resulting from FF hulls presence. Moreover, L* is mostly phenotypic thus it is influenced by environmental conditions.

3.5. Effect of faba bean flour addition on gluten strength of enriched flours

The gluten is an important component of WF that provides texture and strength to baked wheat products, so the gluten content affects directly the quality of wheat flour (Kaushik and Kumar, 2015). The sedimentation test is used as an indicator for gluten strength estimation (Feillet, 2000). It can be observed from the Fig. 1 that the sedimentation test values ranged from zero for FF to 61.40 (ml) for WF. So, the gluten strength of EF decreased as the incorporation ratio increased.

The significant ($p < 0.05$) decrease of gluten strength is mainly due to gluten reduction; this reduction was resulted from the fortification of wheat gluten proteins by those of FF. In fact, a higher gluten strength index shows good quality (Feillet, 2000). However, if we consider the quality classes in durum wheat based on corrected SDS values that was proposed by Cubadda et al. (2007) for screening purposes for rapid quality evaluation in the durum wheat industry, we can say that our 100% WF definitely belongs to "excellent" gluten class, EF at 25, 30 and 35% substitution levels span from "good to very good" gluten class, EF at 40% substitution level is in "the average or above average" gluten class, while 100% FF definitely belongs to "the inadequate" gluten class. Thereby, EF at 40% substitution level could result in composite durum wheat-faba bean bread with acceptable sensory quality for consumer.

3.6. Consumer sensory analysis (Acceptance and preference Testing)

In consumer sensory analysis the investigator is interested in whether the consumer likes the product, prefers it over another product, or finds the product acceptable based on its sensory characteristics (Lawless and Heymann, 1999). Regular bread and composite bread were prepared and compared on the sensory level; the results (Fig. 2) showed that composite bread from 40% FF and 60% WF was generally accepted by all consumers. With respect to consumer preference, regular bread texture, taste and color scores (8.11 ± 0.72, 8.13 ± 0.84 and 8.00 ± 0.90 respectively) were higher compared to those recorded for composite bread (7.55 ± 0.99, 7.91 ± 0.87 and 7.80 ± 0.88 respectively). While the higher score (8.15 ± 0.79) of aroma was obtained for composite bread compared to 7.92 ± 1.07 for regular bread. None of the consumers identified the presence of FF as an ingredient in composite bread; before tasting, many consumers have assumed the presence of cacao in composite bread due to its dark color, whereas after tasting many types of grains (barley…) were guessed. Urban consumers commented that composite bread could be eaten as a breakfast and snack. While consumers from rural area commented "bread shape does not matter, if it is more nutritious", and most consumers indicated that composite bread leads to satiety.

The significant higher score showed for regular bread texture compared to the composite one (Fig. 3) is certainly due to its higher content in gluten, which provides texture to various wheat-based products. This result justifies 100% WF belonging to "excellent" gluten class and EF at 40% substitution level belonging to "the average or above average" gluten class. The observed gluten decrease might be in favor of gluten sensitivity sufferers. The not significant variations in taste, color and aroma scores could be considered as an indicator of the acceptability of composite product in terms of these attributes. The slight preference of composite bread aroma might encourage the consumption of this product. The darker color showed for composite bread could be a result of Maillard and caramelization; amino acids and sugars are involved in this type of reaction giving the property of brown color, crispy texture and rich flavor (Protonotariou et al., 2020; Duodu and Minnaar, 2011). The feeling of fullness might be due to the higher fibers content of composite bread which could be in favor of developing countries from an economic point of view, since small slice from composite bread might be, at the same time, nutritive and sufficient. The obtained feeling of satiety could also interest gluten sensitivity sufferers; this property might reduce their bread consumption. Except for aroma, our results were in the same trends with Seleem and Omran (2014) findings, who evaluated the quality of one layer flat bread supplemented with beans and sorghum baked on hot metal surface.

As a food-based approach, the technique used in this study has a number of advantages compared to chemical fortification. Indeed, several chemical fortificants were used, such as sodium Iron ethylenediaminetetraacetate (NaFeEDTA), ferrous sulfate, ferrous fumarate, ferrous bisglycinate, electrolytic Iron, and ferric orthophosphate. Taking NaFeEDTA as an example, which is a chemical Iron fortificant of foods. NaFeEDTA is well suited for fortifying cereals, legumes and other crops. However, this compound still remains not affordable due to many constraints; these include

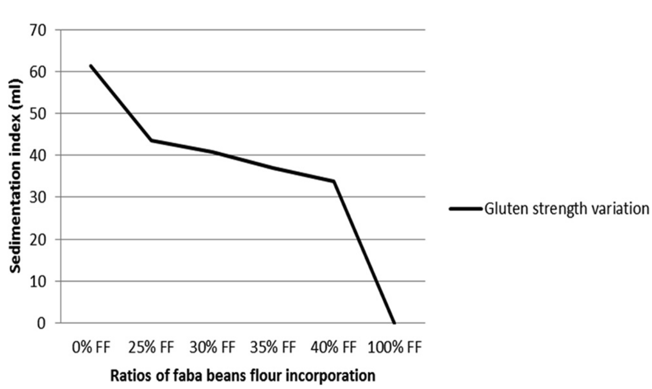

Fig. 1. Gluten strength variation of whole durum wheat flour, whole faba bean flour and their blends.

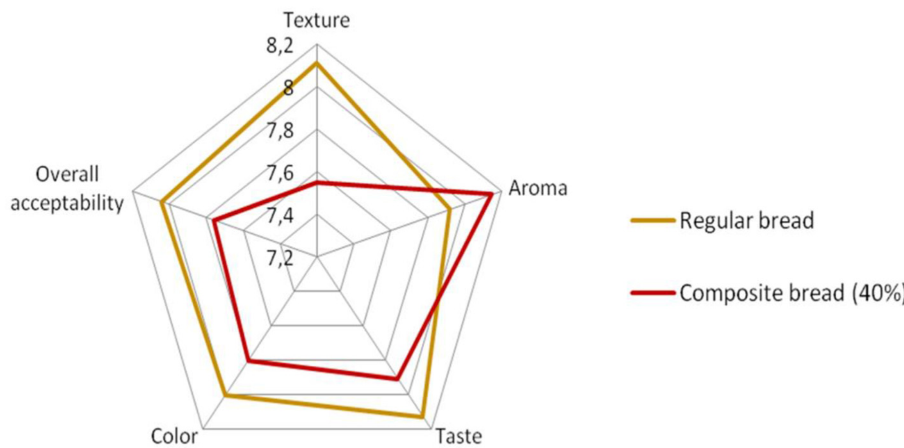

Fig. 2. Consumer sensory analysis - A comparison between whole durum wheat flour and enriched flour at 40% substitution level.

Fig. 3. A photo showing the pieces texture of regular bread (in the right side) and composite bread at 40% ratio (in the left side).

its distribution problems, regulatory issues and relatively high cost for developing countries since they are the most affected by Iron deficiency. Our method is characterized by the fact to be natural and feasible even outside the laboratory, moreover it permits fortifying food with several nutrients and micronutrients simultaneously.

4. Conclusion

Our results suggested that 40% is the appropriate ratio to increase, at the same time, Iron and proteins contents of enriched flours as well as their overall nutritional quality. Moreover, it was possible to prepare natural composite bread at this level (40%) while preserving technological quality and suitable sensory attributes. Our future research concerns physical and nutritional evaluation of the selected composite bread. Also, functional properties of the flour mixtures will be assessed to study the possibility of preparing another type of nutritionally improved products. Efforts to fortify food using natural methods to fight malnutrition are recommended. They must be encouraged in each country to meet both the physiological and economical goals of millions of people worldwide, mainly in developing countries. Indeed, malnutrition could have dramatic effects on human health since it affects the function and recovery of every organ system. For instance, nowadays cognitive and emotional dysfunctions in turn pose an increasing burden in our society. Previous studies have indicated the importance of our diet in cognitive protection; a diet poor in minerals such as Iron and in vitamins such as folic acid has been associated to cognitive functions. Fortification with legumes as a good source of nutrients and micronutrients could be useful to prevent such health issues. Thus, more researches are needed in this regard and clinical trials should be conducted.

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