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Rheological Properties of Soft Wheat Flour and Sensory Characteristics of Bread Added with Bean Flour (*Vicia faba*. L)

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ABSTRACT

Background: Given the eating habits prevailing in our society, the bread is considered one of the most important commodity of the Arab family, who can you be indispensable because of its particular position on the table and where it is the most important energy source and cheaper than other sources, it is understood that the quality of bread depends primarily on the quality of the flour used and from one year to another are obtained in poor flour, less tenacious, with tolerances of gaps in fermentation and often less elasticity. It is in this light that is this work which aims to assess the ability of flour produced from bean flour (*Vcia faba*. L) as improving in food formulations, the rheological and organoleptic properties including bread.

Methods: The chemical composition of the breadmaking flours incorporated in the broad bean flour as well as the technological and functional properties (wet and dry gluten (WG and DG), hydration capacity (HC), Zeleny index, Alveographic measurements W, G, P, L and the P/L ratio) and even the sensory analyzes were determined.

Result: Addition of bean flour particularly flours with 2 and 3% of beans has an improving effect in a bread formulation. It promotes fermentation and the crust color when cooked.

Key words: Bean flour, Bread making, Chemical composition, Enriched bread, Rheological properties.

INTRODUCTION

Wide cultivation and spread of faba bean (*Vicia faba* L.) in the temperate and the subtropical regions has ranked it fourth most important legume crop in the world, next to dry beans, dry peas and chickpea. The crop contributes to human nutrition as a result of its high protein content and other essential nutrients. In Algeria broad beans and chickpeas are the most cultivated dry legumes widely consumed and are almost present in all traditional dishes. Various traditional oriental foods are prepared using bean floor slurry, both at household and industrial levels (Abou-Khater *et al.* (2022). The nutritional value of faba bean has always been traditionally attributed to its high protein content, which ranges from (27-34%) Multari *et al*. (2015) depend on genotypes. Most of these proteins comprise of globulins (79%), albumins (7%) and glutelins (6%) (Hossain and Mortuza, 2006). Legume seeds contain several comparatively minor proteins including trypsin inhibitors, lectins, lipoxygenase and urease, which are relevant to the nutritional quality of the seed. Although till recently consumers have neglected legumes, currently they are becoming increasingly health mindful. Bread fortification is one of the most successful strategies to mitigate nutrition deficiencies in developing countries (Ouazib, 2015). Legumes combined with cereals constitute one of the worldwide staple commodities. Combination of cereal and legumes is effective and interesting; both have limiting essential amino acids that human body is not able to synthesize and it is needed to get them from food intake. Legumes are limited in methionine essential amino acid and rich in lysine, while cereals are lysine limiting amino acid. In fact, several studies have focused on the influence of the addition of legume flours on the functional properties of doughs and final baked products quality (Hossain and Mortuza, 2006). In addition, some attentions have been paid to the effect of different types of pulses added to wheat flour to obtain baked goods and processed bread.

Nevertheless, there is no information about the effect of diverse processed bean flours on wheat flour replacement for breadmaking. Since bean is considered as an ideal complement to cereals in a healthy diet, it is taken into concern the possibility of replacing cereal-based products by the substitution of bean flour to reduce the dependence of some countries on wheat importations (Ouazib *et al.*, 2016).

Taking into account the nutritional properties of legumes, it has been proposed the application of bean flour as a functional ingredient in some gluten-free bakery products such as breads, cakes and snacks (Han *et al*. 2010; Miñarro *et al*., 2012; Aguilar *et al*., 2015). Broad bean (*Vicia faba* L.)

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is a legume belonging to the Papilionaceae family. The Middle East (especially Egypt) and the western regions are major consumers (Marchetti *et al.* (2012). The use of bean flour in gluten-free formulas is based only on nutritional supplementation but also on the improvement of their technological and sensory characteristics (Witczak *et al*. 2010). Broad bean flour consists of 27 to 31% protein, 2% lipids, 48.9 to 52% total carbohydrates, 4 to 5% minerals and 10% fiber. Compared to cereals, the broad bean is characterized by a greater quantity of protein of different quality than that of cereals, hence its role in nutritional supplementation (Baljeet *et al*. 2014; Rachwa-Rosiak *et al*. 2015; FAO, 2016).

The present work was undertaken to better understand the effects of substitution of wheat flour with bean flour at six levels 1, 2, 3, 5, 7 and 10% on physical, chemical and sensorial parameters of final bread.

MATERIALS AND METHODS

This work was carried out in the "Laboratory of Natural and Life Sciences of the University of Mascara (Alegria) and the laboratory of the industrial and commercial complex (Mascara Mills). This work lasted 3 months.

Wheat flour

Soft wheat flour was intended for the manufacture of bakery dough from the regional enterprise of cereal and derived food industries of Mascara (in the West of Algeria) with a rate of 75% extraction (type 55) packaged in 1 kg paper bags. The flour was stored in the refrigerator at 4°C throughout the working period.

Grinding grains and preparing bean flour

Vicia faba L. Seville type bean seeds were harvested from the Mascara region in Aout 2020 in the form of beans packaged in 1 kg bags. The beans were brown and almost ovoid in shape, have an average length of 2.5 cm and an average width of 2 cm. The bean seeds were ground using a grinder. The shredded grain was sieved manually using a sieve 200 µm in diameter. Sieving was used to obtain flour with a particle size that meets the requirements of bread-making (diameter < 212 µm). After this operation, the bean flour was then stored in synthetic fiber bags in a cool, dry place. The salt was fine iodized in the form of small pure white crystals (average size±800 µm), obtained by recrystallization after evaporation under vacuum at high temperature. The salt was purchased commercially, it was produced National Salt Company) with 1 kg of the same batch. The water used in this work was laboratory tap water with a pH of 6.9±0.01. The dry yeast used was an instant yeast, *Saccharomyces cerevisiae* produced and distributed by Sarl VITA FERM F (Turkey) in the form of small dry granules of uniform sizes, brown in color with a characteristic odor of yeast. It was vacuum packed in order to guarantee the stability of the product at room temperature in packs of 500 g. After opening, the yeast was stored in an airtight container in the refrigerator at 4°C throughout the study period.

Physicochemical characterization of broad bean flour

Table 1 shows physicochemical and compositional of broad bean flour, as expected, the addition of bean four affected the composition of flour. The addition of high amounts of bean flour decreases humidity content, compared with the control bread wheat flour. Water activity is related to bean flour quality because it is highly related to the firming process in starch-based products.

The ash content was determined according to standard NA 732/1990, which was in perfect technical agreement with standard NF V 03.760 (Bouhadi *et al*. 2020) by weighing the residue obtained after incineration of a test portion in an atmosphere oxidizing at a temperature of 900°C until complete combustion of the organic matter which was estimated by simple difference with the ash content.

Fatty acidity was the conventional expression for acids, essentially free fatty acids. It was expressed in grams of sulfuric acid per 100 g of dry matter. Weigh and introduce approximately 5±0.01 g of flour into the centrifuge tube. To a test sample of 5±0.01 g of flour, introduce into the centrifuge tube. It was added 30 ml of 95% ethanol and the tube was closed tightly, for one hour using the stirrer mechanical rotary, operating at a temperature of 20±5°C. Then centrifuge twice and successively for 2 min. Let stand 24 hours. Pipette 20 ml of the perfectly clear supernatant and pour into a conical flask. 5 drops of phenolphthalein were added and the mixture was titrated with NaOH 0.05 N (Mustapha *et al*., 2015; Delfrate *et al.*, 2005). Acidity was expressed in grams of sulfuric acid per 100 g of fresh material (A):

$$A\ (\%) = (7.35 \times (V1-V0)/m) \times T$$

Acidity expressed in grams of sulfuric acid per 100 g of dry matter (A):

$$A\ (\%) = (7.35 \times (V1-V0) \times T/m)\ T) \times (100/100-H)$$

V1: Volume in ml of NaOH used for the sample.
V0: Volume in ml of NaOH used for the control test.
m: Mass in grams of the sample.
T: Concentration of NaOH (0.05).
H: Water content of the flour in percentage.

Technological analysis

Three rheological analyzes were carried out during this study. Wet gluten was made by preparing a dough using a sample of flour and a solution of sodium chloride and isolating the wet gluten by washing this dough with the sodium chloride solution, then draining and weighing the product obtained (NA 735.1991, ISO 55 31). Then, it was dried in an oven for 15 hours at 130°C, given dry gluten (NA, 736.1991, ISO 6646).

Zeleny test was performed according to ICC standards n° 116/1 and 118. It was obtained by measuring the height of the deposit obtained after stirring and sedimentation of a flour preparation in a reagent (lactic acid and bromophenol blue) (Hetty, 2011; ISO, 2007). The results were expressed according to the following values:

- Less than 18 ml: insufficient.
- From 18 to 28 ml: Good baking strength.
- From 28 to 38 ml: Very good baking strength.

Chopin alveograph test was performed according to ISO 5530-4: 2002 standard. The principle of the method was based on the swelling of a sample of dough subjected to air pressure. The volume of the bubble depended on the extensibility of the dough. The evolution of the pressure in the bubble was measured and reported in the form of a curve called Alveogram (Hetty, 2011). The alveograph helped to study the tenacity (P), the extensibility (L), the swelling (W) and the balance between the tenacity and the extensibility (P/L) of the dough.

Sensory analysis

Once production was complete, a hedonic test was performed for the six blends. It focused on consumer preferences and aimed to compare the overall hedonic appreciation of different bread by focusing on individual feelings related to the pleasure or displeasure caused by the food. Slices of bread were presented on coded dishes and served in random order under normal lighting conditions and at room temperature (Stone and Sidel, 2004). The sensory evaluation was carried out one hour after removal from the oven by the tasters. The tasters were invited to note their appreciation of the different products (external aspect of the bread and aspect of the crumb) using tasting sheets (scale defined according to a structured scale corresponding to the criteria tested). The number of subjects (tasters) recommended by AFNOR standards (NF V09500 December 2012) for this type of test was 60 consumers (Thomas, 2016).

Statistical analysis

The results were expressed by the mean ± the standard deviation. The results were the subject of an analysis of variance (ANOVA), followed by a multiple comparison of the means using Statistica software. Differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

Physicochemical and biochemical analyzes

The water content of wheat flour was very important, in order to stabilize storage conditions and marketing. Several authors have considered that the determination of the water content was important for the precision of the various analytical results related to the dry matter and for the implementation of the technological tests of breadmaking. The moisture of different flours decreased after the incorporation of bean powder (Table 1). The decrease in flour humidity as the incorporation rate increases was explained by the low humidity rate of 10% bean flour and by the particular nature of the powder. In general, bakery flours have a water content of 13 to 15%. The average water content of samples was considered to be within standards. The ash content was the official parameter to characterize the purity of bakery flours. The determination of flour ash offered the possibility of knowing the total mineral content of wheat and its derivatives. According to Table 1, the ash content of different flours increased after the addition of bean powder from 0.60% (control) to 0.98% for the BF10% sample. This can be explained by the richness in mineral and cellulosic elements that come from the bean flour. The percentage of acidity was 0.03±0.01%. This acidity does not exceed the limit content µ= 0.05%; beyond that, the quality of gluten was altered (Joye, 2009). The five samples of flour prepared plus the control did not undergo sudden degradation of its fat, proof of its freshness and its good preservation. Concerning the gluten rate, it was observed a decrease in wet gluten for the six samples, in particular for the flour added with 10% of BF. The values were from 28% to 22.85% for wet gluten and from 9.33% to 7.61% for dry gluten and consequently there were a stability of the hydration capacity (Fig 1). However, these values remained within the standards for dry gluten (DG) of breadmaking flour (7 to 12%). The increase in bean powder incorporation rates varied inversely with the quality and quantity of gluten. This was explained by the low gluten content of bean flour. The hydration coefficient (HC) or calculated hydration capacity averaged 66.6±0.01% for all samples. This hydration rate, comparable to that of gluten in normal flour, which was around 66%. It depended on the quality of wheat and can reach 69% in some cases. The hydration capacity of gluten was involved in the absorption of water during kneading in bakery. According to the results mentioned in Table 2, it seemed that the seven samples were classified among the flours of good baking strength and this according to the notation which showed the relationship between this index and the baking strength. The Zeleny index, which depended on the quantity and quality of gluten (main factors of baking strength) decreased as a function of the rate of incorporation of the bean flour, more the rate of incorporation increased, more the index of Zeleny decreased.

Rheological properties of pastes by the chopin alveograph

The characterization of adough by the Chopin alveograph was an indication of its rheological behavior during its development.

Table 1: Chemical characterization of wheat flour incorporated at different bean flour levels.

Baking properties	Rate						
	C	BF1%	BF2%	BF3%	BF5%	BF7%	BF10%
Humidity %	16.5±0.99	13.8±0.84	13.7±1.10	13.7±0.87	13.4±0.59	13.2±1.05	13.1±0.83
Total ashes %	0.60±0.16	0.61±0.28	0.63±0.31	0.67±0.19	0.77±0.59	0.87±0.56	0.98±0.61
Acidity	0.03±0.01	0.03±0.01	0.04±0.01	0.03±0.02	0.03±0.02	0.04±0.01	0.04±0.03

P/L: Curve configuration ratio of tenacity and extensibility

The configuration ratio P/L is the ratio between the maximum overpressure and the length of the curve. High P/L indicates resistant and inextensible dough, while low P/L indicates weak and extensible dough. The value is dimensionless.The control formed dough represented a configuration ratio of 1.81 (Table 2). This ratio was significantly higher than the Italian cereal trade association for a flour superior bread-making (0.8 - 1.2). The configuration ratio was characterized by an irregularity from 2 to 1.14 at the rates of 1 to 3% and from 1.66 to 2.27 at the rates of 5% to 10% of BF, against 3.03 for the control. Flours that have a P/L ratio >1 will give doughs that were too tenacious, not very tolerant to kneading, showing a tendency to absorb a lot of water, as well as low swelling. Against doughs that were too stretchy and difficult to handle for low tenacity and the extensibility ratios < 0.3.

Swelling index (SI)

The swelling index (SI), also known as swelling capacity (SC), Swelling capacity (index) is considered a quality measure in some food products such as bakery products. It is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the ±-amylose and amylopectin ratios Iwe *et al*. (2016). The swelling capacity (index) of flours are influenced by the particle size, species variety and method of processing or unit operations. The values of the swelling indices recorded were lower than those indicated by the Algerian breadmaking standards (>20 cm³). According to Table 2, it can be seen that the swelling index decreased as the rate of incorporation of the bean flour increased, in particular at the rate of 10%.

Strain work (W)

Baking strength is a key parameter for dough analysis; it's the famous "W" of the Alveograph test result chart. Over the years, the "W" has established itself as one of the most widely used measurements internationally. The control soft wheat flour has a work of deformation of 205, higher compared to the Algerian bread-making requirements. According to Table 2, only the work of deformation of different flours characterized by an irregularity after the addition of the bean powder but still within the standards which classified them as flours of good baking strength according to the 2006 company standards (W between 200 and 250 ×10-4 joule).

Organoleptic analyzes

Results on the organoleptic Analyzes (external appearance and interior appearance) of bread containing 1, 2, 3, 5, 7 and 10% bean flours are shown in (Fig 2,3 and 4).

The analysis of variance (ANOVA) between the rheological parameters (P/L, W, G),_technological (specific volume) and textural shows that there is a significant difference (p<0.0001) between the qualities of our pasta**.**

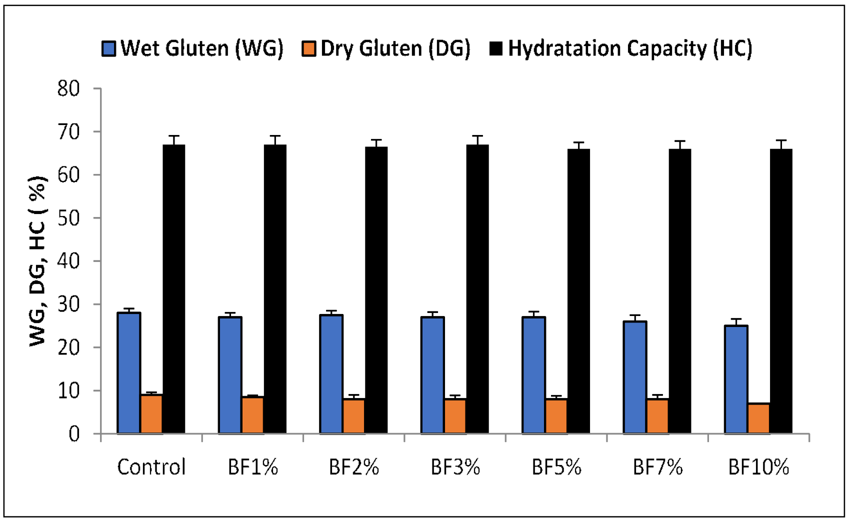

Fig 1: Evolution of wet gluten, dry gluten and hydration capacity according to bean powder incorporation rates.

Table 2. Rheological characteristics of different flours after incorporating bean powder.

Baking properties		Rate						
		C	BF1%	BF2%	BF3%	BF5%	BF7%	BF10%
Alveographic measure	W (ergs)	205	155	125	155	125	155	125
	SI (cm³)	15.25	14.07	12.82	16.25	14.04	14.74	12.96
	P (mm)	.	83.05	84.07	61.81	67.26	81.18	79.2
	L (mm)	.	40.5	34	54.24	40.8	44.60	34.8
	(P/L)	1.81	2	2.49	1.14	1.66	1.82	2.27

Color in baked goods could come from different sources: intrinsic color imparted by individual ingredients, developed color resulting from the interaction of ingredients, like Maillard or caramelization reactions, besides processing changes associated to chemical or enzymatic reactions (Singh *et al.*, 2011). The incorporation of bean flour affects the color properties of breads, inducing a reduction in the whiteness in the breads, especially for the 7 and 10% which had the darkest crumb.

This might be due to the chemical browning reactions during toasting (Stone and Sidel, 2004). It has been reported that the addition of legume flours to baked products led to darker crumbs in some legume based products (Shin *et al.,* 2013). Similar results have been reported when partial substitution of wheat flour was carried out with different levels (up to 30%) of raw chickpea flour (Sakr *et al.*, 2007). The color of crust and crumb got progressively darker as the level of bean flour substitution increased. The color was not affected when the wheat flour was substituted with 1, 2 an 3% of bean flour. This improvement can be explained by a good development of the gluten network and the presence of protein substances and other substances that can give a positive change in the color of bread and browning reactions.

For the other parameters of the interior aspect, the textural properties of breads were highly significantly

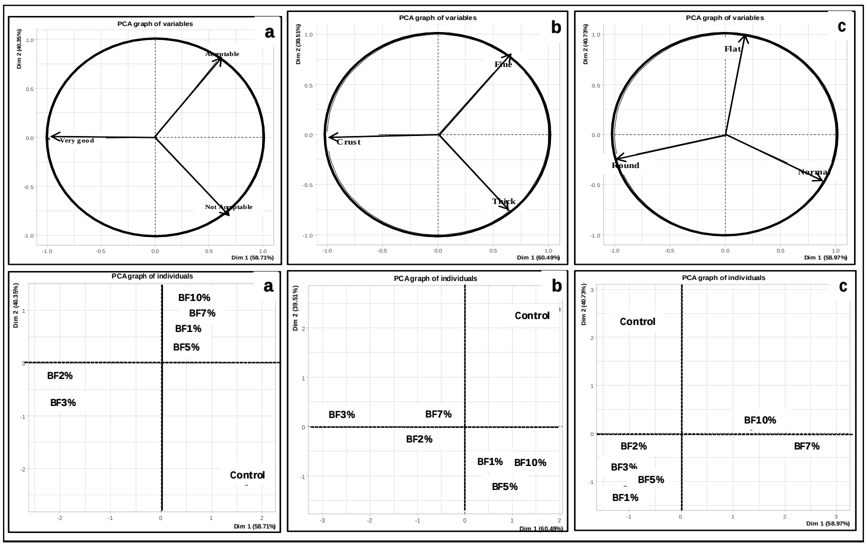

Fig 2: Biplot representation of the external appearance of unsold items and variables. a) the crust color, b) the crust fineness, c) the shape of the section.

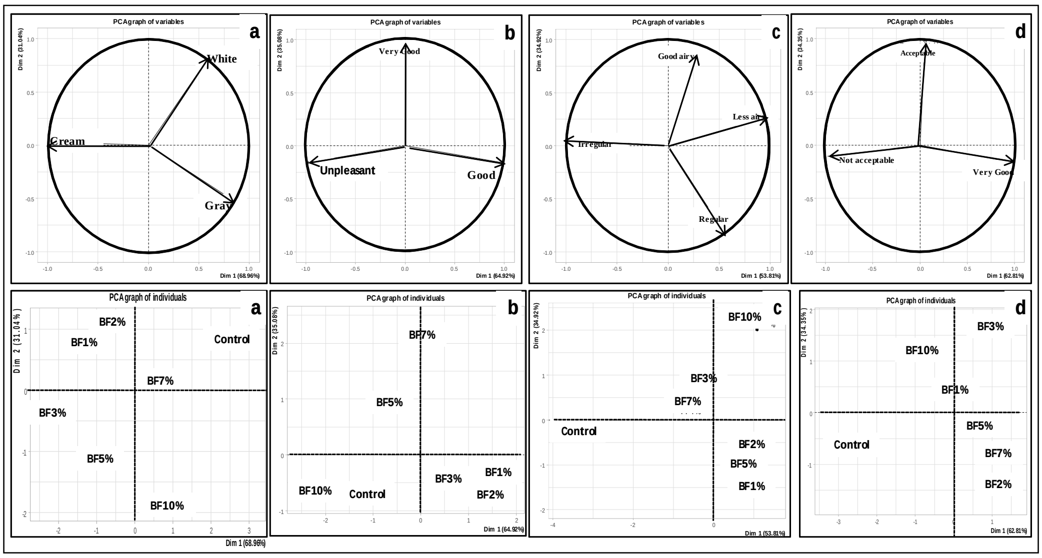

Fig 3: Biplot representation of unsold items and interior appearance variables. (a) crumb color, b) crumb odor, c) crumb texture, d) chewiness.

dependent on the type of flour and level of substitution. All the texture parameters tested were statistically ($P<0.05$) affected by the level of substitution. Breads at 7 and % level of substitution had higher hardness and chewiness and less springiness. This can be explained by the richness of the bean flour of proteins and formation of networks which improved the texture during the fermentation of bread by retaining more CO_2.

From the examination of axis variable correlations, it was found that the qualities of the variables are globally well represented in the C1 × C2 plane. The texture, the fineness and the shape of section were moderately

Fig 4: Photographs of dough with bean flour.

Fig 5: The appearance of slices of bread is added with bean flour.

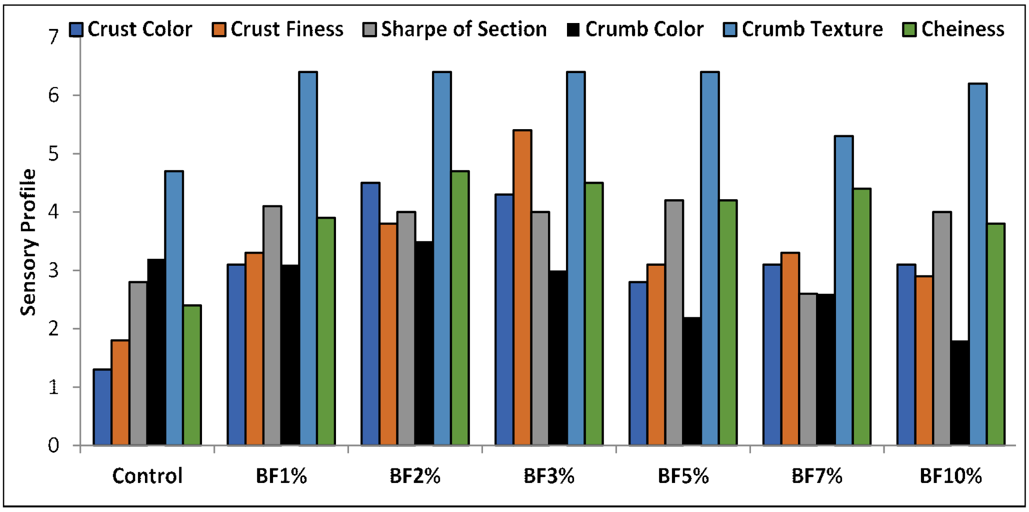

Fig 6: Sensory profile of bread as a cobweb graph.

represented by the plan. The other variables, the primer were very well represented by the plane C1 × C2.

Photographs of breads made with different processed bean flour are shown in (Fig 5). Cross-section of bread slices displayed open and aerated crumb structure, which had even bigger gas cells than the wheat bread.

In general, bread added with bean flour gave sensory acceptable breads and met sensory standards receiving approval by judges (Fig 6). In terms of appearance the panel considered that BF3% had the best appearance comparing with other breads and control wheat bread. Concerning flavor, breads containing BF2% flour were highly appreciated due to cooking liberated some volatile compounds making the bread smell good.

CONCLUSION

The study showed that the dough's characteristics improved after the bean flour's incorporation. The results of the rheological characteristics (P/L, G and W) of the dough studied allow us to deduce the following classification starting from the best quality paste. Overall, it can be concluded that bean flour was a dough improver that also gave a nice color to the bread crust and promoted the fermentation and preservation of bread. The best bread was the one obtained with 2 and 3% bean flour.

In perspective, the various results obtained are encouraging and promising for industrial and artisanal exploitation. Thus, the production of breads enriched with bean powder for the benefit of consumers can become a reality. Our tests deserve to be continued and deepened: Refining the estimation of molecular dissociation by spectroscopic methods such as infrared spectrometry, with a view to assessing the quality of the interactions actually affected and explaining certain phenomena observed. The generalization of the application of our method for the various other types of cereal pasta (biscuits, pastries, *etc*.).

Conflict of interest: None.

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