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ORIGINAL ARTICLE

Germinated, toasted and cooked chickpea as ingredients for breadmaking

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Abstract The effect of processing (germination, toasting and cooking) of chickpea beans was investigated on the resulting flours characteristics and their potential for obtaining gluten free breads. Rheological properties of dough were recorded using Mixolab® and breads were analyzed for their instrumental quality, nutritional and sensory properties. Chickpea based doughs showed low consistency and their rheological behavior was defined by the starch gelatinization and gelification. The bread made with cooked chickpea flour exhibited the lowest specific volume (0.58 mL/g), brightest crumb ($L^* = 76.20$) and the softest texture, but cooking decreased the content of carbohydrates, ash and protein, although increased the protein digestibility. The highest specific volume was obtained in bread made with toasted chickpea flour, although crumb hardness was higher. Overall, processing of chickpea beans, concretely toasting and cooking led to flours that could be used for obtaining gluten free breads with the nutritional characteristics of the legumes and acceptable sensory characteristics.

Keywords Chickpea · Processing · Mixolab · Gluten free bread · In vitro protein digestibility · Chemical composition

Introduction

Legumes (pea, lentils, beans, soybean and chickpea) are one of the most important crops owing to their nutritional quality. Legume seeds and flours are important sources of protein, carbohydrates, vitamins, minerals and dietary fibre (Almeida Costa et al. 2006; Baljeet et al. 2014; Rachwa-Rosiak et al. 2015). Legumes are usually consumed as cooked meal form or in the dry seed form after toasting as snack food (Rachwa-Rosiak et al. 2015). In addition, legumes are also used as nutritional additives or for replacing part of the wheat flour in baked products due to its chemical composition (de la Hera et al. 2012; Petitot et al. 2010).

Chickpea (*Cicer arietinum L.*) is the third important legume of the world on the basis of total production after soybean and bean, which is mainly grown in the hot climates of India, Pakistan, Iran, Ethiopia, Mexico, and the Mediterranean area (FAO 2013). Chickpea is a protein (19–29 g/100 g) and carbohydrates (60–65 g/100 g) rich legume (Boye et al. 2010) and it is a source of B complex vitamins and minerals (Seena and Sridhar 2005). These nutritional properties can be even improved using processing methods like germination, cooking or toasted that increase the protein digestibility (Almeida Costa et al. 2006; Xu et al. 2014).

Taking advantage of chickpea nutritional properties, it has been proposed the application of chickpea flour as functional ingredient in some bakery gluten free foods such as breads, cakes and snacks. In fact, Han et al. (2010) developed 100 % chickpea-based cracker snacks, which fulfilled consumer demands providing health benefits. Gluten free breads have been produced with chickpea flour with acceptable loaf specific volume and good sensory acceptance (Aguilar et al. 2015; Miñarro et al. 2012). Even

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cakes have been developed by Gularte et al. (2012), who studied the influence of incorporation of different pulses like chickpea on gluten free cakes (rice flour/legume flour, 50:50), which resulted with higher total protein, available proteins, minerals and fat. However the complete substitution of wheat flour by 100 % of chickpea flour is difficult to achieve in bakery products especially in bread where the gluten is responsible of its texture quality.

Despite that processing methods have been applied to improve nutritional properties of chickpea beans, scarce information exits about the use of the resulting flours for producing bakery products. The objective of this study was to investigate the impact of processing treatments (germination, toasting, cooking) on rheological properties of chickpea flours using Mixolab, as well as to study the effect of replacing the wheat flour by 100 % of raw and treated (germinated, toasted and cooked) chickpea flour on quality, nutritional and sensory properties of final breads.

Materials and methods

Material

Chickpea was grown in winter 2013 and harvested in June 2013, in the region of Merj-Ouamane, commune of Amizour, wilaya of Bejaia; Algeria. Wheat flour was supplied by Harinera La Meta, (Lleida,Spain), dry baker's yeast (Lesaffre, France) and salt were purchased from the local market. Freshbake improver Hydroxypropylmethyl cellulose K4 M (HPMC K4 M) was from Dow Chemical, USA.

Methods

Preparation of legume's flour

Four types of chickpea flour were compared: raw chickpea, germinated chickpea, cooked and toasted chickpea.

Germinated chickpea flour: Chickpea seeds were soaked in tap water for 12 h, at room temperature (22 °C ± 2) and kept in the dark. Then seeds were germinated between two sheets of wet filter papers for 48 h at room temperature in the dark (22 °C ± 2). Germinated seeds were dried overnight in stove at 60 °C.

To obtain cooked chickpea flour, chickpea seeds were soaked in tap water (1:10 w/v) for 12 h at 22 °C ± 2 in a dark room and then cooked in boiling tap water using a seed-to-water ratio of (1:10 w/v). Samples were cooked for 15 min until reaching soft texture when pressing between the fingers. Cooked seeds were rinsed with tap water, drained and dried overnight at 60 °C.

Toasted chickpea flour was obtained by toasting cleaned chickpea seeds in a stove (Bergstr.14D-78532, Tuttlingen) at 180 °C for 20 min.

All the processed chickpea seeds and the raw chickpea seeds were ground into flour with a mortar and a pestle and then with a coffee grinder. The obtained powder was passed through a 0.5 mm screen to remove particle clumps and then flours were stored in air-tight plastic containers and held at 4 °C until further analysis.

Flour hydration properties

Water binding capacity (WBC) defined as the amount of water retained by the sample under low-speed centrifugation was determined as described the standard method (AACCI 2010). Samples (1.000 ± 0.001 g) were mixed with distilled water (10 mL) and centrifuged at $2000\times g$ for 10 min. WBC was expressed as grams of water retained per gram of solid. Three replicates were made for each analysis.

Water absorption of the flours was determined in a Farinograph (Brabender® GmbH & Co, Duisburg, Germany) equipped with a 300 g bowl, following the standard method (AACCI 2010). The water absorption was used for further rheological analysis and breadmaking process.

Mixolab measurements

Mixing and pasting behaviour of the legume based recipes were studied using the Mixolab® (Chopin, Tripette et Renaud, Paris, France), which allows mixing the dough under controlled temperature and also a temperature sweep until 90 °C followed by a cooling step. It measured in real time the torque (expressed in Newton meters) produced by passage of dough between the two kneading arms, thus allowing the study of its physicochemical behavior. Recipes, with the exception of yeast, were used for analysis instead of flours, to identify the rheological profile of the chickpea based doughs and to be as close as possible of breadmaking process. Samples for Mixolab® analysis included based on % of flour basis: 1.63 % salt, 4 % sugar, 2 % vegetable oil, 2 % HPMC K4 M and the amount of water varied depending on the type of flour. The amount of water for raw, germinated, toasted and cooked flours was 120, 141, 141 and 205 %, respectively, which corresponded to the water absorption previously determined, to ensure complete hydration of flours constituents. Total weight for each analysis was 90 grams. All ingredients were introduced into the Mixolab® bowl and mixed. The settings used in the test were 8 min for initial mixing, temperature increase at 4 °C/min until 90 °C, 7 min holding at 90 °C, temperature decrease at 4 °C/min until 50 °C, and 5 min holding at 50 °C; and the mixing speed during the entire assay was 80 rpm. Parameters that were used to characterize dough behavior included: peak torque or the maximum torque during the heating stage (C3), the minimum torque during the heating period (C4) and the torque obtained after cooling at 50 °C (C5), all of them expressed in Newton meters (Matos and Rosell 2013). Two replicates were carried out for each formulation.

Bread making process

Bread formulation based on % of flour basis were 1.63 % salt, 0.6 % dry bakeŕs yeast (Saf- instant, Lesaffre Group, France), 4 % sugar, 2 % vegetal oil, 2 % HPMC K4 M. The amount of water was variable depending on the water absorption of the flours. Water, flour and oil were mixed in Brabender Farinograph bowl at low speed for 40 s. After this period, the other ingredients were added and mixed again at speed 2 for 6 min. Then 100 g of dough pieces were transferred into baking pans and proofed for 40 min at 35 °C in a fermentation cabinet (Salva, Spain). The baking process was performed at fixed oven temperature of 180 °C for 15 min except for the bread made with cooked chickpea floor, where the time was extended to 25 min. After baking, bread loaves were rested for 30 min at room temperature to cool down.

Instrumental quality parameters

The breads were weighed (using a digital balance with 0.01 g accuracy) and loaf volume was determined by rapeseed displacement method (10-05.01 AACCI Method). Specific volume was calculated as the ratio between the volume of the bread and its weight. Three measurements were carried out for each batch.

Color parameters of the bread slices (10 mm thickness) were measured at three different locations by using a Minolta colorimeter (Chroma Meter CR-400/410, Konica Minolta, Japan) after standardization with a white calibration plate ($L^* = 96.9$, $a^* = -0.04$, $b^* = 1.84$). The color was recorded using CIE-L^* a^* b^* uniform color space (CIE-Lab), where L^* indicates lightness, a^* indicates hue on a green (−) to red (+) axis, and b^* indicates hue on a blue (−) to yellow (+) axis.

Crumb texture was measured using a Texture Analyzer TA-XT$^{\text{Plus}}$ (Stable Microsystems, Surrey, UK) equipped with a 30 kg load cell and cylindrical stainless steel probe (diameter 25 mm). The Texture Profile Analysis (TPA) used double compression test up to 50 % penetration of its original height, with a test speed of 1 mm/s, and a 30 s delay between the first and second compressions. Hardness, cohesiveness, springiness, chewiness and resilience were calculated from the TPA plot. Measurements were made on four central slices from each batch of bread.

Chemical composition of breads

Chemical composition was determined following ICC standard methods (1994) for moisture (ICC 110/1), fat (ICC 136), and crude protein (ICC 105/2). The UNE-EN ISO 2171:2010 modified method was followed to measure ash content. Carbohydrates were determined by difference. Chemical composition values are the mean of two determinations.

In vitro protein digestibility of the bread samples was determined following the methods of Hsu et al. (1977) and Bilgicli et al. (2007), with some modifications. Briefly, 1 mL of aqueous protein suspension having 6.25 mg protein/mL was prepared. Samples were placed at 37 °C in a compact thermomixer (Eppendorf, USA) and pH was adjusted to 8.00 using 0.1 N NaOH or 0.1 N HCl. Then, 0.1 mL of trypsin solution (13,766 BAEE units/mg proteins, 1.6 mg/mL at pH 8.0) was added to the protein suspension, which was continuously stirred at 37 °C. The pH drop was recorded 15 s after enzyme addition and at 1-min intervals for 10 min. The enzyme solution was always freshly prepared before each series of experiments. The percent protein digestibility (Y) was calculated by using (Hsu et al. 1977): Y = 210,464—18,1x Where x is the change in pH after 10 min.

Sensory analysis

A descriptive sensory analysis was performed for evaluating the sensory characteristics of the bread samples. Bread slices, including crust and crumb, were presented (1 cm thick) on plastic dishes coded and served in randomized order. A quantitative descriptive sensory analysis was carried out by nine panelists with a panel of descriptors under normal lightening conditions and at room temperature. Attribute intensity was scored on a scale varying from 1 to 9 (1: dislike extremely, 2: dislike very much, 3: dislike moderately, 4: dislike slightly, 5: neither like nor dislike, 6: like slightly, 7: like moderately, 8: like very much, 9: like extremely). The attributes assessors finally agree were appearance (by observing the product slice), flavor, color and taste.

Statistical analysis

One-Way analysis of variance (ANOVA) and multiple sample comparison were used for the statistical analysis of the results, which was performed by using Statgraphics Centurion XV (Statpoint Technologies, Warrenton, USA). Fisher's least significant differences (LSD) test was used to describe means with 95 % confidence.

Results and discussion

Flour hydration properties

Water absorption and water binding capacity were selected to determine the hydration properties of raw and processed chickpea flours (Table 1). The processing of chickpea significantly ($P < 0.05$) increased the water absorption ability. The highest effect was observed with the cooked chickpea, which showed a significant increase of the water absorption and the WBC. Toasted and germinated chickpea flours showed similar hydration. Padmashree et al. (1987) reported that polar amino acids of a protein have an affinity for water and denatured protein binds more water. Cooking and also toasting might have caused the denaturation of protein, explaining the results obtained for those flours. This is in accordance with results found by Obatolu et al. (2001) in boiled and roasted yam bean. Regarding germination, the hydrolysis induced by enzymes activation could also increase the amount of polar compounds enhancing the ability to bond water molecules, as has been observed in germinated legumes (Benitez et al. 2013). Hydration properties of raw materials are decisive when developing gluten free baked goods, especially bread because the specific volume is positively dependent on the dough hydration (de la Hera et al. 2014; Marco and Rosell 2008). Therefore, it should be expected that flour from processed chickpea would improve the quality of gluten free breads.

Mixolab measurements

Figure 1 shows the curves obtained from the Mixolab® corresponding to the four formulations. The initial profile (first 10 min), corresponding to mixing stage, showed rather low consistency, which agrees with the batter consistency that usually show gluten free doughs (Matos and Rosell (2013). Dough containing germinated flour led the highest consistency during mixing, likely the hydrolysis products resulting from the germination are responsible for this behaviour. During heating, consistency increased due to starch gelatinization, which was followed by a cooling stage with further rose of consistency that reflected the starch properties of tested formulations (Fig. 1). Only parameters defining that behavior were assessed (C3, C4, C5) (Table 1), because it have been reported that they were significantly positively correlated with crumb hardness, and thus to gluten free bread quality (Matos and Rosell 2015). The consistency at C3 that reflects starch gelatinization was significantly reduced when cooked chickpea flour was used, which was attributed to the previous starch gelatinization occurred on chickpea during cooking process. Also it must remark that water absorption was much higher for cooked chickpea flour, thus starch dilution could not be disregarded. C4 and C5 decreased significantly ($P < 0.05$) in treated seeds (germinated and toasted), which partly was explained by starch dilution because higher amount of water was needed to hydrate all compounds, compared to dough containing raw chickpea flour. Nevertheless, the difference in the pattern plot suggested additional changes in the doughs containing germinated and toasted chickpea flours. Presumably, activation of enzymes during germination might explain the decrease in C4 and C5 observed in germinated doughs, as has been reported for rice flours (Cornejo and Rosell 2015; Charoenthaikij et al. 2009) and oat flour due to increase in the α-amylase, proteolytic and lipolytic activities (Makinen et al. 2013). Results obtained for dough containing toasted chickpea flour suggested that thermal treatment modified flour compounds despite the limited amount of water, as confirmed results obtained with the hydration properties. Similar behavior has been reported for toasted yam bean (Obatolu et al. 2001).

Quality properties of breads

Pictures of bread slices made with differently processed chickpea flours are illustrated in Fig. 2. It must be remark that the recipe, and specially the amount of water added (defined using the water absorption of the flours), allowed obtaining acceptable breads with even porous crumbs. The most noticeable changes were observed on the crumb color that varied significantly depending on the chickpea treatment. The specific volume (Table 2) of breads was significantly higher for toasted chickpea bread (1.79 mL/g),

Table 1 Hydration properties of the chickpea flours and rheological parameters of gluten free doughs determined using the Mixolab®

Chickpea type	Water absorption %	Water binding capacity g/g	C3 Nm	C4 Nm	C5 Nm
Raw	120 ± 4a	1.35 ± 0.02a	0.42 ± 0.01b	0.41 ± 0.01c	0.67 ± 0.01c
Germinated	141 ± 3b	1.81 ± 0.04b	0.42 ± 0.00b	0.32 ± 0.00b	0.61 ± 0.01b
Toasted	141 ± 3b	1.87 ± 0.01b	0.35 ± 0.00a	0.28 ± 0.05a	0.53 ± 0.04a
Cooked	205 ± 5c	2.69 ± 0.07c	n.d.	n.d.	n.d.
P value	0.0402	0.0000	0.0123	0.0034	0.0142

Means in a column with different letters are significantly different ($P < 0.05$)

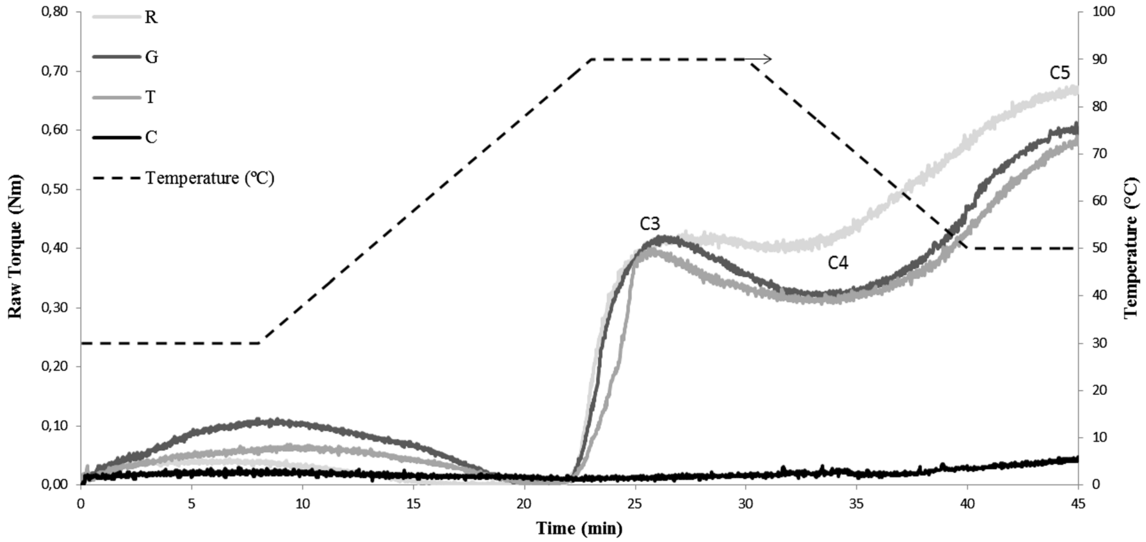


Fig. 1 Mixolab® curves of raw (R), germinated (G), toasted (T) and cooked (C) chickpea flours

Fig. 2 Cross section of the gluten free breads slices

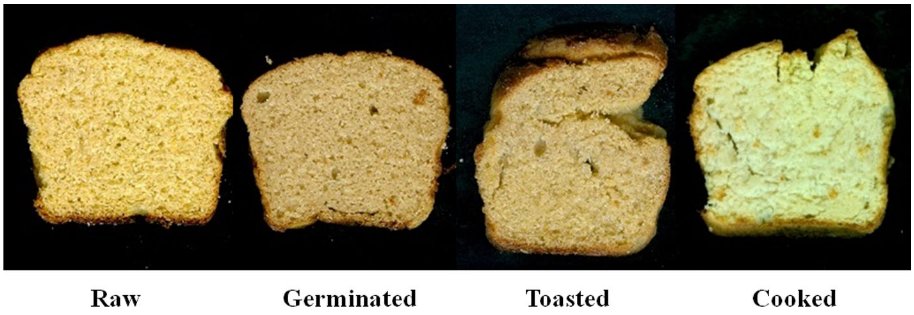


Table 2 Effect of chickpea processing on the specific volume, moisture content and color parameters of chickpea based breads

Chickpea processing	Specific volume (mL/g)	Moisture (%)	*L**	*a**	*b**
Raw	1.72 ± 0.04c	49.24 ± 0.05a	71.66 ± 0.56b	0.43 ± 0.13b	29.62 ± 0.85b
Germinated	1.53 ± 0.02b	51.34 ± 0.04b	66.17 ± 0.53a	3.89 ± 0.28d	28.84 ± 0.44ab
Toasted	1.79 ± 0.05d	52.41 ± 0.05c	71.00 ± 1.26b	1.57 ± 0.59c	31.37 ± 1.56c
Cooked	0.58 ± 0.02a	60.58 ± 0.01d	76.20 ± 0.99c	−0.46 ± 0.22a	27.64 ± 1.83a
P value	0.0000	0.0000	0.0000	0.0000	0.0000

Means in a column with different letters are significantly different ($P < 0.05$)

followed by raw chickpea and germinated chickpea breads, whereas cooked chickpea flour yielded the lowest specific volume. It was expected that the bread made with germinated flour had higher specific volume, due to the increase in protein solubility, resulting in better emulsifying capacity and foaming properties during germination (Aguilar et al. 2015; Mostafa et al. 1987), but it has been also described that excessive germinated flours resulted in lower specific bread volume (Cornejo and Rosell 2015). Bread made with cooked chickpea flour had the lower specific volume (0.58 mL/g) that might be ascribed to the reduction of protein solubility caused by denaturation during heating and also to the released of water soluble compounds to the boiling water. This result is in accordance with findings of Shin et al. (2013), where breads made with heat-treated soy flours had lower specific loaf volume than breads prepared by raw and germinated soy flours. The moisture content of breads was rather high because very high hydration was used for obtaining better shaped breads. The moisture content of the breads followed the trend of the water added for breadmaking process, thus bread containing cooked flour showed the highest moisture content (Table 2). De la Hera et al. (2014) reported that the moisture content in gluten free bread was related with the

Table 3 Effect of chickpea processing on the texture parameters of chickpea based breads

Chickpea processing	Firmness (N)	Springiness	Cohesiveness	Chewiness (N)	Resilience
Raw	251 ± 5c	0.848 ± 0.018a	0.51 ± 0.02c	109 ± 4c	0.22 ± 0.01c
Germinated	289 ± 13d	0.742 ± 0.046a	0.54 ± 0.02c	117 ± 10c	0.23 ± 0.01c
Toasted	167 ± 9b	0.704 ± 0.02a	0.43 ± 0.04b	50 ± 8b	0.18 ± 0.02b
Cooked	81 ± 3a	1.754 ± 2.329a	0.3 ± 0.02a	14 ± 1a	0.07 ± 0.05a
P value	0.0000	0.5524	0.0000	0.0000	0.0000

Means in a column with different letters are significantly different ($P < 0.05$)

amount of water added in the recipe. Regarding color the germinated chickpea bread showed the darkest crumb, while cooked chickpea bread was the lightest ($L^* = 66.17$ and $L^* = 76.20$, respectively), the reddish value (a^*) was higher in germinated chickpea bread and lowest in cooked chickpea bread ($a^* = 3.89$ and $a^* = -0.46$ respectively); whereas the yellowish value was higher in toasted chickpea bread followed by raw chickpea bread ($b^* = 31.37$ and $b^* = 29.62$ respectively).

The texture profile including firmness, springiness, cohesiveness, chewiness and resilience of the different breads is presented in Table 3. The hardness of germinated chickpea bread tended to be higher (2837 g) compared with raw chickpea bread (2460 g). Conversely, breads made with pre-heated chickpea flour (toasted or cooked) were softer, especially the one made with the cooked chickpea flour (794 g). The high amount of water absorbed during dough mixing might contribute to this behavior (de la Hera et al. 2014). No significant differences ($P > 0.05$) were observed for the crumb springiness. The cohesiveness, which quantifies the internal resistance or cohesion of food structure, significantly ($P < 0.05$) increased in breads made with raw and germinated chickpea flour comparing with those made with pre-heated chickpea flours. The same trend was observed regarding resilience. Bread with high cohesiveness is desirable because it forms a bolus rather than disintegrates during mastication, whereas low cohesiveness indicates increased susceptibility of the bread to fracture or crumble (Onyango et al. 2011). In addition, chewiness was more pronounced in breads made with raw and germinated chickpea flour (1067 and 1145 g respectively) compared to the low values exhibited by the breads made with pre-heated chickpea flour. These low chewing values would indicate easy break of the bread in the mouth.

Nutritional properties of breads

The proximate composition of breads comprises the estimation of ash, fat, proteins and carbohydrates (Table 4). All these parameters varied significantly ($P < 0.05$) among chickpea based breads. Ash content decreased highly in breads made with toasted and cooked chickpea flour (−13 and −38 % respectively). A slight decrease was observed in bread made with germinated chickpea flour compared to that made with raw flour, probably caused by leaching of minerals during soaking and cooking. Similar trend in the reduction of ash content induced by cooking and germination was observed by Baik and Han (2012) and Mittal et al. (2012), respectively, in chickpea flour.

Concerning fat, a significant ($P < 0.05$) decrease was observed when germinated chickpea flour (3.37 %) was used. Likely due to the use of fat as energy during the germination process (Mittal et al. 2012). However, a significant ($P < 0.05$) increase was noticed in breads made with toasted and cooked chickpea flour, which should be attributed to the concentration of fat after leaching out other water soluble constituents in the cooking or soaking water. Regarding the crude protein content, again there was a significant ($P < 0.05$) decrease among breads made with toasted and cooked chickpea flours. This reduction in protein content was reported previously by Clemente et al.

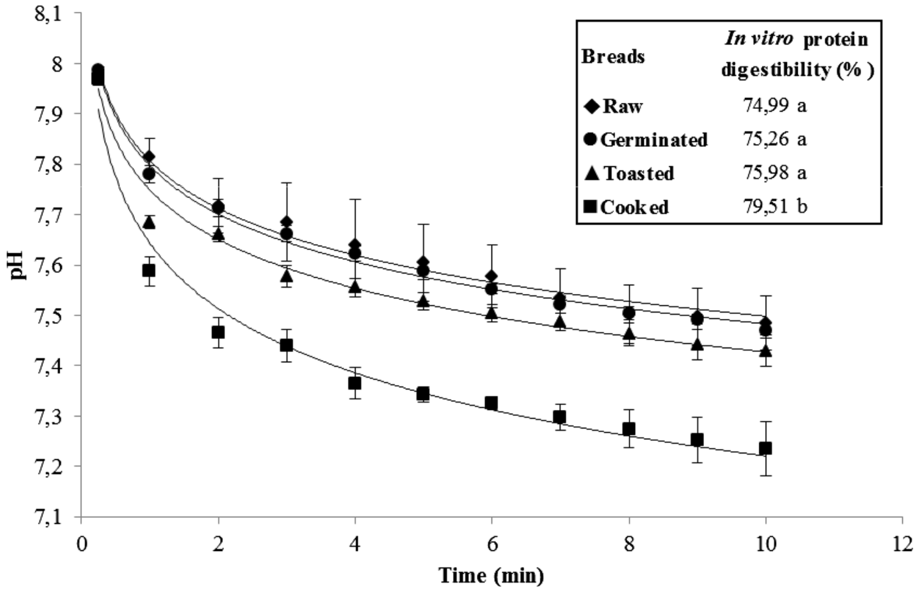
Table 4 Chemical composition of chickpea based breads

Chickpea processing	Ash content (% as is)	Fat content (% as is)	Protein content (% as is)	Carbohydrate * content (% as is)
Raw	2.17 ± 0.00d	3.73 ± 0.00b	11.16 ± 0.18c	33.70 ± 0.18d
Germinated	2.11 ± 0.01c	3.37 ± 0.06a	11.22 ± 0.07c	31.96 ± 0.12c
Toasted	1.89 ± 0.01b	4.33 ± 0.06c	10.14 ± 0.02b	31.23 ± 0.07b
Cooked	1.35 ± 0.00a	4.41 ± 0.01c	8.66 ± 0.05a	25.00 ± 0.06a
P-value	0.0000	0.0000	0.0000	0.0000

Means in a column with different letters are significantly different ($P < 0.05$)

* Carbohydrate content was calculated by difference

Fig. 3 In vitro digestibility of protein in gluten free breads



(1998) and Attia et al. (1994) in cooked chickpea, owing to the leaching of protein into cooking water. Similar pattern was observed in the protein content, obtained after removing TCA-soluble compounds containing nitrogen, although the amount was lower due to the removal of soluble nitrogen, amino acids and peptides. Also carbohydrate decreased significantly ($P < 0.05$) in bread made with processed chickpea flours and the highest reduction was observed with cooked chickpea flour (25 %). Since the carbohydrate content was calculated by difference, this variation was due to the differences in the contents of other constituents.

The in vitro protein digestibility (IVPD) values were not affected among breads made with germinated and toasted chickpea flour compared with bread made with raw chickpea flour (Fig. 3). However, a significant ($P < 0.05$) decrease in IVPD was observed in bread made with cooked chickpea flour (79.51 %). The improvement in digestibility might result from the denaturation of protein, destruction of the trypsin inhibitor or reduction of tannins and phytic acid in cooked chickpea flour. Processing can improve the digestibility of proteins by destroying protease inhibitors and opening the protein structure through denaturation (Hsu et al. 1977). An improved IVPD of cooked chickpea flour was also reported by Baik and Han (2012) and Alajaji and El-Adawy (2006). A rapid decline in pH (Fig. 3) was observed in bread made with cooked chickpea floor, followed by ones made with toasted, germinated and raw chickpea flour respectively. This decline in pH was caused by the release of carboxyl groups during enzymatic digestion of the protein Hsu et al. (1977). Protein digestibility is indicative of its amino acids availability for evaluating the nutritive quality of a protein.

Sensory characteristics of breads

The collected scores for each sample are listed in Table 5. Panelist evaluated all the attributes very low, this may be due to the unexpected type of breads, since legume breads are not very common. Only the appearance showed significant difference ($P < 0.05$), specifically breads made with raw and germinated chickpea flour had higher score (6.22 and 6.00, respectively), suggesting that panelists like slightly the appearance of these two breads compared with those made with toasted and cooked chickpea flour. For the bread made with cooked chickpea flour, the appearance

Table 5 Sensory attributes of chickpea based breads

Chickpea processing	Appearance	Texture	Taste	Aftertaste	Aroma	Overall acceptability
Raw	6.22 ± 1.48b	5.56 ± 1.74a	4.11 ± 1.36ab	5.22 ± 1.79	6.11 ± 0.93	5.56 ± 1.01
Germinated	6.00 ± 1.41b	5.33 ± 1.50a	4.00 ± 1.22a	4.11 ± 1.96	6.33 ± 1.31	4.33 ± 1.32
Toasted	4.78 ± 1.56ab	5.67 ± 1.22a	4.78 ± 1.92ab	5.33 ± 1.50	6.00 ± 1.32	5.11 ± 1.17
Cooked	3.67 ± 2.29a	4.33 ± 1.50a	5.56 ± 1.59b	5.44 ± 1.67	5.44 ± 1.74	5.33 ± 1.58
P value	0.0123	0.2394	0.1442	0.3489	0.5609	0.2246

Means in a column with different letters are significantly different ($P < 0.05$)

was the most undesirable attribute (score 3.67). For the texture, breads scored between 4.33 for the bread made with cooked chickpea flour and 5.67 for the bread made with toasted chickpea flour. Bread made with cooked chickpea flour was tastier than other breads. Regarding the aftertaste, scores ranged between 4.11 and 5.44, which meant that panelists dislike the beany taste that persisted in mouth after tasting the breads. Panelists appreciated the aroma of breads made with raw, germinated and toasted chickpea flours and were indifferent about the bread made with cooked chickpea flour.

Conclusion

Chickpea beans subjected to germination, toasting or cooking provided flours with high water binding capacity and, with exception of the cooked flour, their rheological profile (measured with the Mixolab) was predominantly determined by starch properties. Chickpea breads were developed using different chickpea flours (germinated, toasted and cooked). The chickpea bread quality differed depending on the previous process of the bean. The highest specific volume was obtained in bread made with toasted chickpea flour. However, the softest texture was noticed in bread made with cooked chickpea flour. On other hand, the bread made with germinated chickpea scored the lowest overall acceptability concerning the sensory properties. Regarding the nutritional quality, the bread made with raw chickpea flour had the highest content of protein, but the bread made with cooked chickpea flour showed the highest in vitro protein digestibility. Overall, processing of chickpea beans, concretely toasting and cooking led to flours that could be used for obtaining gluten free breads with the nutritional characteristics of the legumes and acceptable sensory characteristics.

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