Characterization of Two Chickpea Varieties and the Effect of Cooking on their Physico-chemical and Functional Properties of Flours

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Abstract

Considering the nutritional and functional characteristics of chickpea, flours of two varieties of chickpea ("Blanco Noroeste" and "Costa 2004") were prepared to know the effect of cooking. Thus the objective of this study was to compare their physicochemical and functional properties in both, raw and cooked flours. Physical properties of the grain, for the two varieties were similar, whereas the physicochemical and functional properties of the flours exhibited differences as a function of the variety and the processing. The chickpea cooked flours showed lower lightness and higher redness and yellowness with respect to raw flours. The proximal composition of cooked flours presented significant differences in fat (5.98% - 6.09%) and moisture contents (0.48% - 0.54%) with respect to raw flours. The particle size distribution determined for the raw and cooked flours samples, indicated a unimodal behavior with a wide distribution. The water absorption capacity and oil capacity showed significant difference among flour varieties. For pasting properties, a higher viscosity was measured for Costa 2004 (380 cP) and Blanco Noroeste (272 cP) raw flours, raw flour exhibited better pasting properties than cooked flours.

Keywords: Chickpea flour, physicochemical properties, functional properties

1. Introduction

Legumes and cereals are the two main groups of crops grown worldwide, and these groups represent the staple meal of several human populations (Lee, 2007). Studies reveal that consumption of legumes contributes to a healthy lifestyle. Like other legumes, the chickpea is considered a good source of carbohydrates, proteins, dietary fiber, vitamines and minerals. It is rich in lysine and arginine, but deficient in sulfur amino acids. It contains two times more protein than cereals, which allows to balance the protein content and improve the nutritional value when is combined with cereals in the diet (Ionescu et al., 2009; Jukanti et al., 2012; Muhammad et al., 2013).

The chickpea is part of the traditional diet in Africa, Asia, Mediterranean, Arabia, Latin America and southern U.S. communities. México ranks eighth in chickpea production worldwide (FAOSTAT, 2014) with 271894 tons/year, making this legume a crop of commercial importance (Ultrilla-Coello et al., 2007). Most of the production is destined for exportation, due to its grain quality characteristics such as color and size, however the consumption of this legume in México is limited. Two types of chickpea have been well recognized, they are identified as "Desi" and "Kabul". The desi type is characterized by the small size of the seed, yellow or brown color and rough surface, while kabul seeds are usually large, light colored, smoothly coated, and have a ram's head shape (Iqbal et al., 2006; Nizaka et al., 2007; Özer et al., 2010; Jukanti et al., 2012).

Several authors have investigated the main physicochemical properties of the chickpea protein isolates and their possible use in the food industry as the main objective (Sánchez-Vioque et al., 1999; Liu et al., 2008). Kaur and Singh (2007) obtained protein isolates from desi and kabul chickpea cultivars, they evaluated their functional and thermal properties finding significant differences for two varieties. Osorio-Díaz et al. (2008) evaluated the influence of the chickpea flour level on chemical, functional and nutritional properties of a composite pasta (spaghetti), finding that the enrichment with chickpea flour may be a dietetic alternative for people with special caloric or metabolic requirements. Gomez et al. (2008) mentioned that it is possible to use chickpea flour for

total or partial substitution of wheat flour in the preparation of different kinds of cakes. They found that the increasing of chickpea flour caused a decreasing of the cake volume, a firmer texture and a gummier consistency, and also the cakes resulted less cohesive. Similarly, Kohajdová et al. (2011) studied the incorporation of chickpea flour at different levels in substitution of wheat flour to produce cookies, observing that higher levels of addition affected significantly properties such as density, width, thickness and spread ratio of the final products.

One of the best options to preserve crops is by processing them into flours. In order to know and compare characteristics of different flours, Mir et al. (2014) complete a study with two types of flour from water chestnut determining their physicochemical, pasting and thermal properties, focused to bakery industrial application. Sankhon et al. (2014) also compared the physicochemical and functional properties of locust bean flour and its extract to be incorporated by food developers, finding good results with different applications for the flour and for the extract. Kaur et al. (2013) developed a comparative study of physicochemical and functional properties between three types of flour, using taro, corn, potato and soya, observing different viscosity peaks, foaming and thickening characteristics with good potential to be used in different food products. In other study Ladjal and Chibane (2015) determined the physicochemical and functional properties of three legume whole flours, to prove the great potential of these products to be incorporated as elements of new food items. Most of the applications of the legume flours have been studied in bakery meal and very few works have considered the chickpea products as potential complements.

There is scarce research regarding the characterization of Mexican chickpea varieties, implying the necessity to study their composition and characterization in order to promote their potential applications. New product development and applied science are responding to consumer demands for the production of better foods with desired properties. Therefore, the objective of this study was to characterize two kabul chickpea varieties grown in Mexico, as well as their flours, to compare their properties, with the future idea of using them to enrich some dairy foods.

2. Materials and Methods

2.1 Raw Materials

Chickpea seeds (*Cicer arietinum* L.) of kabul type, Blanco Noroeste (BN) and Costa 2004 (C4) of the 2013 harvest, were provided by the "Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias" (INIFAP), Celaya, México.

2.2 Physical Characteristics of Seeds

To characterize both seeds, physical properties were measured by following the methods used from Ayman et al. (2010), typical for this type of food materials.

Geometric diameter (Dg). Taking a random sample of one hundred seeds from of each variety, the major (L), intermediate (W) and minor (T) dimensions were measured, meaning length, width, and thickness, respectively, using a Vernier (Scala, México), in which Dg is given as:

$$D_g = (LWT)^{1/3} \tag{1}$$

Sphericity. To obtain the sphericity of seeds, a dimensionless ratio of two dimensions was applied and expressed as percentage:

$$Sphericity = (D_g/L) *100 \tag{2}$$

Weight. The weight of one hundred seeds was recorded and expressed by unity.

Bulk density. It was calculated for the crop, by dividing the weight of a quantity of seeds of each variety on its volume, the last was measured by using a graduated cylinder, as follows:

$$\rho_b = M/V_b \tag{3}$$

Where: ρ_b = bulk density of seeds, kg/m^3; M = weight of the bulk seeds, kg; V_b = volume of the bulk seeds, m^3.

2.2 Flour Preparation and Characterization

2.2.1 Raw Chickpea Flour

To obtain the raw flour, 50 g of chickpea seeds without any treatment, were weighed and milled in a 0.5 HP electric miller equipment (Torrey, Mexico), the obtained flour was stored in plastic bags until analysis. As a treatment in agreement with experiments of Osorio-Díaz et al. (2008).

2.2.2 Cooked Chickpea Flour

To produce cooked flour, 50 g of chickpea seeds were subjected to heating for 140 min in water using a ratio of

1:3 w/v at a temperature of 90 ℃ ± 3 ℃, lately the heated seeds were cooled down and milled with a food processor (150 W, top speed, Taurus, Mexico). The sample was dried in the oven (Telco, Model 6 Precision Scientific Chicago, Illinois, USA) for 48 hours at a temperature of 40 ℃, and finally the electric miller (0.5 HP, Torrey, Mexico) was used to complete the preparation process.

2.3 Physicochemical Properties

2.3.1 Color

Color was determined with a Gardner colorimeter (System 0.5 Inc., Silver Spring, Maryland, USA), in reflectance mode, previously calibrated with black and white tiles with values of the Hunter parameters L*, a* and b* (92.89, -1.05 and 0.82, respectively). Ten gram of seeds and also ten gram of flour samples were placed on a plate (Guzmán-Maldonado et al., 1995; Kaur and Singh, 2005).

2.3.2 Water Activity (a_w)

Water activity was determined with an Aqualab meter (Series 3TE, Decagon Device Inc., USA). The instrument was calibrated, first with the introduction of activated carbon with $a_w = 0.5$ and subsequently with distilled water having $a_w = 1.0$. Two gram of flour sample was placed in the proper compartment of the instrument, obtaining the automatic reading in 3-5 min.

2.3.3 Chemical Analysis

Each sample was analyzed according to AOAC (2000) international methods. The moisture content was carried out by the gravimetric method 925.09, by drying the samples up to 100 ℃ to constant weight. Ash was determined by calcination, following the method 923.03. Fat was quantified following the Soxhlet method 920.30, after 4 hours of extraction with petroleum ether. Protein was determined by the micro Kjeldahl method 920.87, multiplying the nitrogen content by 6.25. Crude fiber, was determined by the gravimetric method 920.86, in which the samples were subjected to acid-alkaline hydrolysis. Total carbohydrates were obtained by difference.

2.3.4 Particle Size Distribution.

Five gram of sample was weighed and placed at the sieve. The screening was performed for 5 min. After each sieve, the sample was weighed to determine the amount of retained material and those particles which passed each mesh. From the particle size distribution three parameters were evaluated: d_{10}, d_{50} and d_{90}, corresponding to an accumulated mass of 10%, 50% and 90%, respectively. Whereas the arithmetic mean (d_m) for a class of n subsamples with their respective mass and size, and the dispersion factor (FD) were evaluated by the equations 4 and 5 (Jiménez-Munguía, 2007):

$$d_m = (\Sigma\ m_i\ \cdot D_i)\ /\ (\Sigma\ m_i) = \Sigma\ x_i \cdot D_i \qquad (4)$$

$$FD = (d_{90} - d_{10})\ /d_{50} \qquad (5)$$

Where: D_i = diameter of particles in the class subsample, m; m_i = mass of particles in the class subsample, kg; x_i = mass fraction of particles belonging to the class subsample i.

2.4 Functional Properties

2.4.1 Determinations of Water and Oil Absorption Capacity

To determine these absorption capacities, one gram of sample was weighed and then stirred in 10 mL of distilled water or corn oil (Mazola, CPI International) during one minute. These suspensions were then centrifuged at 3000 rpm for 30 min and the volume of the supernatant was measured. Water-absorption capacity was expressed as mL of absorbed water per gram of sample, whereas oil-absorption capacity was expressed as mL of absorbed oil per gram of sample (Kaur and Singh, 2005).

2.4.2 Gelation Properties.

Suspensions of flour and water at 4%, 12% and 20% (w/v) from which 5 mL of sample, were taken and placed in test tubes. They were kept in a water bath at boiling temperature during 1 hour and then placed in ice for 1 additional hour. Gel formation was determined as the lowest concentration at which the sample, in the inverted tube, did not slide down the wall of the tube (Coffman-Garcia, 1977; Kaur and Singh, 2005).

2.4.3 Pasting Properties

Pasting properties of flours were done with a Rapid Visco Analyzer (RVA-4. Newport Scientific Pty Ltd., Warriewood, Australia) with a data analysis software (Thermocline). Pasting properties were carried out with three gram of the flour sample dispensed into the test canister, 25.0 mL of distilled water also was added into the

canister. The temperature-time conditions included a heating step from 50 ℃ to 90 ℃ at 5 ℃/min, a holding stage at 90 ℃ for 5 min, a cooling step from 90 ℃ to 50 ℃ at 5 ℃/min and a holding stage at 50 ℃ for 2 min. A constant paddle rotational speed (160 rpm) was used throughout the entire analysis, except for rapid stirring at 960 rpm for the first 10 s of the test, for dispersion of the sample. Each sample was run in duplicate.

2.5 Statistical Analysis

With exception of the pasting test that was done by duplicate, the rest of the determinations were done in triplicate. Data were compared by using the Student-t test for physical characterization of seeds, whereas an analysis of variance (ANOVA) and Tukey test were applied to the physical and functional data of flours, with a confidence level of 95%, using the Minitab v.16.0 software (Minitab Inc., Pennsylvania, USA).

3. Results and Discussion

3.1 Physical Characterization of Seeds

The mean value of the physical characteristics, grain size, weight, geometric diameter, bulk density and seed color for kabul chickpea type, corresponding to varieties of Blanco Noroeste (BN) and Costa 2004 (C4) are presented in Table 1. It may be observed that both varieties had a general similarity, with exception of the yellowness and redness parameters that exhibited significant difference (p<0.05). The variety C4 was less red and more yellow than the variety BN. Both may be described as large grains, with 10.26 mm for C4 and 10.33 mm for BN, weighing 0.571 and 0.604 g, respectively.

Table 1. Physical characteristic of chickpea*

Parameters	Varieties**	
	Blanco Noroeste	Costa 2004
Length (mm)	10.33 ± 0.09^a	10.26 ± 0.09^a
Width (mm)	8.26 ± 0.07^a	8.31 ± 0.07^a
Thickness (mm)	7.80 ± 0.08^a	8.24 ± 0.08^a
Weight (g)	0.604 ± 0.11^a	0.571 ± 0.13^a
D_g	8.8^a	8.93^a
ρ_b (kg/m^3)	1211^a	1191^a
Sphericity (%)	84.6 ± 0.04^a	86.8 ± 0.05^a
L*	60.66 ± 0.85^a	66.76 ± 0.31^a
a*	5.30 ± 0.00^a	3.02 ± 0.21^b
b*	21.33 ± 0.02^a	24.18 ± 0.48^b

* Means and standard deviation of triplicate measures.

**Different letters in the value represent significant difference (p<0.05)

These results are higher compared to those reported by Ayman et al. (2010), who reported average values of length, width and thickness in a range of 7.92 - 8.14, 6.10 - 6.37 and 6.43 - 6.84 mm respectively, with a weight of 0.142 to 0.184 g, being these seeds smalls and really lights, 3.5 times lighter than BN and C4. The bulk density of 1191 kg/m^3 for C4 and 1211 kg/m^3 for BN, which is importantly higher than those reported by Ravi (2005) of 763-769 kg/m^3, implies a higher mass to volume relationship and a better compacting structure. The properties of the studied varieties, and particularly their higher sizes, it is considered a convenient characteristic for grain processing.

3.2 Flour Characterization

3.2.1 Chemical Analysis

The proximal composition of the raw and cooked chickpea flours is presented in Table 2. As expected, chemical composition of kabul chickpea flours was affected by cultivar and cooking process. In all the samples, total carbohydrates were the predominant component.

Protein content of flours ranged between 14.89 and 18.16% and it did not show significant difference. These results are relatively low compared to that reported by Boye et al. (2010) for desi type chickpea flour (20.5%), also higher values were found by Arab et al. (2010) for chickpea flour (21.8 - 24.9%) and processed chickpea flours (22.9% - 24.6%). Aguilera et al. (2011) reported a decrease in protein from 23.7 to 19.0% for Castellano chickpeas subjected to soaking, cooking and dehydration. In other works, Kohajdová et al. (2011) also reported a protein value of 20.6%; Du et al. (2014) obtained 22.37% and Ladjal and Chibane (2015) determined 24.41%

that are higher than the content of the studied seeds. These differences in protein content may be related to the seed variety, location, harvest and processing.

Table 2. Chemical composition and physicochemical properties of flours

Component (%)	Samples			
	RBNF[1]	RC4F[2]	CBNF[3]	CC4F[4]
Protein*	18.16 ±.29[a]	16.08 ±1.5[a]	17.94 ±1.4[a]	14.89 ±.13[a]
Fat	2.67 ±0.13[b]	4.04 ±0.11[b]	5.98 ±0.32[a]	6.09 ±0.57[a]
Moisture	1.13 ±0.04[a]	1.19 ±0.04[a]	0.54 ±0.00[b]	0.48 ±0.17[b]
Ash	3.22 ±0.05[a]	3.21 ±0.18[a]	3.22 ±0.05[a]	3.43 ±0.12[a]
Fiber	3.94 ±0.60[a]	2.87 ±0.14[ab]	3.65 ±0.23[a]	2.59 ±0.10[b]
Carbohydrates[5]	70.88 ±0.74	72.61 ±0.11[a]	68.67 ±0.26[a]	72.52 ±0.38[a]
Color				
L*	85.55 ±0.23[a]	86.83 ±0.49[a]	72.36 ±0.91[c]	77.58 ±0.29[b]
a*	-0.02±0.013[a]	-0.11±0.011[b]	2.11 ±0.17[c]	0.74 ±0.36[d]
b*	26.01 ±0.71[b]	24.18 ±0.48[b]	30.80 ±0.19[a]	30.57 ±0.79[a]
a_w	0.538 ±0.01[a]	0.508 ±0.01[a]	0.486 ±0.07[a]	0.512 ±0.02[a]

[1]RBNF = Raw Blanco Noroeste flour; [2]RC4F = Raw Costa 2004 flour, [3]CBNF = Cooked Blanco Noroeste flour; [4]CC4F = Cooked Costa 2004 flour. [5]Calculated by difference.

Means (± standard deviation) of triplicate analysis. Values followed by a different superscript in row are significantly different ($p<0.05$).

*Total nitrogen x 6.25.

Fat content showed a wide variation, and ranged between 2.67 and 6.09%. The applied treatment, particularly the cooking stage, had a significant effect ($p<0.05$) on fat. It could be attributed to the processing, in which cooking and drying resulted in lipids solubilisation and water loss. When the starch is solubilized and gelatinized during cooking and solvent input is allowed, this phenomenon favors the oil extraction; that it does not happen in the raw starch because fat and protein are strongly embedded in the starch matrix (Rodríguez-Sandoval et al., 2006). Other studies have reported higher fat contents, 6.70 to 7.60% by Sanjeewa et al. (2010), 6.63% by Du et al. (2014) and 5.57% by Ladjal and Chibane (2015) in different types of chickpea flours.

The moisture content of the raw flours, 1.13% for BN and 1.19% for C4 was not significantly different ($p>0.05$), however the cooked flours (0.48 and 0.54%, respectively) significantly decreased their percentage of moisture with respect to the raw flours, this component was also affected by the thermal treatment.

The ash content was constant in the four flours (3.21 - 3.43%), results that are greater than those determined by Kaur and Singh (2005) of 2.72 to 2.88%, Boye et al. (2010) of 2.76 to 3.04%, and Du et al. (2014) of 3.16% of 2.45% for analogue legume flours, indicating a higher richness in minerals for the studied chickpea. While the crude fiber which ranged from 2.59 to 3.94%, was significantly different ($p<0.05$) among the varieties and treatments. It is interesting to note that the BN variety contains more fiber that C4 variety, and it may be incorporated into other foods with low fiber content.

3.2.2 Color and Water Activity

The color and water activity of both raw and cooked flours, are also included in Table 2. Raw flours showed a higher lightness, 85.55 for BN and 86.83 for C4; while the cooked flours exhibited a luminosity of 72.36 and 77.58 with significant differences among treatments; this may be attributed to the applied stages of cooking and drying that affected the lightness of the cooked flours. With respect to the parameter a*, with negative values, shows trend toward green for flours obtained by a raw process, while the trend is towards redness for flours subjected to cooking process (0.74 and 2.11). For the parameter b* the four flours had yellow hues, maintaining this characteristic from the seeds. The three color parameters were significantly different ($p<0.05$) between treatments.

The water activity of flours maintained a range of 0.486 to 0.538; without significant difference between varieties and treatments. It was only lower than 0.5 for the BN cooked flour, attributed to the drying process in which water was removed, but it was not the case of the C4 flour. However, the four flours have a water activity that guaranty a certain stability through the storage.

3.2.3 Particle Size Distribution

Particle size is a very important concept in flour milling. The studied flours varied in particle size and differed in chemical and mainly in physical properties. The particle size distribution of the raw and cooked meals (Table 3), indicates that 50% (d_{50}) of them are below 0.257 mm, and those particles with sizes ranging between 0.259 and 0.573 mm represented 90%, whereas the particles with size ranging between 0.056 and 0.085 mm were the rest (10%). In all cases, the difference between the arithmetic median diameter (d_m) and d_{50} indicates a distribution with values of bias and a dispersion factor (FD) over 1, in which is observed a wide distribution, being notably lower for the C4 variety. Ladjal and Chibane (2015) reported particle sizes lower than 0.160 mm for chickpea, pea and lentil flours, as the most important and representing 70, 54.5 and 53.2% of their particle distributions, respectively. Flores-Far ás et al. (2002) commented that some factors affecting the size of flour particles are the grain hardness, cooking time, and of course the speed of the mills and degree of sieving.

Table 3. Particle size distribution of chickpea flours

Diameters (mm)	Samples			
	RBNF[1]	RC4F[2]	CBNF[3]	CC4F[4]
d_m	0.392[a]	0.324[c]	0.344[b]	0.316[d]
d_{50}	0.257[a]	0.215[c]	0.237[b]	0.211[d]
FD	1.86[a]	1.1[c]	1.72[b]	0.96[d]

[1]RBNF = Raw Blanco Noroeste flour; [2]RC4F = Raw Costa 2004 flour,

[3]CBNF = Cooked Blanco Noroeste flour; [4]CC4F = Cooked Costa 2004 flour.

Means (± standard deviation) of triplicate analysis. Values followed by a different superscript in column are significantly different (p<0.05).

d_m=arithmetic median diameter; d_{50}=50% cumulative oversize. FD=dispersion factor.

The size distribution of the chickpea flour samples showed a unimodal distribution for all of them, exhibiting a more homogeneous distribution in flours obtained by the cooking process. The analysis of the granulometric distribution for the cooked flours is finer than raw flours, with lower values for the three quantified parameters. Brou et al. (2013) obtained sorghum flours with finest diameters, 0.16 to 0.315 mm, and they observed that the type of crushing and size of the particles has an impact on the final concentration of some flour nutrients. In another study, Wook and Yao (2014), determined the particle size of waxy-wheat flours, all samples had trimodal size distribution patterns; and the first, second, and third modes were < 10 μm, 10-50 μm and 51-300 μm, respectively, indicating a typical variability for this parameter as a consequence of some of the aforementioned factors.

3.3 Functional Properties

The functional properties determined for the chickpea flours are shown in Table 4.

3.3.1 Water Absorption Capacity

Chickpea flour was characterized by a great water absorption capacity (WAC, 5.92 - 7.21 g H_2O/g sample). The cooked flours showed a higher capacity of water absorption than raw flours. These differences can be attributed to the cooking process that denatures proteins (albumins) and therefore polar amino acids are present and have a high affinity for water, favoring this increase (Granito et al., 2004). Pragati et al. (2012) also establish, that this capacity has been associated with the increase in the amylose leaching and solubility, as well as loss of starch crystalline structure. In relation to the varieties BN (raw and cooked) were statistically different (p<0.05) to the C4, that showed a higher water absorption capacity. The water absorption capacities of raw and cooked flours were substantially superior to ten legume flours (1.2-1.9 g/g) reported by Du et al. (2014), and other three flours (0.95-2.1 g/g) determined at three temperatures by Ladjal and Chibane (2015), including in both works chickpea flour. Thus, the WAC of our characterized flours indicates a higher porosity and chemical binding properties. This water absorption property is desirable in foods such as desserts and bakery products.

3.3.2 Oil Absorption Capacity

The oil absorption capacity (OAC, Table 4) was also affected by the thermal treatment and drying through the cooking process. In contrary to WAC, raw flours showed a higher capacity (7.29 and 7.41 g oil/g sample) compared with cooked flours (5.92 and 6.19 g oil/ g sample), being the BN better than C4. This behavior may be

related to the number of non-polar chains of proteins which bind to fatty hydrocarbon chains. Granito et al. (2004) and Ladjal and Chibane (2015) mention that this capability is determined by the structure of the protein matrix, the arrangement of amino acids within the protein structure, which in turn determines the hydrophobic protein-fat relation, also affected by the fat type and the presence of starch. Those observed capacities for our flours (> 5g/g) resulted higher than ten flours (0.9-1.4 g/g) studied by Du et al. (2014), and three flour (0.6-0.9 g/g) measured at 25, 50 and 75 ℃ by Ladjal and Chibane (2015). The oil absorption property is desirable in seasoning and emulsion products, among others.

Table 4. Functional properties of chickpea flours

Samples	WAC g H$_2$O/g sample	OAC g oil/g sample	Gelation properties		
			4%	12%	20%
RBNF[1]	6.16 ± 0.25[ab]	7.41 ± 0.51[a]	-	±	+
RC4F[2]	5.92 ± 0.68[b]	7.29 ± 0.48[ab]	-	±	+
CBNF[3]	7.21 ± 0.21[a]	6.10 ± 0.11[ab]	-	±	+
CC4F[4]	6.97 ± 0.09[ab]	5.92 ± 0.55[b]	-	±	+

[1]RBNF = Raw Blanco Noroeste flour; [2]RC4F = Raw Costa 2004 flour. [3]CBNF = Cooked Blanco Noroeste flour; [4]CC4F = Cooked Costa 2004 flour.

Means (± standard deviation) of triplicate analysis. Values followed by a different superscript in column are significantly different (p<0.05) by Tukey test.

(-) No gel formation; (±) partial gel formation; (+) Strong gel formation.

3.3.3 Gelation Properties

The gelation properties at the three concentrations (4%, 12% and 20%) showed that the different meals did not form a gel at low concentration (Table 4). As the concentration increased to 12% a partial gel formation was observed, while at 20% a strong gel was detected. Our findings contrast with those reported by Kohajdová et al. (2011), in which a 6% concentration was enough to form a gel, whereas Ladjal and Chibane (2015) observed gel formation at 8% for chickpea flour and 12% for lentil and pea one. Kaur et al. (2007) suggest that these variations in different legume flours are attributable to reactions between proteins, lipids and carbohydrates and those interactions may have a significant effect on grain functional properties, in addition to the processing influence.

3.3.4 Pasting Behavior

The pasting curve for both types of flour is illustrated by Figure 1, showing clear differences. It may be observed which the native starch present in the flour and the treatment also, directly contributed to generate different responses under the same conditions, raw flours exhibited higher viscosities in contrast to cooked flours.

Pasting temperature (temperature at the onset of the rise in viscosity) of raw flours chickpea were 74.6 and 85.9 ℃. RC4F presented the highest value or peak viscosity. RC4F chickpea flour showed a gradual increase in viscosity with temperature augment because of amylose release from the swelling starch granules, higher than RBNF. This temperature is high compared with other flours, Sanjeewa et al. (2010) reported a range of 61.7 to 68.0 ℃.for chickpea ones, and those values of 73-83 ℃ obtained for ten legume flours (Du et al., 2014). According to Kaur and Singh (2005), flour from Indian chickpea cultivars had pasting temperatures ranging from 73.1 to 75.2 ℃. Furthermore, both raw flours did not show another peak in viscosity during the heating ramp, and during the holding phase the viscosity continued to increase progressively, reaching a final viscosity of 380 (RC4F) and 272 cP (RBNF). This behavior exhibited the non-existence of structural breakdown during heating and reflected high thermal stability of both flours. On the other side, the cooked flours showed low viscosity during the test, CC4F reached a maximum viscosity 64.5 cP at 90 ℃, whereas CBNF reached 77 cP at the same 90 ℃.
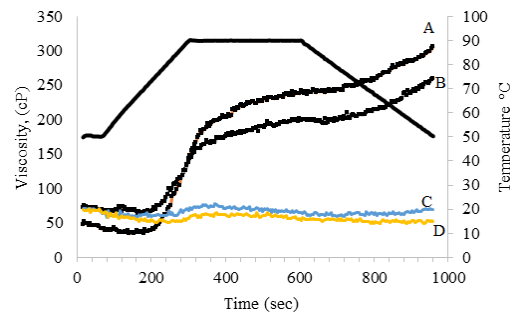
Figure 1. RVA viscogram of chickpea flours (A) RC4F, (B) RBNF, (C) CBNF and (D) CC4F.

The maximum viscosity is considered a balance between the capacity of the granules to swell and the leaching of polymers that form the starch; this process is affected by the processing conditions. A gelatinized starch does not develop high viscosity, and conversely one native starch tends to develop its maximum viscosity. These patterns demonstrate that changes during starch cooking, modified their behavior because amylose chains are solubilized and there is a lower contribution of these molecules to viscosity. The final viscosity was significantly affected by temperature, obtaining higher viscosity values in raw samples. It is possible, that during the cooling of the samples, an association of starch molecules was carried out, particularly between amylose chains, which resulted in the formation of a gel and an increase in the viscosity (Chaunier et al., 2007). Mendez-Montalvo et al. (2006) mention that high final viscosity values reflect a large amount of leached amylose. Therefore, raw flours could be incorporated to foods that need viscosity increasing, such soups and juices, while the cooked ones should be added in food formulations that do not need thickening.

We will utilize one of these cooked flours to formulate dairy desserts and another raw flour as an ingredient for an acidified beverage, for future researches and as an application of the results obtained in the present work.

4. Conclusion

The results of this study reveal that the chickpea grain varieties present similar physicochemical characteristics, whereas their flours had different physicochemical properties. Preparation processing significantly affects the physicochemical properties in studied flours. The applied processes had a significant effect on color, fat and moisture contents of cooked flours, and also affected the particle size significantly, in comparison with raw flours. The water absorption capacity for cooked flours was significantly higher. The gelation response required a concentration of 20% to achieve a strong gel. The raw flours showed higher pasting properties. In general, the chickpea flour with higher potential to be used in the food industry, either with the purpose of new product formulation, cereal flours replacement or foods complement is the obtained from the Costa 2004 variety.

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