Food ©2011 Global Science Books

Physicochemical and Cooking Characteristics of Tunisian Chickpea Varieties

Dorra Sfayhi* • **Mohamed Kharrat**

Field Crops Laboratory, National Institute of Agricultural Research of Tunisia (INRAT), University of Carthage, Rue Hédi Karray 2049 Ariana, Tunisia

Corresponding author: * sfayhi.dorra@yahoo.fr

ABSTRACT

Seed weight, size and volume, hydration and swelling capacities and cooking time of six Tunisian Kabuli chickpea varieties were evaluated and compared to one Desi accession. Physicochemical characteristics (water solubility and water absorption indices, bulk density and hunter color) of flours were determined for all of them. The Tunisian chickpea varieties showed higher seed weight, size and volume than the Desi type. This tendency was also observed for swelling and hydration capacities and cooking time. Cooking time was positively correlated with hydration capacity (R^2=0.67), and was positively correlated to seed size (R^2=0.77). Concerning the physicochemical characteristics of chickpea flours, significant variability between Tunisian chickpea varieties was observed. Compared to Desi type 'JG62', they presented lighter flours with low bulk density ranging between 0.6 and 0.67 g/ml and high water solubility index varying between 25.2 and 30.8%.

Keywords: seed, flour, legume, quality
Abbreviations: ADF, acid detergent fiber; **INRAT**, National Institute of Agricultural Research of Tunisia; **NDF**, neutral detergent fiber; **WAI**, water absorption index; **WSI**, water solubility index

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop in the world, considered as a major food legume crop in many countries (FAO 2008) and an important source of protein ranging from 20 to as much as 40 g/100 g dry matter (Saxena *et al*. 1987). It contains high levels of carbohydrates (57-60 g/100 g), vitamins and minerals (1950-1695 mg/100 g dry matter) and is relatively free from anti-nutritional factors (Muzquiz *et al.* 2007; Wood *et al.* 2007, Wang *et al.* 2010). Furthermore, chickpea's oil is enriched with polyunsaturated fatty acids accounting for about 6.58-9.12 g/100 g dry matter (Abdul Wajid *et al.* 2007; Lou *et al.* 2010). Many reports have proposed this grain legume as part of the dietary treatment due to the fact that the chickpea extract decreases the level of triglycerides, cholesterol (Perry 1980; Wu *et al*. 2001) and could be used in the prevention of obesity and on the treatment of non-insulin-dependent diabetes (Gu *et al*. 2008).

Based on seed colors and shapes, chickpeas are grouped into two types: Desi (Indian origin) and Kabuli (Mediterranean and Middle East origin) (Kaur *et al*. 2005). Desi type is characterized by small, angular dark-colored seed whereas Kabuli type is large smooth coaled, beige seeds (Gil *et al*. 1996). Some reports already indicated variation in physical qualities as well as in the chemical composition of this grain legume. These variations might be due either to intrinsic factors (mainly genetic) or extrinsic factors such as storage, soil types, agronomic practices, climatic factors and technological treatments (Amir *et al*. 2007). Kharrat *et al*. (1990) reported high variations of protein and fiber (Acid Detergent Fiber and Neutral Detergent Fiber) contents between Desi and Kabuli chickpea types. These variations were much more important between both types for ADF and NDF. In fact they found that Kabuli genotypes varied for ADF from 3.9 to 7.7% and for NDF from 6.0 to 12.7% whereas Desi genotypes ranged between 10.4 and 17.5 for ADF and between 13.6 and 20.7% for NDF. However the range of variations is almost similar for protein between Kabuli and Desi genotypes, which vary from 20.6 to 27.3% and 19.9 to 26.8%, respectively.

In recent years, due to their high protein content, much more interest was given to the incorporation of grain legumes into flour to improve their composition for various food formulations (Walsh 1997; Sterner *et al*. 1999; Birkina *et al*. 2004). Nevertheless, the benefits of these proteins are usually dependent on their physical and chemical characteristics and also on their interactions with other food compounds. These characteristics influence the preparation process and the quality attributes of food (Kaur and Singh 2005).

The consumption of chickpea in the world is around 6 Kg/person/year, however in Tunisia it is only about 3 Kg/person/year with a total production of 9400 T/year during the period 2004-2008 (Anonymous 2009) and where only Kabuli varieties are grown. In Tunisia, researches conducted in field crops laboratory of INRAT are mainly focused on selection of high-yielding and tolerant varieties to Ascochyta blight and Fusarium wilt. These researches permitted to release of six Kabuli chickpea varieties based mainly on disease resistance and yield performance. However, the physicochemical properties of these varieties are not sufficiently studied.

The objectives of this work were to determine the physicochemical properties of seed and flour of six Tunisian Kabuli chickpea varieties. The cooking characteristics were also evaluated. The obtained results were correlated and compared to those of a Desi type genotype.

MATERIALS AND METHODS

Material

Seven chickpea varieties obtained from Field Crops Laboratory of the National Institute of Agricultural Research of Tunisia were

Received: 5 January, 2011. Accepted: 26 May, 2011.

Original Research Paper

used in this study. Six of them are Tunisian Kabuli type: 'Béja 1', 'Béja 2', 'Neyer', 'Kasseb', 'Bouchra', 'Chetoui' and the seventh is 'JG-62', a Desi type.

Seeds of different chickpea varieties were ground by using Cyclotec (Foss, France) to obtain flour.

Proximate composition

Moisture, fat, NDF and protein contents (N×6.25) of chickpea varieties were determined by employing standard methods of analysis (AOAC 1984).

Physical characteristics of chickpea seeds and cooking time

Seed weight (g/seed): 100 seeds were weighted. The test is done on three samples (Williams *et al*. 1988).

Seed volume (ml): volume of 100 seeds was measured by absolute displacement using distilled water (Attia *et al*. 1994).

Seed size distribution (mm): a rack of sieves with round holes of 9, 8, 7 and 6 mm diameter was used. Amount of 100 g of chickpea seeds were transferred to top (9 mm) sieve and shacked mechanically for 3 min. The seeds of each sieve were weighted and the seeds size distribution was calculated from the amount of seeds of each sieve (Williams *et al*. 1988).

Hydration capacity (g/seed): 100 chickpea seeds were weighted and placed in a beaker. 150 ml of distilled water were added and the samples were held for 16 h at room temperature. After removing the surplus water and non swelling seeds, the sample was weighted. The hydration capacity per seed is the weight of water absorbed by the seeds (Williams *et al*. 1988). This is given by the following formula:

$$Hydration\ capacity = \frac{(Y-(X-(X/100)\times N_2))}{(N_1-N_2)}$$

where Y = weight of seeds after soaking, X = weight of seeds before soaking, N_1 = original number of seeds, N_2= number of non hydrated seeds.

Swelling capacity (ml/seed): is a volumetric measurement based on the difference in volume between dry and soaked seeds. 100 seeds were placed in a 150 ml graduated cylinder and leaved for 16 h at room temperature. The non hydrated seeds were removed and the remaining seeds were replaced in a 250-ml graduated cylinder with 100 ml water. Volume of hydrated seeds is then recorded. Swelling capacity is calculated using the following formula (Williams *et al*. 1988):

$$Swelling\ capacity/seed = \frac{(Y_1-Y_2)-(X_1-X_2)-(((X_1-X_2)/N_1)\times N_2)}{(N_1-N_2)}$$

where Y_1 = volume of water + hydrated seeds, Y_2 = volume of water added to hydrated seeds, X_1 = volume of water + dry seeds, X_2 = volume of water added to dry seeds, N_1 = original number of seeds, N_2 = number of non-hydrated seeds.

Cooking time (min): determined using Williams *et al*. (1988) method after boiling 100 seeds of each chickpea variety in beaker containing 800 ml of distilled water.

Physicochemical characteristics of chickpea flours

Water Solubility Index (WSI) and Water Absorption Index (WAI): WSI and WAI were evaluated using the method of Kaur and Singh *et al*. (2005). Samples (1 g/variety) were dispersed in 12 ml of distilled water using a glass rod and cooked at 90°C for 15 min in water bath. After cooling at room temperature, sample was centrifuged at 3000 × *g* for 10 min. The supernatant was decanted for determination of its solid content into a tarred evaporating dish and the sediment was weighted. The weight of dry solid was recovered by evaporating the supernatant overnight at 110°C. WSI and WAI were calculated by the following formulas:

$$WSI(\%) = \frac{Weight\ of\ dissolved\ solids\ in\ \text{supernatant}\times 100}{Weight\ of\ dry\ solids}$$

$$WAI = \frac{Weight\ of\ \text{sediment}}{Weight\ of\ dry\ solids}$$

Bulk density (ρ_A): The flour samples were placed in a known volume stainless cylinder. The bottom of cylinder was gently tapped on a laboratory bench 10 times until there was no further diminution of the sample level. Bulk density was obtained dividing the sample mass by the cylinder volume (g/ml) (Kaur and Singh 2005).

Hunter color characteristics: Color measurements of chickpea flour samples were done with a Minolta colorimeter Model (Minolta Ltd, Japan). *L*, *a* and *b* color values were recorded and compared with a white standard possessing the following values:

L_s = 97.63; a_s = 0.78; b_s = -2.85.

where the 'L' value indicates the lightness, 0 to 100 representing dark to light, the 'a' value gives the degree of the red-green color, with a higher positive a value indicating more red. The 'b' value indicates the degree of the yellow-blue color, with a higher positive b value indicating more yellow.

Statistical analysis

The data reported in all the tables are the averages of triplicates observation. The data were subjected to statistical analysis using Statistica software version 5 (USA) using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test comparison among mean. Significance was defined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Proximate composition

Proximate composition of the seven chickpea varieties are presented in **Table 1**. Protein contents ranged between 25.2% for both 'Béja 2' and the Desi line 'JG62' and 28.65% for 'Kasseb'. These high protein contents confirm the interest of using chickpea seeds to obtain protein products with added value (Clemente *et al*. 2005). Moisture and natural detergent fiber (NDF) of flours from different Tunisian chickpea varieties ranged from 9.95 to 10.70% and 15.98 to 28.28%, respectively. Compared to 'Desi', the Tunisian Kabuli chickpea varieties presented low NDF values. This is in agreement with results reported by Kharrat *et al*. (1990) showing highest values of NDF for Desi as compared to Kabuli chickpea genotypes. The crude fat values of the Tunisian chickpea varieties have almost similar levels than Desi variety. They vary from 3.94 to 4.9%.

Physical characteristics of chickpea seeds and cooking time

Physical characteristics of Tunisian chickpea varieties varied significantly (**Table 2**). The seed weight fluctuated from 26.5 to 34.7 g/100 seeds. Highest value was observed for 'Béja 2' and the lowest for 'Chetoui'. The 'Desi' type JG62 had the lowest seed weight 13.8 g/100 seeds. Kaur *et al*. (2005) reported similar results. This variation might be due to intrinsic factors, mainly genetic (Amir *et al*. 2007) and appears to be correlated to seed size. Indeed, the Tunisian chickpea varieties presented higher seed size ranging from 6.29 mm to 7.66 mm, with lowest value for 'Chetoui' and highest one for 'Béja 1'. Seed size was positively correlated with seed weight (R^2 = 0.95, P < 0.05) and could be correlated to the enzymes activity in sugar metabolism for chickpea cotyledon's development (Turner *et al*. 2009).

Seed volume showed also significant differences between varieties. It varied from 17.5 ml to 26.5 ml for Tuni-

Table 1 Proximate composition of flours from different chickpea varieties.

Varieties	Ash (%)	Moisture (%)	Crude fat (%)	Protein (%)	NDF (%)
Nayer	3.12 ± 0.02 c	10.28 ± 0.04 ab	4.81 ± 0.07 a	26.26 ± 0.07 e	21.07 ± 2.46 bcd
Kessab	3.22 ± 0.02 a	10.37 ± 0.04 a	3.94 ± 0.21 bc	28.65 ± 0.07 a	25.40 ± 6.07 bc
Bouchra	3.15 ± 0.07 b	10.70 ± 0.47 a	4.27 ± 0.09 b	27.75 ± 0.21 b	15.98 ± 4.16 d
Chetoui	3.14 ± 0.01 bc	10.27 ± 0.05 ab	4.6 ± 0.27 a	27.32 ± 0.007 c	28.28 ± 5.82 b
Béja 1	3.21 ± 0.01 a	10.33 ± 0.29 ab	4.9 ± 0.16 a	26.65 ± 0.21 d	19.12 ± 2.04 cd
Béja 2	3.12 ± 0.02 c	9.95 ± 0.023 b	4.24 ± 0.14 bc	25.20 ± 0.2 f	19.12 ± 2.05 bc
Desi (JG62)	2.99 ± 0.02 d	9.77 ± 0.36 b	3.9 ± 0.18 c	25.20 ± 0.14 f	32.22 ± 7.33 a

Mean ± standard deviation for triplicate analyses.
Means followed by same letter within a column do not differ significantly ($P < 0.05$) using Duncan's multiple range test for mean comparison.
NDF: Neutral Detergent Fiber

Table 2 Physicochemical and cooking characteristics of different chickpea varieties.

	Seed weight (g/100 g)	Seed size (mm)	Seed volume (ml)	Hydration capacity (g/seed)	Swelling capacity (ml/seed)	Cooking time (min)
Chetoui	26.5 ± 0.52 c	6.29 ± 0.005 e	17.5 ± 0.5d	0.29 ± 0.01 cd	0.35 ± 0.01c	112.0 ± 2.64 a
Kasseb	32.5 ± 0.52 ab	7.03 ± 0.05 c	23.5 ± 0.5 c	0.28 ± 0.01 d	0.42 ± 0.01 b	92.66 ± 1.52 c
Bouchra	34.3 ± 1.26 a	6.92 ± 0.07 d	24.83 ± 0.7 b	0.31 ± 0.025 c	0.43 ± 0.011 ab	96.66 ± 1.15 b
Béja 1	34.1 ± 1.57 a	7.66 ± 0.025 a	26.5 ± 0.5 a	0.36 ± 0.02 6b	0.43 ± 0.011 ab	111.66 ± 2.08 a
Béja 2	31.66 ± 1.35 b	7.07 ± 0.089 c	24.16 ± 0.28 bc	0.4 ± 0.005 a	0.44 ± 0.01 1a	113.66 ± 1.52 a
Neyer	34.46 ± 1.11 a	7.47 ± 0.060 b	26.5 ± 0.5 a	0.35 ± 0.005 b	0.43 ± 0.005 ab	95.33 ± 0.57 bc
Desi (JG62)	13.83 ± 0.35 d	5.21 ± 0.06 f	11.16 ± 0.28 e	0.14 ± 0.005 e	0.12 ± 0.011 d	76.33 ± 2.08 d

Mean ± standard deviation for triplicate analyses.
Means followed by same letter within a column do not differ significantly ($P < 0.05$) using Duncan's multiple range test for mean comparison.

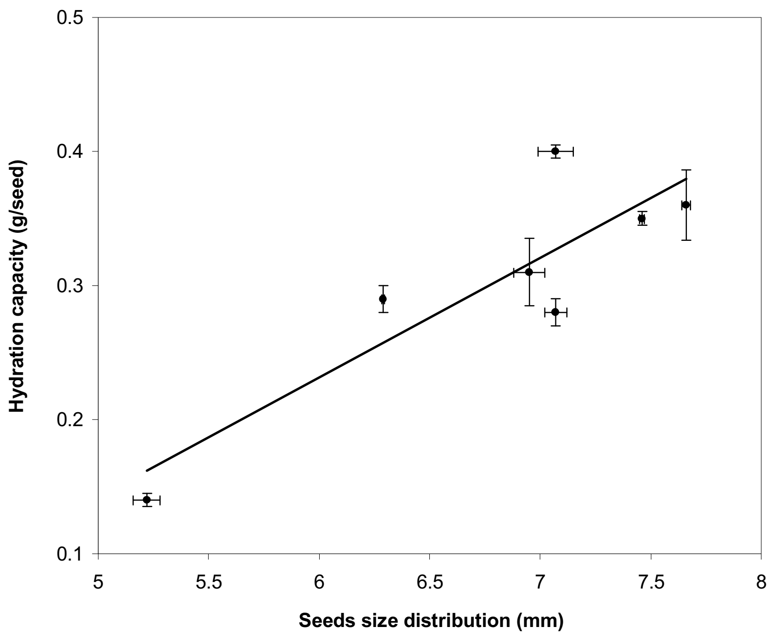

Fig. 1 Relationship between hydration capacity and seed size of chickpea varieties.

sian chickpea varieties. 'Chetoui' had the lowest volume whereas 'Béja 1' had the highest one. The differences could be mainly due to the carbohydrate and fat contents (Kaur *et al*. 2005). These authors found a positive correlation between seed volume and these both components.

For Tunisian varieties, swelling and hydration capacities ranged between 0.35-0.44 ml/seed and 0.28-0.4g/seed, respectively (**Table 2**). 'Béja 2' had the highest values (0.44 ml/seed; 0.4g/seed) whereas 'Chetoui' had the lowest value for swelling capacity and 'Kasseb' had the lowest value for hydration capacity. As compared to 'JG62', these values were higher and could be due to the size of the seeds and its composition. Positive correlation was observed between seed size and hydration capacity (**Fig. 1**). Muller (1967) had shown that the water absorption capacity depends on cell wall structure, composition of seed and compactness of the cell in the seeds.

The cooking time is an important aspect of cooking quality. It is a heritable characteristic that differ widely among genotypes (Kaur *et al*. 2005). The cooking time for Tunisian chickpea varieties varied from 92.7 to 113.7 min, with an average of 103.6 min. The highest value was for 'Béja 2' and the lowest for 'Kasseb' variety. The 'Desi' genotype needed only 76.3 min for cooking. The difference in cooking time could be attributed to the difference in the hydration capacity. The later influences the water penetration in order to reach the intermost portions of seeds (Kaur *et al*. 2005). **Fig. 2** shows a positive correlation between hydration capacity and cooking time. Ibarz *et al*. (2004) studied the kinetic model for water absorption and cooking time in chickpea, as well as the effect of soaked sample in the cooking time. They showed that the cooking time decreases as the soaking time increases. Moreover, they found a correlation between cooking time and initial water content in chickpea. In our study, the varieties studied had almost same initial humidity around 10% (**Table 1**).

Physicochemical properties of chickpea flours

Table 3 presents Hunter color values of flour for the different chickpea varieties. The Hunter *a* value of 'Chetoui', 'Kasseb' and 'Bouchra' varieties are higher than 'Béja 1',

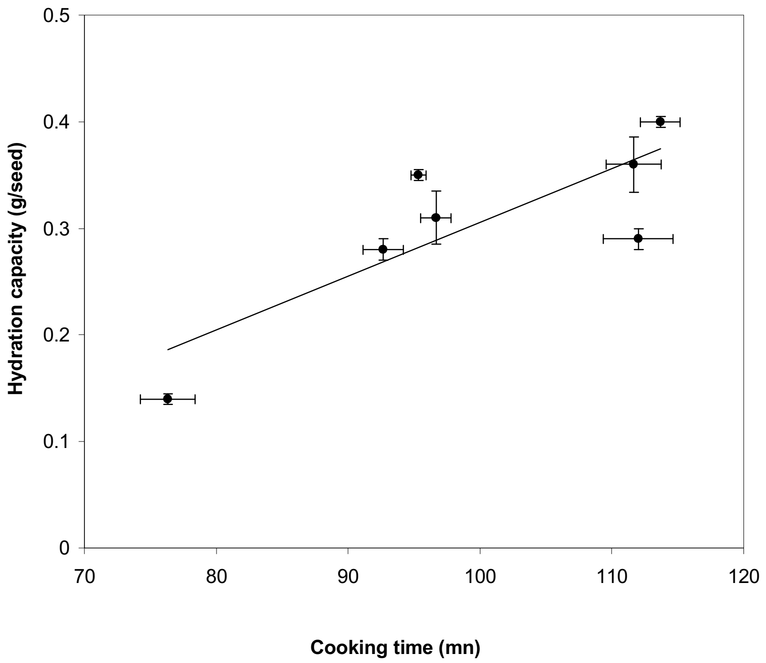

Fig. 2 Relationship between hydration capacity and cooking time of chickpea varieties.

Table 3 Hunter color values of flours from different chickpea varieties.

	a	b	L
Chetoui	1.79 ± 1.15 a	33.56 ± 1.06 b	77.91 ± 3.94 cd
Kasseb	1.25 ± 0.54 abc	30.52 ± 2.39 c	81.82 ± 2.84 abc
Bouchra	1.37 ± 0.46 ab	35.02 ± 1.02 b	82.77 ± 1.88 ab
Béja 1	0.41 ± 0.035 bc	37.57 ± 0.58 a	80.11 ± 2.29 bc
Béja 2	0.94 ± 0.13 abc	33.62 ± 0.29 b	83.55 ± 0.82 ab
Neyer	0.76 ± 0.29 bc	31.36 ± 1.22 c	84.88 ± 3.03 a
Desi (JG62)	0.25 ± 0.08 c	23.12 ± 0.2 d	74.97 ± 0.17 d

Mean ± standard deviation for triplicate analyses.
Means followed by same letter within a column do not differ significantly ($P < 0.05$) using Duncan's multiple range test for mean comparison.

Table 4 Physicochemical properties of flours from different chickpea varieties.

	Bulk density (g/ml)	**WSI (%)** [a]	**WAI*** [b]
Chetoui	0.63 ± 0.02 bc	30.80 ± 0.66 a	6.84 ± 0.33
Kasseb	0.64 ± 0.02 bc	29.85 ± 1.48 a	6.47 ± 0.64
Bouchra	0.60 ± 0.03 c	25.93 ± 1.79 b	7.05 ± 0.93
Béja 1	0.67 ± 0.03 ab	25.27 ± 2.09 b	6.19 ± 0.69
Béja 2	0.66 ± 0.01 ab	28.77 ± 1.23 a	6.46 ± 0.68
Neyer	0.61 ± 0.01 c	25.24 ± 0.87 b	6.92 ± 0.29
Desi (JG62)	0.71 ± 0.03 a	21.67 ± 1.15 c	5.35 ± 0.34

Mean ± standard deviation for triplicate analyses.
Means followed by same letter within a column do not differ significantly ($P < 0.05$) using Duncan's multiple range test for mean comparison.
[a]. Water solubility index
[b]. Water absorption index. No significant differences was observed
* No significant differences observed

'Béja 2' and 'Neyer' varieties, indicating that their flours are more reddish in color. The *b* and *L* values of different Tunisian chickpea flours ranged between 30.52 to 37.57 and 77.91 to 84.88, respectively. Among the Tunisian chickpea varieties, 'Chetoui' had the highest *b* value and the lowest *L* value, indicating that it is the darkest reddish in color. Comparing to 'Desi' variety, all these values were higher. The *b* value indicates the degree of the yellow-blue color, with a higher positive *b* value showing more yellow. This suggests that Tunisian chickpea flours were light yellow in color comparing to 'Desi' (**Table 3**).

The values of bulk density of different flours issued from Tunisian chickpea varieties varied significantly (**Table 4**) and ranged between 0.6 and 0.67 g/ml. The highest value was for 'Béja 1' flour and the lowest one for 'Bouchra'. However the 'Desi' type had the highest bulk density (0.71 g/ml). This result suggests that 'Desi' chickpea flour is denser than the Tunisian chickpea flours. Significant differences were also observed for water solubility index (WSI) in flours from different Tunisian chickpea varieties. The WSI is related to the presence of soluble molecules, which had sometimes been related to dextrinization according to Colonna *et al.* (1983). Milàn-Carrillo *et al.* (2000) showed the decrease in WSI with extrusion of the chickpea flour. They suggested that this behavior is caused by a higher bulk density and lower particle size index of extruded chickpea flour. In our work, the flour issued from Tunisian chickpea varieties presented higher values of WSI (25.24-30.80%) comparing to 'Desi' variety (21.67%). These results are in agree of those of Kaur and Singh (2005), who showed significant differences between Kabuli and Desi types in WSI. Concerning WAI, no significant differences were observed among all the samples.

CONCLUSION

Significant differences were observed in physicochemical, cooking characteristics of different Tunisian chickpea varieties. Seeds with high size have higher hydration capacity and long cooking time. Among all the tested chickpea varieties, the Tunisian variety 'Beja 2' has the highest value in seed size, weight, hydration capacity and cooking time. Concerning physicochemical flours characteristics, the Tunisian chickpea flours present lighter flours with low bulk density and high water solubility index comparing to 'Desi' variety (JG62).

REFERENCES

AOAC (1984) *Official Method of Analysis* (14th Edn), Association of Official Analytical Chemists, Arlington, 1141 pp

Abdul Wajid K, Aurang Z, Fazal M, Saima T, Amal Badshah K, Hamidullah S (2007) Comparison of sprout quality characteristics of desi and kabuli type chickpea cultivars (*Cicer arietinum* L.). *LWT – Food Science and Technology* **40**, 937-945

Anonymous (2009) Available from the statistics data base-agriculture of the General Direction of Agricultural Production (GDPA), Agricultural Ministry of Tunisia

Amir Y, Haenni AL, Youyou A (2007) Physical and biochemical differences in the composition of the seeds of Algerian leguminous crops. *Journal of Food Composition and Analysis* **20**, 466-471

Attia RS, El Tabey Shehata AM, Aman ME, Hamza MA (1994) Effect of cooking and decortication on the physical properties, the chemical composition and the nutritive value of chickpea (*Cicer arietinum* L.). *Food Chemistry* **50**, 125-131

Birkina VV, Lisun AV (2004) Mixture for producing of ice-cream "snow muss". Russian patent N° RU2240702. Available online: http://ep.espacenet.com

Clemente A, Vioque J, Sánchez-Vioque R, Pedroche J, Bautista J, Millán F (1999) Protein quality of chickpea (*Cicer arietinum* L.) protein hydrolysates. *Food Chemistry* **67**, 269-274

Colonna P, Tayeb J, Mercier C (1983) Extrusion cooking of starch and starchy products. In: Mercier C, Linko P, Harper JM (Ed) *Extrusion Cooking*, American Association of Cereal Chemist, St Paul MN, USA, pp 281-308

FAO Food and Agriculture Organization of the United Nations (2008) available online http://www.fao.com from the FAOSTAT statistics database-agriculture, Rome, Italy

Gil J, Nadal S (1996) Variability of some physico-chemical characters in Desi and Kabuli Chickpea types. *Journal of the Science of Food and Agriculture* **71**, 179-184

Gu Y-J, Yue X-H, Yang Y (2008) Chickpea extracts as therapeutic agents and foods in the treatment and prevention of obesity and non-insulin-dependent diabetes. United States Patent N° US2008138453. Available online: http://ep.espacenet.com

Kaur M, Singh N, Sodhi N (2005) Physico-chemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. *Journal of Food Engineering* **69**, 511-517

Kaur M, Singh N (2005) Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. *Food Chemistry* **91**, 403-411

Kharrat M, Jimenez MD, Gil J, Cubero JI (1990) Genetics of some quality components in Desi × Kabuli cross. *International Chickpea Newsletter* **22**, 16-18

Ibarz A, González C, Barbosa-Cánovas GV (2004) Kinetic models for water adsorption and cooking time in chickpea soaked and treated by high pressure. *Journal of Food Engineering* **63**, 467-472

Muller FM (1967) Cooking quality of pulses. *Journal of the Science of Food and Agriculture* **18**, 292-295

Muzquiz M, Wood JA (2007) Anti-nutritional factors. In: Yadav SS, Redden B, Chen W, Sharma B (Ed) *Chickpea Breeding and Management*, CAB International, Wallingford, UK, pp 143-166

Milàn-Carrillo J, Moreno-Reyes C, Armienta-Rodelo E, Carabez-Trejo A, Mora-Escobedo R (2000) Physicochemical and Nutritional characteristics of extruded flours from fresh and hardened chickpea (*Cicer arietinum* L). *LWT-Food Science and Technology* **33**, 117-123

Lou Z, Wang H, Zhang M, Wang Z (2010) Improved extraction of oil from chickpea under ultrasound in a dynamic system. *Journal of Food Engineering* **98**, 13-18

Perry LM (1980) *Medicinal Plants of East and South-East Asia Attributed Properties and Uses*, The Massachusetts Institute of Technology Press, pp 217-222

Saxena MC, Singh KB (1987) *The Chickpea*, The International Center for Agricultural Research in the Dry Areas (ICARDA) Wallingford Oxon UK, pp 329-356

Sterner MH, Sterner MM, Zane RO (1999) Method for preparing dehydrated pea soup and product thereof. United State Patent N° US5863592. Available online: http://ep.espacenet.com

Turner NC, Furbank RT, Berger JD, Gremigni P, Abbi S, Leport L (2009) Seed size is associated with sucrose synthase activity in developing cotyledons of chickpea. *Crop Physiology and Metabolism* **49**, 621-627

Walsh D (1997) Method for manufacture of dehydrated leguminous food products. Worldwide Patent N° WO9703575. Available online: http://ep.espacenet.com

Wang N, Hatcher DW, Tyler RT, Toews R, Gawalko EJ (2010) Effect of cooking on the composition of beans (*Phaseolus vulgaris* L.) and chickpeas (*Cicer arietinum* L.). *Food Research International* **43**, 589-594

Williams P, El Haramein FJ, Nakkoul H, Rihawi S (1988) *Crop Quality Evaluation Methods and Guidelines*, International Center for Agriculture Research in the Dry Areas (ICARDA), Syria, pp 109-125

Wood JA, Grusak MA (2007) Nutritional value of chickpea. In: Yadav SS, Redden B, Chen W, Sharma B (Eds) *Chickpea Breeding and Management*, CAB International, Wallingford, UK, pp 101-142

Wu SJ, Wang JS, Lin CC, Chang CH (2001) Evaluation of hepatopreoctive activity of legumes. *Phytomedicine* **8 (3)**, 213-219