

Hydration and cooking behaviour of three Portuguese Chickpea (*Cicer arietinum* L.) cultivars

Comportamento de três cultivares portuguesas de grão-de-bico (*Cicer arietinum* L.) durante os processos de hidratação e cocção

A. Cristina Ramos^{1*}, Armando Ferreira¹, Beatriz Sousa¹, M. João Trigo¹, Isabel Duarte² e M. Paula Esteves¹

¹ National Institute for Agrarian and Veterinary Research (INIAV), Unit of Technology and Innovation, Quinta do Marquês, 2780-157 Oeiras, Portugal

² National Institute for Agrarian and Veterinary Research (INIAV), Biotechnology and Genetic Resources Unit, Apt. 6, 7350-901 Elvas, Portugal

(*E-mail: cristina.ramos@iniav.pt)

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ABSTRACT

Seeds of three Portuguese kabuli type chickpea cultivars (Elvar, Eldorado and Elixir) were studied for their physicochemical characteristics (biometry, hydration, swelling, texture) and traditional cooking behaviour. A commercial non-identified cultivar from Argentina was used for comparison purposes. Significant differences in seed weight and firmness were observed between the commercial variety and the Portuguese ones. Concerning hydration capacity there are no significant differences between cultivars, however, Eldorado had the lowest hydration and swelling capacities when soaked for 6h at 20°C. Furthermore, Eldorado seeds tend to soften with cooking more than the other cultivars.

Keywords: chickpea, hydration, swelling, cooking, firmness

RESUMO

Sementes de três cultivares de grão-de-bico Kabuli (Elvar, Eldorado e Elixir) foram estudadas quanto às características físico-químicas (biometria, hidratação, intumescimento, textura) e comportamento após cozimento tradicional. Uma cultivar comercial não identificada, proveniente da Argentina, foi usada para fins de comparação. Diferenças significativas no peso e firmeza das sementes foram observadas entre a variedade comercial e as portuguesas. Em relação à capacidade de hidratação não há diferenças significativas entre as cultivares, tendo a Eldorado apresentado as menores capacidades de hidratação e intumescimento quando demolhada durante 6h a 20°C. As sementes de Eldorado são ainda as que apresentam maior perda de firmeza após cozimento.

Palavras-chave: grão-de-bico, hidratação, intumescimento, cozimento, firmeza

INTRODUCTION

Chickpea (*Cicer arietinum* L.), the third most important pulse crop in the world, is a spring crop, sown during March-April and is extremely affected by long periods of drought during the reproductive phase, thus yields are normally low. This legume conserves the soil and protects it from erosion, adds organic matter, fixes and saves soil nitrogen, and helps in controlling cereal diseases. The contribution of chickpea like a grain legume to soil fertility is one of the key factors in sustaining the

production of cereal crops in rainfed dry areas in the developing world. In fact, it is a very important crop to be included in crop rotation.

The grain legumes (GL) are a valuable source of protein, energy, vitamins and minerals for animal feed. For human food they present additional benefits for consumers who are increasingly aware of environmental costs of production, the relation between diets and health, and requiring tasty and convenient food which offers nutritional benefits. Despite its important protein content, generally GL are reported

to have low protein digestibility and the presence of non-nutritional compounds such as tannins, phytic acid and saponins. Hydration and cooking processes are thus necessary in order to improve nutritional properties by reducing the amount of these compounds (Alajaji & El-Adawy, 2006).

Chickpea seeds are an important source of protein constituting an excellent origin of this nutrient in the diet of many people. The seeds contain about 20% protein, 5% fat and 55% total carbohydrates. The chickpea characteristics for human consumption are strongly associated with their technological properties, particularly the ability to absorb water during soaking and cooking processes so that the grains soften and starch gelatinization occurs, generating food with added nutritional properties. Rapid hydration with maximum weight and/or volume gain is most desirable for canning purposes with the minimization of leaching and/or loss of nutrients or even microbial problems (Wood & Harden, 2006).

Portugal is a country with a deficit in chickpea production, although it is able to grow it all over the country excepting the humid regions of the North and coastal regions of Portugal. Almost 80% of consumed chickpea is currently imported from other countries. After many years of genetic plant breeding held at the National Institute for Agrarian and Veterinary Research (INIAV) in Elvas, it was observed that most of GL adapts very well to the soil and climate conditions of continental Portugal.

The breeding strategies were based on adaptation to biotic and abiotic factors developed by chickpeas plants. Breeding programs and the selection of elite chickpea genotypes can make use of the phenotypic plasticity of the species by which plants can adjust to limiting conditions as, for example, shifts in leaf phenology and flowering time (Duarte-Maçãs, 2003; Duarte & Pereira, 2016).

This program has already led to three “successful” cultivars of chickpeas – Elvar, Eldorado and Elixir – which are already registered at the European and National Catalogue of Varieties (CNV). These catalogues are based on the plant varieties registration at EU countries. This variety registration is a precondition for the seed certification. Elvar was registered in 1993, Elixir and Eldorado in 2006.

In food processing and domestic use, chickpea seeds are usually subjected to a soaking period before the cooking process. Both processes, hydration and cooking, are related and improve the physical and nutritional characteristics of cooked grains as they become softer and starch is best gelatinized. During the soaking period the seeds adsorb a certain amount of water which is evidenced by their weight and volume gain. By definition, Hydration Capacity (HC) of pulses is the amount of water that whole seeds absorb after soaking in excess water for 16 h at room temperature ($20 \pm 2^\circ\text{C}$), and is expressed as the amount of water absorbed per 100 g of seeds (AACC International, 2012b). Swelling capacity (SC) is similarly defined as the increase of volume instead of weight determined after 16 or 24 h soaking (Wood & Harden, 2006). The methods for maximum quantification of chickpeas water absorption have been extensively studied by several authors (Ibarz *et al.*, 2004; Shafaei *et al.*, 2016) and methodologies are well established (Wood & Harden, 2006). With new cultivars, the knowledge of technological characteristics is an important tool, particularly the study of hydration and cooking behaviour should be done. The purpose of this work was to study the physicochemical characteristics (biometry, hydration, swelling, texture) of three Portuguese kabuli type chickpeas – Elvar, Eldorado and Elixir – based on the existing knowledge about kinetics of hydration previous to cooking and obtained hydration and swelling capacity (Ibarz *et al.*, 2004; Wood & Harden, 2006).

MATERIAL AND METHODS

Samples

Seeds of three Portuguese Kabuli chickpea (*C. arietinum* L.) varieties (Elvar, Eldorado and Elixir) were obtained from INIAV, Elvas. They were grown under the same field conditions at Elvas and harvested in June 2015. The seeds were then stored in opaque paper bags at room temperature until this study. One single batch of commercial chickpea from Argentina was obtained in a local retailer was used as reference. Its harvest date and genotype was not referred.

Biometry

For the seed companies and processing industry the seed size is an important attribute then prior to soaking process the seed size was determined (Hossain *et al.*, 2010). Samples of clean seeds (without foreign materials and broken seeds) were randomly prepared with 100 seeds and size evaluated by two approaches: (1) the weight of 100 seeds (Wood & Harden, 2006; AACC International, 2012b) (2) proximate volume of sample on assumption of a spherical form of each seed and based on the measurements of *a* (height) and *b* (width) dimensions (mm) (Figure 1). The average dimensions (*a* and *b*) of 30 seeds of each cultivar were measured and the proximate volume, referred to 100 seeds, was calculated.

The data were obtained from three samples of each cultivar.

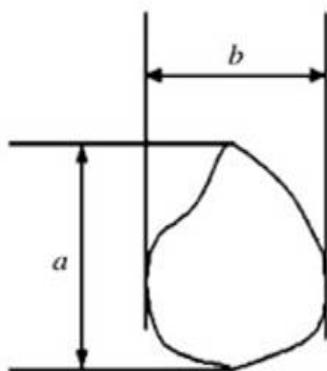


Figure 1 - Chickpea grains dimensions in mm (*a*-height; *b*-width).

Soaking and swelling – hydration properties

The water adsorption of dried seeds was evaluated by the weight gain and the volume increase after different soaking times. The study was performed at $20 \pm 2^\circ\text{C}$ as described by Wood & Harden (2006), with small adaptations: three batches of 100 seeds of each cultivar were weighted and the dimensions (*a* and *b*) of 10 randomly selected seeds were measured with a digital calliper. After 3, 6, 9 12 and 24h of soaking time, the seeds size was again determined following those procedures. For each cultivar the process was carried out in triplicate, at each time of soaking.

Weight gain (WGt) was expressed (g water/g seed) as the weight of water adsorbed by each 100 seeds sample, divided by initial weight of the sample ($\text{WGt} = (\text{Wt}-\text{W0})/\text{W0}$, where *Wt* is the weight recorded at time *t* and *W0* is the initial weight (Wood & Harden, 2006).

The proximate volume of 100 seeds was calculated from the individual volume considering each seed as a sphere ($V=4 \pi r^3/3$) where *r* is half of *b* value.

Volume gain (VGt) is referred as swelling capacity and was similarly obtained, according to $\text{VGt}=(\text{Vt}-\text{V0})/\text{V0}$, where VGt is the proximate volume gain estimated at time *t* and *V0* and *Vt* are, respectively, the initial volume and the one recorded at time *t*.

Texture

Firmness of cooked pulses is defined as the maximum force required to shear the cooked pulses and is expressed as the maximum shear force per gram of cooked sample (AACC International, 2012a). In this work the seeds firmness was determined by using a texture analyzer TA-HDi with a Mini Kramer shear cell consisting of a sample holder (2.7cm [L] × 2.7cm [W] × 2.5cm [H]) and a five-blade shear probe (dimensions for each blade: 2.5cm [W] × 2.5cm [H] × 0.25cm [T]). Samples of chickpea seeds with 7.5 ± 0.5 g weigh were placed into the shear cell holder and the test was run and maximum shear force (*Fi*) was measured at the test speed of 1.5 mm/s at room temperature ($20 \pm 2^\circ\text{C}$). Six determinations were done, for each sample and average firmness (*n*=6) is expressed in N/g of sample according to AACC International (2012a).

Cooking

The traditional cooking process in boiling water was conducted on electrical cookers. Samples composed of 100 soaked seeds were cooked in boiling tap water during 2, 3 and 4 hours. For this study it was realized another assay and for each cultivar and cooking time, three replications were done. It was chosen the time of 6 hours as soaking time, considering the firmness values and not the grain weight.

Statistical analysis

The biometric data were analyzed using SPSS statistical software (Version 19.0; IBM, Armonk, NY). The values are reported as means and standard deviations. To compare the biometric characteristics, biometric data were subjected to variance analyses and, when significant differences were found, post-hoc Scheffé test was performed and the differences were considered significant at $p \leq 0.05$. Different letters are connoted to statistical significances.

RESULTS AND DISCUSSION

Biometric characteristics of seeds

These Portuguese cultivars have been obtained from breeding programs with other objectives than seed size, although this is one of the phenotypic characteristics with interest in many breeding programs. The diversity is referred and Upadhyaya (2003) observed a variation of 40 to 630 mg/seed in more than 16 000 accessions from the World's chickpea collection. Usually, authors characterize the size by weight of 100 seeds (Wood & Harden, 2006; Hosseini *et al.*, 2009; Jha *et al.*, 2015; Mukhopadhyay *et al.*, 2015) and these were grouped in small to medium size (13-30 g/100 seeds), large seeds (35-45 g/100 seeds), and extremely large seeds (55-62 g/100 seeds) (Siddique & Regan, 2005; Hosseini *et al.*, 2009).

Table 1 shows the seed size results obtained by the two approaches for the studied cultivars. Seed weights (100 seed weight) have small differences between cultivars with Eldorado presenting the highest value (42.7 g). With regard to the

dimensions and proximate volume, Elvar has the smallest value with significant ($p < 0.05$) difference from other Portuguese cultivars. Based on experimental measurements Elixir seed density was found to have the lowest value (1.23g/mL).

Kinetics of water absorption

During the soaking period at $20 \pm 2^\circ \text{C}$ the chickpea seeds adsorbed a certain amount of water which was reflected in the weight and the volume gain.

Biometry

The behaviour of chickpea seeds Elvar, Eldorado, Elixir and "Argentina" during soaking operation was assessed by changes in the size of the seed. The seeds weight undergoing hydration (at $20 \pm 2^\circ \text{C}$), reported to 100 seed weight, is shown in Table 2.

Weight gain results reported in Table 3 show the ability of Portuguese cultivars to duplicate their weight during soaking process, although

Table 2 - Weight of 100 seeds (g) of analysed chickpea varieties as a function of hydration time at 20°C . Results are expressed as means \pm standard deviations

Time (h)	Elvar	Eldorado	Elixir	"Argentina"
0	33.74 \pm 0.53 ^d	42.71 \pm 0.55 ^d	36.91 \pm 0.50 ^d	40.55 \pm 0.72 ^c
3	55.18 \pm 0.97 ^c	71.96 \pm 0.78 ^c	61.82 \pm 1.04 ^c	70.97 \pm 1.46 ^b
6	66.06 \pm 0.48 ^b	80.08 \pm 0.71 ^b	72.03 \pm 0.46 ^b	81.64 \pm 0.68 ^a
9	68.71 \pm 0.61 ^a	84.12 \pm 1.53 ^a	74.43 \pm 1.09 ^a	83.17 \pm 0.87 ^a
12	70.71 \pm 0.44 ^a	86.23 \pm 1.54 ^a	75.22 \pm 1.22 ^a	84.69 \pm 0.70 ^a
24	71.03 \pm 1.72 ^a	85.74 \pm 1.47 ^a	75.45 \pm 0.38 ^a	82.80 \pm 2.64 ^a

Mean Values of Portuguese Cultivars with similar letter in a column do not differ significantly ($p < 0.05$)

Table 1 - Size of studied Portuguese and commercial chickpea cultivars. Results are expressed as means \pm standard deviations, based on triplicate measurements of 100 seeds

Cultivar	Weight (g/100 seeds)	Height (mm)	Width (mm)	Proximate volume (mL/100 seeds)	Density (g/mL)
Elvar	33.74 \pm 0.53 ^d	9.08 \pm 0.48 ^c	7.32 \pm 0.37 ^b	20.71 \pm 3.05 ^b	1.63 ^a
Eldorado	42.71 \pm 0.55 ^a	9.85 \pm 0.44 ^b	8.13 \pm 0.40 ^a	28.36 \pm 4.02 ^a	1.51 ^a
Elixir	36.91 \pm 0.50 ^c	9.35 \pm 0.43 ^{bc}	8.28 \pm 0.39 ^a	29.92 \pm 4.61 ^a	1.23 ^b
"Argentina"	40.55 \pm 0.72 ^b	10.06 \pm 0.51 ^a	7.94 \pm 0.56 ^a	26.54 \pm 5.47 ^a	1.53 ^a

Mean Values of Portuguese Cultivars with similar letter in a column do not differ significantly ($p < 0.05$)

at different times. Eldorado cultivar only reaches double weight after 12h of soaking, which illustrates that this cultivar requires more time to achieve this result.

The results for proximate volume (V_2) of chickpea seeds, reported to 100 seeds, were plotted and are presented in Figure 2.

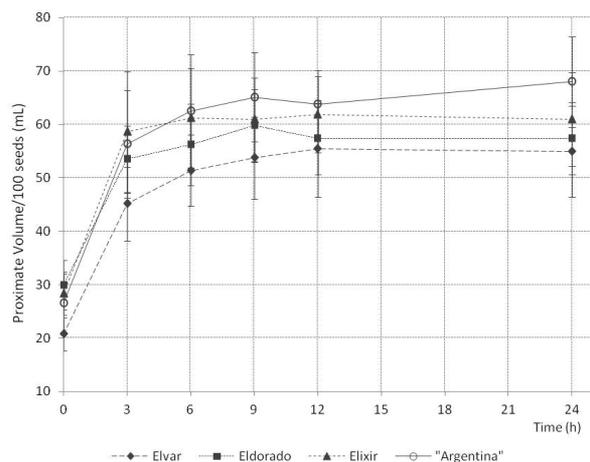


Figure 2 - Proximate volume V_2 (mL) referred to 100 seed volume plotted versus soaking time for Elvar, Elixir, Eldorado and “Argentina” cultivars. Results are expressed as means \pm standard deviations (error bars).

The experimental data show that most increase weight and volume occurred during the first 6 hours of soaking which is in accordance with Ibarz *et al.* (2004) and Wood & Harden (2006), who refer that the most water absorption occurred during the initial 7h of soaking. Other authors refer that a negligible amount of water is generally absorbed by chickpeas and most other pulses after the initial 16 h of soaking (Marconi *et al.*, 2000; Wood & Harden, 2006). In industrial applications, particularly canning, the process of hydration usually varies between 12 to 16 hours but the reduction of time is an important task, as it minimizes the growth of undesired microorganisms and loss of nutrients. For studied cultivars, significant volume increases were observed until 6h soaking period. Subsequent variations of weight and proximate volume are not significantly different ($p > 0.05$) until 24h of soaking.

Hydration Capacity

The weight and volume increases of chickpeas as a function of soaking time, express the hydration behaviour of the seed: the weight is related to Hydration Capacity (HC) and the volume to Swelling Capacity (SC). Hydration Capacity or Hydration Coefficient expressed as a percentage of original sample weight is not dependent on seed size and presents the best way to express hydration properties.

Figures 3 and 4 represent the hydration behaviour of studied cultivars undergoing soaking at $20 \pm 2^\circ\text{C}$.

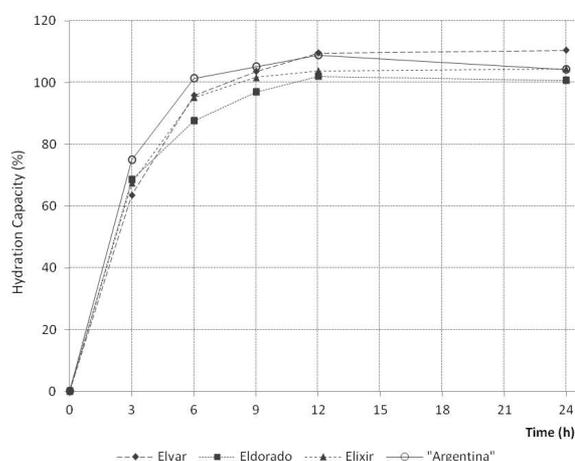


Figure 3 - Average Hydration Capacity at different soaking times for Elvar, Elixir, Eldorado and “Argentina” cultivars.

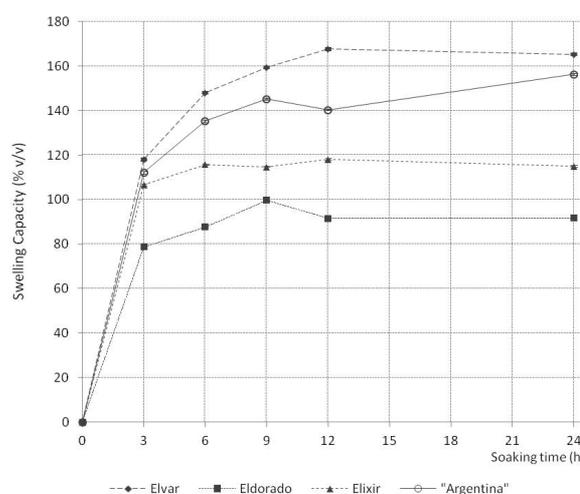


Figure 4 - Average Swelling Capacity at different soaking times for Elvar, Elixir, Eldorado and “Argentina” cultivars.

The chickpea hydration capacity (HC) was similar ($p > 0.05$) between cultivars. From Figure 4, one can observe that Eldorado presents a smaller hydration capacity, although without statistical significance, until 24 h of hydration time. The swelling capacity (SC) as a percentage of initial proximate volume makes it possible to determine, for each variety, the maximum volume increase after each soaking time.

Table 3 - Average Weight Gain (g water/g seed) of studied chickpea varieties as a function of soaking time (20°C)

SoakingTime (h)	Elvar	Eldorado	Elixir	"Argentina"
0	0.00	0.00	0.00	0.00
3	0.64	0.68	0.67	0.75
6	0.96	0.87	0.95	1.01
9	1.04	0.97	1.02	1.05
12	1.10	1.02	1.04	1.09
24	1.11	1.01	1.04	1.04

Swelling Capacity and Hydration Capacity are two independent variables of water absorption process. Portuguese cultivars, after 6h soaking, presented slightly different maximum Hydration (HCmax) and Swelling (SCmax) capacities. Eldorado cultivar hydrated and swelled the least (HCmax=88% and SCmax=88%), Elvar and Elixir cultivars presented similar hydration capacity (HCmax=95%) after 6h soaking but different swelling capacity (SCmax=148% for Elvar and SCmax=116% for Elixir).

Texture

The firmness was determined in chickpea seeds undergoing soaking process until 24h. All studied cultivars displayed a significant decrease ($p < 0.05$) of firmness after hydration, until 6 hours of soaking (20 ± 2°C) (Figure 5).

After 6h soaking the firmness maintains similar values (60 – 70 N/g) to every tested period except for Eldorado cultivar, which seems to present a slightly different behaviour. Based on obtained results, the following cooking process was performed after 6h soaking time for all cultivars.

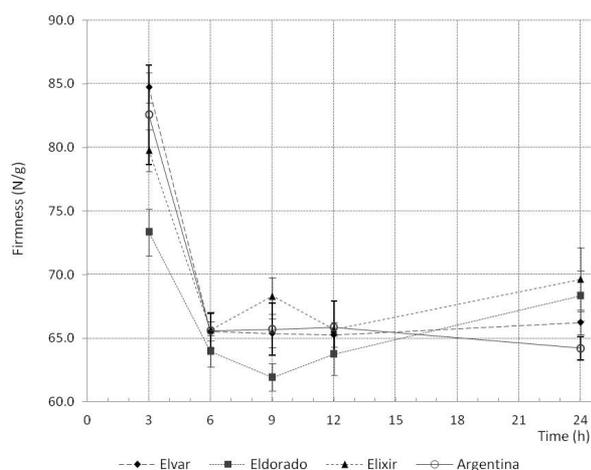


Figure 5 - Firmness (N/g) behaviour as function of soaking time for Elvar, Elixir, Eldorado and "Argentina" cultivars. Results are expressed as means ± standard deviations (error bars).

Cooking

The traditional cooking in boiling water was carried out after 6h of soaking time, at room temperature (20 ± 2°C), which was found to be enough time for hydration of seeds (Figure 4). As formerly referred, after this time of soaking the chickpea seeds absorbed a considerable amount of water and softened, which is reflected in both weight and volume increase and firmness decrease. After the cooking process those parameters were registered.

Biometry

Average weight of 100 seeds undergoing cooking (100 ± 2°C) is shown in Table 4 and the average dimensions (a and b) and proximate volume referred to 100 seeds (V_2) are presented in Table 5.

With the cooking process the weight gain of all cultivars was similar (between 1.3 and 1.6 g/g) (Figure 6) and the highest values were obtained after 4h, with 1.4, 1.6, 1.5 and 1.5 g/g weight gain for Elvar, Eldorado, Elixir and "Argentina", respectively.

The proximate 100 seed volumes (V_2) increase with cooking time but the results suggest a different behaviour between cultivars. Seed volumes varied between 56 and 82 mL /100 seeds, the highest value (81.5mL) for Eldorado cultivar after 3h cooking. In terms of volume gain (Figure 7) Eldorado and

Table 4 - Weight of 100 seeds (g) of chickpea cultivars, after 6 h of soaking, as a function of cooking time at 100°C. Results are mean values ± standard deviations

Time (h)	Operation	Elvar	Eldorado	Elixir	“Argentina”
0		34.28±0.31	43.28±0.38	36.28±0.28	40.62±0.42
6	soaking	63.10±0.26	79.27±0.72	67.61±0.61	77.22±0.58
2	cooking	79.60±1.08	107.32±0.93	83.06±0.75	94.39±2.96
3	cooking	79.04±0.85	108.91±0.71	86.51±1.16	97.91±2.38
4	cooking	81.48±2.98	111.59±1.06	88.94±1.31	100.17±1.40

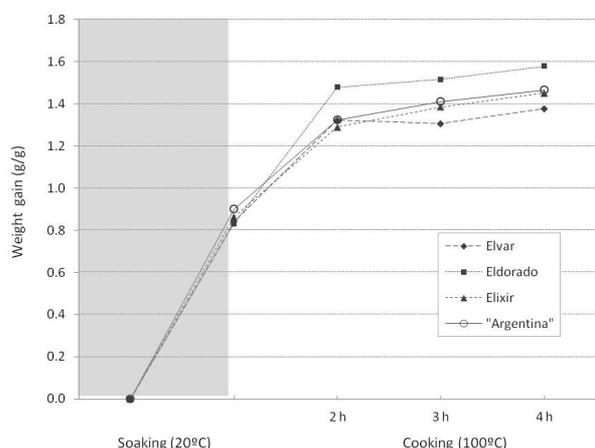


Figure 6 - Weight Gain/100 seeds during soaking (6h-20°C) followed by cooking (100°C).

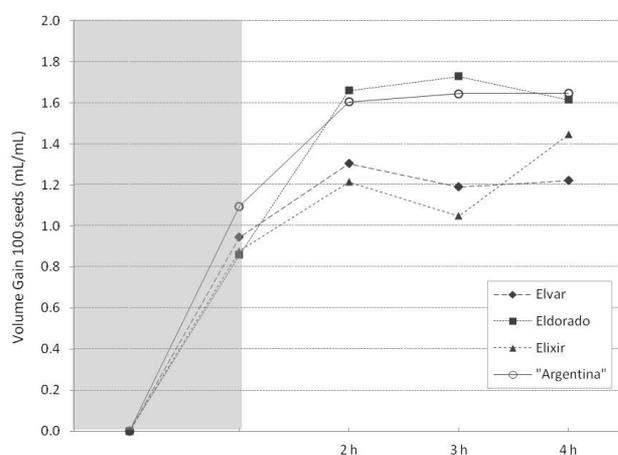


Figure 7 - Volume Gain/100 seeds during soaking (6h-20°C) followed by cooking (100°C).

“Argentina” have similar volume gains (1.6 – 1.8) from 2 to 4 h cooking. In contrast, Elvar and Elixir have a volume gain below 1.5 mL/mL

Firmness

The chickpea seeds firmness at different traditional cooking times are shown in Figure 8. Four brands of canned chickpeas from local trade were also analyzed for firmness in order to have a reference value range. The measured firmness average values varied from 5.2 to 10.4 N/g which shows a wide variety of industrial presentation.

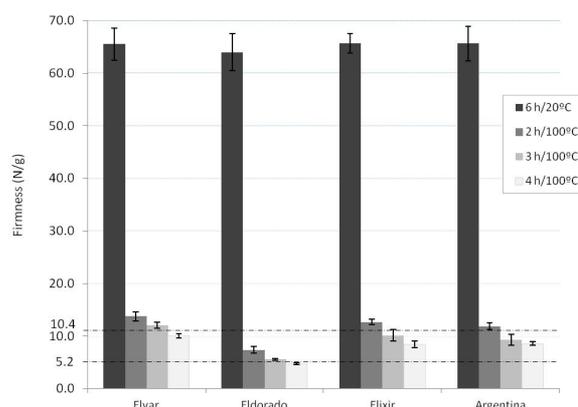


Figure 8 - Firmness (N/g) behaviour as function of cooking time for Elvar, Elixir, Eldorado and “Argentina” cultivars after 6h of soaking time. Straight lines represent maximum and minimal firmness (N/g) of analyzed canned brands. Results are expressed as means ± standard deviations (error bars).

Table 5 - Dimensions a (height) and b (width) of chickpea seeds, and Proximate Volume V_2 (mL) referred to 100 chickpea seeds, after 6 h of hydration, as function of cooking time at 100°C. Values are means \pm standard deviations

	Time (h)	Operation	Width (mm)	Height (mm)	Vol. 100 seeds (mL)
Elvar	0		7.83 \pm 0.49	9.22 \pm 0.38	25.38 \pm 4.89
	6	soaking	9.78 \pm 0.51	11.89 \pm 0.66	49.36 \pm 7.60
	2	cooking	10.32 \pm 0.68	12.23 \pm 0.88	58.48 \pm 11.66
	3	cooking	10.16 \pm 0.62	11.96 \pm 0.71	55.58 \pm 10.40
	4	cooking	10.20 \pm 0.73	12.11 \pm 0.63	56.41 \pm 12.23
Eldorado	0		8.27 \pm 0.42	10.08 \pm 0.47	29.88 \pm 4.59
	6	soaking	10.17 \pm 0.48	12.65 \pm 0.49	55.52 \pm 7.88
	2	cooking	11.45 \pm 0.69	13.84 \pm 0.72	79.49 \pm 13.89
	3	cooking	11.54 \pm 0.78	13.59 \pm 0.62	81.54 \pm 16.43
	4	cooking	11.37 \pm 0.84	13.82 \pm 0.65	78.12 \pm 17.15
Elixir	0		8.09 \pm 0.38	9.31 \pm 0.41	27.89 \pm 3.69
	6	soaking	9.98 \pm 0.45	11.94 \pm 0.53	52.38 \pm 6.95
	2	cooking	10.62 \pm 0.66	12.30 \pm 0.67	61.76 \pm 9.14
	3	cooking	10.28 \pm 0.47	12.10 \pm 0.61	57.15 \pm 7.69
	4	cooking	10.88 \pm 0.73	12.29 \pm 0.69	68.23 \pm 13.62
"Argentina"	0		8.08 \pm 0.38	9.98 \pm 0.60	27.78 \pm 3.76
	6	soaking	10.33 \pm 0.56	12.69 \pm 0.64	58.21 \pm 9.35
	2	cooking	11.10 \pm 0.65	13.45 \pm 0.74	72.32 \pm 12.89
	3	cooking	11.16 \pm 0.59	13.28 \pm 0.67	73.43 \pm 12.61
	4	cooking	11.17 \pm 0.61	13.17 \pm 0.87	73.50 \pm 12.04

Elvar, Elixir and "Argentina" cultivars displayed significant firmness decreases ($p < 0.05$) during traditional cooking process. After 3 h of treatment the Eldorado seeds firmness shows a slight decrease (6.1 to 5.1 N/g) without statistical significance.

Elvar is the only studied cultivar with firmness value (11-16 N/g) above range of canned chickpeas after 2h cooking (Figure 8). Eldorado tends to soften with cooking more than the other cultivars and after 4h cooking, seeds present firmness values below the canned chickpeas range.

CONCLUSIONS

Interesting technological properties of three Portuguese kabuli chickpeas were observed in this study and some differences in the biometric characteristics and hydration behaviour are reported. Eldorado cultivar hydrated and swelled the least under the studied conditions, Elvar and Elixir showed similar hydration capacity, with Elvar presenting the highest swelling capacity. Excepting Elvar, the firmness of grains after 3h cooking presented firmness values within the range of canned chickpeas from local trade.

This study has shown that there is a strong potential use of these cultivars in both domestic usage and the food industry. Since there is a wide

variation associated to the production, it is important to follow these studies with seeds from further years of harvest.

REFERENCES

- AACC International (2012a) – *Approved methods of analysis, 11th Ed. Method 56-36.01. Firmness of cooked pulses. Approved August, 2012.* AACC International, St. Paul, MN, USA.
- AACC International (2012b) – *Approved methods of analysis, 11th Ed. Method 56-35.01. Method for Determining Water Hydration Capacity and Percentage of Unhydrated Seeds of Pulses, 2012.* AACC International, St. Paul, MN, USA.
- Alajaji, Saleh A. & El-Adawy, Tarek A. (2006) – Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis*, vol. 19, n. 8, p. 806-812. <https://doi.org/10.1016/j.jfca.2006.03.015>
- Duarte-Maçãs, I. (2003) – *Seleção de linhas de grão-de-bico (Cicer arietinum L.) adaptadas ao ambiente Mediterrânico – critérios morfológicos e fisiológicos.* Ph.D. Dissertation, Évora University, Portugal, 171 p.
- Duarte, I. & Pereira, G. (2016) – Caderno técnico de práticas agrícolas para culturas leguminosas-grão I-Grão-de-bico (*Cicer arietinum* L.). *Vida Rural*, vol. 1820, p. 30-33.
- Hossain, S.; Ford, R.; McNeil, D.; Pittock, C. & Panozzo, J.F. (2010) – Inheritance of seed size in chickpea (*Cicer arietinum* L.) and identification of QTL based on 100-seed weight and seed size index. *Australian Journal of Crop Science*, vol. 4, n. 2, p. 126-135.
- Hosseini, N.M.; Palta, J.A.; Berger, J.D. & Siddique, K.H.M. (2009) – Sowing soil water content effects on chickpea (*Cicer arietinum* L.): Seedling emergence and early growth interaction with genotype and seed size. *Agricultural Water Management*, vol. 96, n. 12, p. 1732-1736. <https://doi.org/10.1016/j.agwat.2009.07.010>
- Ibarz, A.; González, C. & Barbosa-Cánovas, G.V. (2004) – Kinetic models for water adsorption and cooking time in chickpea soaked and treated by high pressure. *Journal of Food Engineering*, vol. 63, n. 4, p. 467-472. <https://doi.org/10.1016/j.jfoodeng.2003.09.008>
- Jha, A.B.; Ashokkumar, K.; Diapari, M.; Ambrose, S.J.; Zhang, H.; Tar'an, B.; Bett, K.E.; Vandenberg, A.; Warkentin, T.D. & Purves, T.D. (2015) – Genetic diversity of folate profiles in seeds of common bean, lentil, chickpea and pea. *Journal of Food Composition and Analysis*, vol. 42, p. 134-140. <https://doi.org/10.1016/j.jfca.2015.03.006>
- Marconi, E.; Ruggeri, S.; Cappelloni, M.; Leonardi, D. & Carnovale, E. (2000) – Physicochemical, Nutritional, and Microstructural Characteristics of Chickpeas (*Cicer arietinum* L.) and Common Beans (*Phaseolus vulgaris* L.) Following Microwave Cooking. *Journal of Agricultural and Food Chemistry*, vol. 48, n. 12, p. 5986-5994. <https://doi.org/10.1021/jf0008083>
- Mukhopadhyay, S.P.; Wood, J.A.; Saliba, A.J.; Blanchard, C.L.; Carr, B.T. & Prenzler, P.D. (2015) – Evaluation of puffing quality of Australian desi chickpeas by different physical attributes. *LWT – Food Science and Technology*, vol. 64, n. 2, p. 959-965. <https://doi.org/10.1016/j.lwt.2015.06.068>
- Siddique, K.H.M. & Regan, K.L. (2005) – Registration of kabuli chickpea 'Kimberley Large'. *Crop Science*, vol. 45, p. 1659-1660.
- Shafaei, S.M.; Masoumi, A.A. & Roshan, H. (2016) – Analysis of water absorption of bean and chickpea during soaking using Peleg model. *Journal of the Saudi Society of Agricultural Sciences*, vol. 15, n. 2, p. 135-144. <https://doi.org/10.1016/j.jssas.2014.08.003>
- Upadhyaya, H.D. (2003) – Geographical patterns of variation for morphological and agronomic characteristics in the chickpea germplasm collection. *Euphytica*, vol. 132, n. 3, p. 343-352. <https://doi.org/10.1023/A:1025078703640>
- Wood, J.A. & Harden, S. (2006) – A Method to Estimate the Hydration and Swelling Properties of Chickpeas (*Cicer arietinum* L.). *Journal of Food Science*, vol. 71, n. 4, p. 190-195. <https://doi.org/10.1111/j.1750-3841.2006.00009.x>