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The effect of drying temperatures on morphological and chemical properties of dried chestnuts flours

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ABSTRACT

The effect of drying conditions on morphological and chemical properties of two Portuguese *Castanea sativa* varieties (Longal and Martainha) was evaluated. All chestnut drying curves were found to be different according to drying temperatures (40 °C, 50 °C, 60 °C and 70 °C). Those conditions also affected both chemical composition of flours and morphological properties of starch. Colour parameters of the flours ($L^* c^* h°$) generally decreased with increasing drying temperature, total colour difference (TCD*) also significantly changed for samples dried at different tested conditions. The drying temperature seems to affect starch morphology, with Longal starch granules always somewhat smaller. The results showed that the higher the drying temperature, the higher the reducing sugars content and the lower the starch content. In what concerns differences among the studied varieties, it can be stated that Longal presents whiter flours, higher reducing sugars content, lower starch and sucrose contents. In opposition, Martainha flours presented lower percentage of amylose and damaged starch. From the results it can be concluded that the marked effects that drying temperature exerted on the characteristics and properties of chestnut flours are different in both varieties studied.

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1. Introduction

The chestnut (*Castanea sativa* Mill.) is a traditional nut from European Mediterranean countries and one of the most popular across the world. The European production of chestnut fruit represents about 12% of the world production, being Portugal the second producer. The average for domestic production of fruits was reported to be 22.17 metric ton 2005–2006 season, representing 3% of world production (GPP, 2007). The high consumption values of the fresh fruit, probably linked to the high nutritional and organoleptic value, and also to the increasing interest of the consumers towards organic products (Bellini et al., 2005). Not only is the consumption of the fruit popular in Portugal but also the use of chestnut flours. Some ancient documents refer that in the Middle Ages chestnut was used as the main ingredient in bread production (two parts of chestnut flour and one part of wheat) and as a kind of porridge (Lage, 2003).

Despite the drying appearance, chestnuts are perishable presenting a limited shelf-life. This is mainly due to the high metabolic activity of the nuts and the epicarp characteristics that are porous and not lignified (Sacchetti et al., 2005). Drying is one of the traditional preservation and storage techniques. As it is generally known, dried products are stabilized as the water activity decreases. Most of the references about chestnut drying focus mainly on the drying process itself and only few on the effect of the drying temperature on the fruit's composition and properties. Although more focused on the drying process itself, the work of Fernandes et al. (2005) also presented some evidence of the effect of the process on the chemical properties. But more relevant in this scope is work of Attanasio et al. (2004) focused on a specific Italian variety which dried at two different temperatures (40 °C and 60 °C). Both studies clearly showed modifications in chestnut properties, mainly in starch fraction. However, little information about morphological and chemical modification after drying on chestnuts flours is available in the literature.

The present study aims to bring a contribution to a deeper understanding of the effects of drying temperature on some morphological, physical and chemical properties of selected native Portuguese chestnut varieties.

2. Materials and methods

2.1. Samples

Chestnut fruits were collected from "Soutos da Lapa" region, one of the three PDO (protected designation of origin) regions found in Portugal for chestnuts. In this region the most representative

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chestnut varieties were identified to be Martainha and Longal. Mature chestnuts were harvested and three sets of 1 kg each were randomly collected for each variety. Samples were stored at 4 °C until experiment.

2.2. Drying process

The drying process was conducted in two steps. First, chestnuts were pre-dehydrated at 40 °C for 24 h in a FD 115 Binder ventilated drying chamber, with a air flow of 300 m^3/h. Afterwards, fruits were peeled, the nuts chopped into little pieces, in order to make the milling operations easier, and dried in the same equipment at 40 °C, 50 °C, 60 °C and 70 °C, till a final a_w value of about 0.2. Chestnut pieces were then milled in a SK 100 Cross Beater Retsch hammer mill to pass a 1 mm sieve.

To establish the drying curves the water activity variations were monitored at 25 °C using a BTsrl Selecta Unitronic hygrometer. The water activity was measured every two hours in samples of 4–5 g, taken from the drying chamber.

2.3. Morphology analysis

The fresh chestnut fruits and the dried chestnut flours were observed directly by a scanning electron microscope (SEM) and light microscopy. The dimensions (length and width) of two hundred starch granules in flours were measured by SEM.

Samples were analysed by taking images from an environmental scanning electron microscope (ESEM) model Quanta 400 (FEI Company, USA), at 10 KV and 4 mbar. Fresh chestnuts and the dried chestnut flours were sprayed onto a double-sided tape on a microscope stub.

A light microscope model HBO50 Oxiplan 2 (Zeiss) with a colour video camera CCD-Iris Contax Aria was used. The samples were coloured by a iodine solution (0.2 g of iodine and 2 g potassium iodide for 100 ml H_2O) diluted with water at a ratio of 1/10.

2.4. Colour evaluation

The colour of fresh chestnuts and flours was assessed by the CIELAB (1986) using a Chroma Meter CR-300 Minolta (Osaka, Japan) colorimeter. From L^* a^* b^*, the chroma (c^*) and hue angle ($h°$) were determined. A white tile (L^* = 97.46, a^* = −0.02, b^* = 1.72) was used as reference. Total colour difference (TCD*) (McGuire, 1992; Silva and Silva, 1999) as defined by eq. 1 was also calculated:

$$\mathrm{TCD}^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2}, \tag{1}$$

At least twenty measures were performed for each sample.

2.5. Chemical analysis

Raw material composition was evaluated for: moisture, protein (% N × 5.23), fat, fibre, ash and reducing sugars contents (AOAC, 2000). All reagents used were analytical grade.

Moisture content was determined by gravimetric method at 100–105 °C, till constant weight.

Nitrogen free extract (NFE) was calculated by difference:

$$\%\mathrm{NFE}(dwb) = 100 - (\%\mathrm{Protein} + \%\mathrm{Fat} + \%\mathrm{Ash} + \%\mathrm{Fibre}). \tag{2}$$

Total starch and amylose content were determined by polarimetric method as proposed by Garcia and Wolf (1972), as suggested by Knutson (2000), and colorimetric method proposed by Juliano (1971), as used by Yadav and Jindal (2007).

Total reducing sugars were determined by the Munson–Walker method (AOAC, 2000) and some individual sugars by HPLC, equipped with a 6000A pump, RI 400 detector and Sugar-pack column (Waters Corporation, USA) at 90 °C, using EDTA-Ca 50 ppm aqueous solution at 0.5 ml/min, as proposed by Medlicott and Thompson (1984). The external standard method was used to identify and quantify sugars. All reagents were HPLC grade. As the used column does not clearly separate sucrose and maltose, presenting similar retention times, sucrose and maltose are always considered as a whole (sucrose + maltose).

Damaged starch was determined following the method proposed by AACC (2000), being reducing sugars determined by the Hizukuri et al. (1981) method.

All reported values are expressed on a dry weight basis (dwb) and represent the average value of the analysis of at least three different replicates.

2.6. Statistical analysis

The data reported in this work are average of at least three different determinations. A Statistic® versus 6 and Excel® 2003 software was used for statistic analysis. Colour and chemical results were subjected to a variance analysis and the significance of differences between means was determined with Fisher LSD test at a 5% level.

3. Results and discussion

3.1. Drying process

The evolution of water activity (a_w) during drying process as well as the time needed to reach an a_w of 0.2 are shown in Fig. 1. Drying patterns are quite similar for both studied cultivars at tested drying conditions. The second order polynomial of the form:

$$y = a + bx + cx^2 \tag{3}$$

was used to adjust curves, and the results of the fittings are presented in Table 1.

As expected the free water evaporation rate is lower when the drying temperature is lower, being the time needed to reach the same a_w value (0.2) inversely proportional to drying temperature.

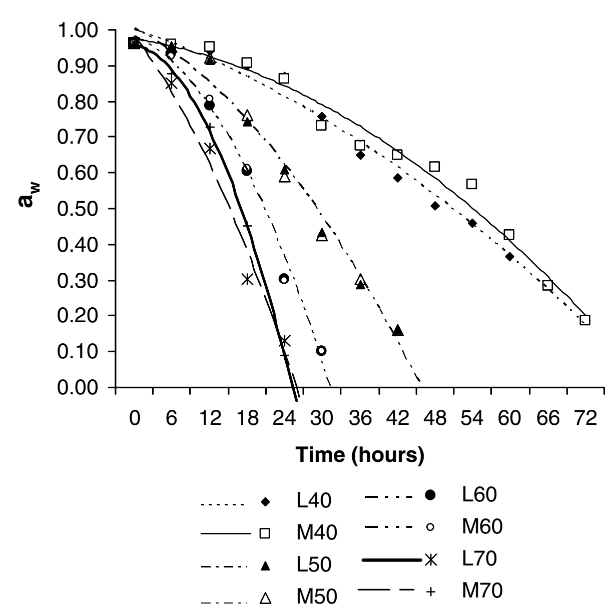

Fig. 1. Evolution of water activity during the drying process (L – Longal and M – Martainha).

Table 1
Second order polynomial adjusted equations for drying process

Variety	Drying temperature (°C)	*a*	*b*	*c*	R^2
Longal	40	1.0005	−0.006	−0.0001	0.989
	50	0.9993	−0.009	−0.0003	0.986
	60	0.9799	−0.007	−0.0008	0.990
	70	0.9827	−0.0026	−0.0006	0.989
Martainha	40	0.9752	−0.003	−0.0001	0.982
	50	1.0037	−0.009	−0.0003	0.983
	60	0.9799	−0.007	−0.0008	0.990
	70	0.9595	−0.004	−0.0012	0.999

Table 2
Influence of drying temperature on the moisture content of chestnuts

Variety	Moistures content (g/100 g)	Moisture loss [(*)] (%)			
	Fresh chestnuts	Dried at 40 °C	Dried at 50 °C	Dried at 60 °C	Dried at 70 °C
Longal	48.2 ± 0.02[a]	84.2	86.3	86.9	88.8
Martainha	47.9 ± 0.05[a]	81.6	82.9	83.5	86.6

(*) Variation = (Moisture$_{(initial)}$ − Moisture$_{(final)}$)/Moisture$_{(initial)}$*100%.
[a] Means ± standard error of mean.

These results are in accordance to those found by Koyuncu et al. (2004). The authors also showed that temperature is the most important drying parameter affecting the total drying time and the consumed energy, where time and the heat energy decrease with increasing temperatures. Besides, drying in the range 50–60 °C was found to be least energy consuming.

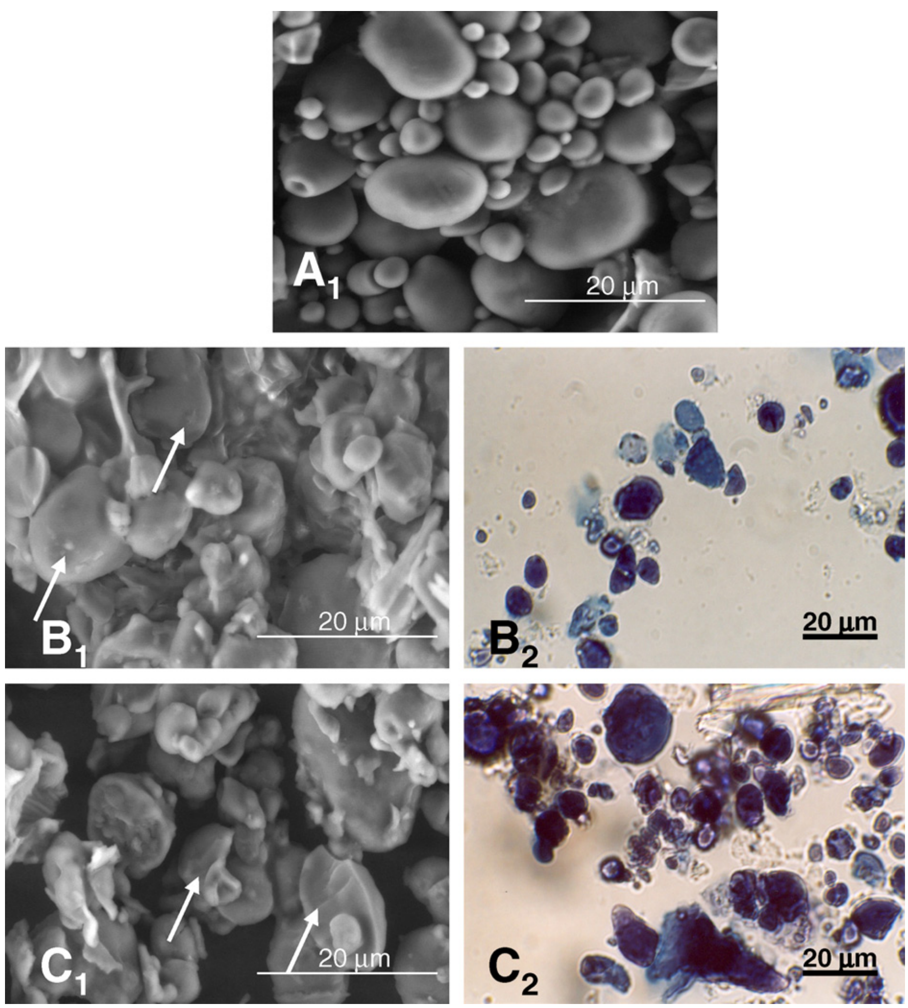

Fig. 2. Images of Longal chestnut flours: (A) fresh fruit flour, (B) and (C) dried fruit flours at 40 °C and 70 °C, respectively. Lowercases: 1 – SEM, 2 – light microscopy. Fractures are signed by an indication arrow.

Moisture losses during drying processes are shown in Table 2. Increasing temperature increase the amount of water released from the product. The total moisture loss is not significantly differing for both varieties. It is worth to remark that the percentage of moisture loss is always somewhat smaller in the Martainha variety than that observed in Longal.

3.2. Morphological characteristics of starch granules

The SEM of the chestnut flours for both studied varieties are shown in Figs. 2 and 3. Starch is considered as the main compounds of chestnut flours (about 47–48% in fresh fruit), it is also expected to be responsible for the chestnut flour characteristics. Starch granules seem to be surrounded by some amount of other materials, like fibres and proteins, giving a "raising dust" appearance (mainly on dried chestnut flours) that may also contribute to those characteristics. Drying flours of both varieties presented similar morphology for all drying temperatures, except the Martainha dried at 70 °C. Starch granules were always found to be round or oval shaped, and the surface smooth in fresh fruit granules. On the other hand, the starch granules from dried material exhibited some fractures. This effect was also observed by Grant (1998) on wheat granules, and the fractures become more evident at higher drying temperatures. Starch granules of flours produced from dried fruits show a kind of vesicles that come from inside starch granules, probably due to starch modifications.

Drying at 70 °C leads to starch granules becoming more shapeless, flattened and rough, mainly in Longal variety. This behaviour was also observed by Attanasio et al. (2004). It was seen that, temperature significantly influences the morphology of starch granules and so it is likely that other properties will also be affected.

Both dimensions, length and width, of starch granules presented high variability. The majority of the starch granules are small, with a predominated length between 4 and 8 μm and width between 4 and 6 μm (Fig. 4 and Table 3), only 2–6% smaller than 2 μm and about 2% larger than 18 μm. In general, starch granules from Longal are smaller than those of Martainha. The results observed for the other drying temperatures were similar to the ones presented for the temperature of 50 °C. By analysing the dimensions, it is possible to state that increasing drying temperature did not significantly affect the length and the width of starch granules.

3.3. Colour evaluation

The colour of chestnut flours showed to be different depending on drying conditions. The appearance of chestnuts Martainha and Longal after drying can be seen in Fig. 5.

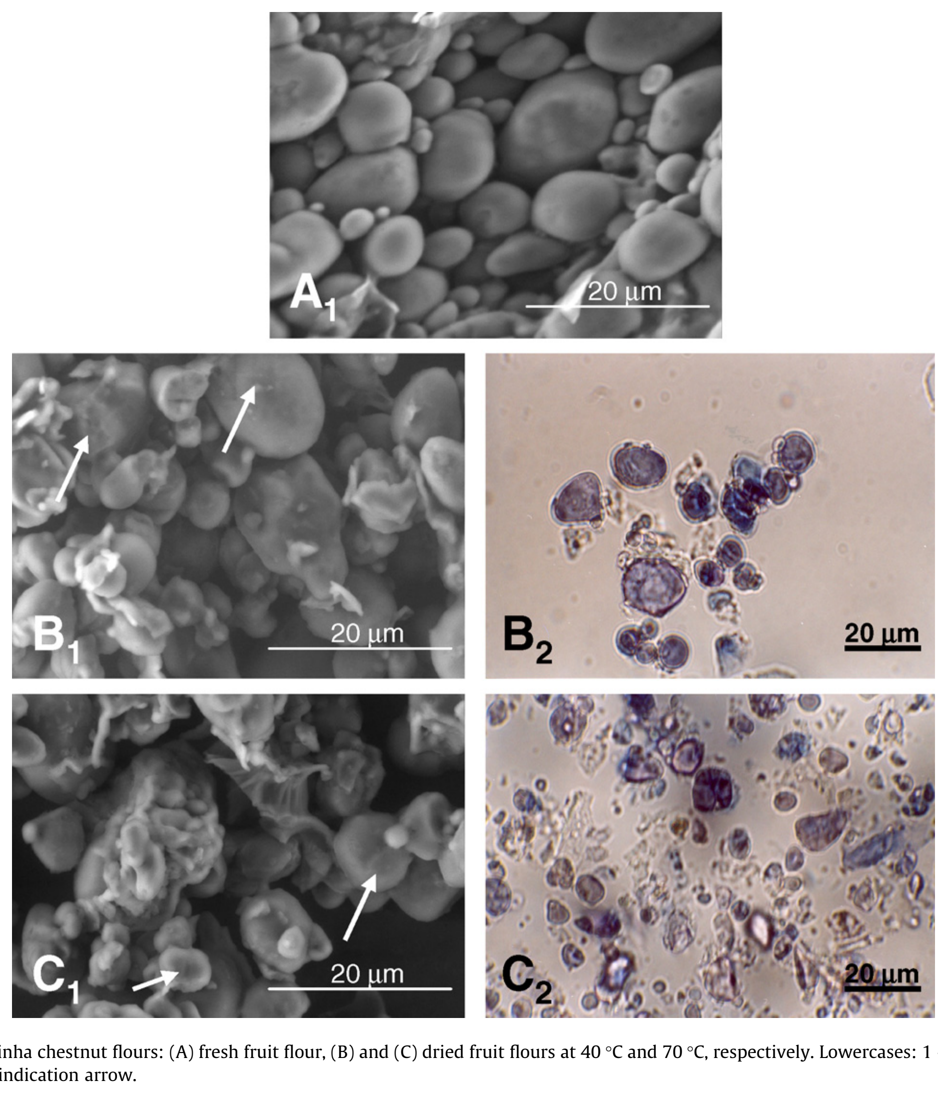

Fig. 3. Images of the Martainha chestnut flours: (A) fresh fruit flour, (B) and (C) dried fruit flours at 40 °C and 70 °C, respectively. Lowercases: 1 – SEM, 2 – light microscopy. Fractures are signed by an indication arrow.

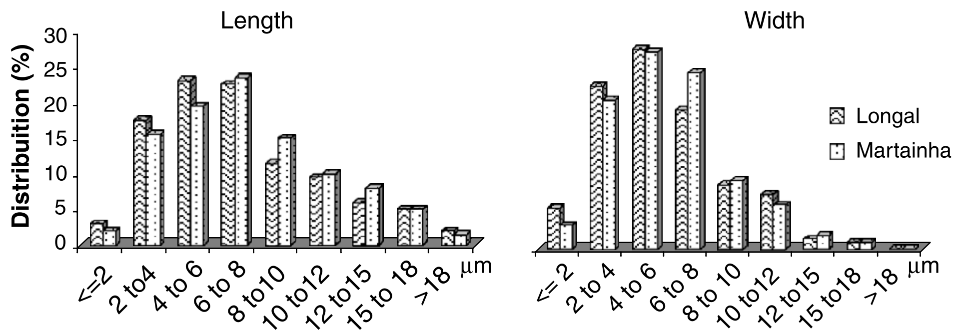

Fig. 4. Length and width distributions for Longal and Martainha flours dried at 50 °C.

Table 3
Analysis of starch granules dimensions of fresh fruits

	Length (µm)			Width (µm)		
	Mean ± σ	Maximum	Minimum	Mean ± σ	Maximum	Minimum
Longal	6.7 ± 3.34	19.9	1.4	5.5 ± 2.48	13.0	1.4
Martainha	7.2 ± 3.58	23.3	2.0	5.8 ± 2.75	15.8	2.0

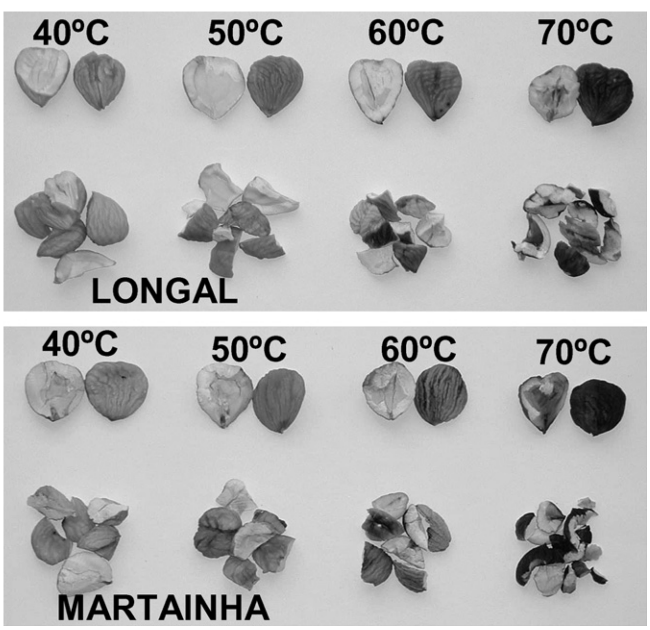

Fig. 5. Aspect of chestnut fruits after drying.

Fresh fruits presented similar results in the colour parameters (Table 4). However, these parameters change with drying temperature.

Fresh fruits flours presented a darker colour compared to the dried fruits flours, therefore presenting higher L^* values. For drying temperatures of 40 °C, 50 °C and 60 °C, the differences in lightness are not so evident, mainly in Longal variety. As the colour of fresh fruits flours was measured immediately after milling, the darker colour may be attributed to phenolic oxidations. As drying temperatures increase, the flours become darker probably due to a larger extension of caramelization and Maillard reaction. These reactions could also be responsible, for some extent the presence of a red/purple dominant colour at 70 °C. All the chestnut flours from both cultivars presented a yellow predominant colour ($h°$ values about 90°). It was also observed that the vivid colour (c^*) decreased with the increasing drying temperature, probably due to the loss of water during the drying process, turning the flours more dull. The encountered colour difference might be classified according to Drlange (1994) as great (TCD* between 6.0 and 12.0) to very great (TCD* > 12.0). The results showed that either for the variety Martainha or the Longal, the chestnut flours dried at 50 °C and 60 °C presented similar values, being these higher than those obtained for 40 °C or 70 °C.

Table 4
Colour parameters of dried chestnuts flour

Cultivar	Drying temperature (°C)	L^*	c^*	$h°$	TCD*
Longal	None	86.1 ± 0.52^{a}	22.4 ± 0.70^{a}	98.4 ± 0.32^{a}	–
	40	91.8 ± 0.18^{b}	12.4 ± 0.09^{b}	95.2 ± 0.16^{d}	9.1 ± 0.12^{b}
	50	93.7 ± 0.07^{b}	$10.2 \pm 0.09^{c,d}$	95.3 ± 0.07^{d}	11.7 ± 0.09^{a}
	60	91.8 ± 0.07^{b}	9.9 ± 0.09^{d}	92.8 ± 0.07^{b}	11.5 ± 0.09^{a}
	70	83.5 ± 0.23^{a}	12.2 ± 0.35^{c}	84.4 ± 0.20^{c}	10.0 ± 0.08^{c}
Martainha	None	85.9 ± 0.21^{c}	23.4 ± 0.50^{c}	98.7 ± 0.10^{d}	–
	40	90.4 ± 0.09^{d}	13.2 ± 0.14^{b}	92.8 ± 0.06^{c}	11.7 ± 0.16^{a}
	50	89.7 ± 0.09^{a}	12.0 ± 0.11^{a}	91.1 ± 0.06^{a}	12.6 ± 0.12^{b}
	60	89.4 ± 0.12^{a}	12.0 ± 0.12^{a}	91.1 ± 0.07^{a}	12.6 ± 0.13^{b}
	70	84.0 ± 0.18^{b}	11.9 ± 0.13^{b}	86.7 ± 0.08^{b}	11.7 ± 0.08^{a}

Results are the mean ± standard error of mean. For each colour parameter values followed by the same uppercase letter are not significantly different at $p < 0.05$, Fisher LSD test.

Table 5
Proximate analysis of fresh chestnuts (g/100 g)[a]

Variety	Moisture	Protein	Fat	Ash	Fibre	NFE
Longal	48.2 ± 0.02	5.0 ± 0.07	2.6 ± 0.04	1.9 ± 0.01	3.2 ± 0.02	87.3 ± 0.04
Martainha	47.9 ± 0.05	4.3 ± 0.04	3.0 ± 0.04	2.1 ± 0.03	3.5 ± 0.04	87.1 ± 0.04

[a] Results are the means ± standard error of mean, expressed in dry weight basis.

Table 6
Reducing sugars and total starch contents of chestnuts fruits dried flours[a,b]

Variety	Drying temperature (°C)	Reducing sugars (g/100 g)	Starch (%)
Longal	None	1.76 ± 0.01[c]	46.8 ± 1.0[a]
	40	4.59 ± 0.02[b]	42.2 ± 1.8[b]
	50	4.68 ± 0.02[d]	34.7 ± 2.3d
	60	4.74 ± 0.04[d]	32.3 ± 0.9[e]
	70	5.18 ± 0.01[a]	36.2 ± 2.5[c]
Martainha	None	1.61 ± 0.01[e]	48.6 ± 0.6[a]
	40	3.42 ± 0.04[d]	44.1 ± 1.8[a]
	50	3.52 ± 0.03[c]	33.4 ± 2.4[b]
	60	3.60 ± 0.02[b]	31.7 ± 0.6[b]
	70	3.87 ± 0.01[a]	35.3 ± 2.6[b]

For each determined parameter values followed by the same uppercase letter are not significantly different at $p < 0.05$, Fisher LSD test.
[a] Percentage on dry weight basis.
[b] Results are the mean ± standard error of mean.

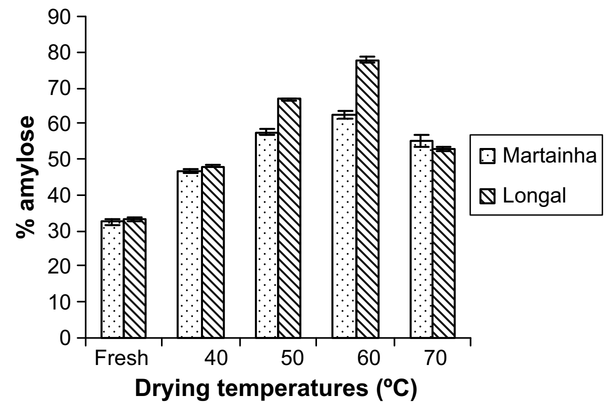

Fig. 6. Effect of drying temperatures on the amylose content (percentage on dry weight basis). Each data value is the average of three determinations ± SD.

3.4. Chemical analysis

3.4.1. Proximate components of raw materials and dried flours

The results of fresh chestnut fruits proximate analysis are presented in Table 5. Flours dried at different conditions had no significant differences ($p \geqslant 0.05$). As expected, drying temperature did not affect total amounts of protein, fat, fibre and ash. Similar results were found for both varieties at study. Pereira-Lorenzo et al. (2006), Míguelez et al.,(2004) and Borges et al. (2008) obtained similar results for the chemical composition of different chestnut varieties, including Martainha and Longal. From data presented in Table 4, it is also possible to state that the main difference among studied varieties is found in fat and protein content.

3.4.2. Reducing sugars, starch and amylose contents

Results on the effect of drying conditions on carbohydrates content are shown in Table 6. It may be observed that reducing sugars content increased in both cultivars with drying temperature. Longal flour presented higher reducing sugars content. This effect may be explained, as already stated, by a lower degree of starch damage observed in Martainha (Figs. 2, 3 and 7).

Concerning starch content (Table 6), the Martainha variety presents higher values than Longal, considering the fresh fruit and flour dried at 40 °C. These results are similar to those obtained by Pereira-Lorenzo et al. (2006) for Spanish varieties. The results show that when the drying temperature increases the starch content decreases. This is more evident for drying temperatures at 50 °C and 60 °C, corresponding to the enzymatic optimum temperatures. These results are in accordance to Attanasio et al. (2004) researches.

Fresh chestnuts amylose content was found to be 33.1% and 32.4%, in Longal and Martainha varieties, respectively. As it can be seen in Fig. 6, Martainha variety presents lower amylose contents. The amylose content increased with drying temperature, being the effect more evident in the Longal variety.

The observed increase of amylose content may be due to the combined action of enzymes during the chestnut drying process. This effect may also explain the reducing sugar increase. Enzymes that show amylolitic properties are, mainly, α-amylase, β-amylase, glucoamylase and pullulanase (Atwell et al., 1980; Madi et al., 1987). Those enzymes hydrolyze both amylose and amylopectin, but the extent of amylopectin hydrolysis is different because of the α, 1-6 branching (Delatte et al., 2006). The majority of amylolitic enzymes, mainly α-amylase, β-amylase and glucoamylase, are active at the tested drying temperatures, with an optimum temperature between 55 °C and 60 °C (Matherwson, 1998), promoting therefore, the increase on reducing sugar content, i.e. glucose (Table 5).

In chestnuts, the enzyme activities have been mainly attributed to β-amylase, so a major trend in producing maltose units should be detected (Nomura et al., 1995). Furthermore, some authors mentioned by Zhang and Oates (1999) stated that starch susceptibility to enzyme attack which influenced by several factors, such as amylose and amylopectin content, crystalline structure (believed to be the most important), particle size and the presence of enzyme inhibitors. The enzymes action may be eventually related to a different starch organization. As known, glucose polymers are the major components of starch, being amylose mainly linear and amylopectin highly branched. However, the exact location of amylose inside the granule and the extent and nature of its interaction with amylopectin is still unclear (Li et al., 2004), and so the effect of those in functional properties are also not yet clarified. However, as referred by the same author, the way of action of amylases is still incomplete and, therefore, it becomes difficult to consider the variety of α-amylase sources and the complex structure of starch granules. When fruits were dried at 70 °C an increase in amylose content was identified, probably due to enzymes inactivation, when compared to the other drying temperatures.

3.4.3. Sugar content

The values obtained in the present study for fresh fruits were higher than those obtained by other authors (Míguelez et al., 2004) for Spanish varieties. This could be related to several factors,

Table 7
Values of simple sugars in chestnuts (g/100 g dry solids)

Variety	Drying temperature (°C)	Sucrose + maltose	Glucose	Fructose
Longal	None	27.54 ± 0.00[e]	0.73 ± 0.01[e]	1.00 ± 0.02[e]
	40	31.54 ± 0.55[c]	1.84 ± 0.01[c]	2.70 ± 0.01[d]
	50	34.72 ± 0.15[b]	1.73 ± 0.00[d]	2.88 ± 0.01[b]
	60	35.92 ± 0.07[a]	1.99 ± 0.03[b]	2.79 ± 0.01[c]
	70	30.31 ± 0.22[d]	2.18 ± 0.04[a]	2.97 ± 0.03[a]
Martainha	None	30.86 ± 0.10[a]	0.54 ± 0.00[a]	1.02 ± 0.01[b]
	40	42.68 ± 0.76[b]	1.38 ± 0.01[c]	2.11 ± 0.01[c,d]
	50	44.57 ± 0.31[b]	1.59 ± 0.02[b]	2.03 ± 0.00[d]
	60	37.77 ± 0.66[c]	1.41 ± 0.01[c]	1.83 ± 0.13[a]
	70	36.31 ± 0.20[c]	1.56 ± 0.03[b]	2.26 ± 0.02[c]

Results are the means of three determinations ± standard error of mean. For each sugar parameter values followed by the same uppercase letter are not significantly different at $p < 0.05$, Fisher LSD test.

like specific varieties, growth and storage conditions and the period after harvesting (Nomura et al., 1995).

The influence of drying temperature on individual sugar content is shown in Table 7. Significant differences ($p \leqslant 0.05$) between analysed materials were found. Considering the effect of drying temperatures on flours, Longal presents more significant differences. The effect of the drying temperature is different in the Longal and Martainha disaccharides content, as Martainha shows a higher increase in disaccharides. Generally, sucrose + maltose increased with drying temperature probably due to thermal and enzymatic degradation, as previously mentioned, and it is more visible in Longal variety. This variety seems to be more affected by drying process. It is observed that sucrose + maltose content Martainha presents higher values than Longal. Concerning the monosaccharides content, this increases with drying temperature, showing a similar behaviour for both varieties.

3.4.4. Damaged starch

Damage starch is the fraction of starch that is mechanically disrupted during processing (Thomas and Atwell, 1999). The word "damaged" can be interpreted in a general sense to imply any change in granular structure or, more specifically, to describe particular changes in structure that are manifested as important technological advantages (Evers and Stevens, 1985) and not necessarily as a detrimental effect. Observing Fig. 7, it is possible to conclude that Martainha presented lower percentage of damaged starch. The effect of drying temperature on damaged starch is more visible in Longal flours. Considering the drying process temperatures applied to chestnut fruits, flours from fresh fruits and the ones obtained with drying temperatures of 60 °C showed a lower level of damaged starch.

Starch damage affects physicochemical properties, such as water absorption. This in turn influences the functionality of damaged starch in food applications and, subsequently, the quality of the final product. Extensive starch damage causes disruption in the molecular structure of the starch (Niba, 2006). Therefore, modifications to the starch granule results in an increased swelling ability and a higher susceptibility to enzymatic hydrolysis (Stark and Lynn, 1992).

Belitz et al. (2004) stated that when starch granules are damaged by grinding or by applying of pressure at various water contents, the amorphous portion is increased, resulting in improved dispersibility and swell ability in cold water, a decrease in gelatinization temperature and an increase in enzymatic vulnerability.

4. Conclusions

The aim of the present study was to evaluate the effect of drying temperature on morphology and chemical properties of two Portuguese chestnut varieties. Based on the results obtained, it was possible to conclude that drying temperature affecting flour properties. In fact, all of the studied properties were significantly affected by drying temperature in both varieties. However, Martainha and Longal showed to be differently affected by drying conditions. It is possible to state that Longal presented bigger starch granules, whiter flours, higher reducing sugar content and lower starch and sucrose contents. Martainha flours showed less starch damage. Therefore, if the highest temperature does not affect quality parameters, the fastest process is the best one. Chestnut flour dried at 60 °C seems to be the one that dried faster and with a lower content of damaged starch.

Considering the importance of these effects, more work must be done in order to study the influence of the drying temperature on the functional properties of the flours, and their relation to those morphological and chemical changes.

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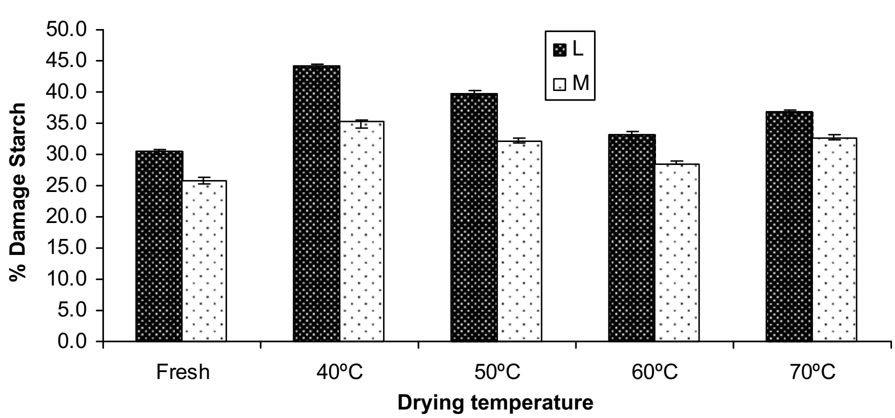

Fig. 7. Percentage of damage starch of Longal (L) and Martainha (M) chestnut flours. Each data value is the average ± SD.

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