Original article

Effect of drying temperatures on chemical and morphological properties of acorn flours

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Summary   Drying curves at different temperatures were established for *Quercus suber* and *Quercus rotundifolia* fruits. Flours produced by milling fruits dried at different conditions were evaluated for colour, starch granules morphology, amylose and sugars content. The drying temperature was positively related to the reducing sugar content and negatively to starch content. The amilose content generally increased with drying temperature and the effect was more evident for the Q. *rotundifolia*. Results showed that flour colour parameters generally decreased with increased drying temperature. However, the drying temperature does not seem to affect starch morphology. It can also be stated that *Q. suber* produced darker flours, higher amylose and reducing sugar content, and bigger starch granules. *Q. rotundifolia* showed a lower level of damaged starch and higher fat and disaccharides content. According to the results, it was possible to conclude that drying temperature exerted marked effects on the properties of acorn flours in both studied species.

Keywords   Acorn (*Quercus suber* and *Quercus rotundifolia*), chemical properties, drying, morphology.

Introduction

In Europe sclerophyllous forests are characterised by a dominance of evergreen broad-leaved trees such as *Quercus suber* L. and *Quercus rotundifolia* Lam. Although particularly abundant in Spain and Portugal, these forests are characterised by the dispersion of individual trees and groups of trees known respectively as *dehesas* and *montados* (Pinto-Correia, 1993). These open wooded landscapes can also be found in Greece, Italy and France (Grove & Rackham, 2001). In Portugal, the total forest area is 38% of the used soil area, being 13% and 23% of that total area occupied respectively by *Q. rotundifolia* and *Q. suber*,(GPP, 2007). *Montados* are predominant in the Centre and South of Portugal, producing about 400–700 kg/ha/year of fruits (Oliver, 1993). Most of the fruit production goes to animal feeding, mainly to the pig. However, the use of acorn flour for human nutrition is also traditional in the Iberian Peninsula. Ribeiro (1992) referred that primitive Lusitanian people (III-I b.C. centuries) feeding was based on oats porridge, dark

bread and acorn flour. Nowadays, in Portugal, there are some uses of acorn flours in traditional recipes. These fruits are also consumed in other European countries, as referred by Rakic *et al.* (2006). However, the valorisation of under exploited resources is now a major trend in order to improve sustainability of agri-food chain. In order to find new potentialities of these materials further studies are needed. The first step should be to improve fruit preservation along the year, by the establishment of convenient drying conditions.

The aim of the present study was the optimisation of drying process conditions and a further understanding of the effect of drying temperature on some morphological and physical-chemical properties of *Q. suber* and *Q. rotundifolia* fruit flours.

Materials and methods

Samples

Acorns from *Q. suber* L. and *Q. rotundifolia* Lam. were collected in 'montados' located in Idanha-a-Nova (Centre East of Portugal). Mature acorns were harvested and three sets of 1 kg each were randomly

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collected for each species. Samples were stored at 4 °C until testing.

Drying experiments

Fresh fruits were subjected to hand peeling (removing the tegument and pericarp) and the nuts chopped into little pieces, to facilitate the milling operations. Acorn pieces were then milled in a SK 100 Cross Beater Retsch hammer mill to pass a 1 mm sieve.

The drying process was conducted in two steps. First, acorns were pre-dehydrated at 40 °C for 24 h in a FD 115 Binder ventilated drying chamber, with an air flow of 300 m^{-3} $hour^{-1}$. Afterwards, fruits were hand peeled, the nuts chopped into little pieces and dried in the referred equipment at 40, 50, 60 and 70 °C, until a final a_w value of about 0.2. The dried fruit pieces were subject to the same milling process as the fresh fruits.

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 2 h in samples of 4–5 g, taken from the drying chamber.

Chemical analysis

Samples were evaluated for: moisture, protein (% N * 6.25), fat, fibre, ash and reducing sugars content (AOAC, 2000). All reagents used were from analytical grade.

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

Nitrogen Free Extract (NFE) was calculated by difference (Nap et al., 1991):

$$\%NFE \ (dwb) = 100 - (\%Protein + \%Fat + \%Ash + \%Fibre) \quad (1)$$

Total starch content was determined by polarimetric method as proposed by Garcia & Wolf (1972), as suggested by Knutson (2000). The colorimetric method proposed by Juliano (1971) and referred by Yadav & Jindal (2007), was used to determine amylose content. Amylose content was expressed on starch basis.

Total reducing sugars were determined by the Munson–Walker method (AOAC, 2000) and some individual sugars by HPLC, equipped with a 6000 A pump, RI 400 detector and Sugar-pack column (Waters Corporation, Milford, MA, USA) at 90 °C, using EDTA-Ca 50 ppm aqueous solution at 0.5 ml min^{-1}, as proposed by Medlicott & Thompson (1984). The external standard method was used to identify and quantify sugars. All reagents were HPLC grade. Since the column used does

not clearly separate sucrose from maltose, which present 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.

Scanning electron microscopy

The milled fresh acorns and the dried flours were observed directly by scanning electron microscope (SEM). The dimensions (length and width) of 200 starch granules in flours were measured by SEM.

For SEM, fresh acorns and the dried fruit flours were placed onto double-sided tape on a microscope stub. Samples were analysed by taking images on an environmental scanning electron microscope (ESEM) model Quanta 400 (FEI Company, USA), at 10 KV and 4 m bar.

Colour evaluation

Colour of milled fresh acorn and flours was assessed by CIELAB (1986) system using a Chroma Meter CR-300 Minolta (Osaka, Japan) colorimeter. From L^* a^* b^*, chroma (c^*) and hue angle (h^o) were determined. Colour lightness (value), L^* (100: white to 0: black), measures how light/dark is the colour of the object; chroma or saturation, c^* (0–60), measures how dull/vivid is the object colour; hue angle, h^o (0°–360°), express the characteristic/dominant colour (0° red/purple; 90° yellow; 180° bluish/green). A white tile ($L^* = 97.46$; $a^* = –0.02$; $b^* = 1.72$) was used as reference. Total colour difference (TCD^*) (McGuire, 1992; Silva & Silva, 1999) as defined by eqn 2 was also calculated:

$$TCD^* = \sqrt{\left(L^* - L_0^*\right)^2 + \left(a^* - a_0^*\right)^2 + \left(b^* - b_0^*\right)^2} \quad (2)$$

Twenty five individual measurements were performed for each sample.

Statistical analysis

The data reported in all the tables and figures are averages of at least three different determinations. A Statistic® vs. 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 the Fisher LSD test at a 5% level.
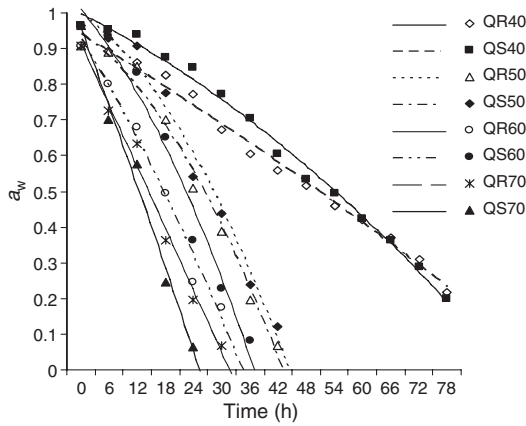
Figure 1 Evolution of water activityduring the fruits drying, showing the 2nd order polynomial fitting for each drying process (QR, Quercus rotundifolia; QS, Quercus suber, 40, 50, 60, 70 °C stand for temperature).

Results and discussion

Drying process

The drying curves expressed by the evolution of water activity (a_w) until having reached a final value of 0.2 are shown in Fig. 1. The second order polynomial of the form:

$$y = a + bx + cx^2 \qquad (3)$$

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

Drying patterns were found to be similar for both studied species at tested drying conditions. However, *Q. rotundifolia* fruits generally presented a lower drying rate. As expected free water evaporation rate was lesser when the drying temperature was lower.

Total moisture loss results for the drying processes are shown in Table 2. The total moisture losses are not much different for both species at the tested drying temperatures. Studies based on other fruits, like chestnuts, made by Koyuncu *et al.* (2004) showed that temperature was the most important drying parameter affecting the total drying time and, therefore, the consumed energy, the time and the heat energy which decrease with increasing temperatures. Being so, the fastest process is the best, provided that the higher temperature does not affect the quality parameters.

Chemical analysis

Proximate components of raw materials and dried flours
The results of fresh acorn fruits proximate analysis are presented in Table 3. In what concerns flours dried at different conditions, no significant differences were found ($P \geq 0.05$), showing, as expected, that drying temperature did not affect the total amounts of protein, fat, fibre and ash. *Q. rotundifolia* results are similar to those found by Ferreira (2000).

Comparing the study species, *Q. rotundifolia* presented higher values of fat content. This result is corroborated by Ferreira-Dias *et al.* (2003). These authors studied the fat content and fatty acid profile of three *Quercus* species (*Q. rotundifolia*, *Q. suber* and *Q. pyrenaica*) and they concluded that *Q. rotundifolia*

Table 2 Influence of drying on the moisture content of chestnuts

Specie	Moistures content (g/100 g)	Moisture loss [1] (%)			
	Fresh fruits	Dried at 40 °C	Dried at 50 °C	Dried at 60 °C	Dried at 70 °C
QS	42.0 ± 0.03[a]	78.8	84.0	79.3	86.4
QR	37.6 ± 0.01[a]	79.8	82.2	80.1	85.1

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

Table 1 Second order polynomial fitting for the drying processes

Variety	Drying temperature	*a*	*b*	*c*	R^2	Drying rate[a]
Quercus rotundifolia	40 °C	0.9388	–0.0079	–0.00001	0.991	–0.00002
	50 °C	0.9413	–0.0088	–0.00030	0.987	–0.00060
	60 °C	0.9258	–0.0215	–0.00020	0.981	–0.00040
	70 °C	0.9136	–0.0285	–0.00001	0.988	–0.00002
Quercus suber	40 °C	0.9982	–0.0066	–0.00005	0.993	–0.00010
	50 °C	0.9964	–0.0091	–0.00030	0.982	–0.00060
	60 °C	1.0093	–0.0156	–0.00030	0.977	–0.00060
	70 °C	0.9565	–0.0357	–0.00008	0.986	–0.00016

[a]Drying rate is the constant rate (cr) of the equation obtained by derivation of the second order polynomial equations ($y = k + cr.x$).

	Moisture	**Protein**	**Fat**	**Ash**	**Fibre**	**NFE**
QS	42.0 ± 0.03	4.2 ± 0.15	5.2 ± 0.08	1.7 ± 0.02	2.7 ± 0.03	86.2 ± 0.09
QR	37.6 ± 0.01	4.8 ± 0.04	11.1 ± 0.06	1.9 ± 0.03	3.0 ± 0.11	79.2 ± 0.06

Table 3 Proximate analysis of fresh acorns (g/100 g)[a]

[a]Results are the means ± standard error of mean, expressed in dry solids.
NFE, nitrogen free extract.

Table 4 Reducing sugars and total starch contents of acorn drying flours[ab]

	Drying temperature (°C)	Reducing sugars (g/100 g)	Starch (%)
QS	None	5.4 ± 0.01[e]	49.0 ± 1.82[a]
	40 °C	13.9 ± 0.02[d]	36.3 ± 0.95[b]
	50 °C	13.3 ± 0.03[c]	33.7 ± 1.41[c]
	60 °C	14.3 ± 0.02[b]	31.4 ± 0.50[c]
	70 °C	15.3 ± 0.01[a]	33.3 ± 0.30[c]
QR	None	6.6 ± 0.03[e]	48.0 ± 2.54[a]
	40 °C	7.5 ± 0.01[d]	35.7 ± 2.49[b]
	50 °C	7.9 ± 0.02[c]	33.5 ± 1.17[b]
	60 °C	8.8 ± 0.03[b]	31.6 ± 0.36[b]
	70 °C	9.3 ± 0.03[a]	34.2 ± 1.49[b]

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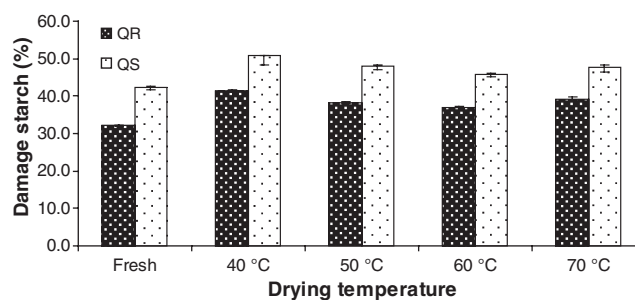

Figure 2 Percentage of damage starch of *Q. suber* and *Q. rotundifolia* acorn flours. Each data point is the average ± SD.
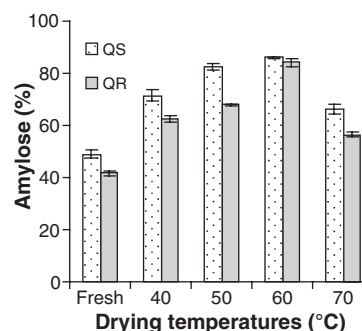

Figure 3 Effect of drying temperatures on the starch amylose content (starch dry weight basis). Each data value is the average ± SD.

presented the highest average oil content followed by *Q. suber*. Due to these characteristics, the extraction of the oil from *Q. rotundifolia* acorns was carried out in some oil extraction plants in Portugal until the early 70s, due to the very similar fatty acid composition to olive oil (Ferrão & Ferrão, 1988).

Reducing sugars, starch and amylose contents
Results on the effect of drying conditions on carbohydrates content are shown in Table 4. It may be observed that reducing sugars content increased in both species with drying temperature and that *Q. suber* flours presented higher reducing sugars content, when compared to *Q. rotundifolia*. This effect may be explained by a lower degree of starch damage observed in *Q. rotundifolia* flours (Fig. 2). Both species presented similar starch contents and the drying temperature seems to exert a marked effect on it compared to the milled fresh fruit. This effect was also observed in chestnuts fruits by Attanasio *et al.* (2004).

Fresh acorns amylose content was found to be 41.7% and 48.9% for *Q. rotundifolia* and *Q. suber* (Fig. 3). For *Q. rotundifolia* the value determined was much higher than that found by Ferreira (2000), 24.6%. Encountered

differences may be justified by differences in the botanical source, the climatic conditions and soil type during growth (Singh *et al.*, 2003). As it can be seen in Fig. 3, the amylose contents are, in all cases, higher for *Q. suber* when compared to *Q. rotundifolia*. As to the effect of drying temperature, the amilose content generally increased with drying temperature and the effect was more evident for the *Q. rotundifolia*. The observed increase on amylose content for drying temperatures until 60 °C, inclusively, may be due to the combined action of enzymes during the acorn drying processes. Besides, this effect may also explain the reducing sugar increase. Amylolitic enzymes are, mainly, α-amylase, β-amylase, glucoamylase and pullulanase (Atwell *et al.*, 1980; Madi *et al.*, 1987). These enzymes hydrolyse both

Table 5 Values of simple sugars in acorns (g/100 g dry solids).

	Drying temperature (°C)	Sucrose + Maltose	Glucose	Fructose
QS	Fresh	20.1 ± 0.13[d]	2.0 ± 0.04[a]	4.3 ± 0.02[a]
	40	19.8 ± 0.05[d]	6.0 ± 0.03[c]	9.0 ± 0.01[c]
	50	19.0 ± 0.09[a]	6.0 ± 0.01[c]	9.0 ± 0.02[c]
	60	15.7 ± 0.03[c]	6.3 ± 0.01[b]	9.5 ± 0.02[b]
	70	16.3 ± 0.07[b]	6.3 ± 0.01[b]	9.5 ± 0.01[b]
QR	Fresh	30.2 ± 0.38[c]	0.8 ± 0.01[e]	6.6 ± 0.02[a]
	40	29.9 ± 0.49[c]	2.0 ± 0.01[cd]	6.9 ± 0.02[b]
	50	29.2 ± 0.17[ac]	2.0 ± 0.02[cd]	6.9 ± 0.01[b]
	60	26.7 ± 0.31[ab]	2.1 ± 0.01[bd]	6.8 ± 0.24[ab]
	70	24.4 ± 0.16[b]	2.2 ± 0.02[ab]	7.1 ± 0.01[b]

[a]Percentage on dry weight basis.

[b]Results are the means ± standard error of mean.

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.

amylose and amylopectin, but the extent of hydrolysis of the amylopectin 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, as their optimum temperature situates between 55 °C and 60 °C (Mathewson, 1998), therefore, promoting the increase on amylose (as seem previously in Fig. 3) and reducing sugar content (as expressed in Table 4 and also in Table 5 for glucose). As referred by Li *et al.* (2004), since the way of action of amylases is not yet completely known, it becomes complicated to consider the variety of α-amylase sources and the changes in the complex structure of starch granules. When fruits were dried at 70 °C the amylose content presented lower values probably due to enzymes inactivation.

Sugar content
The sugar content of both species and the influence of drying temperature on individual sugar content are shown in Table 5. For both species the effect of the drying temperature on the disaccharides and monosaccharides content was quite different. Milled fresh fruit flours and flours from fruits dried at 40 °C presented similar values for both species.

Disaccharides decrease with the increase of the drying temperature, being the differences more evident for higher drying temperatures. This decreasing affect could be due to thermal and enzymatic degradation, as previously mentioned, obviously leading to an increase in the monosaccharides content. *Q.suber* presented a lower content of disaccharides and a higher content of monosaccharides. Flour obtained from *Q. suber* fresh fruits presented lower content of monosaccharides,

significantly different from the dried flours, and for fruit flours dried at 40/50 °C and 60/70 °C the results are respectively similar for glucose and frutose. In what concerns glucose content, *Q. rotundifolia* flours presented distinct results, but fructose values are quite similar. From these results, it could be stated that the drying temperature exercised a marked effect on sugar content and the two species responses are quite different, suggesting different flour characteristics.

Damaged starch
Damaged starch is the fraction of starch that is mechanically disrupted during processing (Thomas & 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 & Stevens, 1985) and not necessarily as a detrimental effect. As previously stated, by observing Fig. 2, it is possible to conclude that *Q. suber* presented higher percentage of damaged starch for all acorn flours. Considering the drying process temperatures applied to acorn fruits, flours from fruits dried at 50 °C and 60 °C presented slightly lower levels of damaged starch, when compared with those at 40 °C and 70 °C.

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). Modifications to the starch granule, therefore, result in increased swelling ability and a higher susceptibility to enzymatic hydrolysis (Stark & Lynn, 1992). Belitz *et al.* (2004) referred that when starch granules are damaged by grinding or by application of pressure at various water contents, the amorphous portion is increased, resulting in improved dispersibility and swellability in cold water, a decrease in gelatinisation temperature and an increase in enzymatic vulnerability.

Morphological characteristics of starch granules
The SEM of the acorn flours for both studied species is shown in Fig. 4. Starch is the main compound of acorn flours (as corroborated by the chemical analysis). Starch granules seem to be surrounded by little pieces of other materials, like fibres and proteins, giving the appearance of 'raising dust' (basically on fresh acorn flours). Starch granules of both species presented similar morphology after drying at the tested temperatures.

Starch granules were always found to be round or oval in shape. However, in the fresh fruits the surface was not so clearly defined, because it was more evident the inclusion of the granules in a matrix. Starch granules
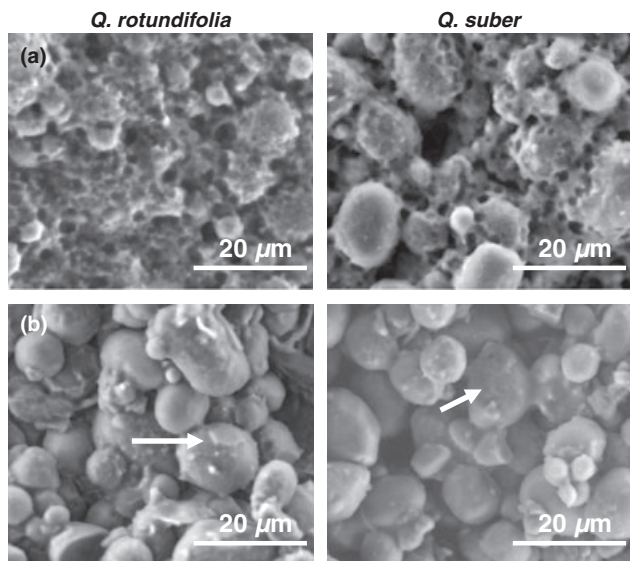
Figure 4 SEM and light microscopy of the fresh (a) and dried acorn flours at 40° (b) Fractures are signed by an indication arrow.

Figure 6 Aspect of acorn friuts after drying, (a) Q. Suber, (b) Q. rotundifolia.

from dried material exhibited some fractures. This effect was also observed by Grant (1998) for wheat granules and the fractures were more evident for higher drying temperatures.

Both dimensions, length and width, measured on starch granules presented a high variability: some smaller than 2 µm and others larger than 18 µm (Fig. 5). In the case of *Q. suber*, the dimensions showed a normal distribution, different from *Q. rotundifolia*. For *Q. suber* the predominant length and width are between
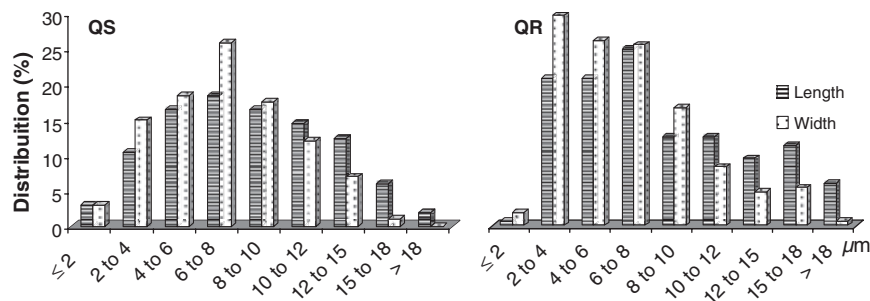
6 and 8 µm and *Q. rotundifolia* starch granules are between 2 and 4 µm wide and 6–8 µm long. *Q. rotundifolia* starch granules seem to be smaller and less regular than the ones of *Q. suber*. This is further confirmed by the mean values presented in Table 6.

From further studies carried out, it was also observed that the drying temperature did not significantly ($P > 0.05$) influence the dimensions of the starch granules in both species.

Colour evaluation
Colour of acorn flours showed to be different depending on drying conditions. The appearance of *Q. suber* and *Q. rotundifolia* fruits after drying can be seen in Fig. 6. It could be observed that *Q. suber* fruits are darker comparing with the *Q. rotundifolia*. Colour parameters of flours produced after drying and fresh fruits are significantly different (Table 7). Dried fruit flours results

Figure 5 Length and width distributions for *Q. suber* (QS) and *Q. rotundifolia* (QR) flours dried at 40 °C.

Table 6 Analysis of starch granules dimensions of fresh fruits

	Length (µm)			Width (µm)		
	Mean±σ	Maximum	Minimum	Mean±σ	Maximum	Minimum
QS	7.7 ± 3.60	19.4	1.2	5.9 ± 2.57	15.6	1.2
QR	6.0 ± 3.31	19.8	1.2	4.8 ± 2.63	18.1	1.1

Table 7 Fresh fruits and dried acorn flours colour parameters

Specie	Drying temperature (°C)	L*	c*	hº	TCD*
QS	None	84.9 ± 0.25[a]	31.4 ± 0.21[a]	92.3 ± 0.30[a]	__
	40 °C	73.5 ± 0.25[b]	18.5 ± 0.16[c]	84.4 ± 0.17[b]	15.1 ± 0.07[b]
	50 °C	75.2 ± 0.12[b]	19.0 ± 0.06[c]	83.3 ± 0.06[b]	16.2 ± 0.08[b]
	60 °C	68.2 ± 0.15[c]	21.0 ± 0.10[b]	82.1 ± 0.11[c]	20.2 ± 0.14[a]
	70 °C	67.3 ± 0.18[c]	21.8 ± 0.07[b]	82.2 ± 0.11[c]	20.6 ± 0.17[a]
QR	None	88.4 ± 0.41[a]	28.3 ± 0.80[c]	95.8 ± 0.26[a]	__
	40 °C	79.8 ± 0.12[d]	17.0 ± 0.07[c]	86.4 ± 0.07[d]	14.6 ± 0.07[c]
	50 °C	80.3 ± 0.15[d]	16.9 ± 0.13[c]	86.1 ± 0.08[d]	14.5 ± 0.07[c]
	60 °C	75.4 ± 0.16[b]	17.8 ± 0.17[bc]	83.8 ± 0.07[b]	17.4 ± 0.09[b]
	70 °C	72.4 ± 0.24[c]	18.7 ± 0.16[b]	82.6 ± 0.13[c]	19.4 ± 0.25[a]

[a]Percentage on dry weight basis.
[b]Results are the means ± standard error of mean.
Results are the means ± 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.

are quite different comparing to fresh fruit flours. All the acorn flours presented a yellow predominant colour (hº values near 90°). Fresh fruit flours presented a darker colour comparing to the dried fruits flours. The darker colour may be attributed to the oxidation of phenolic compouds, even though the colour of milled fruits flours was measured immediately after milling. As expected, the whitest (*L**) samples are those produced by drying at lower temperatures, like 40 °C and 50 °C, for both species. As drying temperatures increase, the flours became darker, most probably due to a larger extension of caramelisation. On the other hand, the intensity and vivid colour (c*) decreased with the drying temperature. Comparing the drying temperatures, for both species, the c* was lower in flours obtained at 40 °C and 50 °C, increasing in those obtained at 60 °C and 70 °C. The encountered colour difference might be classified as according to Drlange (1994) as very great (TCD* > 12.0) for all flours. In what concerns the species, flours from 40 °C and 50 °C presented equal values for colour parameters for both species. *Q. suber* flours obtained from drying temperatures of 60 °C and 70 °C are quite similar. *Q. suber* flours are darker and more vivid, then *Q. rotundifolia* flours, with a higher colour difference, probably due to a higher content of reducing sugars.

Conclusion

The aim of the present study was to evaluate the effect of drying temperature on morphology and physicochemical properties of *Q. suber* and *Q. rotundifolia* acorn species. Based on results, it could be concluded that drying temperature was a relevant parameter to the physico-chemical properties of flours, but not so important to the starch morphology. In fact, the physicochemical properties were significantly affected by drying temperatures

in both species. However, *Q. suber* and *Q. rotundifolia* showed to be differently affected by drying conditions. It can be said that *Q. suber* presented bigger starch granules, darker flours, high reducing sugar and amylose contents. Starch was less damaged and presented higher disaccharides contents in *Q. rotundifolia*. Based on the results, for both species flour dried at 60 °C, it seems to be the one where the drying process was faster than the drying at 40 °C and 50 °C and with a lower content of damaged starch. Considering 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 its relation to those morphological and chemical changes.

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