Food Measure
DOI 10.1007/s11694-016-9340-1

ORIGINAL PAPER

Nutritional characterization of acorn flour (a traditional component of the Mediterranean gastronomical folklore)

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Received: 11 January 2016 / Accepted: 25 April 2016

Abstract Nowadays, acorns, the fruits of *Quercus* trees, are mostly associated with animal feed. However they are part of the traditional gastronomical folklore of several Mediterranean countries. Though several uses can be mentioned, one of the most common uses is powdering the acorns in order to produce a flour that can substitute regular corn flour in the manufacture breads and cakes. An example of this is acorn bread, a typical Portuguese loaf. However, to the best of our knowledge, there is no information about the nutritional value of these flours. As such, the main goal of this work was to describe the nutritional value of acorn flours from two different subspecies of *Quercus* abundant in Portugal (*Quercus ilex* and *Quercus rotundifolia*) obtained using two different traditional methods (drying and roasting). The results demonstrated that all flours possessed interesting nutritional properties, namely the absence of gluten and elevated values of both monounsaturated and polyunsaturated fatty acids. Because of these facts and it's low production cost, acorn flour poses as an interesting alternative to traditional flours particularly for gluten intolerant individuals.

Keywords Acorns · Nutritional value · Gluten-free flour · Lipid profile

Introduction

Acorns can be found virtually everywhere that oaks are found. In fact, the term acorn is used to identify the fruits produced by several trees belonging to the *Quercus* genus such as Black, Bur, Cherry Bark, Laurel or Holm oaks. In Portugal, the most common acorns come from Oak (*Quercus faginea*), Holm Oak (*Quercus ilex* and *Quercus rotundifolia*) and Cork Oak (*Quercus suber*) [1].

While typically perceived as animal feed, this fruit is an important part of both gastronomical and medicinal folklore of the regions where these species are found. From a gastronomy standpoint, acorns may be used instead of chestnuts and dried fruits or, in a powdered form, used to replace regular corn flour in the manufacture of bread and cakes. In fact, the acorn flour is part of the gastronomical folklore of several Mediterranean countries, having been a staple food in times of low food availably. On a different note, several traditional beverages are also produced using this fruit such as Raccahout (a Turkish drink similar to hot chocolate), Eichel Kaffee (acorn coffee) or Licor de Bolota (traditional Portuguese alcoholic beverage) [1].

Overall, acorns are described as being rich in water, carbohydrates, proteins and lipids though no information was found concerning the nutritional value of acorns from both fresh and processed *Q. ilex* and *Q. rotundifolia*. Accordingly, the main objective of this work was to evaluate the nutritional value of flour from different varieties, contemplating the impact of two variations between different varieties and processing methods.

Materials and methods

Samples

Quercus ilex and *Q. rotundifolia* acorns were collected at Herdade do Freixo do Meio (Montemor-o-Novo, Portugal) and kept at 4 °C, under vacuum, until processing. The acorns were shelled and the pulps were either dried (45 °C

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Published online: 04 May 2016

for 3 days) using a tray dryer with parallel air flow (Armfiled, Technical Education, Hampshire, UK), or oven roasted (200 °C for 15 min). The resulting pulp was powdered using an A327R1 appliance mill (Moulinex, Barbastro, Spain).

Nutritional composition evaluation

Several nutritional parameters were assayed using sample duplicates for each analysis. Water content was estimated through the mass variation after oven drying at 130 °C as described in MSDA method 14/3.1.1 [2]. The total minerals were determined using a dry ashing at 550 °C (AOAC method 932.03 [3]). The total protein was determined through the Kjeldahl method as described on ISO 1861 [4] and the total lipidic fraction was assayed using the acid digestion soxhlet extraction MSDA method 14/3.3.2 [2]. Starch was extracted from the samples using an ethanolic solution, enzymatic digestion and quantified through a gravimetric assay based upon the MSDA method 14/3.6.1 [2] and NP 1419 [5]. The fiber content was assayed using an enzymatic gravimetric method based upon AOAC methods 985.23 and 991.43 [3]. Gluten was extracted by washing the sample with a saline solution and weighting the residue after water removal (NP 2244 [6]). The total carbohydrates were determined by calculation.

Fatty acid profile

The fatty acids were extracted from the samples according to the method described by Cohen et al. [7], using heptadecanoic acid as an internal standard and acetyl chloride as a catalyzer. The qualitative and quantitative profile of fatty acids was determined using a Hewlett Packard 5890 Gas Chromatograph (Palo Alto, California), equipped with a SP-2380 capillary column (60 m × 0.25 mm × 0.20 µm) (Supelco, Bellefonte, PA). Oven temperature was set at 90 °C for 3 min and posteriorly raised to 200 °C at a rate of 1.5 °C/min and left at this temperature for 20 min. The absorbance spectra and retention time were then compared to those of standard solutions (Sigma, Darmstadt, Germany). The area of each peak was then evaluated using a HP-3395 integrator (Hewlett Packard) and quantification performed according to the AOCS Official Method Ce Ib-89 [8].

Statistical analysis

Analysis of variance (ANOVA) was applied to all experimental results produced, in attempts to assess the effects of the main parameters on flour composition—type of acorn and drying method differences between the composition of flour obtained from two acorn varieties and submitted to two drying processes. The normality of the distribution was determined through the Shapiro–Wilk's test. Since the samples had a normal distribution, the one-way ANOVA with Turkey's post hoc test was used. Differences were considered statistically significant at the 5 % level. All analyses were conducted using IBM SPSS Statistics v. 21.0.0 (New York, USA) software.

Results and discussion

From a nutritional standpoint (Table 1), all acorn flours appeared to be rich in carbohydrates (75–84 %), particularly starch (75–84 %). They also exhibited relevant amounts of lipids (8–14 %) and low protein content (4–5 %). When comparing the nutritional characterization of the flours with the results reported for acorns it is possible to see that, for *Q. rutondifolia*, the values reported for ash, protein and carbohydrates (21.1–15.9, 39.4–48 and 843.4 g/kg dry matter, respectively) fall in line with those reported in the present work for the flours [9, 10]. On the contrary, the amount of starch, fiber and lipids were significantly different. The starch content was lower in acorn flour (517.9 g/kg DM) than in the one previously reported

Table 1 Nutritional characterization of the different flours (g/100 g of fruit)

	Q. rotundifolia		*Q. ilex*	
	Dry	Roasted	Dry	Roasted
Ash content	2.04 ± 0^{a}	2.00 ± 0.09^{a}	1.81 ± 0.09^{b}	1.81 ± 0.02^{b}
Total protein	4.55 ± 0^{a}	4.32 ± 0^{b}	4.57 ± 0.09^{a}	5.00 ± 0.24^{a}
Total lipids	8.44 ± 0.32^{a}	10.17 ± 1.27^{a}	13.41 ± 0.36^{b}	13.86 ± 0.03^{b}
Carbohydrates	84.09 ± 0.09^{a}	83.21 ± 1.12^{a}	75.22 ± 1.65^{b}	78.76 ± 0.30^{c}
Starch	51.79 ± 1.35^{a}	52.07 ± 6.86^{ab}	57.82 ± 3.47^{b}	54.48 ± 0.65^{ab}
Fiber	17.90 ± 2.95^{a}	16.76 ± 2.24^{a}	10.89 ± 1.40^{b}	13.00 ± 0.13^{b}
Gluten	nd	nd	nd	nd
Moisture	7.45 ± 0.21^{a}	22.05 ± 4.60^{b}	5.4 ± 0^{c}	9.65 ± 1.91^{d}

The different letters express the significant differences found ($P < 0.05$) between the different flours for acorns (536.1 to 582.8 g/kg DM) [10, 11], while fiber content was higher in acorn flour, 179 versus 55.3 g/kg DM [9], than in the acorn. The same results were observed for the lipid content, which was lower in the acorn flour (84.4 versus 111.4 g/kg dry matter) [9], when in comparison with the fruit. It is important to denote that, while differences were found between the reported information for acorns and the results reported in the present work for the flours, it is impossible to tell whether these differences stem from the processing of the fruits or are merely a consequence of different growth conditions and environmental stresses.

Statistically, no significant differences were found between the processing methods (roasting or drying) for the different nutritional parameters assessed. The only exception was observed for the water content that is higher in the roasted samples, explainable considering that the dry samples are subjected to a continuous flow of warm and dry air until a stabilized content is achieved, while during the roasting process the amount of water present in the surrounding atmosphere is higher, as it accumulates instead of being removed by continuous circulation of air. The lower amount of moisture present in the dried flours will likely translate to lower water activity of said flours thus they are likely to possess a longer shelf life than the roasted flours [12]. When comparing the flours from *Q. ilex* and *Q. rotundifolia* it was observed that, though *Q. ilex* was richer in total lipids it has lower amounts of dietary fiber and carbohydrates. The differences are likely due to either specific variations between, cultivars motivated by different metabolic processes, or responses to environmental stresses, possibilities that have been reported by several authors for other plants [13–15].

An important characteristic of both flours, that is interesting to highlight, is absence of gluten. Catassi et al. [16] reported an accentuated increase of celiac individuals and adults that lose the immunological tolerance to gluten. As the only remedy for gluten intolerance is a gluten free diet, the demand for high quality gluten free alternatives is also rising [17]. Bread and other flour based products are staple foods therefore there is an industrial and scientific interest in the development of recipes containing alternative, gluten free flours [17, 18]. Acorn flour has been used to produce bread by several different cultures and, as such, it could provide an interesting alternative to the alternatives used nowadays [19–21]. Additionally, as acorns have been described as possible substitutes of corn meal, it is possible that the range of application can be extended to other applications such as cakes, pasta and foodstuffs that require thickening agents.

When comparing the present flours with the literature concerning wheat flour (Table 2) acorn flour, besides being gluten free, possesses a considerably higher amount of lipids (5–10 times higher) and fiber than its wheat counterpart. However, acorn flour possesses a considerably lower amount of proteins (ca. 5 times lower). As Kuktaite et al. [22] stated that, in flours, high protein contents are associated with higher gluten contents, it stands to reason that this difference shall be seen for most gluten free flour alternatives. On another note, acorn flour exhibited a considerably higher amount of fiber (5–9 times higher) than wheat flours. As dietary fibers have been associated with many health benefits (among which is reducing the risk of developing coronary heart disease, stroke and diabetes), the fiber content appears to be another factor that accentuates the possible interest in using acorn flour [23].

Table 2 Nutritional composition of wheat flour as described in literature

	Percentage of dry matter (%)	References
Protein content	10–18	[33]
	11.8	[34]
	12.1	[35]
	10–15	[36]
Lipid content	1.34	[35]
Carbohydrates	70	[35]
Starch	60–75	[33]
Gluten	36	[34]
Fiber	1.9	[35]
Ash	0.5	[34]
	0.54	[35]

The high lipid content of acorn flours may be a double edged sword; while on one side it may imply the presence of beneficial compounds (e.g. lipidic antioxidants and polyunsaturated fatty acids—PUFA—particularly Omega-6), on the other hand there is a well-documented link between the development of major coronary heart disease and the ingestion of dietary fatty (though the type of fatty acids is a determinant marker of risk) [24]. Therefore, and considering the relatively high amount of lipidic components in acorn flour, it is necessary to further characterize this fraction in order to determine its true potential and/or risk. As can be seen in Table 3, the most prevalent fatty acids found were oleic (C18:1(n-9)), palmitic (C16:0), linoleic (C18:2(n-6)) and stearic (C18:0) acids, which correspond to ca. 89–91 % of the lipophilic fraction. These results stand in accordance with those reported in previous studies by [1, 25] and Bernardo-Gil, Lopes [26]. It is interesting to note that, while the fatty acid profile of the different flours is similar, there are a few differences between them, namely in C18:3(n-3) which is higher in *Q. rotundifolia* samples. The roasting process appeared to have little to no influence on the overall oil and fatty acid composition, which stands in accordance with what has been reported for other dry fruits such as hazelnut [27].

Saturated fatty acids (SFA) have been described as an important factor for the development of hypercholesteremia

Table 3 Fatty acid profile of the different flours and important ratios

Fatty acid	*Q. rotundifolia*		*Q. ilex*	
	Dry	Roasted	Dry	Roasted
C14:0 Miristic (%)	0.09	0.10	0.09	0.08
C15:0 Pentadecanoic (%)	0.04	0.04	0.04	0.03
C16:0 Palmitic (%)	14.21	14.76	14.98	14.09
C18:0 Stearic (%)	2.33	2.76	3.25	3.27
C16:1(n-7) Palmitoleic (%)	0.10	0.10	0.08	0.08
C18:1(n-9) Oleic (%)	60.92	60.89	59.85	60.35
C18:1(n-7) cis-Vacenic (%)	0.93	0.91	0.82	0.82
C20:0 Araquidonic (%)	0.28	0.30	0.38	0.39
C18:2(n-6) Linoleic (%)	15.91	15.69	15.49	15.34
C18:3(n-3) Linolenic (%)	0.71	0.84	0.63	0.65
C20:1(n-9) Eicosenoic (%)	0.55	0.53	0.53	0.54
C20:2(n-6) Eicosadienoic (%)	0.18	0.17	0.19	0.01
PUFA/SFA ratio	0.99	0.93	0.87	0.90
MUFA/SFA ratio	3.69	3.48	3.27	3.46
(MUFA + PUFA)/SFA ratio	4.68	4.41	4.14	4.36
(n-6)/(n-3) ratio	22.66	18.88	24.89	23.62

PUFA polyunsaturated fatty acids, *SFA* saturated fatty acids, *MUFA* monounsaturated fatty acids

and their intake has been strongly correlated with coronary death [28–31]. For that reason their abundance in any given food may present a disadvantage [28–30]. In the proposed flours, the SFA percentage ranges from 17 to 19 %. On the other hand PUFA, and to a lesser extent monounsaturated fatty acids (MUFA), have been reported to reduce cholesterol levels, e.g. through the reduction of atherogenic low density lipoprotein-cholesterol (LDL-C) [28–30]. As the major fraction of lipids is constituted by unsaturated fatty acids (61–63 % MUFA and 16–17 % PUFA), the flours appear to possess an interesting lipidic profile. However, excessive PUFA intake also has undesirable effects (e.g. increase of oxidative stress) therefore the intake of PUFA and SFA must be balanced. As there isn't a consensus on the optimal lipidic composition, the inference of potential benefits of the proposed flours must be made with some caution. The monounsaturated fatty acids (MUFA) appear to help prevent the free radical oxidation of LDL, a phenomenon that is reported to help the formation of arterial plaque [32]. As such, high MUFA/SFA ratios, as observed for the sampled flours (Table 3) could also be beneficial.

Conclusions

Acorn flours possess an interesting nutritional profile, rich in fiber and lipids (particularly unsaturated fatty acids) while possessing no gluten. These facts make acorn flours an interesting matrix for the development of gluten free foodstuffs by employing a commonly disregarded and cheap alternative, acorns.

Acknowledgments The authors would like to acknowledge the project Pest-PE/EQB/LA0016/2013 granted by FCT for the funding provided and Herdade do Freixo do Meio (Montemor-o-Novo, Portugal) for providing the acorns used. Additionally the authors S. Silva and E.M. Costa would like to acknowledge FCT for their Ph.D. grants, references SFRH/BD/90867/2012 and SFRH/BDE/103957/2014 respectively.

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