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Research Article

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Agri-Food Valuation of Oak Fruits in Human Consumption: Formulation of Desserts

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Abstract

Among the fruits whose economic value was underestimated, oak acorns (*Quercus* sp.) are gradually arousing interest by their biochemical and biological properties. The objective of this study was to incorporate acorns into human food through the formulation of new desserts. Acorns were collected from a cork oak forest located in northwestern Tunisia. Firstly, the physicochemical characteristics of the fruits as a base product were determined. Then, four dessert formulations were tested by adding ingredients to acorns: water, sugar, cocoa powder and sesame paste. A sensory analysis was carried for the products obtained such as: color, appearance, smell, sweetness and texture. The results indicated a moisture content equal to 44.71% ± 1.02 and showed total polyphenol and tannin contents estimated, respectively, in oak acorns at 8 ± 0.34 mg / ml EAG and at 25.88 ± 9.62 mg / ml EC. The extract obtained from the acorns is endowed with a high anti-free radical power. Thus, acorns are interesting as a food except that tannins content is high giving a bitter taste. Therefore, boiling method was selected to be the best to reduce bitterness. Then, this method was used to product acorns for dessert formulation. The results of the sensory analysis showed percentages of acceptability estimated at 53% and 40%, respectively, for the C formulations based on acorns and. chocolate and for D made from acorns and sesame. These desserts can be classified as natural foods that contain agro-food elements beneficial to human health.

Keywords

Quercus suber sp., Fruit dessert, Gluten free, Tannins, Antioxidant activity, Consumer

Introduction

The agri-food sector is one of the industrial sectors driving the global economy. In view of the growing global demand for natural products, a lot of efforts have recently been developed to expand the range of value-added forest products in order to promote sustainable rural development on the one hand and internalize innovation on the other hand.

Among the neglected plants, genus *Quercus* acorns belong to the family *Fagaceae,* have interesting properties. Throughout the Mediterranean basin, the acorns, the fruits of the oak, have been used for centuries for edible purposes as a staple food [1]. Being a fundamental high-energy nutritional resource in subsistence economies and during times of shortage, acorns were considered a food for the poor, and were abandoned when the economic conditions improved. Therefore, the culture of using acorns in human nutrition practically disappeared after the Second World War [2]. Due to the high variability of genus *Quercus* acorns, the chemical composition of this fruit varies with species and origin [3] but most acorn species, indeed, show a high content of tannins, which are astringent and behave as anti-nutrients. In the past, local populations identified and selected the trees bearing sweeter acorns, directly used for edible purposes, whereas the excessively bitter acornswere subjected to appropriate heat treatments and leaching or detoxification with clay [4]. In the context of the increased recognition of the nutritional properties of all nuts, acorns have recently become the object of renewed interest being nutritious fruits [4], with good contents of carbohydrates, fats, and fibers, acorn kernels are nutritionally comparable to many cereal grains. Moreover, these kernels contain proteins, high content of essential amino acids, vitamins (mostly A and C), and minerals. In addition, acorns are a good source of active compounds with an interesting antioxidant activity [5]. Moreover, in *Quercus* fruits starch constitutes over 58% of the kernel [6]. As starch is the main reserve nutrient in plants, providing 70 to 80% of the world's human caloric consumption [7]. Acorn flour is also gluten free [6] making it an alternative for celiac patients. In a recent research, extracts of acorns showed rich phenolic composition and exhibited an important inhibition of a-amylase activity which confirmed the traditional use of acorns for diabetes treatment. Chlorogenic acid was identified as the major compound in extracts from *Q. ilex*, *Q. coccifera* and *Q. suber*. Its amount was respectively 44.12%, 41.2% and 27.27% [8]. Therefore, these benefits have led to the use of oak nuts as wheat substitutes for making bread and biscuits [4] or as Cocoa powder in the manufacture of chocolate products, the most popular sweet food in the world [9].

Traditionally, several acorn plants have been widely used in Mediterranean medicine and foods. Due to their high concentration of tannic acid, a mild toxin giving them a bitter taste [7], the acorn fruits are not used in food industry. The great content of tannins in acorns influences the taste of acorn-based food products and tannins may also form a complex with proteins and sugars, which reduce the digestibility and absorption rate of protein, cellulose, starch, and fat in the human body [10].

In this context, the aim of the present work is to valorize oak acorns in human food through formulation of dessert after reducing the bitter taste by testing difeerent methods. This will facilitate its availability on the market at an affordable price and give added value as agro-products to a poorly exploited forest bioresource.

Materials and Methods

Plant material

Acorns were collected in late November (acorn picking season) 2019 from a cork oak (*Quercus suber* L.) forest (Beni M`Tir: 36°44'37.68"N, 8°43'51.07"E, 458m) situated in Northwestern Tunisia. After harvest, only morphologically ripe and healthy fruits were used then were stored in a cold room at a temperature of 4°C during two months.

Physico-chemical and biological properties of acorns

Percent moisture (%) was quantified using whole acorns. The other compounds were determined from dry acorn flour (figure 1). Indeed, a sample of 2 kg of acorns was shelled manually then dried at 40 °C for 5 days; until weight stabilizes and finally ground using an electric grinder (1 mm screen, RetschR300). The powder yield was calculated in relation to the fresh matter of the shelled acorns. Acorn flour was stored in the cold room (4 °C) until use.

Figure 1: A corn powder obtained from dried shelled a corns at 40°C/5 days.

For water content, a sample of 400 acorns divided into 4 batches were placed in an oven at 105°C until a constant weight was obtained (24 hours). The fresh weight (FP) was noted as well as the dry weight at the exit of the oven. Humidity was calculated using the following formula:

$$H(\%) = (\frac{F-S}{F}) * 100$$

Where: H (%): humidity in percentage, F: fresh weight, S: dried weight.

Acorn acidity was measured as the pH of acorn flour extract using a digital pH meter (model Bante 920, bench top pH/ORP meter). The meter was calibrated with a commercial buffer solution at pH 7.0. 10 ml of samples were placed in a 50 ml beaker with a magnetic stirrer and a pH electrode inserted. Samples were measured at 20 (±2°C). Crude oil content in acorns was determined according to the methodologies in AOAC (2000) [11]. 20 g of acorn powder was placed in a Soxhlet deviceto extract oil using petroleum ether as a solvent. The oil yield (%) was calculated according to the Dry Matter (DM).

Total phenols were determined by Folin Ciocalteu reagent [12]. A quantity of 500 µl of the acorn flour extract was mixed with 100 µl with Folin–Ciocalteu reagent (1:10) and 2 ml of sodium carbonate Na_2CO_3. The whole is incubated at room temperature for 30 minutes and the total phenols were determined by colorimetric method against a blank without sample at 765 nm. The standard curve was arranged using 0, 0.03, 0.06, 0.12, 0.25, 0.5 g/L solutions of gallic acid in water. Total phenol values are expressed in terms of gallic acid equivalent (mg/g DM).

The total flavonoids content in the crude extract was determined by the aluminum chloride colorimetric method [13]. 1 ml of diluted sample was mixed with 1 ml of 2% methanolic aluminum chloride solution. The mixture let stand for 15 minutes and the absorbance was measured at 430 nm. The total flavonoids content was calculated from a calibration curve and the result is expressed in mg of rutin equivalent per g of dry weight.

The method described by Broadhurst and Jones [14] was used to determine the total content of condensed tannins in acorn extract. 0.5 ml of the extract was mixed with 3 ml of vanillin (4% in Methanol) and 1.5 ml of sulfuric acid. After 15 min incubation at 20°C in the dark, the absorbance was read at 500 nm. Condensed tannin content was calculated from a calibration curve prepared with a catechin solution (30 ppm). The results are expressed in mg of catechin equivalent per g of dry mass of acorn flour (mg CE/g).

Antioxidant activity was measured using the method described by Broadhurst and Jones [14]. 5 ml of extracts were mixed with 5 ml of 2, 2-diphenyl-1-picrylhydrazyl (DPPH) solution (0.004%, in methanol). The reaction mixture was incubated for 30 minutes at room temperature and the absorbance was read at 517 nm 15]. The radical scavenging activity is calculated using the following formula:

$$\text{Scavenging effect (\%)} = \left[1 - \frac{Do\ Sample}{Do\ Control}\right] \text{x } 100$$

Preparation of acorns for the formulation of desserts

To reduce the tannins content, 4 methods have been tested on peeled acorns (figure 2):

Method 1: The acorns were watered for 48 hours, changing the water once in between.

Method 2: The acorns were soaked in baking soda and water for 48 hours, changing the water once in between.

Method 3: The acorns were put in the oven for (15 min) at (180°C).

Method 4: The acorns were boiled by changing the water until it was clear.

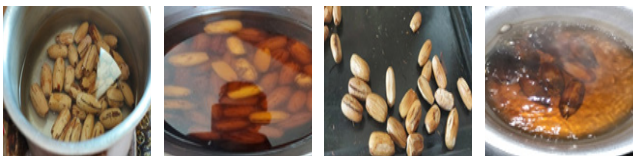

Figure 2: The 4 methods of tannin reduction. M1 : soaking in water (48 hours), M2 : soaking in water soaked and baking soda (48 hours), M3: Oven (180°C/15minutes), M4 : boiling and changing water until clarity.

In order to choose the best tannin reduction method, a preference test was carried out on the samples produced by the 4 former methods by 4 lots of thirty amateur random tasters. Each assessor chooses only 1 among the 4 tested samples and the percent of acceptability was calculated for the desserts in each lot as the number of individuals preferring one of the products in relation to the total number (30).

Formulation of desserts

The best method selected by tasters to reduce tannins in acorns was used to prepare the base product for desserts. The mixing plan method was used to achieve dessert formulations that are appreciable by changing the constituents each time. Additives used were: water, sugar, cocoa powder and sesame paste. Four formulations were tested and evaluated by sensory analysis.

Formulation (A): 54% acorns, water and sugar

Formulation (B): 49% acorns, water, sugar.

Formulation (C): 43% acorns, water, sugar, 6% cocoa powder.

Formulation (D): 38% acorns, water, sugar, 11% sesame paste.

The 4 tested dessets were cooked slowly over low-temperature cooking (**<82°C)** using a gaz stove stirring often, until the compote has condensed . To determine the organoleptic characteristics of the 4 obtained desserts, a descriptive analysis (profiling) was carried out by testing several descriptors such as: color, appearance, smell, sweetness and texture. The tasting panel was made up of 4 groups of 30 amateur random assessors. The sensory analysis was carried out in such a way as to assign a score from 1 to 4 for each descriptor: 1: poor 2: average 3: good 4: very good. Afterward, the percentage of acceptability of the 4 formulation desserts was determined for each group.

Statistical analysis

Data were processed using one-factor analysis of variance, according to the General Linear Models (GLM) procedure of Statistical Analytic System (SAS, 2002) AS program. The model included only the effect of the method used to reduce tannins and the formulation of the dessert. The comparison between the 4 methods and formulated desserts were performed using LSMEANS test.

Results and Discussion

Physico-chemical properties and antioxidant activity

Results on flour yield, water and crude lipids contents and acidity (PH) of cork oak acorns are presented in table 1. As regards wheat, commercial mills tend to operate to extraction rates in the range 70-80% 16]. In addition to the quality of the fruits, the shelling and grinding conditions that affect the yield of shelled acorns flour, the dry matter content is low because they are recalcitrant seeds [17]. A low content of lipids was determined in acorns. Mezni et al. [8], recorded an oil yield ranging from 0.89 to 2.02% depending on the growing area of the tree. In fact, in the food industry, it is advisable to present foods that are less fatty and beneficial to health [18]. Since this work aims to produce a dessert, these results are encouraging for the formulation of this product. Moreover, acorns showed an interesting antioxidant activity (37.73 ± 13.08% DM) and a high amount of polyphenols (433.4 mg GAE/ml) as it is presented in table 2. The content of tannins in acorns is equal to 35.95±29.22 mg/ml EC. These findings were similar with those previously reported by Papoti et al. [19] revealing that acorns materials (nuts, flour, shells) are good phenolic sources. Similar studies showed comparable results for polyphenol content in *Quercus suber* acorns: 480 mg GAE/ ml E [20] and 405.6 mgGAE/ml E [21]. For Belghith et al. [22], the antioxidant activity of acorns ranged between 19.09% DM and 36.55% DM.

Table 1: Physico-chemical parameters of cork oak acorns.

Parameter	Flour Yield (% FM)	Water content (% FM)	Crude Lipids content (% DM)	PH
Cork oak Acorn	57 ± 2.02	44.72 ± 0.89	1.33 ± 0.3	5.54 ± 0.4

Table 2: Total polyphenols, flavonoids, tannins content in cork oak acorn and DPPH radical scavenging activity.

	Polyphenols	Flavonoids	Tannins	DPPH
Cork oak Acorn	433.4 ±44.76 (mg/ml EAG)	0.006±0.0009 (mg/ml ER)	35.95±29.22 (mg/ml EC)	37.73±13.08 % DM

EAG : Equivalent Acide Gallique/ ER : Equivalent Rutin./EC : Equivalent caté catéchine.

Formulation of the desserts

The figure 3 shows the results of the percentage of acceptability of tasters for acorns produced by the 4 methods carried out to choose the best technique to reduce the tannins content. A significant difference ($p<0.001$) was found between the 4 techniques. The tasters reported the absence of bitterness with the method M4 (using boiled water) and was therefore selected to be the best to give treated acorns for dessert formulation. This result was in accordance with previous studies. Actually, dehulling the seed reduces the tannin content. However, this process does not eliminate the factors heat-labile antinutrients [23]. As well, soaking or cold leaching cause a reduction of tannins in seeds but other reported that soaked seeds cause significant increase (by 7.0%) in tannins contents [24]. This increase may be due to the hydrolysis of high molecular weight insoluble polymer into small molecular weight soluble polymers, during soaking [23]. The tannin content decrease better with hot-water soaking than alkaline leaching [25].

Furthermore, the sensory profiles of the 4 formulations and the acceptability percents for the 4 desserts are summarized in figure 4 and figure 5, respectively. A significant difference ($p<0.001$) was found between the 4 formulations acceptability percents with a preference for the dessert D (53.33 ± 5.44%) followed by the dessert C (40.83 ± 6.87%).

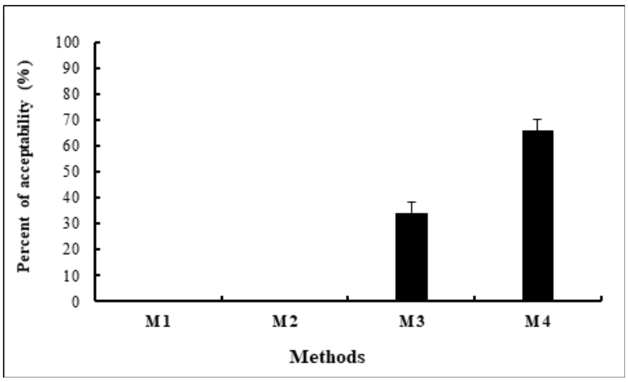

Figure 3: Percentage of acceptability of tasters for acornsproduced by the 4 methods.

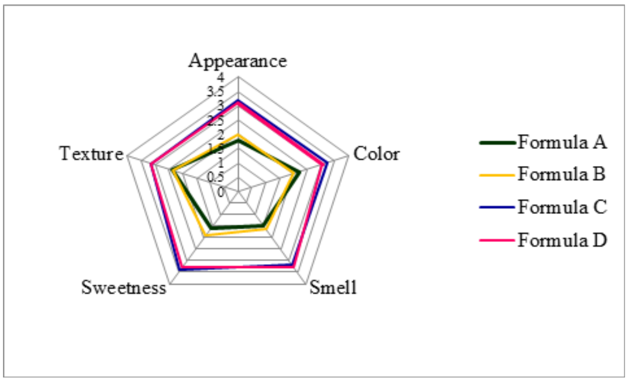

Figure 4: The sensory profiles of the 4 formulations. Formula A: 54% acorns, water and sugar, Formula B: 49% acorns, water, sugar, Formula C: 43% acorns, water, sugar, 6% cocoa powder, Formula D: 38% acorns, water, sugar, 11% sesame paste.

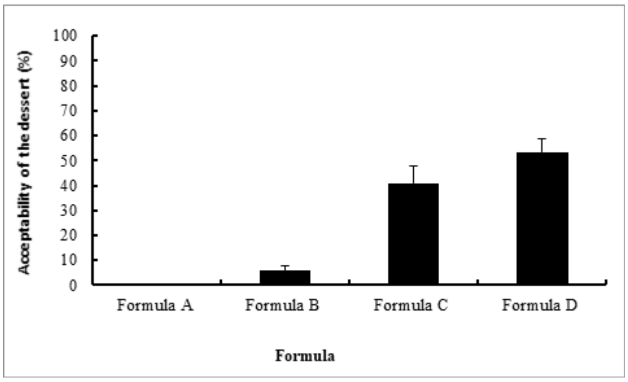

Figure 5: The percentages of acceptability for the 4 formulations.

Conclusion

The aim of this work was to add a value to cork oak acorns by testing new dessert formulations for the human alimentation. The results showed that cork oak acorns as base products are characterized by significant antioxidant activity which makes this fruit an inexpensive source of natural antioxidants. This antioxidant activity is due to the presence of polyphenols which give color to the fruit and improve human health. Acidity, an important factor for flavor, was around 5.5. In addition, acorns are low in lipids, constituents that contribute to the smell of fruits. However, acorns contain significant amount of tannins which gives an astringent taste which could be toxic to humans if used in large amounts. To solve this problem, 4 methods were experimented to reduce tannins content. They varied by changing water temperature and soaking time. A taste test allowed the choice of the best method that eliminates astringency by boiling the acorns. The acorns from this method were used to make 4 dessert formulations which may be appreciated by consumers, especially, patients suffering from celiac disease since acorns are gluten free. The results showed that the best formulations for the tasters were C and D including, in addition to acorns, cocoa powder and sesame paste, respectively. Indeed, these desserts can be classified as natural foods that contain agro-food elements beneficial to human health and may be appreciatef by specific consumers such children, celiac patients, etc. The enrichment of desserts with oak acorns proved to be a very effective strategy for conferring antioxidant properties to them, without excessively altering the sensory features. Bringing light on the use of acorns for edible purposes could increase their economic value and thus contribute to enhance local population income which has a positive impact on forest sustainability. Stiti et al. [26] showed no remarkable impact of acorn post-dispersal and use on the early stages of regeneration. An adequate management strategy based on a wise sharing of acorn stock involving both forest managers and local households can be a considerable step toward socio-economic development since no impact on oak regeneration [26]. Actually, this study is ongoing in order to better characterize acorn composition and dessert properties.

Acknowledgements

None.

Conflict of Interest

None.

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