Acorn: staple food from the past or novel food for the future? - An investigation into the desirability and acceptability of acorn flour products

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For thousands of years acorns, the fruit of oak trees, have been a staple food throughout North America, Asia, the Middle-East, North Africa, and Europe. However, in the present day, it has almost disappeared as a food for human consumption. One testimony of the importance of the oak tree in Irish and English culture is shown by the fact that the word "druid", may have originated from dru-wid, which stands for "oak knowledge". The oak had great symbolic significance, as it provided wood for fire and shelter, as well as acorn flour for bread making.

Recent interest in foraging for wild food could make this once major food source an attractive novel ingredient for the future. Increasing environmental awareness, and the search for health and wellbeing through balanced nutrition, would also represent a strong argument for inclusion of acorns in cooking.

Oak tree species vary greatly (e.g. white, red, black oak) and result in large differences in taste and flavour of the fruit, though acorns, are, above all, characterised by a considerable amount of bitterness caused by tannins. The process of acorn flour production is time consuming as it involves, leaching, particle size reduction, drying and milling. Commercial acorn processing today is mainly limited to countries such as Korea, China and to a lesser extent, the U.S.A.

The objective of this research paper was to perform and document a complete production cycle of acorn flour starting from the foraged tree nuts, collected in December. The acorns were allowed to dry naturally and then shelled. The meal was coarsely ground and submerged in water in 2 L jars. The water was changed twice daily in a 6-day period to leach the tannins. The acorn paste thus obtained was dried at 45°C for 24 h and milled. The resulting flour was used to produce muffins to assess the desirability and acceptability of baked products. The muffins will consist of one of the three flour mixes: a 50-50% plain Wheat flour-self raising Wheat flour (WHE), a 50-50% Chestnut flour-self-raising Wheat flour (CHEWHE) and a 50-50% Acorn flour-self raising Wheat flour (ACOWHE). The purpose is to establish the public perception of cakes made with less common starch sources by means of sensory analysis.

Besides linking to ancient culinary tradition and foraging, using acorn flour is desirable from a nutritional point of view. The public is craving novel foods with a more balanced distribution of nutrients and a high nutrient density. Acorn flour contains on average 59% starch, 33% fat, of which over 80% is unsaturated, and approximately 8% protein. In addition, acorn flour contains a considerable amount of electrolytes (calcium, magnesium, potassium and phosphorus), but little or no sodium, and is rich in iron, copper and zinc.

The paper will explore the possibility of including acorn as a novel and healthy ingredient, while appealing to the increasing desire for foraging in the professional kitchen and reaching out to ancient culinary traditions worldwide.

1. Introduction

During times of first industrialization and then globalization an oversupply of food changed foraging from being a necessity for many to a hobby for only a few. The knowledge of wild edible plants and seeds (e.g. acorns), passed from generation to generation over thousands of years started to being lost (Fleischhauer, 2011). However This is not the case in times of food shortage such as war or in todays lesser developed countries, where foraging still plays a major part in human survival and nutrition according to Redžić (2010) and Batal et al. (2007).

An oversupply of mass manufactured and far travelled exotic foods is common place in today's supermarkets. As the appetite for foreign fruit and vegetables is satisfied as well as the overwhelming offer of mass and force produced edible goods remains, the search for different, new and unusual products continues (Eastoe, 2008).

Many Chefs have only rediscovered the use of wild edible plants in the last number of years. As the knowledge about foraging had almost disappeared, these wild foods started fetching high prices and are sold to restaurants as a premium product. This was seen as an opportunity for some establishments to distinguish themselves. The high prices were passed on to consumer, turning something supposedly free like wild foods into something exclusive (Fleischhauer, 2011).

In the above context it is interesting, that at the first signs of the worldwide recession in 2008 the pocketsize book 'Food for Free' first published in 1972 by Richard Mabey tripled in sales. Cox (2011) and Alter (2009) are both of the opinion that the economic downturn could be a driving factor in the popularity of foraging.

Acorns, the fruit of oak tree, have been foraged and used for thousands of years in most parts of the world. According to Bainbridge (2006) acorns were a staple food throughout Europe, the Mid-East, North Africa, Asia, and North America.

There are thought to be as many as 600 different species of oak trees worldwide and the use of acorns as part of the human diet has been well documented by Claudia (2013), Bethany (2009), Mason and Nesbitt (2009), Sommerfeld (2008), Creel (1920).

Kelleher et al. (2010) state that native Irish oak woods only occupy approximately 0.1% of the land area in Ireland. The demise started around 5000 BC due to deforestation in order to utilise the land for livestock and agriculture. Nonetheless in Irish and English history the oak tree itself played an essential roll, as the word "druid" is derived from *dru-wid* which stands for "oak knowledge". This knowledge is thought not only to be

related to the spiritual existence of the druids, but the oak was seen as a symbol for survival itself by providing many fundamental materials, such as wood for fire and shelter, as well as acorn flour for making bread (Da Silva, 2009).

With regard to health, there is a strong argument to be made in favour of a diet partially consisting of wild edible foraged foods based on the nutritional composition alone (Irving, 2009). According to Rakić et al. (2006) acorns are nutritional dense functional food with health properties. Some of the health benefits are ascribed to the high level of phenolic compounds found in acorns, which are similar or greater than in almonds, hazelnuts and peanuts even after the leaching process (Kobs, 2008). These phenolic compounds are of the hydroxy-benzoic acids group and provide acorn flour with high levels of antioxidants, which could have potential health benefits (Sabrin, 2009).

The aim of this study is to investigate the suitability of a home production method for acorn flour using foraged acorns and explore the desirability and acceptability of acorn flour in a bakery product as a novel food ingredient.

2. Materials and Methods

2.1. Plant material

The acorns used to produce the acorn flour were gathered during the third week in December. The collected acorns were inspected in order to remove rotten and infested specimens. Remaining acorns were then allowed to dry naturally by spreading them in a single layer on trays for approximately four weeks.

The two other flours used in the experiment were white flour, used as a control and chestnut flour, which were obtained by commercial processes, while the acorn flour did not undergo any treatment that would greatly alter the nutritional composition of the acorn, once shelled.

2.2. Production of the acorn flour

After the drying period, acorns were manually shelled. The skin remaining on the outside of the fruit body's was then removed by soaking the acorns in water for 24 hours after which they were blanched for five seconds in boiling water.

In order to remove the large amounts of tannins present in acorns, the process of leaching was applied. The shelled and peeled acorn kernels were roughly ground in a Thermomix food processor (model no. TM31, Wuppertal, Germany) for 1 minute at speed 5. The obtained acorn flour was than combined with water in sealable kilner jars at a ratio of 1:1 (w/v). The jars were shaken for a total of 1 minute, after which they were placed in a fridge at a constant temperature of 4°C.

After 12 hours the jars were removed from the fridge. The acorn meal settled to the bottom of the jar and the water collecting above was discarded. Fresh water was added at the same ratio of 1:1. The acorn paste was taste tested after each cycle, until the bitterness caused by the tannins was reduced to an acceptable level. The process of shaking, chilling and replacing the water was repeated every 12 hours over the total duration of six days. After the leaching process was completed the content of the jar was placed in a colander lined with a muslin cloth and allowed to drain over four hours. The remaining acorn paste was then spread evenly onto silicon paper and placed in a dehydrator (model no. KN-128 ST, Chang Yue Industrial Corp., Taiwan) for 24 hours at 45°C.

After the drying process was completed the product was placed again in the Thermomix food processor and ground into a fine meal (1 min, speed 10), ready to be used in cooking and baking applications. The breakdown of yields during the processing steps is displayed in Table 2.1.

Table 2.1: Product yields during processing

Product	**Weight**	**Percentage of initial total**
Acorns Whole	2800g	100%
Acorns shelled	1385g	49.5%
Acorns skinned	1325g	47.3%
Acorn flour	1283g	45.8%

2.3. Production of the muffin samples

Three different types of muffins were produced using a planetary mixer (Crypto Peerless, model no. EG20, Halifax, UK), with the exact recipe formulation displayed in Table 2.2. The variations contained the following flours respectively:

- WHE – 50% self-raising and 50% plain wheat flour (Plain Muffin),
- ACOWHE – 50% self-raising and 50% acorn flour (Acorn Muffin),
- CHEWHE – 50% self-raising and 50% chestnut flour (Chestnut Muffin)

Table 2.2: Recipes for Muffins (n=36)

WHE Plain Muffin (n=36)		ACOWHE Acorn Muffin (n=36)		CHEWHE Chestnut Muffin (n=36)	
Weight	Ingredient	Weight	Ingredient	Weight	Ingredient
675 g	Self-Raising Flour	675 g	Self-Raising Flour	675 g	Self-Raising Flour
675 g	Plain Flour	675 g	Acorn Flour	675 g	Chestnut Flour
15 g	Baking Powder	15 g	Baking Powder	15 g	Baking Powder
700 g	Brown Sugar	700 g	Brown Sugar	700 g	Brown Sugar
1125 ml	Milk	1125 ml	Milk	1125 ml	Milk
6 unit	Whole Egg	6 unit	Whole Egg	6 unit	Whole Egg
540 ml	Sunflower Oil	540 ml	Sunflower Oil	540 ml	Sunflower Oil
40 ml	Vanilla Essence	40 ml	Vanilla Essence	40 ml	Vanilla Essence

For each of the three recipes the same method was followed. Firstly all wet ingredients (milk, whole egg, sunflower oil and vanilla essence) were mixed in a stainless steel bowl, by whisking them for one minute. In the bowl of the planetary mixer the dry ingredients (flours, baking powder and brown sugar) were combined using a paddle beater attachment for three minutes at speed one. The wet ingredients were then added two the dry mix and combined again using the paddle beater attachment for one minute at speed one. The batter was then portioned with a 100ml scoop into paper muffin liners which had been placed in muffin tins. The samples were placed in a preheated deck oven (Sveba-Dahlen, model no. OC-33, Fristad, Sweden) at 180°C for 20 minutes. Once the baking cycle was completed the muffin were allowed to cool in the tins at room temperature for 20 minutes, after which the muffins were removed from the tins and fully cooled for two hours on metal wire racks. The samples were then stored in airtight containers prior to being portioned for the sensory evaluation.

2.4. Sensory Analysis

For the purpose of sensory analysis, the muffin samples were prepared by cutting two samples of 1.25 cm (L) × 2.5 cm (W) × 4 cm (H). Each set of two samples was placed on a plate that was randomly numbered using a three-digit code, and presented to the panellist. Eighty-five untrained panellists were asked to assess different attributes of the muffin samples. The test consisted in assessing on a 9-point hedonic scale the colour intensity, the colour preference, the aroma, the texture and the taste of the three muffin samples. A 15-cm structured scale with anchor points in the middle (7.5 cm) and at each end was used for evaluating the different attributes. The point 1 of the scale corresponded to dislike extremely point 9 to like extremely. The colour intensity was assessed on a similar scale where point 9 corresponded to ‘too dark’, point 1 corresponded to ‘too light’ and point 5 was ‘just right’.

According to Meilgaard et al. (2007) affective testing is the most suitable form “to assess the personal response (preference or acceptance) of current or potential customers to a product, a product idea, or specific product characteristics”.

The test took place in the Food Science laboratory at GMIT featuring semi partitioned areas which allowed for independent assessment. A total of eighteen booths were available to participants, containing water to refresh the palate in between tastings and napkins. The three samples were placed on the tables and each participant was provided with a consent form as well as the Sensory Analysis Questionnaire, containing details to communicate the nature of the test prior to commencement.

2.5. Statistical Analysis

All data were subjected to statistical analysis using SPSS (Version 21.0). The effect of treatment (different ingredient) was compared using a one-way analysis of variance (ANOVA). Post-hoc tests were performed using Tukey’s pair-wise comparisons to identify significant differences ($p < 0.05$) between the treatments.

3. Results and Discussion

The processing of acorns into flour took a total five weeks; however, the yield of 45.8% was considered to be satisfactory, despite the lengthy process. The results of the sensory analysis on the muffins are reported in Table 3.1.

Table 3.1: Statistical Analysis of Sensory Evaluation

	Treatment				
	Plain	Chestnut	Acorn	SED	P
Colour intensity	3.7^{a}	5.4^{b}	6.7^{c}	.20	***
Colour preference	6.8^{c}	4.7^{a}	5.4^{b}	.28	***
Aroma	6.4^{b}	5.0^{a}	5.9^{b}	.29	***
Texture	6.3^{c}	5.1^{b}	3.4^{a}	.29	***
Taste	6.3^{c}	5.5^{b}	3.8^{a}	.29	***

Note: means with different superscripts within the same row are significantly different to a level of $P<0.05$

The inclusion of different types of flour in the muffin recipes resulted in three products that were different in colour (Figure 3.1). This was reflected in the results that showed significant differences across the treatments ($P<0.001$). While the three types of muffin showed a typical yellow/bronze, a chocolate brown a more unusual beige colour, they were considered by the panellists to be 'too light', close to the optimum value (5) or 'too dark'. It is worth noting that the muffin that was scored closest to optimum colour intensity was not the classic muffin that panellists would have been used to but the more unusual one made with chestnut flour.

Figure 3.1: Detail of the three muffins used in the study: a) plain muffin; b) chestnut muffin and c) acorn muffin

This aspect was more visible when panellists were asked to rate the colour of the samples based on their preference. There was a significant difference across the treatments ($P<0.001$) with the plain flour muffin scoring the highest (6.8), followed by the acorn flour muffin (5.4), while the chestnut flour muffin scored the lowest (4.7). This result also may partly be explained in terms of exposure and expectation. The majority of what is available in bakeries and supermarkets are variations on recipes predominantly made of white flour. An exception to this is the manufacturing of chocolate muffins (and variations thereof). The acorn flour muffin, purely based on visual appraisal, looked no different to a chocolate muffin, thereby providing a stimulus that the panellist is likely to be used to. The chestnut flour muffin was the most unusual colour of the three, and perhaps that could explain the low score achieved.

In the assessment of the aroma, the panellists scored the plain white flour muffin the highest (6.4), although this was not significantly different from the muffin made with acorn flour (5.9). The lowest score was obtained by the muffin made with chestnut flour (5.0), which was significantly lower ($P<0.001$) than both the other two treatments. In the white flour muffin, in the absence of any strong aroma, the vanilla essence that was included among the ingredients had a dominant note. This was less the case of the acorn muffin, which had a slightly baked nutty note complementing the vanilla essence, or the chestnut, where the dominant note was that of boiled/roasted chestnut, and the vanilla was less dominant.

The texture results showed significant differences ($P<0.001$) across the treatments, with the plain flour muffin obtaining a score greater than the chestnut flour muffin (6.3 vs. 5.1, $P<0.001$), which in turn was greater than the acorn flour muffin (3.4). A possible explanation of the wide differences that were obtained in relation to the texture could be represented by the different composition of the flours used. There are considerable differences in the total carbohydrate and lipid content between the white flour, chestnut flour and acorn flour. An average composition of white flour would consist of approximately 75% starch, 10 % protein, very little lipids (1%) and 3-4% of dietary fibre (McCance and Widdowson, 2002). Commercial chestnut flour would consist of a similar if not higher starch content (78-79%), a lower protein content (5-6%) and a greater presence of lipids (approximately 5%) (Demiate et al., 2001). Compositional analysis of acorn flour has been shown to have values as low as 55% starch, but approximately 30% lipids and 7% protein (Sabrin, 2009). The muffins containing the acorn flour seemed to be very dry in comparison, a fact echoed by comments made by

participants after completion of the evaluation process. A contributing factor to the dryer texture of the acorn flour muffins may be attributed to the lower starch content, which in due course may have reduced the ability to trap moisture during the baking process (Figoni, 2011; Coultate, 2009).

Nutritionally, the profile of acorn flour is very favourable as it matches closely what is generally recommended in terms of overall energy intake. However many varieties contain substantial amounts of tannins which require processing by ways of leaching, entailing the shelling, peeling and grinding of acorns (Bainbridge, 2006).

Suggested figures for energy intakes of carbohydrates, lipids and protein are to be at 50-60%, 30% or less, and 10-15%, respectively (Drummond and Brefere, 2009). It is widely documented that in the 'Western' diet there is excessive reliance on carbohydrates and fats for energy and that the nature of the fat intake is predominantly of the saturated type. As a vegetable fat source, acorns contain mostly unsaturated fatty acids (Sabrin, 2009) and negligible levels of cholesterol (Charef et al., 2008; Lopes and Bernardo-Gil, 2005).

The overall taste assessment showed a preference for the plain muffin, significantly greater than the chestnut muffin, which in turn was preferred to the acorn flour muffin, mirroring very closely the results of the texture.

Another causative factor to the low score during the taste evaluation of the acorn flour muffin may be related to the issue of 'Stimulus Error'. Stone et al. (2012) reported that this error tends to emerge when participants have or may think they have previous knowledge about the food samples. The participants in the current study mentioned, after the test, that they were expecting chocolate muffins based on the colour of the acorn flour muffins, which may have resulted in a 'Stimulus Error', as the colour perception created a taste anticipation which was not satisfied.

The lower score of the acorn flour muffin and chestnut flour muffins compared with the plain flour muffins with regard to the attributes of colour preference, aroma, texture and taste may have its origin in the previously mentioned issue of exposure and expectation. Cardello (2007) suggests that expectations develop over time, leading to consumers adjusting their expectation in line with their product experience. Participants may have had considerable exposure to muffins made with plain flour, previous to the sensory analysis, influencing their expectations of the products.

4. Conclusion

As part of this study acorn flour was produced and the desirability and acceptability of acorn flour in a bakery product as a novel food ingredient was investigated.

The production of the acorn flour involved a large number of individual steps and processes, which was labour intensive, suggesting a possible elevated production cost. During sensory evaluation panellists found that the muffins produced from the acorn flour were considerably different in regard to appearance, texture, aroma and taste when compared with the muffins made with chestnut flour and plain flour. Optimisation of recipe formulation and the cooking protocol will be required to obtain an acorn flour product that is more in line with the expectations of the public, to account for the compositional nature of the acorn flour. The moisture retaining properties of baked goods containing acorn flour needs to be further investigated in order to improve its acceptability. The opportunity to set expectation of the panellists by disclosing all the ingredients will also be considered in the future, as well as the exploration of different levels of incorporation of the flour.

This last aspect is particularly relevant as partial wheat flour replacement would be a desirable feature, based on the nutritional composition, with the additional benefits that may derive by the absence of cholesterol and the significant presence of antioxidant polyphenols. Further investigation would be required to establish an efficient and streamlined procedure for flour production.

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