Possibilities of using acorn flour in products Based on flour

Polimac, Mirjana; Koceva Komlnić, Daliborka; Lukinac, Jasmina

POSSIBILITIES OF USING ACORN FLOUR IN PRODUCTS BASED ON FLOUR

UDC

Mirjana Polimac[1]*, Daliborka Koceva Komlenić[2], Jasmina Lukinac[2]

*[1]*Ivana Gorana Kovačića 6, HR- 31000 Osijek, Croatia*
**Corresponding author: mpolimac@lycos.com*

[2]Josip Juraj Strossmayer University of Osijek, Faculty of Food Technology Osijek, Franje Kuhača 20, HR-31000 Osijek, Croatia

ABSTRACT

Oaks (*Quercus* spp.) are widespread species of temperate zone of the northern hemisphere including Europe, North Africa, Middle East, Asia and North America. Acorns, the fruit of the oak, have been used in human nutrition for thousands of years and more recently archaeological research confirms that in the past acorns have been important sources of food in different cultures around the world. Today it is used as food in Turkey, Korea, North Africa, China, the USA and as an important part of cultural heritage in some parts of Spain.

Acorn was staple food in the diet of the Balkan peoples, but despite its long culinary tradition acorn has been neglected. The sad fact is that we have forgotten all about nutritional value of acorns that our ancestors knew and used.

The aim of this study is a qualitative analysis of the existing literature concerning the investigation of food products from acorns, primarily the possibility of using acorn flour in products based on flour. Based on citation bases Web of Science and Scopus 42 articles have been selected that included the period from 1977 to 2015. Most of the studies were published by authors from the United States (14), Italy (6) and China (5). Additional searches were done by using Google Web Search. Regarding these results acorn flour can be used in modern diet as a replacement for wheat flour in wide range of applications in food production, primarily production of cakes, cookies, muffins, pancakes, pasta, noodles, flatbreads, pizza crust, pie crust, and also for thickening sauces and soups.

However, analysis of the literature reveals a lack of research in Croatia, and generally points out the need for greater representation of these issues in the future.

Keywords: oak; acorn; food; acorn flour; products based on flour

INTRODUCTION

Oak (*Quercus*) is a significant and rich genus of the *Fagaceae* family, containing 300-500 species of trees and shrubs (Nixon 1993; Trinajstić 2007). It is widely distributed species of temperate zone of the northern hemisphere, including Europe, North Africa, Middle East, Asia and North America, which reaches a height of up to 50 m, a diameter up to 2.5 m, and the age up to 1500 years. There are 12 oak species registered in Croatia (Trinajstić 2007). Well known fruit of the oak is acorn. Acorns of pedunculate oak (*Quercus robur* L.) are elongated oval, light brown or yellowish in color, with longitudinal darker stripes. Acorn's „cap" called cupula by experts is covered with tiny, taped shells, ripen in September and October. Due to the large share of alkaloids, acorns are bitter and astringent, but in the past they were used as food, especially in times of famine.

There is a strong link between human civilization and the oak, at least 30 000 years ago in Europe and Asia, as well as 14 000 years in North America. The oaks have been an important source of building materials and food supplies for people since prehistoric times, and still are, significant renewable resource of many modern economies.

As the world faces increasing challenges from climate change, consumption of natural resources, biodiversity loss, poverty and population growth, it is increasingly clear that it is necessary to find and switch to new forms of sustainable production and consumption. Accordingly, the demand among consumers for healthier and natural products, resulting from environmentally friendly production, shows a growing trend globally.

In this literature review, we want to give a picture of what the use of acorn is, with special reference to flour and flour-based products in different parts of the world, in the past and the beginning of this century.

MATERIALS AND METHODS

In February 2015 started an online search of the following citation databases:

1. Web of Science, published by ISI-Thomson Reuters - the oldest citation database of magazines classified according to three thematic citation indexes: SCI (Science Citation Index) natural, technical and biomedical sciences; SSCI (Social Science Citation Index) Social Sciences; A & HCI (Art and Humanities Citation Index) Humanities and Arts

2. Scopus - recent citation database, which includes a large number of Croatian magazine.

3. Google web search - Google's Internet search engine owned by Google Inc.

As a keyword in the search were used the name of the genus (*Quercus*) and the name of its fruits-acorns, and subsequent results were defined as articles relating to human consumption of acorn or acorn flour. A total of 42 separate articles were published in the period from 1977 - 2015.

Further analysis of articles was done according to the subject of this article, the author, scientific area, chronological distribution and geographical location.

RESULTS AND DISCUSSION

Summary of the literature pertaining to the possibilities of using acorn flour in products based on flour.

Citation databases

Table 1. A literature review on the use of meal of acorns (citation database)

Subject:	**%**	**Author and year:**
Historical data about the acorn consumption and technologies related to the processing of acorns for human consumption	69 %	(Revedin *et al*. 2015),(Stevens & McElreath 2015), (Morales *et al*. 2015), (Antolín & Jacomet 2015), (Valamoti 2015), (Yang *et al*. 2014), (Tushingham & Bettinger 2013), (Saul *et al*. 2012), (Morgan 2012), (Regnell 2012), (Liu *et al*. 2011), (Fuller & Qin 2010),(Yang & Jiang 2010), (Borojević *et al*. 2008)(Pringle 2008), (Fuller *et al*. 2007), (Sadori & Susanna 2005), (Lev *et al*. 2005), (McCreary 2004), (Gremillion 2002), (Mason 2000), (Bouby *et al*. 1999), (Kubiak-Martens 1999), (Ivanhoe & Chu 1996), (Ivanhoe 1995), (Regnell *et al*. 1995), (McCorriston 1994), (Schneider 1990), (Jorgensen 1977)
The content of tannin in the acorn	31 %	(Luczaj *et al*. 2014)
Acorn Bread		(Claudia 2013)
Acorn Starch		(Cappai *et al*. 2013), (Correia & Beirão-Da-Costa 2010), (Yang & Jiang 2010), (Choi & Jun 2008)
Acorn Cake		(Pignone & Laghetti 2010)
Nutritional and antioxidant value of acorns (properties of polysaccharides, phenolic compounds) functional properties of polysaccharides isolated from acorns		(Tadayoni *et al*. 2015), (Benmahdi-Belarbi *et al*. 2007), (Rakić *et al*. 2007), (Rakić *et al*. 2006)
Allergy to acorns		(Roux *et al*. 2003)
Anti-inflammatory properties of acorns (anti-asthma effect)		(Moon *et al*. 2013)

Table 1 shows the results of researching scientific papers, dealing with acorn flour as a food source. The greatest number of scientific articles (69 %) refined on archaeological research, which recorded that the acorn was used as food for thousands of years, virtually wherever there were oak trees. Only a small number of authors (31 %) explore the possibility of using the nutritional value of acorns, as well as food products that have been at the disposal from the distant prehistoric times until today.

Acorns of various oak species, used as the main food products distributed around the world from prehistoric times until today, has been documented in a number of articles. Acorn is a traditional food of many indigenous tribes of North America, but a particularly important role was played by the tribes in California that are using acorn in their diet with as many as 20 species of oaks (Schneider 1990). North American Indians are generally very dependent on this source of food, which are collected and processed (McCreary 2004; McCorriston 1994; Pringle 2008; Ivanhoe & Chu, 1996; Ivanhoe 1995, Gremillion 2002, Stevens & McElreath 2015). Acorns were gathered and processed for consumption mainly by women. Processing, in three main phases was used to remove the bitter tannins and it included the cleaning of acorns from the outer shell, crushing with pestle in a mortar, then rinse obtained acorn flour repeatedly pouring water in the sand pool, which was sometimes lined with grass or in open baskets coated with sand. After rinsing, the flour was cooked in baskets, stone bowls or containers made of wood or bark, with the hot stones, and consumed as porridge or soup. Bread is also made from acorn flour, baked on a stone or coal, in a clay oven or ashes. Less intensive processing methods (e.g. passive flushing water over the acorns, before chipping and grinding) were common in some areas of Northern California, but these techniques have played a minor role compared to intensive methods described previously (Tushingham & Bettinger 2013; D. Prichep 2014). Analysis of different storage techniques during the Holocene period in California showed that the hunters - gatherers stored food. Ethnographers describe the technology for storage of acorns, which were used by the California Mono tribe. Mono guarded collected acorns in their camps and villages in covered barns, built on platforms mounted on wooden poles, or on the ground. They also built stone barns, composed of laying big and small stone pieces. They are found almost exclusively on large granite plateaus of southern exposure that favors the drying of acorns (Morgan 2012).

The second region of importance is Asia. Exploring the use of plant hunter - gatherers in the late Paleolithic in China revealed the remains of starch on the analyzed artifacts and show that the former residents gathered and grind into flour, including oak acorns (Liu *et al.*, 2011; Yang & Jiang 2010). Research basin of the Yangtze River in China show that the cultivation of rice is slowly taking over, during the middle Holocene, greater importance in society that was previously very dependent on seasonal gathering acorns (Fuller & Qin, 2010; Fuller *et al*. 2007). Recent archaeological finds of ceramic fragments of cookware, which date back more than 10,000 years, found in the northern part of China, confirming that this early pottery was used for cooking grains, especially millet and acorns (Yang *et al.* 2014). Traces of eating acorns in prehistoric times were found during archaeological-botanical research in Kebara cave in Israel, based on the excavated plant remains from the Middle Paleolithic (Lev *et al*. 2005).

Third in importance is the whole area around the Mediterranean, from Turkey to Spain and other parts of Europe and the world (Saul *et al*. 2012). Archaeological records from 24 sites in the northwestern part of the Iberian Peninsula, which date from the Neolithic period, confirmed by regular practice of eating acorns (Antolín & Jacomet 2015), which also reveal the plant remains found in northern Greece (Valamoti 2015). Numerous finds dating from the late Mesolithic in southern Scandinavia, also show a significant use of acorns in the human diet, and even the management of oak forests for the production of acorns in northwest Europe (Regnell 2012; Regnell *et al*., 1995; Mason 2000). Acorn in the Stone Age as a food source is mentioned in 1977 (Jorgensen, 1977).

Newer archaeobotanical and ethnographic research confirm that oak acorns were used as an important food source in Tunisia. In addition to being nutritionally highly valuable food source, its advantage was that it could easily keep for a long time (Morales *et al*. 2015). Acorns are especially rich in content of carbohydrates and fats, with a relatively high content of protein, fiber and ash, and they ate them as porridge or baked on a flat stone, after the removal of tannins immersion in mud, or rinsing in water. From the Middle Ages onwards, the acorn has got an important role in the production of meat by breeding pigs fed on acorns in the forest (Schneider 1990).

A growing awareness of the connection between diet and health resulted in the creation of a new concept of functional foods. IFIC (International Food Information Council) has given a definition, which says a functional food is that which provides greater health benefits than basic nutrition (Friganović *et al*. 2011). Despite the low representation of articles aimed at exploring the use of acorns in the diet of modern man, they confirm its nutritional value and antioxidant properties. In the area of Algiers, for acorn flour of three oak species, it was found that it does not contain tannic substances in amounts harmful to health. On the contrary, total polyphenols content is similar to that in other fruits and vegetables and is characterized by high antioxidant capacity (Benmahdi-Belarbi *et al*. 2007). Studies of probiotic potential and some functional properties of polysaccharides isolated from acorn fruit show that are not only suitable for technological application, but have properties of functional foods too (Tadayon *et al*. 2015). Popovic (Popovic *et al*. 2013) also states that, given the high antioxidant potential, acorn of pedunculate oak (*Quercus robur L*.) and sessile oak (*Q. petraea L*.) from the territory of Vojvodina, can be recommended as a source of natural antioxidant and a promising raw material for use in food industry and pharmaceutical industry. Rakic was investigating phenolic compounds and antioxidant activity of methanol extract of pedunculate oak and Turkey oak acorns (Rakic *et al*., 2007; Rakic *et al*. 2006). The results confirm the high antioxidant value, which is by thermal treatment still increased, and that the pedunculate and Turkey oak acorns are suitable source for the preparation of functional foods. The content of phenols and tannins in oak acorns of different species varies. In one of the recent research of acorns from Polish, author describes the phytochemical parameters of more oak species (*Q. robur, Q. petraea, Q. pubescens, Q. rubra*). The amount of phenol in the acorn of *Q. robur* and *Q. petraea* is similar and tannins form a major component. *Q. pubescens* sample differs the lowest content of tannins and total phenols, and a relatively high amount of non-tannin phenols. *Q. rubra* had slightly lower tannin content than acorns of *Q. robur* and *Q. petraea*,

but other levels of phenols were much higher. Results for *Quercus robur* indicate geographical variability of phenol content, and the connection between phytochemical and biometric parameters of oak acorns (Luczaj *et al*. 2014).

Results of archaeological research confirm that the production of flour from acorns was a common practice throughout Europe at least 30 000 years ago (Revedin *et al*. 2015).

Oak acorns, used as food, appear in the archaeological findings in one of the oldest known remains of a town of Catal Huyuk (Čatal Hik) in Turkey, which date back to 6000 g. BC. There is information that the oak trees carefully inventoried during the reign of the Assyrian king Sargon II. The Grapčeva cave in Croatia, on the southern slopes of the island, near the village of Humac, is one of the oldest archaeological sites of the remains of civilization and culture in the Adriatic, which date back to between four and five thousand years before Christ. It is a key place for the Adriatic and the Mediterranean prehistory. Recent excavations on the site have revealed an abundance of plant residues. The most common are the remains of acorns of holm oak (*Quercus ilex L*.). It is assumed that during the Late Neolithic cave dwellers brought in some cereals and acorns collected from the wild, and as they are rich in carbohydrates, are considered to be the main source of food (Borojevic *et al*. 2008).

Archaeobotanical records reveal the use of acorns in times of famine and shortages in central Italy, a few years before the fall of the Roman Empire (Sadori & Susanna 2005). During the late Bronze Age, in southern France, the ancient inhabitants were gathering wild fruits, especially acorns (Bouby *et al*. 1999). One of the best-preserved examples of the Mesolithic in Europe, the period between 5600 - 400 BC, in Denmark, is Tybrind Vig. There were found fragments of acorn parenchyma, which were an important food for the survival of the people there (Kubiak-Martens 1999).

Despite the fact that our ancestors regularly consumed food of acorns, in its natural form, as the simplest form of functional foods, today bread from acorns is no longer part of the daily diet. We meet it in some parts of Italy (Sardinia), where it is still prepared in the traditional way, from local acorns with the addition of clay and ash, (Claudia 2013). Preparing of acorn cake is also recorded in Ogliastra, Italy (Pignone & Laghetti 2010), but that knowledge lives only in the memories of some elderly residents of rural areas. Acorn flour is regularly consumed just in few countries, such as Korea. Acorn starch has been explored by several authors (Cappai *et al*. 2013; Correia & Beirão-Da-Costa, 2010), and also boron content in frequently consumed acorn jelly (Choi & Jun 2008).

It is interesting that in the literature about nut allergy, acorn is recorded only in two cases (Roux *et al*., 2003; Vega *et al*. 1998), and it was confirmed that due to its anti-inflammatory properties, acorn has a beneficial effect on the health of people with asthma. (Moon *et al*. 2013).

Popular literature, books and the Internet:

The following table (Table 2) shows the results that we have selected by using an Internet search engine.

Table 2. Review of information from the internet (Google web search)

Subject:	**Uniform Resource Locator (Url):**
The legislation of the Republic of Croatian on collecting acorns and other non-timber forest products	*Official sources:* http://narodne-novine.nn.hr/default.aspx http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi.pdf http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi%20cjenik_n.pdf http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi%20dozvola.pdf http://narodne-novine.nn.hr/clanci/sluzbeni/2006_10_111_2462.html http://narodne-novine.nn.hr/clanci/sluzbeni/2008_12_141_3935.html *Unofficial sources:* http://casopis.hrsume.hr/pdf/196.pdf http://www.crpsisak.hr/wp-content/uploads/2014/08/Bro%C5%A1ura-%C5%A0umski_plodovi.pdf
Acorns as Food, History, use, recipes, and bibliography	https://www.academia.edu/3829415/Acorns_as_Food_Text_and_Bibliography (Uploaded by David A. Bainbridge)
Suppliers and manufacturers of acorn flour and other flour-based products Acorn Flour Suppliers & Manufacturers	*America:* http://buyacornflour.com/ http://www.oakloreproducts.com/ *Europe and surrounding countries* http://www.bilje-zdravlje.com/knjiga-upoznaj-sebe.html http://www.agroklub.com/vocarstvo/hrvatski-ljekoviti-proizvodi-od-zira-prvi-u-europi/13525/ http://www.martinezvibes.com/hotdogdepot/ http://www.wildpantry.com/wildnuts.htm http://www.ekomarket.at/gefundene-produkten/eiche/ *Asia* http://qq791728113.en.ec21.com/ http://www.tradekorea.com/products/Acorn.html
Allergy to acorns	(Vega *et al*. 1998)
The antioxidant properties of acorns	(Popović *et al*. 2013)
Other Literature	(Grlić 2005), (Trinajstić 2007), (Friganović *et al*. 2011), http://books.wwnorton.com/books/Oak/
Traditional technology for gathering, processing and cooking	http://www.californiaoaks.org/ExtAssets/acorns_and_eatem.pdf http://nativeamericannetroots.net/diary/1055 http://www.theatlantic.com/health/archive/2010/12/recipes-for-the-mighty-acorn-a-forager-experiments/67228/ http://www.dailykos.com/story/2011/09/07/1014246/-Indians-101-Acorns# http://www.thepeoplespaths.net/NAIFood/acorns.htm http://www.earthisland.org/journal/index.php/elist/eListRead/this_thanksgiving_consider_cooking_with_acorn_flour/ http://www.fs.fed.us/psw/publications/documents/psw_gtr217/psw_gtr217_39.pdf http://www.iloveacorns.com/ http://advancedsurvivalguide.com/wp-content/uploads/2014/03/Hatch-Acorn-Ind.-study.pdf

The author of the best-known Croatian Encyclopedia of wild edible plants, Grlić, calls for changing the usual eating habits, as compared with the cultivated plants wild plants and their fruits have a higher nutritional value and are not so polluted by pesticides. In his work, the author has recorded use of acorns as bread grain among the Balkan people. In some parts of Macedonia, the poor population prepared bread from acorns ("želadov hleb") until the First World War, so that the acorn was baked, then ground and kneaded for bread. The use of flour from acorns was also known in Bosnia, Serbia and Montenegro, and during the Second World War, such bread was baked on some Croatian islands (Solta, Molat, Veli Iz). In the 19th century, bread made from acorn flour was eaten in Sweden and Norway, while in Ukraine acorn flour was mixed with flour from grain. In Sardinia farmers still make bread from the Holm oak (*Quercus ilex L.*). The acorn has been used as a substitute for coffee in Germany, peeled, fried, and milled, and acorns coffee (Eichelkaffe) is famous term (Grlić 2005).

Ecologist and writer Bainbridge, propagated acorns as an example of grain that grows on a tree. Oak is among the species that can play an important role in sustainable food production. Oak trees can be grown with less distortion of the annual agricultural ecosystems, and their deep roots can reach nutrients and water deep in the soil. They are adapted to temperate and semiarid climate and do not require intensive input of fertilizer and water. Until recently, the acorn was the staple food of people in many parts of the world and still is in a number of countries commercially exploited for food (in China, Korea and Japan). Food products from acorn are sold in the United States, in many Korean stores of imported and locally processed acorns. In San Diego, according to the author, in 2005 it was possible to buy starch and flour from acorns from four different companies, and products of acorns are also sold in the form of cubes, like tofu, and are used in cooking in the same way (Bainbridge 2006).

In recent decades the various websites, magazines and newspapers, recommended reintroduction of acorns in the diet of people. With growing interest in collecting local, edible wild plants, and the need for gluten free ingredients, acorn could be on the way of food recovery. As part of this trend, coffee from acorns appeared in health food stores in Poland and many other countries (Łuczaj *et al*. 2012). In Estonia, in health food stores, mainly the products of non - local origin are offered. Articles published in Scientific American (Starin 2014) and NPR (D. Prichep 2014) launched a new interest in products based on acorns. The first who responded were small family producers. In Texas recently started a new promotional campaign of manufacturer named Mighty Wild, for the production and sales of gluten-free vegan crackers, with a few different flavors, made from the acorn of local origin (http://www.mightywild.com/buy-acorn-crackers). In California Sue's Acorn Café & Mill (http://www.buyacornflour.com/about.php) sells a wide range of bakery products and flour made from acorns. South Korea is one of the few countries where the acorn has never disappeared from the diet. Dotorimuk is a traditional dish, made of acorn starch. Gathering acorns is an important source of income for small farmers in the villages of South Korea (L.Smith 2014) (https://translate.google.hr/?hl=en&tab=wT#en/hr/countryside). However, competition from China has pushed

domestic acorn processing industry by placement of acorn flour and starch at lower prices (http://qq791728113.en.ec21.com/).

At the same time, in Europe and in the region, some local producers and collectors are trying to get acorns from oblivion. In Germany, we find a product called "NewTella", sweet acorn spread, (http://www.eattheweeds.com/acorns-the-inside-story/). In Croatia exists a similar product under the name "Žirko" (http://www.agroklub.com/vocarstvo/hrvatski-ljekoviti-proizvodi-od-zira-prvi-u-europi/13525/), and in Serbia, it is "Žirkomed", (http://www.bilje-zdravlje.com/knjiga-upoznaj-sebe.html).

Both manufacturers in the product range offer drinks from roasted and ground acorns and flour made from acorns. Manufacturer in Serbia offers another product "Žirkosir" and powder mixture as a complete meal named "Kosmajski šejk". Acorn flour from produced from locally collected acorns at a low heat treatment is recommended as a supplement up to the 20 % whole grain flour. It is used for making bread, pastries, pancakes, cakes and other products. In Slovakia is acorn flour produced from controlled organic farming. They recommend their customers the use of the flour in the ratio of 1: 3, together with wheat flour to produce bread dough, biscuits, cakes and other sweets. They say that the acorn flour is a complete substitute for wheat flour in the chopped steak with vegetables, potato pancakes and omelets, and the declaration stated nutritional values on the dry product: sodium 17 mg/kg; potassium 4500 mg/kg; phosphorus 730 mg/kg; calcium 740 mg/kg; magnesium 340 mg/kg; 16.8 % fiber; 4.1 % protein; unsaturated fatty acids 5.1 %; minerals 1.2 %; and carbohydrates 72.8 % (http://www.ekomarket.at/gefundene-produkten/eiche/). On the Greek island of Kea, Marcie Mayer launched Hamada initiative to revive the island's tradition of processing acorns (http://iloveacorns.com). They buy acorns collected by local residents and create their own range of products based on flour, from biscuits to the gluten-free, vegan bun. Hamada has brought together two seemingly disparate items. On the one hand, it encourages the development of local people which generates revenue by selling the collected acorns, on the other hand, revenue stream encourages local people to preserve the environment (particularly oak trees) and cultivate traditional heritage.

In Figure 1. we showed schematic diagram of the possibility of using acorn flour in flour-based products obtained by data analysis. On the left side are products that were consumed in the past and have been known from the historical and archaeological records. On the right side are the products that today's consumers are interested in and accessible, and we found them mainly through the website. Possibilities of using acorn flour in flour-based products are varied. The product range consists of bread, cakes, cookies, muffins, acorn starch noodles (dotori guksu), acorn starch jelly (dotorimuk), acorn coffee, sweet spreads and powder mixture for shake. Different possibilities of application were stated by manufacturers on declarations of their products, and they recommend it as total or partial substitute for other grain flour in bakery products, as well as the addition to the chopped vegetable steaks, omelets, soups, or for their thickening. In the recent history acorn flour was used only in the times of famine, but today a group of exclusive products appears for the consumers with specific needs, such as certified organic products, gluten – free products and vegetarian and vegan products. Acorn flour and acorn flour based products satisfy all these criteria. We can see that throughout history types of acorn

products changed, from simple soup and unleavened bread, through very sophisticated products in some Asian countries, to the exclusive products sold in specialty shops or as a part of attractive tourist offer in Spain and Italy.

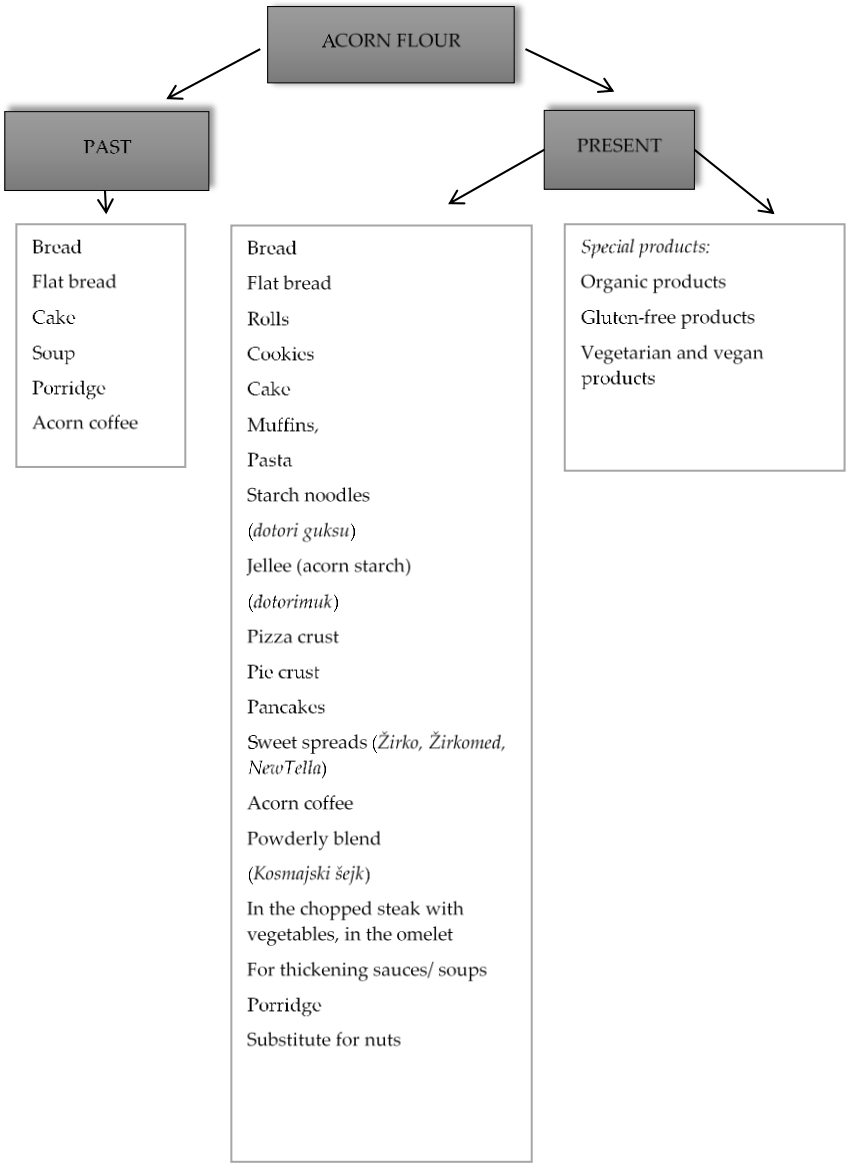

Figure 1. Examples of products based on Acorn Flour

Acorn as a raw material is literally all around us, in the parks, alleys, gardens and forests. Its collection in forests that are owned by the Republic of Croatia is regulated by a range of legislation such as the Law on Forests, the Nature Protection Act, the Rules on the use of non-timber forest products and Forest management plans, and needs prior permission of the Croatian Forests Ltd., a company owned by the state. To collect acorns, either for personal use or for the purpose of processing, trade and other business, you have to pay certain fees. We have shown current legislations in Table 2.

CONCLUSIONS

Newer and older, archaeobotanical researches confirm that the oak acorn (*Quercus*) has been used since prehistoric times for feeding people in various cultures around the world. At the same time, tools and technologies for the processing of acorns into flour have been developed. Throughout history, the types of products made from flour changed, from a simple soup, via unleavened bread to highly sophisticated products in some Asian countries. In the recent history acorn flour was used only in times of famine. Today the spread is present only in some countries, as a part of the diet of ethnic groups (America, Asia), or as a part of a culinary experiment of nature lovers and collectors of edible wild plants. However, following the trend of the market, a group of special acorn products developed (organic, vegan, vegetarian and gluten-free products) for a specific group of consumers. Recently, acorn flour products appear as a part of tourism, in campaigns that promote traditional local cuisine and customs (Spain, Sardinia). Scientific studies confirm that flour from acorns, considering the nutritional value and antioxidant potential, can be considered a functional food or food whose nutritional bioactive components have beneficial health effects on the human body. The acorn is suitable as a material for organic production, if collected under control, unlike the conventional grains which are generally treated with pesticides. Possibilities of using flour from acorns in flour-based products are varied. The product range of acorn flour, which is already on the market, consists of bread, cakes, cookies, muffins, acorn starch noodles (dotori guksu), acorn starch jelly (dotorimuk), acorn coffee, sweet spreads and Powderly shake mixture. It can be used as a complete or partial replacement for the cereal flour in bakery products, as well as the addition to chopped steaks with vegetables, omelets, soups, or thickening of the same.

Analysis of literature in Croatia reveals a lack of research opportunities using acorn flour in flour-based products, and generally refers to the need for greater representation of these issues in the future.

REFERENCES

Antolín, F. & Jacomet, S., 2015. Wild fruit use among early farmers in the Neolithic (5400–2300 cal bc) in the north-east of the Iberian Peninsula: an intensive practice? *Vegetation History and Archaeobotany*, 24(1), pp.19–33. Available at http://link.springer.com/10.1007/s00334-014-0483-x.

Bainbridge, D. a., 2006. Acorns as Food , (January), pp.1–32. Available at https://www.academia.edu/3829415/Acorns_as_Food_Text_and_Bibliography.

Benmahdi-Belarbi, M., Vassilev, G. & Mashev, N., 2007. Contribution to the investigation of food and antioxidant value of acorns of various oak species spread in the Tlemsen region (Algeria). *Oxidation Communications*, 30(1), pp.77–81. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-34248579598&partnerID=tZOtx3y1.

Borojević, K. *et al*., 2008. Plant use at Grapčeva cave and in the eastern Adriatic Neolithic. *Journal of Field Archaeology*, 33(3), pp.279–303. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-60949347923&partnerID=tZOtx3y1.

Bouby, L., Leroy, F. & Carozza, L., 1999. Food plants from late Bronze age lagoon sites in Languedoc, southern France: Reconstruction of farming economy and environment. *Vegetation History and Archaeobotany*, 8(1-2), pp.53–69. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-0033148098&partnerID=40&md5=727cae0515adabe86c762557bb924f82.

Cappai, M.G. *et al*., 2013. Electron microscopy and composition of raw acorn starch in relation to in vivo starch digestibility. *Food & function*, 4(6), pp.917–22. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-84878717676&partnerID=tZOtx3y1 [Accessed July 20, 2015].

Choi, M.-K. & Jun, Y.-S., 2008. Analysis of Boron Content in Frequently Consumed Foods in Korea. *Biological Trace Element Research*, 126(1-3), pp.13–26. Available at http://dx.doi.org/10.1007/s12011-008-8179-7.

Claudia, P., 2013. Acorn bread: A traditional food of the past in Sardinia (Italy). *Journal of Cultural Heritage*, 14(3), pp.S71–S74. Available at http://www.sciencedirect.com/science/article/pii/S1296207413000228 [Accessed June 7, 2015].

Correia, P.R. & Beirão-Da-Costa, M.L., 2010. Chestnut and acorn starch properties affected by isolation methods. *Starch/Staerke*, 62(8), pp.421–428.

D. Prichep, 2014. Nutritious Acorns Don't Have To Just Be Snacks For Squirrels : The Salt : NPR. NPR. Available at: http://www.npr.org/sections/thesalt/2014/10/24/358527018/nutritious-acorns-dont-have-to-just-be-snacks-for-squirrels [Accessed October 8, 2015].

Friganović, E. *et al*., 2011. FUNKCIONALNA HRANA I POTROŠAČI. *Praktični menadžment, stručni časopis za teoriju i praksu menadžmenta*, 2(1), pp.51–57.

Fuller, D.Q., Harvey, E. & Qin, L., 2007. Presumed domestication? Evidence for wild rice cultivation and domestication in the fifth millennium BC of the Lower Yangtze region. Antiquity, 81(September 2006), pp.316–331. Available at http://discovery.ucl.ac.uk/1347896/.

Fuller, D.Q. & Qin, L., 2010. Declining oaks, increasing artistry, and cultivating rice: the environmental and social context of the emergence of farming in the Lower Yangtze Region. *Environmental Archaeology*, 15(2), pp.139–159. Available at http://www.maneyonline.com/doi/abs/10.1179/146141010X12640787648531.

Gremillion, K.J., 2002. Foraging Theory and Hypothesis Testing in Archaeology: An Exploration of Methodological Problems and Solutions. *Journal of Anthropological Archaeology*, 21(2), pp.142–164. Available at http://linkinghub.elsevier.com/retrieve/pii/S0278416501903915.

Grlić, L., 2005. Enciklopedija samoniklog jestivog bilja Treće izda., Rijeka: Rijeka: Ex libris, 2005 - (Biblioteka Natura; knj. 1).

Ivanhoe, F., 1995. Secular decline in cranioskeletal size over two millennia of interior central California prehistory: Relation to calcium deficit in the reconstructed diet and demographic stress. *International Journal of Osteoarchaeology*, 5(3), pp.213–253. Available at: http://dx.doi.org/10.1002/oa.1390050303.

Ivanhoe, F. & Chu, P.W., 1996. Cranioskeletal Size Variation in San Francisco Bay Prehistory: Relation to Calcium Deficit in the Reconstructed High-seafoods Diet and Demographic Stress. *International Journal of Osteoarchaeology*, 6(4), pp.346–381. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-0345839832&partnerID=tZOtx3y1.

Jorgensen, G., 1977. Acorns as a food- source in later stone- age. , pp.233–238.

Kubiak-Martens, L., 1999. The plant food component of the diet at the late Mesolithic (Ertebølle) settlement at Tybrind Vig, Denmark. *Vegetation History and Archaeobotany*, 8(1-2), pp.117–127. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-0033147709&partnerID=40&md5=0bde223cfb9a4f358f4f31e5a2462260.

L.Smith, 2014. ACORNS: The Most Overlooked Food In America. Available at: http://www.foodday.org/acorns_the_most_overlooked_food_in_america [Accessed October 8, 2015].

Lev, E., Kislev, M.E. & Bar-Yosef, O., 2005. Mousterian vegetal food in Kebara Cave, Mt. Carmel. *Journal of Archaeological Science*, 32(3), pp.475–484. Available at http://linkinghub.elsevier.com/retrieve/pii/S0305440304001694.

Liu, L. *et al*., 2011. Plant exploitation of the last foragers at Shizitan in the Middle Yellow River Valley China: evidence from grinding stones. *Journal of Archaeological Science*, 38(12), pp.3524–3532. Available at: http://www.sciencedirect.com/science/article/pii/S0305440311002949 [Accessed October 4, 2015].

Łuczaj, Ł. *et al*., 2012. Wild food plant use in 21st century Europe: The disappearance of old traditions and the search for new cuisines involving wild edibles. *Acta Societatis Botanicorum Poloniae*, 81, pp.359–370.

Luczaj, L., Adamczak, A. & Duda, M., 2014. Tannin content in acorns (*Quercus* spp .) from Poland. , 72, pp.103–111.

Mason, S.L.R.L.R., 2000. Fire and Mesolithic subsistence — managing oaks for acorns in northwest Europe? *Palaeogeography, Palaeoclimatology, Palaeoecology*, 164(1-4), pp.139–150. Available at http://www.sciencedirect.com/science/article/pii/S0031018200001814 [Accessed July 20, 2015].

McCorriston, J., 1994. Acorn eating and agricultural origins: California ethnographies as analogies for the ancient Near East. *Antiquity*, 68(258), pp.97–107. Available at: href="http://dx.doi.org/10.1017/S0003598X00046238.

McCreary, D., 2004. Managing and restoring California's oak woodlands. *Natural Areas Journal*, 24(3), pp.269–275. Available at <Go to ISI>://000222614700013.

Moon, H.R. *et al*., 2013. Antiasthma Effects Through Anti-Inflammatory Action Of Acorn (*Quercus Acutissima Carr*.) In Vitro And In Vivo. *Journal of Food Biochemistry*, 37(1), pp.108–118.

Morales, J. *et al*., 2015. First preliminary evidence for basketry and nut consumption in the Capsian culture (ca. 10,000–7500BP): Archaeobotanical data from new excavations at El Mekta, Tunisia. *Journal of Anthropological Archaeology*, 37, pp.128–139. Available at http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch&qid=7&SID=V27vfEBT3npU6mxBegx&page=1&doc=4 [Accessed July 20, 2015].

Morgan, C., 2012. Modeling Modes of Hunter-Gatherer Food Storage. *American Antiquity*, 77(4), pp.714–736.

Nixon, K.C., 1993. Infrageneric classification of Quercus (Fagaceae) and typification of sectional names. *Ann. For. Sci*., 50(Supplement), p.25s–34s. Available at http://dx.doi.org/10.1051/forest:19930701.

Pignone, D. & Laghetti, G., 2010. On sweet acorn (Quercus spp.) cake tradition in Italian cultural and ethnic islands. *Genetic Resources and Crop Evolution*, 57(8), pp.1261–1266. Available at http://dx.doi.org/10.1007/s10722-010-9625-x.

Popović, B.M. *et al*., 2013. Antioxidant characterization of oak extracts combining spectrophotometric assays and chemometrics. *The Scientific World Journal*, 2013.

Pringle, H., 2008. Society for American Archaeology meeting. Herring and nuts for the "salmon people". *Science* (New York, N.Y.), 320(5873), pp.174–175. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-42449119696&partnerID=40&md5=c700302c8427ada50c5fbd63c9a3ce8a.

Rakić, S. *et al*., 2007. Influence of thermal treatment on phenolic compounds and antioxidant properties of oak acorns from Serbia. *Food Chemistry*, 104(2), pp.830–834. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-34247487427&partnerID=tZOtx3y1 [Accessed June 6, 2015].

Rakić, S. *et al*., 2006. Oak acorn, polyphenols and antioxidant activity in functional food. *Journal of Food Engineering*, 74(3), pp.416–423. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-31644432659&partnerID=tZOtx3y1 [Accessed June 6, 2015].

Regnell, M., 2012. Plant subsistence and environment at the Mesolithic site Tågerup, southern Sweden: new insights on the "Nut Age." *Vegetation History and Archaeobotany*, 21(1), pp.1–16. Available at http://dx.doi.org/10.1007/s00334-011-0299-x.

Regnell, M. *et al*., 1995. Reconstruction of environment and history of plant use during the late Mesolithic (Ertebølle culture) at the inland settlement of Bökeberg III, southern Sweden. *Vegetation History and Archaeobotany*, 4(2), pp.67–91. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-0002890830&partnerID=40&md5=39f2471676933618 dead30122c21a6fa.

Revedin, A. *et al*., 2015. New technologies for plant food processing in the Gravettian. *Quaternary International*, 359-360, pp.77–88. Available at: http://www.sciencedirect.com/science/article/pii/S1040618214007241 [Accessed August 20, 2015].

Roux, K.H., Teuber, S.S. & Sathe, S.K., 2003. Tree Nut Allergens. *International Archives of Allergy and Immunology*, 131(4), pp.234–244. Available at http://www.karger.com/DOI/10.1159/000072135.

Sadori, L. & Susanna, F., 2005. Hints of economic change during the late Roman Empire period in central Italy: a study of charred plant remains from "La Fontanaccia", near Rome. *Vegetation History and Archaeobotany*, 14(4), pp.386–393. Available at http://www.scopus.com/inward/record.url?eid=2-s2.0-33644688148&partnerID=tZOtx3y1 [Accessed July 20, 2015].

Saul, H. *et al*., 2012. A systematic approach to the recovery and identification of starches from carbonised deposits on ceramic vessels. *Journal of Archaeological Science*, 39(12), pp.3483–3492. Available at: http://www.sciencedirect.com/science/article/pii/S0305440312002816 [Accessed October 8, 2015].

Schneider, M., 1990. Acorns as a staple food-different types and change of exploitation through time. *Bodenkultur*, 41(1), pp.81–88.

Starin, D., 2014. Is Reintroducing Acorns into the Human Diet a Nutty Idea?. *Scientific American*. Available at: http://www.scientificamerican.com/article/is-reintroducing-acorns-into-the-human-diet-a-nutty-idea/ [Accessed August 1, 2015].

Stevens, N.E. & McElreath, R., 2015. When are two tools better than one? Mortars, millingslabs, and the California acorn economy. *Journal of Anthropological Archaeology*, 37, pp.100–111. Available at: http://apps.webofknowledge.com/full_record.do?product=WOS&search_mode=GeneralSearch&qid=7&SID=V27vfEBT3npU6mxBegx&page=1&doc=3 [Accessed August 23, 2015].

Tadayoni, M., Sheikh-Zeinoddin, M. & Soleimanian-Zad, S., 2015. Isolation of bioactive polysaccharide from acorn and evaluation of its functional properties. *International Journal of Biological Macromolecules*, 72, pp.179–184. Available at http://search.ebscohost.com/login.aspx?direct=true&db=ffh&AN=2015-04-Js2581&lang=hr&site=ehost-live.

Trinajstić, I., 2007. O problemu međusobnog razlikovanja hrastova Quercus pubescens Willd. i *Quercus virgiliana* (Ten.) Ten. *Šumarski list*, 131(1-2), pp.57–60.

Tushingham, S. & Bettinger, R.L., 2013. Why foragers choose acorns before salmon: Storage, mobility, and risk in aboriginal California. *Journal of Anthropological Archaeology*, 32(4), pp.527–537. Available at http://linkinghub.elsevier.com/retrieve/pii/S0278416513000512.

Valamoti, S., 2015. Harvesting the "wild"? Exploring the context of fruit and nut exploitation at Neolithic Dikili Tash, with special reference to wine. *Vegetation History and Archaeobotany*, 24(1), pp.35–46. Available at http://dx.doi.org/10.1007/s00334-014-0487-6.

Vega, A. *et al*., 1998. Anaphylactic reaction to ingestion of Quercus ilex acorn nut. *Clinical Experimental Allergy*, 28(6), pp.739–742. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-0031859667&partnerID=tZOtx3y1 [Accessed September 13, 2015].

Yang, X. *et al*., 2014. Starch grain evidence reveals early pottery function cooking plant foods in North China. *Chinese Science Bulletin*, 59(32), pp.4352–4358. Available at http://dx.doi.org/10.1007/s11434-014-0500-6.

Yang, X.Y. & Jiang, L.P., 2010. Starch grain analysis reveals ancient diet at Kuahuqiao site, Zhejiang Province. *Chinese Science Bulletin*, 55(12), pp.1150–1156.

Regulations:

http://narodne-novine.nn.hr/default.aspx

http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi.pdf

http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi%20cjenik_n.pdf

http://portal.hrsume.hr/images/dok/proizvodi/Nedrvni%20proizvodi%20dozvola.pdf

http://narodne-novine.nn.hr/clanci/sluzbeni/2006_10_111_2462.html

http://narodne-novine.nn.hr/clanci/sluzbeni/2008_12_141_3935.html

Web pages:

https://www.academia.edu/3829415/Acorns_as_Food_Text_and_Bibliography

http://buyacornflour.com/

http://www.oakloreproducts.com/

http://www.bilje-zdravlje.com/knjiga-upoznaj-sebe.html

http://www.agroklub.com/vocarstvo/hrvatski-ljekoviti-proizvodi-od-zira-prvi-u-europi/13525/

http://www.martinezvibes.com/hotdogdepot/

http://www.wildpantry.com/wildnuts.htm

http://www.ekomarket.at/gefundene-produkten/eiche/

http://qq791728113.en.ec21.com/

http://www.tradekorea.com/products/Acorn.html

http://books.wwnorton.com/books/Oak/

http://www.californiaoaks.org/ExtAssets/acorns_and_eatem.pdf

http://nativeamericannetroots.net/diary/1055

http://www.theatlantic.com/health/archive/2010/12/recipes-for-the-mighty-acorn-a-forager-experiments/67228/

http://www.dailykos.com/story/2011/09/07/1014246/-Indians-101-Acorns#

http://www.thepeoplespaths.net/NAIFood/acorns.htm

http://www.earthisland.org/journal/index.php/elist/eListRead/this_thanksgiving_consider_cooking_with_acorn_flour/

http://www.fs.fed.us/psw/publications/documents/psw_gtr217/psw_gtr217_39.pdf

http://www.iloveacorns.com/

http://advancedsurvivalguide.com/wp-content/uploads/2014/03/Hatch-Acorn-Ind.-study.pdf