SOUTHWEST COOKING OIL:

ACORN OIL FROM NATIVE OAK SPECIES *Q. MACROCARPA*, *Q. SHUMARDII* AND *Q. POLYMORPHA* ACORNS AS A POTENTIAL HIGH-END COOKING OIL

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Abbreviation	Description
QP	*Quercus polymorpha*
QS	*Quercus shumardii*
QM	*Quercus macrocarpa*
t	Metric tons

ABSTRACT

The oil produced from acorns (*Quercus*) has been consumed by native peoples for hundreds of years. It is a nutritious cooking oil comparable to olive oil. Acorn oil is not currently produced on a market scale. This project attempted to extract oil from three native Texas species; however, due to flawed methods, no oil was produced. This thesis includes those methods as well as an extensive summary of the market potential for acorn oil.

Keywords: Oak, acorn oil, *Quercus*, Fagaceae, cooking oil

1. SUMMARY

Oaks (*Quercus*) are members of the Fagaceae family. Their fruits are indehiscent nuts commonly called acorns. Water comprises 10%–50% of acorns. According to aggregated data from Shimada and Bainbridge, protein comprises 5%–8% of the dry weight of acorns; fat, 2%–8%; fiber, 2%; and nitrogen-free extract, particularly starch, comprises 30%–90% of the dry weight (see Table 1.) (2001; 1985). Acorns also contain 0.1-8.8% tannins, water-soluble phenolics evolved to deter herbivory (Bainbridge, 1987; Shimada, 2001).

1.1. History

Oaks are native across the Northern Hemisphere, particularly in North America, the Mediterranean, and Asia. For centuries, humans have eaten acorns as a source of fat and protein wherever oaks are native (Hoeche et al., 2014). The earliest evidence of acorns as a foodstuff was dated to the late Mesolithic era and found in western Europe (Deforce, 2013; Kubaik-Martens, 1999). In the North American west coast, acorns made up more than half of the diet of native peoples (Bainbridge, 1986).

Acorns were prepared various ways. Native peoples often leached the acorns beforehand to remove the unpalatable tannins. Some Native Americans also sweetened acorns with alkaline ingredients, such as wood ash, in order to neutralize the tannic acid (Bainbridge, 1987). Once primed, Native American peoples ground the acorns into a flour, roasted the acorns for meat, or boiled the acorns for oil (Hoeche *et al*., 2014; Bainbridge, 1987). In the Mediterranean, especially in Italy, acorns were ground to make a bitter, coffee-like beverage (Pieroni, 1999; Rakić *et al*, 2006).

Acorn oil was eaten across North America by native peoples. One account from the English scientist Thomas Harriot's *A Briefe and True Report of the New Found Land of Virginia* describes what he saw in eastern North America:

> Severall kindes of Berries in the forme of Oke akornes, which also by their experience and vse of the inhabitantes, wee finde to yeelde very good and sweete oule. (Harriot, 1590)

There are different accounts of how acorn oil was specifically extracted. In southeastern North America, acorns were most often boiled whole, which allowed the oil to rise to the top and be skimmed off. Comparatively, in the California area, native people ground acorns and then boiled for oil (Driver, 1952). Additionally, there is evidence that acorns were crushed or pressed to extract oil (Bainbridge, 1986). The societies that used acorn oil in their cooking were scattered across North America and the Mediterranean. Because of the large distances between these societies, different extraction methods arose in disparate geographic locations.

Lately, acorn by-products have fallen out of popularity. This is due to the strong, astringent taste caused by the acorn's tannins. However, the water-soluble tannins are not present in oils (Rakić *et al*., 2004). Because of this, acorn oil may have market potential as a source of cooking oil.

1.2. Existing and Potential Markets

Olives (Olea europaea) produce olive oil, which is a high-end cooking oil favored for its flavor and supposed health benefits. The high level of monounsaturated fatty acids (see *Table 2.*) in olive oil has been credited in reducing in the risk of coronary heart disease, lowering blood cholesterol levels, and providing additional cardio-protective effects, although this relationship has not yet been definitively proven (Bendini *et al*., 2007; Covas *et al*., 2006). The phenolic compounds within olive oil include flavanols and lignins (Covas *et al*., 2006). Olive oil phenols have been shown to have beneficial antioxidant effects as well as other general health benefits (Owen *et al*., 2000; Carluccio *et al*., 2003; Covas *et al*., 2006; Bendini *et al*., 2007).

Species	Water	Protein	Fat	Carbohydrate
Q. agrifolia[1]	9.00	6.26	16.75	54.27
Q. chrysolepis[1]	9.00	4.13	8.65	63.52
Q. douglasii[1]	9.00	5.48	8.09	65.50
Q. douglasii[2]	40.75	3.03	4.77	43.39
Q. dumosa[2]	44.58	2.29	3.42	40.65
Q. garryana[1]	9.00	3.94	4.47	68.87
Q. kellogii[1]	9.00	4.56	17.97	55.48
Q. kellogii[2]	37.60	3.43	11.05	32.71
Q. lobata[1]	9.00	4.90	5.54	69.02
Q. lobata[2]	40.57	2.82	4.25	43.44
Q. mongolica[3]	--	4.40	1.70	90.30
Q. serrata[3]	--	4.50	2.50	88.3
Q. wisliznei[i2]	29.80	3.08	14.47	40.40

Table 1. Acorn nutrient composition in percentages ([1]Wolf, 1945; [2]Wagnon, 1946; [3]Shimada, 2001)

The taste of acorn oil has been compared to the widely-used olive oil (Al-Rousan *et al.* 2013; Ferriara-Dias, 2003; Charef *et al*., 2008; Bouderoua & Selselet-Attou, 2003; Bainbridge 1986; Bainbridge, 1987; Wolf, 1945). Not only does acorn oil have a comparable taste, it has been found to have similar nutritional benefits. Al-Rousan and

Table 2. Acorn and olive oils fatty acid profiles ([1]Al-Rousan, 2013; [2]León-Camacho *et al.*, 2004; [3]Özcan, 2007; [4]Vognild *et al.*, 1998)

Fatty acid	*Q. aegilops*[1]	*Q. infectoria*[1]	*Q. calliprinus*[1]	*Q. suber*[2]	*Q. brantii*[3]	Olive oil[4]
Myristic (14:0)	0.17 ± 0.01	0.12 ± 0.01	0.13 ± 0.01	0.10	0.00	0.00
Palmitic (16:0)	18.7 ± 0.60	17.8 ± 0.60	18.4 ± 0.6	14.36	13.5	11.10
Palmitoleic (16:1)	0.19 ± 0.01	0.25 ± 0.01	0.26 ± 0.01	0.50	0.20	0.60
Heptadeconioc (17:0)	0.13 ± 0.01	0.22 ± 0.01	0.14 ± 0.01	0.00	0.10	--
Cis-10-heptadecanoic (17:1)	0.13 ± 0.01	0.22 ± 0.01	0.14 ± 0.01	0.00	0.10	--
Stearic (18:0)	1.02 ± 0.09	1.5 ± 0.10	1.6 ± 0.10	1.20	1.90	2.00
Oleic (18:1)	55.6 ± 1.60	56.1 ± 1.60	53.3 ± 1.50	57.95	54.30	77.40
Linoleic (18:2)	21.7 ± 1.00	21.3 ± 1.00	23.4 ± 1.00	21.95	24.20	6.00
Arachidic (20:0)	0.18 ± 0.01	0.22 ± 0.02	0.22 ± 0.02	0.20	0.40	0.30
Eicosenois (20:1)	0.32 ± 0.02	0.36 ± 0.03	0.35 ± 0.04	0.60	0.70	0.60
Behenic (22.0)	0.12 ± 0.00	0.10 ± 0.00	0.11 ± 0.00	--	0.30	0.10
Lignoceric (24:0)	0.17 ± 0.00	0.24 ± 0.00	0.24 ± 0.00	--	0.20	--
Total saturated (%)	20.52	20.44	21.01	15.96	16.40	13.60
Monounsaturated (%)	56.24	56.93	54.05	54.05	55.30	78.60
Polyunsaturated (%)	23.30	22.90	24.90	24.55	25.70	0.70

colleagues found the nutritional aspects of Jordanian acorn oil comparable to olive oil (see *Table 2.*) (2013). Particularly, significant levels of antioxidants and fatty acids. Their study found that the tocopherol contents were higher than most plant-based oils including olive oil. They concluded that acorn oil has potential as a healthy oil for human consumption and that it may be, in fact, healthier for human diets due to the higher proportion of linoleic acid (see *Table 2.*). Ferriara-Dias and colleagues came to similar conclusions in 2003 when studying Portuguese acorns. Acorn oil has been found to be largely similar olive oil and to have potential as a healthy cooking oil (Charef *et al.*, 2008; Al-Rousan *et al.*, 2013; Ferriara-Dias *et al.*, 2003; Bouderoua & Selselet-Attou, 2003).

Olive oil is the primary high-end culinary oil in Europe and the United States. In the past 30 years, olive oil consumption in the United States has increased 343%, from 88 thousand metric tons (t) in 1990 to 300 thousand t in 2014, as illustrated in *Figure 1*. (International Olive Oil Council, 2014a). The most obviously attributable cause of this increase is the increased preference of olive oil over other fat products within the cooking and health food media.

Acorns have be found to typically contain a smaller oil weight percentage than olives. However, acorn crops have the unique advantage over olive crops in their production of marketable, secondary products. The most significant of these is the pulp itself. Acorn meat can be used as a feed source for livestock (Bainbridge, 1986). It is used in the production of the Spanish and Portuguese delicacy, jamón Ibérico, a cured pork product fed primarily acorn meat. In addition to the meat pulp, acorn oil production produces tannins, used in tanning leather and particleboard adhesive. Finally, oak trees can eventually produce marketable timber when acorn production declines. Oak wood is employed in the crafting of high-end furniture, flooring, and is used nearly exclusively in wine barrels (Logan, 2005).

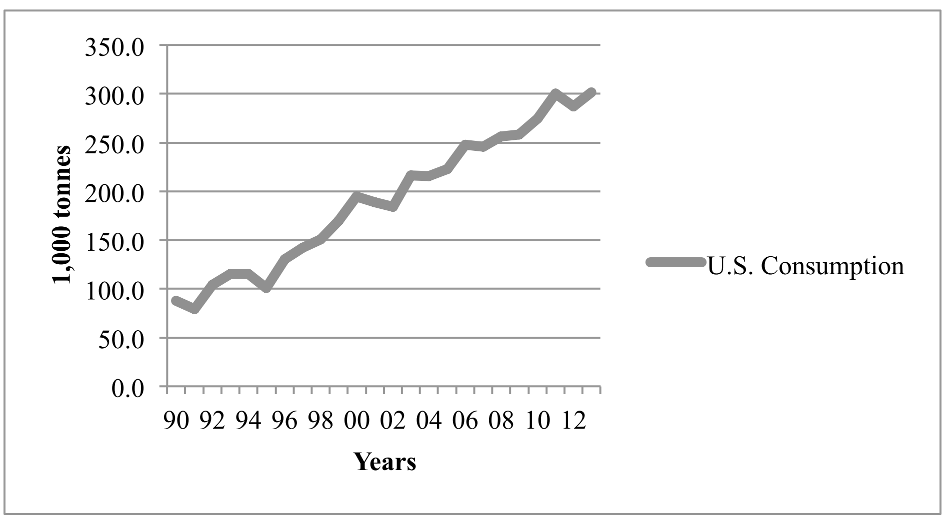

Figure 1. U.S. Olive Oil Consumption 1990-2014 (International Olive Oil Council, 2014a)

Most of the world's olive oil is produced around the Mediterranean, as shown by *Figure 2*. The American Olive Oil Producers Association touts that American olive oil is currently being produced in California, Texas, Oregon, Hawaii, Florida, Arizona, and Georgia. The USDA does not currently publish statewide olive oil production data, but according to the Agricultural Marketing Resource Center, California is the only state to commercially produce olives for oil (Boriss, 2013). Californian olive trees are irrigated to promote fruiting and new growth. The Californian Extension Service recommends 17 gallons/tree/month, or about 120,000 gallons/acre/year (Connell, n.d.). In this limited geographical production and need for irrigation, olive production compares poorly to acorn production.

Figure 2. Map of worldwide olive oil production. Slovenia, Montenegro, Saudia Arabia, USA, France, Argentina, Iran, Albania, Australia, Lybia, Palestine, Lebanon, Israel, Egypt, Chile, Jordan, Algeria & Syria: less than 50,000 t, Portugal: 90,000t, Morocco: 110,000t, Turkey: 190,000t, Tunisia: 260,000t, Greece: 300,000t, Italy: 302,500t, Spain: 825,700t (International Olive Oil Council, 2014b; International Olive Oil Council, 2014c).

There are upwards of 60 *Quercus* species in North America, at least 27 of which are known to have historically been eaten (Driver, 1952). North American oak species are native to nearly every ecoregion on the continent, including montane, wetland, riparian, xeric, and coastal. This wide variety of genetic diversity opens up currently unusable land to production. Alternatively, acorn production could be implemented on hilly land otherwise suited annual grain cropping to prevent soil loss, preserving the land's high yields and it's soil (Bainbridge, 1986). In addition, because the species are natively adapted, their water requirements are likely to be specifically suited to the natural climatic occurrences. Therefore, acorns can be sustainably farmed in arid or semi-arid lands.

1.3. Production Methods

Acorn production would be akin to the established process of nut orcharding. Many nuts are eaten for their meats, and some are also produced for oil and/or flour. Nut specialty oils currently for sale include pecan, walnut, pumpkinseed, avocado, and almond (Cockerham *et al*., 2008).

Because nut trees are a long-term, perennial crop, the managerial aim is to build soil organic material and biological activity and minimize periodic fertilizer application. Most nut harvests are done by collecting fallen nuts (Wilkinson, 2005b). Nut orchards typically propagate asexually, which ensures nut quality and tree morphology and allows growers to select for specific characteristics. Varieties are developed based on flavor, oil content, size of crop, and resistance to disease. If acorns go into production, these varieties will most probably optimize oil content and susceptibility to disease (Wilkinson, 2005a).

Nut propagation is similar to fruit production in that it is primarily done by grafting (Wilkinson, 2005a). Grafting onto selected rootstocks can improve plant vigor, canopy height, and provide resistance to soil borne pests and diseases (Webster, 2002). Because the *Quercus* genus has so many different native habitats, this may allow for easy crosscontinental propagation,. For example, it could allow North African producers to grow Mexican acorns on a native rootstock, or Californian farmers to crop Italian nuts, so on and so forth.

1.4. Extraction Methods

There are three acorn oil extraction methods: solvent (hexane and supercritical CO_2), boiling, and mechanical (pressing or grinding). Hexane extraction not uncommon in commercial oil production but is not allowed in organic operations (Cockerham *et al*., 2008). Pradhand and colleagues compared supercritical CO_2 and hexane extractions in flaxseed oil production. They found the two methods extracted similar products, but observed trace amounts of hexane in the fatty acids of the hexane-extracted product. They, therefore, recommended the supercritical CO_2 method for food product production (2010). Supercritical CO2 extraction is also considered to be a "greener" extraction method than hexane because there is no pollution from it. However, the capital costs for supercritical CO2 extractions are much higher than either of the other two extraction methods (Cockerham *et al*., 2008).

Both of the two mechanical methods are used in home acorn oil production, although this study found significantly more anecdotal evidence of pressing being used on a home production scale than grinding. While supercritical CO_2 may yield marginally more oil than the mechanical methods, it is likely that market production will utilize the mechanical methods. As seen in

other high-end cooking oils, consumers pay more for pressed or ground cooking oil products. In currently marketed nut oils, pressing extractions are used exclusively (Cockerham *et al*., 2008). The boiling extraction is not utilized commercially.

1.5. Measured Oil Weight

There are studies of six acorn species for their oil content in the literature (see *Table 3*.). León-Camacho and colleagues found that *Q. ilex* and *Q. faginea* had 5% oil weight (2004). Al-Rousan and colleagues reported that *Q. infectoria*, *Q. macrolepis*, and *Q. calliprinos* had 7%, 7.5%, and 3.5%, respectively (2013). Özcan in 2008 found a 7.5% oil weight content in *Q. rubra*. 3.5% – 7.5% acorn oil weight percentage can be compared to olive oil 10 – 35% oil weight percentage (Vossen, n.d.). *Q. rubra* is a native of North America, however, Özcan's study was done on trees cultivated in Turkey. All other species studied are native to the Mediterranean region; we have found no research on *Quercus* species' oil content in North America.

Species	Oil Weight
Q. ilex[1]	5%
Q. faginea[1]	5%
Q. infectoria[2]	7%
Q. macrolepis[2]	7.5%
Q. calliprinos[2]	3.5%
Q. rubra[3]	7.5%
Olea europaea[4]	10-35%

Table 3. Oil weight percentages of *Quercus* species and oil seeds ([1]León-Camacho *et al*., 2004; [3]Özcan, 2008; [2]Al-Rousan *et al*., 2013; [4]Vossen, n.d.)

2. MATERIALS AND METHODS

For this study, we attempted to evaluate the oil content of three native Texas *Quercus* species through a boiling extraction. We were unable to perform a chemical extraction because of limited resources. We selected boiling instead of a mechanical extraction for two reasons; the historical evidence supporting the viability of the boiling method, and the current day evidence of boiling used on other nut oil extractions (i.e. hickory, American chestnut). It should be noted that there is no precedent in the literature for acorn oil extraction through boiling.

2.1. Sample Collection

Our study examined *Q. polymorpha* (QP), *Q. shumardii* (QS), and *Q. macrocarpa* (QM). These three species were selected because they varied in acorn size, oak classification (red/white), and were accessible to the project. All acorns were picked green, directly off of the trees, in October and November. They were then decapped and stored over winter in freezers for approximately two and a half months. In spring, the acorns were defrosted and shelled by hand. After being shelled, the acorn meat was left out to dry for several days.

Sample	Uncrushed weight (g)	Crushed weight (g)
Total QS:	3959.5	3686.9
Average QS:	396.0	368.7
Total QM:	2729.7	2454.6
Average QM:	273.0	245.5
Total QP:	741.4	703.4
Average QP:	148.3	140.7

Table 4. Totaland average uncrushed weight of the three species samples.

The acorn meat was then separated into individual samples of ten and five. QP acorns were so small that they were divided into only five samples due to sheer lack of volume. The other two species were divided into ten samples. After being weighed, the 25 samples were left out overnight. Several of the samples got slightly molded overnight; this was not foreseen because the acorn meat had been left out before being divided and weighed and did not have any molding.

2.2. Sample Preparation

The samples were then put in the freezer for several days. They were then defrosted again and ground, using one 14-Cup Cuisinart and one 12-Cup Wolfgang Puck food processor. They were then reweighed and once again frozen. After several days, the meal was defrosted and heated on a burner. The meal was left to simmer for 15 minutes in a 10:1 approximated water ratio rounded to the nearest 10mL.

After the heating was completed, the acorn mixture was left to cool, poured through two sieves, and emptied into graduated cylinders. The samples were then left to settle. They were then left them in the refrigerator to prevent any fungal or bacterial growth.

3. RESULTS AND FUTURE RESEARCH

3.1. Results

No oil was yielded from this experiment. The existing literature is too bare and this study contains too many variables to determine an exact cause of failure. However, we hypothesized several potential downfalls of our experiment.

The molding that occurred on the shelled meat may have limited the oil. Molding can affect not only lipid and fatty acid composition, but also detriment starch content

(Serna-Saldivar, 2010). Additionally, the acorn samples may have been stored for too long or improperly stored. Proteolytic microorganisms can breakdown lipids including fats and oils and commonly result in spoilage in fruit, vegetable, and nut crops (Gould, 2013).

The historical evidence is particularly unspecific when illustrating the methods of oil extraction. There is no evidence supporting or discounting the need for roasting the meat before boiling. There are some anecdotal evidences that roasting was used, but also some claiming that roasting dissipated that oils making them less present in the meats (Driver, 1952).

Finally, there is no account of how long, at what temperature, or in how much water the acorns were historically boiled. It is a distinct possibility that more water or a higher temperature would have garnered better results. Near the end of the experiment, when it became clear that no oil would be yielded, we set aside one QM sample. This sample was simmered for over two hours and closely monitored, in hopes that a longer period of time would cause different results. This caused no difference beyond a darkening of the pulp as it cooked.

3.2. Future Research

This study had numerous variables that could have affected the final yield. Because of this, there are several areas of possible future research. Acorn oil extraction methods should be studied; hexane and supercritical CO_2 have been well documented, but pressing or grinding have a more likely economic use and much less information in the literature.

Other variables that could be studied include, time in growing season of collection, the effects of storage methods, and the length time period stored. Additionally, it could be studied whether acorns yield oil best when picked “green” (directly off of the tree) or “brown” (already dropped to the ground).

All of the above listed variables are as of yet untested. However, was once a staple crop across the world. It has economic potential as a perennial oilseed and can be grown on otherwise unusable cropland. Acorn oil fills an existing market and can become a profitable industry. As the North American Southwest becomes seemingly further entrenched in severe drought every year, a drought resilient crop such as acorn oil should be considered.

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