Fatty Acid and Dietary Fiber of the Mesocarp of Hawai‘i Grown Avocados: Potential for Improved Health Benefits.

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Chapter 1

Literature review
Avocado *Persea americana* origin

Avocado (*Persea americana*) fruits are popular amongst consumers not only because of their flavor but, because of their reported health benefits. Avocado, a berry fruit, has increasing evidence of its many health benefits and potential research opportunities. According to Zhang et al. (2009), avocados contain various amounts of carotenoids, tocopherol and fats. Avocados also contain roughly two times more protein per fruit than any other fruit varieties. Finally, avocados are sources of magnesium, phosphorus, iron, potassium, vitamin E, vitamin C, β-carotene, thiamin, riboflavin, nicotinic acid, and folate (Naveh et al., 2001).

The history of avocado dates back to its original domestication in Mesoamerica in the region of Tehuacan, Mexico in 8000-7000 BC (Chen et al., 2009a). By the 1800s, both Guatemalan and Mexican cultivars of avocado began trekking towards Australia, California and Florida (Chen et al., 2009a). Over the years of open cross-pollination and hybridization, many cultivars have developed and allowed avocado to be introduced to Hawaii in the nineteenth century (Chen, et al. 2009a).

Hawaii-grown avocados mainly come from the cultivars that originated from Australia. The Australian cultivars are a hybrid of both Guatemalan and Mexican avocados, which eventually led to the “Sharwill” cultivar becoming a staple in Hawaii. Multiple factors attribute to the hundreds of avocado varieties that currently grow in Hawaii. These factors include human selection, human hybridization, and natural hybridization of avocados over thousands of years (Love et al., 2009). Evidence of this can be seen in the variation of outward appearance, mesocarp, and even the size of the
avocado fruit. For example, the weight of these Hawaii-grown avocados can range from 0.25 lbs to 3 lbs (Fig 1).

Figure 1. Images of Hawaii-grown avocados
From left to right (Linda, Sharwill, Malama, and Kahaluu variety).
(Pictures courtesy of Ken Love www.hawaiifruit.net).

Season, harvest period, location and fruit ripening of avocados
Overall, nutrient content of avocado varieties differs according to the variety, season, location, and maturation state (Lu et al., 2009 & Naveh et al. 2001). Avocados are picked when they are mature on a tree, and growers can harvest the fruit multiple times throughout a season (Lu et al., 2009). Growers define mature avocado by their color change from a green to a darker green, and a slightly soft touch which yields to pressure (Chen et al. 2009b). Maturation refers to a fruit that has fully developed whereas the ripeness of a fruit refers to the best time to consume a fruit. The Sharwill variety of avocado is unique because it does not darken with maturity. Its maturity is instead determined by lack of glossiness of the skin of the fruit (Chen et al., 2009b).
Nutrient and phytochemical composition depend on what point in the harvest season the fruit was picked and the level of ripeness (Lu et al., 2009). Increased oil content occurs during growth and maturation of the ripening avocado, while on the tree. Previous research has found that once the fruit is harvested, oil content no longer increases (Meyer et al., 2008). However, a recent study by Meyer et al. (2008) contradicts the observation by Meyer et al. (2008). In the study conducted by Meyer et al. (2008), a comparison between storage and ripeness time showed that at various points in the ripening process there was a significant change in oil content. The study looked at various fruit stages of the avocado: under-ripe (UR), medium-ripe (MR), and eating ripe (ER) stage. Ripeness was determined through the firmness range of the various stages. The three levels of ripeness were defined as based on the amount of force required to indent the flesh: UR (>50 N), MR (50-15 N) and ER(<5 N). This study showed that per dry weight (DW), the concentrations of all fatty acids (FA) increased degree of ripeness increased. More specifically, palmitic, palmitoleic, and linoleic acid were greater at the eating-ripe stage as compared to the under-ripe stage. Analytically, as the fruit ripens the oil recovery was shown to improve at the “ripe” stage as compared to the “under-ripe stage.” Based upon DW, all FA concentrations showed an increase concurrent to the degree of ripeness. Individual FA such as palmitic, palmitoleic, and linoleic acid were recovered significantly greater at the “eating-ripe” stage as compared to the “under-ripe” stage. Results showed that oil recovery was improved as fruit ripened, although there were still fatty acids recovered in the earlier stages. The contradiction between the two articles represents the advancement in quantification techniques and could reflect the varying methods used to extract the FA.
Different avocado varieties have different growing and harvest seasons. The later a fruit is harvested in the season, the avocado yields a higher overall fatty acid content and carotenoid content (Pieterse et al., 2005). The point at which avocados are harvested during the maturation process is important. If avocados are harvested immaturely, the fruit will typically shrivel in storage, ripen abnormally, and most importantly affect the eating experience and nutrient quality (Chen et al., 2009b).

Spatial and temporal relationship

A study done by Landahl et al. (2009) is one of the first studies to explore the spatial and temporal relationship of avocados during the ripening process. Spatial analysis refers to the difference in biochemical properties within different sections of the avocado mesocarp. This study investigates how various origins, storage, and growing locations affect the overall nutritional composition of the avocado. Besides the variation in harvest period, the environment and growing location affect the overall nutrient profile. For example, elevation of the orchard affects the overall quality of the avocado. According to Chen et al. (2009b), higher elevations (610 m) tend to delay maturation and cause slower fruit ripening. Fruit grown at lower elevations (427-540 m) were able to ripen faster and had higher oil content and dry matter. In addition, the overall flesh color was often a bright yellow at lower elevations (Chen et al., 2009b).

Avocado does not ripen uniformly due to the biochemical process within the mesocarp of the avocado (Landahl, 2009 and Meyer et al., 2008). Avocado fruit from Chilean, Spanish, and Peruvian origin were compared in Landahl (2009), and it found that the Peruvian variety differed significantly from Spanish and Chilean varieties due to
variation of growing conditions. Overall biochemical composition of the fruit was
governed by different growing conditions (climate, season, soil, agronomic practices).

Few researchers have attempted to explore the spatial differences of various
biochemical properties throughout the avocado. Landahl et al. (2009) showed that
between Spanish and Chilean fruit, both palmitic and palmitoleic acid was found at the
lowest amounts at the base of the fruit. Peruvian avocados where found to have the
lowest palmitic acid levels at the apical portion of the avocado. For the Peruvian
avocados oleic acid, the most abundant FA found in avocados, declined the closer the
sample was to the lower end. In contrast, for the Spanish or Chilean variety oleic acid
had a fairly equal distribution throughout the mesocarp of the avocado.

When comparing origin, storage time and location, the qualities that varied the
most were DM and oil content (mainly in the form of palmitic acid) (Landahl et al.,
2009). The importance of this research is that it gives an in-depth look into the multiple
nutritional parameters affected by origin, storage time, and location. These
characteristics are all important factors when determining the nutritional content of
avocados.

**Hawaii avocado industry analysis**

Hawaii’s tropical environment creates a home to many diverse and successful
agriculture operations. Despite the decline of the pineapple and sugarcane market in
Hawaii, the avocado fruit has expanded to make up around 27% of Hawaii’s agricultural
market (Chan-Halbrendt et al., 2007). From 1995 to 2005, the commercial value of
avocados rose from $273,000 to $600,000 per year. Additionally, the exporting potential
of the Hawaii grown avocado rose from 700,000 lbs in 1999 to 2,130,000 lbs in 2005. These values associated with the production of avocado clearly indicate the potential for the avocado fruit.

In 2005, the Hawaii Agricultural Services indicated that there were a total of 150 avocado farms within the state of Hawaii. The production costs for avocados grown in Hawaii are averaged to be about $900 per acre (Chan-Halbrendt et al., 2007). However, in 2005, the income received from one acre of avocado was roughly $2,761. A survey conducted by Barber et al. (2008), showed that all varieties of avocados that have been tested in Hawaii were able to grow. Many of the cultivars, found throughout the state of Hawaii, are a mixture of the Mexican, West-Indian, and Guatemalan varieties brought in Hawaii to test if it could grow (Chan-Halbrendt et al., 2007).

Though the market for Hawaii-grown avocado is rising, the global export for Hawaii avocados is not yet feasible due to lack of produce and quarantine restrictions. Perhaps the biggest issue facing local farmers is the lack of bargaining power with the large-scale farmers. Hawaii avocado growers are not able to keep up with Hawaii’s consumer demand for local avocado; although many of Hawaii’s consumers would prefer the local variety of avocado, the market is forced to mostly depend on imported produce (Chan-Halbrendt et al., 2007).

In 2008, Barber et al. had both consumers and chefs compare avocado varieties grown in Hawaii. The avocados were scored from 0-10 based on texture and taste of the avocados. Based on the results, Kahaluu, Linda, and Malama avocados had a higher mean score of both taste and texture over both Hass and Sharwill varieties. Interestingly, one characteristic disliked by consumers was the large seed within the Sharwill variety of
avocado. For consumers, the seed-to-meat ratio is an important characteristic when paying per the pound at markets where avocados are sold.

Seasonality of locally grown avocado

There is potential for year round production of avocado in Hawaii by utilizing various cultivars. (Chan-Halbrendt et al., 2007). Figure 2 shows the feasibility of a year-round supply of Hawaii grown avocados. Kahaluu, Linda, Malama, and Sharwill, the four most popular varieties, are mainly found in the fall-winter months.

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Figure 2. Growing seasons of Hawaii-grown avocados

The black color indicates a “high season” for the avocado and the gray color indicates a “low season” for the particular avocado variety.

The low number of smallholder farmers currently limits the bargaining potential for local farmers to compete with the bigger “mainland” large-scale farmers. However, they should be able to meet the consumer preference for local avocado through coordinated efforts. Furthermore, because most farms are individually owned and operated, forming farmer cooperatives may greatly benefit Hawaii avocado growers. Finally, the branding efforts are critical to create awareness that Hawaii is a feasible market for avocado production (Chan-Halbrendt et al., 2007).
Restrictions on export are another factor that have affected the local avocado market. Avocados cannot be exported to the mainland United States without a quarantine treatment to prevent the spread of both the Mediterranean fruit fly \((\textit{Ceratitis capitata})\) and the oriental fruit fly \((\textit{Bactrocera dorsalis})\) (Chen et al., 2009b). The farmers did not use these quarantine treatments, such as methyl bromide and other cold treatments because they degraded fruit quality. Recently, according to the Department of Agriculture: Animal and Plant Inspection Services (APHIS) in 2013, an article pushing to allow the exportation of the Sharwill variety has been published. In the article, it stated that the Department of Agriculture would allow the exportation of Hawaii grown avocados only by registration with the APHIS, regulation of orchards, and sanitation in an APHIS approved facility. As long as these guidelines are followed, if this article is approved, would provide the consumers with the Sharwill variety in a predominately Hass variety avocado market on the mainland of the U.S.

In conclusion, though unsuccessful so far, avocado production and exportation can be improved by changing operation efficiency. Various types of avocados can meet the seasonal demands of the avocado market. Establishment of extension services and a cooperative network are essential to allow Hawaii’s smallholder farmers to meet most of the consumer demand.

**Fatty acids reference values**

Collectively, all reference values are called the Dietary Reference Intake (DRI) and it is made up of Estimated Average Requirement (EAR), Recommended Dietary Allowance (RDA), Adequate Intake (AI) and finally Tolerable Upper Intake Level (UL).
EAR refers to the estimated nutrient intake to meet the need of half of the healthy individuals. The RDA is the average daily intake sufficient to meet the nutrient requirement for around 97-98% of healthy individuals. AI is the average daily intake level based on observed or experimental of healthy individuals that are assumed to be adequate. UL refers to the highest average daily intake that will not pose any risk or adverse health effects.

Fats are a major source of energy for the body and helps absorb both fat-soluble vitamins and carotenoids. However, the adequate intake (AI) and Recommended Dietary Allowance (RDA) is set for total fat because there are insufficient amount of data that suggest an amount that prevents chronic disease (Institute of Medicine, 2005). Whereas, RDA is set saturated fatty acids (SFA), which include palmitic acid (C16:0), are a source of energy for the body and also structural components of cell membranes. Fats including saturated fatty acids, affect the texture and palatability of foods consumed in one’s diet. SFA are able to be synthesized from other fuel sources and therefore have not been associated with any benefit in preventing any chronic diseases. Therefore, saturated FA have neither a AI, nor EAR, or RDA set.

Monounsaturated fatty acids (MUFA) are characterized by having one carbon-carbon double bond. Typically, MUFA are found in the cis-formation and have their hydrogen atoms found on the same side of the double bond. Plant sources such as avocado are sources of cis-MUFA, which are liquid at room temperature (Institute of Medicine, 2005). Oleic acid (18:1 n-9) accounts for 92% of dietary MUFA and plays a role in membrane structural lipids including the myelin tissue which is a part of the human nervous system. Currently, there is no evidence that suggest that MUFA are
Polyunsaturated fatty acids (PUFA) are another type of lipids in the human diet, and are characterized by multiple carbon-carbon double bonds within the carbon chain. Linoleic acid is one of the \( n-6 \) PUFA. Linoleic acid cannot be synthesized within the human body, and therefore is essential in the human diet (Institute of Medicine, 2005). Linoleic acid is a pre-cursor to arachidonic acid, which is a part of the eicosanoid production in tissues (Institute of Medicine, 2005). Eicosanoids are involved in brain function and epithelial cell functions. For adults, 19 and older, various studies have shown that the AI for men is 17 g/d of linoleic acid. For women, the AI is set at 12 g/d of linoleic acid.

Another PUFA is the \( n-3 \) PUFA and is often characterized as having one of the double bonds at 3 carbon atoms from the methyl end of the FA. Linolenic acid, is essential in the diet for its neurological functions and being the precursor to eicosapentaenoic acid (EPA). EPA is beneficial in preventing against coronary heart disease, and arrhythmias (Institute of Medicine, 2005). For men, AI for linolenic acid is set at 1.6 g/d. Whereas for women, the AI is set at 1.1 g/d of linolenic acid (Institute of Medicine, 2005).

**Nutrient composition of avocados**

Avocados have been praised for their nutritional value compared to other fruits (Naveh et al., 2001, Lu et al., 2004, & Ashton et al., 2006). In particular, the lipid content of avocados is much higher than other fruits. Because of their lipid content
avocados may be used as a high-energy food source (Takenaga et al., 2008). The avocado fruit is a fairly energy dense food, providing 1.79 kcal/g of fresh fruit. Within the avocado fruit, the mesocarp lipid content can vary between 15 and 30% of fresh weight depending on the cultivar and season. The avocado is a source of SFA (palmitate) and MUFA (palmitoleate and oleate). In addition, essential, polyunsaturated fatty acids such as α-linolenic and linoleic acid are found mainly in the avocado mesocarp. These FA have helped to establish healthy lipid profile for the avocado, and have much evidence of other health benefits in studies. In addition to their high content of MUFA, avocados contain several bioactive phytochemicals. The yellow-green color of the avocado indicate the presence of the carotenoids (lutein, zeaxanthin, α-carotene, and β-carotene), B-vitamins, vitamins C and E, and other phenols. Avocados are also known for their low simple sugar content and high dietary fiber content.

**Lipid content of avocados**

Avocado is known as an oleaginous or oily fruit, due to its FA content. Total FA content was determined in previous studies using various types of avocados. According to Chen et al. (2009b), avocados contained high amounts of MUFA, mainly in the form of oleic acid. In avocados grown in Japan, total lipid content accounted for 18.2-21.8% of the total weight of the avocado mesocarp (Takenaga et al., 2008). Takenaga et al. (2008) reported the mesocarp to contain roughly 58% oleic acid. The second most abundant FA was indentified as palmitic acid (16:0) accounting for 19.9% of the total FA content. Linoleic acid contributed 11%, and palmitoleic acid (16:1 n7) was shown to
makeup roughly 5.7% of the FA profile. Finally, α-linolenic acid (18:3 n3) made up only 0.8% of the avocado FA profile.

The FA content of the avocado depends on variety, cultivar, season, environment, and soil. The amount of avocado oil is highly correlated with the amount of dry matter content within the mesocarp (Chen et al., 2009b). As the fruit matures, the fruit’s overall oil content increases. Cultivar variation is another factor that affects the FA content in the fruit. In a study done by Lu et al. (2009), the total lipid content of avocados grown in California increased over the growing season as the fruit matured. This same correlation was seen in a Hawaii grown Sharwill variety. Increased dry matter and oil was correlated with being harvested later in the season (Lu et al., 2009).

**Palmitic acid (16:0) and avocado**

Palmitic acid is a main component of avocado oil (Reddy et al., 2011). Moreno et al. (2003) reported palmitic acid made up 21% of the fats found in avocado. The FA profiles of Hass and Fuerte varieties showed that the Hass varieties are more rich in palmitic acid (21.70-25.29%) compared to Fuerte (15.60%-18%). Palmitic acid content can be as high as 28% in avocados grown in Peru.

A standard Nutrition Education and Labeling Act (NLEA) serving of avocado is 30 g of flesh. A single NLEA serving of avocado, contains 0.64 g of palmitic acid (U.S Department of Agriculture, 2012). In relation to the DV, it is required that 20 g of saturated FA is required in one’s diet based on a 2000 calorie intake making a serving of avocado roughly 3% of the DV for SFA. In general, the higher SFA in one’s diet, the higher the serum total and also higher LDL cholesterol concentrations. Obesity is also a
factor with numerous studies showing a relationship of high SFA intake with increase in BMI (Institute of Medicine, 2005). Furthermore, many epidemiological studies have shown a increased risk of diabetes with increased risk of SFA intake.

Palmitoleic acid (16:1 n7) acid and avocado

Palmitoleic acid comprises 3-9% of the total lipids according to current literature (Landahl et al., 2009, Moreno et al., 2003, & Meyer et al., 2008). The concentration of palmitoleic acid in most literature are consistent with each other. In the Spanish varieties of avocado, the palmitoleic acid concentrations were found to be lowest at the base end of the fruit. In some literature, palmitoleic acid was not quantified which could be due to the fatty acid composition and extraction method of the research (Moreno et al., 2003).

Oleic acid (18:1 n9) and avocado

Oleic acid has been consistently been found to be the main FA in avocado (Meyer et al. 2009, Landahl et al., 2009, Takenaga et al. 2008, & Chen et al., 2009b). The range of oleic acid falls between 43-63% of the total FA found in the avocado. Landahl et al. (2009) reported that oleic acid was equally distributed throughout the avocado mesocarp for avocados grown in Chile and Spain. Exploring the variability of ripeness and oleic acid concentration, it was found that oleic acid is at its highest concentration at the “eating ripe” stage of maturation (Meyer et al., 2008).

In a single NLEA serving of avocado (30 g) there is a reported 2.71 g of oleic acid found (U.S Department of Agriculture, 2012). Based on the lack of evidence on adverse effects of overconsumption of MUFA, there is no DV set. However, overconsumption of
energy related to a high oleic acid diet is a possible risk associated with excess MUFA consumption (Institute of Medicine, 2005).

**Linoleic acid (18:2 n6) and avocado**

Linoleic acid (18:2 6), an omega-6 fatty acid, is involved in many physiological functions within the human body. In healthy adults, roughly 10% of the total FA in adipose tissue is made of linoleic acid (Institute of Medicine, 2005). Linoleic acid is an essential FA and cannot be synthesized by humans, and therefore must be obtained through dietary intake (Czernichow et al., 2010). Linoleic acid content of avocado is variable, comprising 1.67-14.89% total FA (Landahl et al., 2009, Dreher et al, 2013, & Moreno et al., 2003). Linoleic acid has an AI of 17 g/d for adults 19-30 years. For women, the AI is set at 12 g/d for women 19-30 years old (Institute of Medicine, 2005). A single NLEA serving of avocado (30 g) provides 0.5 g of linoleic acid which provides roughly 3% of the AI for healthy males 19-30 years of age (U.S Department of Agriculture, 2012).

**Alpha-linolenic acid (18:3 n3) and avocado**

Along with linoleic acid, alpha-linolenic acid is another polyunsaturated FA found in avocado. The amounts of alpha-linolenic acid in avocado are fairly consistent throughout most literature. It is the least abundant of the FA indentified in avocado. The amount of linolenic acid ranges from 0.94 to1.12% total FA (Meyer et al., 2008, Landahl et al., 2009). Some reports have noted that no alpha-linolenic acid was found in avocado samples (Reddy et al., 2012). According to Institute of Medicine, the AI for alpha-
linolenic acid is set at 1.6 g/d for men ages 19-30 years. For women ages 19-30 years, it is set at a slightly lower value of 1.1 g/d (Institute of Medicine, 2005). Therefore, the value of 0.04 grams for 1 serving (NLEA) roughly provides 3.6% of a woman’s AI (U.S Department of Agriculture, 2012).

**Dietary fiber and avocado**

Previous research conducted by Naveh et al. (2001) found that avocados had a relatively high dietary fiber content (Naveh et al., 2002). The total dietary fiber found in avocado is roughly 5.2-6.9 g/100 g of fresh fruit (Naveh et al., 2002; USDA, 2011). Therefore, about 80% of the carbohydrates found in avocado are dietary fiber, consisting of 70% insoluble and 30% soluble (Dreher et al., 2013). The types of fiber found in avocado include insoluble fibers (cellulose and lignin) and soluble fibers (hemicelluloses and pectin). The avocado mesocarp is roughly composed of 2.1% and 2.7% of soluble and insoluble fiber respectively, based on total fresh weight. The AI for dietary fiber is 38 g/day for men and 25 g/day for women (based on 14 g dietary fiber/1000 kcal/day) (Institute of Medicine, 2005). The DV for dietary fiber is 25 g per day (Institute of Medicine, 2005). One NLEA serving of avocado provides 2.0 g dietary fiber, which is 8% DV.

**Mineral content of avocado**

Minerals found in the mesocarp of avocado are primarily magnesium (Mg), calcium (Ca), and iron (Fe). Magnesium is a component of bones, aids in nerve transmission, and is an enzyme cofactor. Magnesium found to be within the range of
941.6-1118.7 µg / g of fresh weight (Reddy et al., 2012). When comparing to a serving of avocado (NLEA; 30 g) the amount of Mg is roughly 9.0 mg of Mg/ serving of avocado.

Calcium, another mineral found in the mesocarp avocado, has many important roles within our body. It is a component of bones and teeth, and has a role in cellular processes and enzyme activation. According to Reddy et al. (2012), the levels of calcium in avocado falls in the range of 337.2-698.7 µg /g of fresh weight. In comparison to a NLEA serving of avocado (30 g) this comes out to 4.0 mg Ca / serving of avocado (USDA, 2011).

Iron, is found in the mesocarp of avocado (0.47 -0.61 mg / 100 g of fresh weight). It plays an important role within the human body. Iron is a component of both hemoglobin and myoglobin, and helps with the cellular use and transport of oxygen. In relation towards a serving of avocado there is roughly 0.18 mg Fe/ serving of avocado.

**Carbohydrate content of avocado**

The amount of sugar found in avocado is minimal when compared to other fruits. According to the USDA (2011), avocados contain only 0.3 g of sugar / 100 g fresh weight. The main sugar in avocado is a seven carbon (C₇) sugar known as mannoheptulose (Meyer et al., 2008). According to Meyer et al. (2008), C₇ sugars have been shown to inhibit insulin secretion and behave more as a phytochemical. The C₇ sugars show a tendency to decline throughout the avocados growing season and could be a key role player in the ripening process once the fruit is removed from the tree (Meyer et al., 2008).
Antioxidant properties of avocado

Several studies have suggested that high dietary intake of avocado provides a rich source of bioactive phytochemicals such as vitamin E, carotenoids, vitamin C, phenols, and sterols. The phytosterols, also known as “plant sterols,” have a chemical structure very similar to that of the cholesterol found in the body. In a study conducted by Plaza et al. (2009) the antioxidant activity in avocados was measured through the use of a stable radical DPPH. The avocados had 820.41 mg of dry weight of avocado/ g of DPPH (Plaza et al., 2009). The antioxidant nature of avocado decreases with both storage time as well as cutting of the avocado. Furthermore, an article published by Rodriguez-Carpena et al. (2011), found that the refuse portion of avocado (peels and seeds) had the highest antioxidant levels as compared to the pulp. The standard was compared the standard curve as previously described and expressed as mmols of trolox per gram of fresh matter. The pulp had a value of 0.33 mmol trolox/g fresh weight which is much lower than both peel (88.94 mmol trolox) and seed (130 mmol trolox). The overall aim of this study was to explore using avocado extract as a means of natural food additive to preserve meat products.

Phytosterols and avocado

Phytosterols are found in plants and have a close structure to that of cholesterol. However, it has a different side chain configuration than cholesterol (Lin et al., 2010). Due to the phytosterols’ similar chemical configuration to cholesterol, it has the ability to reduce intestinal cholesterol absorption (Racette et al., 2010). Previous studies have
shown that the dietary intake of bioactive components such as phytosterols found in avocado reduces serum cholesterol levels (Plaza et al., 2009). Phytosterols are also hypothesized to have a protective affect against many types of cancer.

The most abundant phytosterol found in avocado is β-sitosterol, which accounts for about 89% of the total phytosterol content (Plaza et al., 2009). Many bioactive components in fruits are lost to purification and packaging processes. Avocado is a good source of phytosterols due its stability in storage, which minimizes phytosterol loss (Plaza et al., 2009). Because avocados require minimal process when prepared for consumption, storage degradation is limited. This characteristic shows its potential to be a great export fruit. Interestingly, the antioxidant concentration of avocados has been shown to increase in storage (Plaza et al., 2009). Plaza et al. (2009), hypothesized this prevents the loss of phytosterols and other bioactive components.

**Carotenoids and avocado**

The different pigments of the avocado are not only an indication of nutritional quality but also an important determinant of nutritional marketability. Its pigments are indicators of the presence of carotenoids, flavonoids, sterols, and other bioactive components (Ashton et al., 2006, Plaza et al. 2009). The carotenoids found in avocado are lutein, zeaxanthin, xanthophyl, β-cryptoxanthin, α-carotene, and β-carotene (Dreher et al., 2013; Lu et al., 2005). Several *in vitro* and *in vivo* studies done with avocado noted the anti-tumor properties of its carotenoids (Lu et al. 2005, Ashton et al., 2006).

In most cultivars of avocado, the carotenoid lutein is present in the highest concentration in both the flesh and oil of the avocado (Lu et al 2005 & Ashton et al.,
Lu et al. (2005) and Ashton et al. (2006) found that the higher hue angle of the sample (green color) the higher the carotenoid content. The carotenoids found within the Hass variety of avocado also significantly increased the later in the season the fruit was harvested (Lu et al., 2009). Within the flesh, lutein accounts for 2.93µg/g fresh avocado (Ashton et al. 2009, Lu et al. 2005). Recent literature suggests lutein accounts for about 70% of the total carotenoid content followed by zeaxanthin (0.11 µg/g fresh avocado), β-cryptoxanthin (0.25 µg/g fresh avocado), α-carotene (0.25 µg/g fresh avocado), and β-carotene (0.60 µg/g fresh avocado) (Lu et al., 2005). The carotenoid levels tend to greatly vary according to cultivars and extraction procedure, ranging from 5 -40 µg/g fresh avocado (Ashton et al. 2006).

The concentrations of carotenoids are different between the tissues types found in a typical avocado fruit (Ashton et al., 2006). Lutein, along with other carotenoids, is found in the flesh of the dark green section closest to the skin (1.8 µg/g fresh avocado) (Ashton et al. 2006, Chen et al., 2009b). The oil content found within avocado also contains abundant amounts of carotenoids. Overall, the highest concentrations of carotenoids are found in the oil extracted from the avocado (Ashton et al., 2006). Carotenoids are fat-soluble, thus the presence of oil in the avocado is beneficial for carotenoid absorption in the small intestine (Ashton et al., 2006).

**Avocado health benefits**

Pieterse et al. (2005) explored the benefits of MUFA within avocados and . In this study, participants replacing mixed fats (30 g total fat) with MUFA rich avocado (200 g/day, 30.6 g total fat) while consuming an energy-restricted diet for weight loss
Participants who consumed the avocados had an average decrease of 2.13-2.65 kg (≈3% of total body weight) in their body weight (Pieterse et al., 2005). Those who consumed 200g avocado/day substituted for mixed fat (control) didn’t compromise weight loss, lipoproteins, or vascular function. According to the study, MUFA found in the avocado fruit promoted less fat deposition and increased the overall thermic effect within overweight and obese men and women that were free from chronic disease. Results proved avocados can be incorporated into energy restricted diets, as a substitute for mixed fats without affecting serum lipid concentrations.

A previous study conducted by Carranza-Mardrigal et al. (1997), investigated the benefits of incorporating avocado in a vegetarian diet. Subjects were given a control diet or a treatment diet for 4 weeks. The three treatment diets were: 1) Control: 70% carbohydrate, 10% protein, and 20% lipids, 2) Avocado: 60% carbohydrates, 10% protein, and 30% lipid (with 75% of the diet coming from avocado), and 3) same as Diet 2 without the avocado. The avocado diet (diet 2) significantly reduced LDL in the subjects compared to the non-avocado diets. Carranza-Mardrigal et al. (1997) showed that vegetarian diets with avocado had a better lipoprotein profile.

The National Health and Nutrition Examination Study (NHANES) administered from 2001 to 2008 reported associations between avocado intake and health effects (Fulgoni et al., 2013). The avocado data was retrieved from 24-hour dietary recalls of patients that participated in the Automated Multiple Pass Method (AMPM). Physiological information from each subject was collected through the mobile NHANES centers. In total, this particular examination included 17,567 US adults ≥19 years old. The objective of this research was to compare the consumption of avocado to overall diet,
energy and nutrient intake, and to investigate whether avocado intake is associated with physiological indicators of health and risk of metabolic syndrome.

Approximately 2% of the participants were avocado consumers (n=347). The mean avocado intake for these participants was about 70.1 ± 5.4 g/d, and slightly higher in males than females. Compared to the non-avocado consumers, the diet quality was significantly improved for avocado consumers. Avocado consumers had higher intakes of total fat, MUFA, PUFA, DF, vitamin E, magnesium, and vitamin K (Fulgoni et al., 2013). They also had significantly higher intakes of both vegetable and fruit and a significant decrease of intake of added sugar. Avocado consumers also had significantly lower carbohydrate intake, lower weight, lower BMI, and smaller waist circumference. Avocado consumption increased HDL-C in consumers compared to non-consumers. The improved diet, nutrition intake, HDL-C levels, body weight, and BMI agree with previous clinical studies that looked at the potential health benefits (Pieterse et al., 2005).

This study was limited by its diet assessment technique. A true representative diet cannot be collected through a single 24-hour dietary recall. Perhaps, if both time and financial means permitted, the authors would’ve preferred a diet recall over several days. Data may be inaccurate due to misreporting of foods and memory lapses. Secondly, being that this article analyzed this epidemiological data in a cross-sectional matter, one cannot conclude any causal relationships between avocado consumption and diet quality.

It has been established in literature that a diet with abundant amounts of fruit and vegetable is associated with a healthy lifestyle and with a risk reduction of many forms of cancer. According to Lu et al. (2005), because that avocado contains high amounts of...
the chemopreventative effects. However, Lu et al. (2005) was the first to explore the antiproliferative affects of lipid extract along with lutein. Lu et al. (2005) found that the effects of carotenoids such as lutein, are enhanced with the presence of MUFA. Lutein accounted for limited cell growth inhibition. This particular article provided the preliminary evidence to show that lipid-soluble bioactive components in avocado work together with the MUFA and are better absorbed into the bloodstream.

This study was a well designed study. Through the use of western-blots, the study was able to replicate and show how human prostate cell lines were both affected by lutein extract and avocado extract. However, because this work is in vitro, avocado’s anti-cancer properties need further research using animal or perhaps using human models before associations of avocado consumption and cancer reduction can be established.

In addition, avocado consumption increases lutein and zeaxanthin intake. High intake of lutein and zeaxanthin decreases age-related eye dysfunction (Dreher et al., 2013). Lutein and zeaxanthin, when applied topically, has shown protection against harmful UV rays from the sun (as cited by Dreher et al., 2009).

The avocado industry in Hawaii is unique because thousands of seedlings have flourished in its various growing climate and a diverse variety of avocados have grown as a result. Despite the diversity of avocado that exists in Hawaii, the lack of marketing information hinders the expansion of Hawaii’s avocado industry. The nutritional information for Hawaii grown avocados has not been assessed in previous reports on Hawaii grown avocado. Research has shown that avocados contain fatty acids, fiber, protein, mineral, and bioactive components but the amounts in Hawaii grown avocados is unknown. The nutrients found in avocados may support a wide range of health benefits,
which include decreased CVD risk, weight control, and acting as an anti-carcinogen.

Therefore the purpose of this research is to provide the nutritional information of Hawaii grown avocados, and secondly, to provide this information stakeholders for in the avocado industry in order to strengthen their marketing strategy.
References


and fat content during maturation and from different growing areas. *J Agric Food Chem, 57*, 10408-10413.


Chapter 2

Nutrient content of Hawaii-grown avocados
Abstract

Avocados (*Persea Americana*) contain a variety of essential nutrients including monounsaturated fatty acids, dietary fiber, and beneficial phytochemicals. Currently, there is limited research on Hawaii grown avocados, which limit the agricultural growth of the avocado industry. Research was conducted to determine the nutritional qualities found in four varieties (Kahaluu, Linda, Malama, and Sharwill) grown in Hawaii. Individual fatty acids (FA) were extracted through standard soxhlet method and oil extracts were quantified for FA composition via GC. Total dietary fiber (DF) was determined by quantifying insoluble and soluble fiber found within the avocado mesocarp. Additional experiments included quantification of total protein, mineral content, and determining carbohydrate through difference. One-way analysis of variance (ANOVA) was conducted using SAS statistical software. Oleic acid was predominately found in the Kahaluu variety (10.527 g/100 g fresh wt.), and was significantly higher in content (p=0.0004) than in Linda, Malama, and Sharwill. Second, the Kahaluu variety had a significantly greater amount of TDF (9.59 g/100 g fresh wt.) compared to Linda, Malama, and Sharwill (p=0.0019). Preliminary results on Hass avocado indicate that there are differences in its reported nutritional values in most literature. The research in this current study will provide nutritional professionals and consumers with improved knowledge of nutritional properties of Hawaii grown avocados. Through this knowledge, there is potential to improve marketing strategies to expand the avocado industry in Hawaii.
Introduction

Avocado, *Persea americana* (Lauraceae), a fruit native of Mexico, is valued for its high nutritional content and its delicious flavor (Reddy et al., 2012). The avocado is a nutrient dense fruit that is rich in unsaturated fats, mainly in the form of monounsaturated fatty acids (FA) (Plaza et al., 2009). In addition to its lipid content, avocado also contains fiber, protein, magnesium, phosphorus, iron, potassium, folic acid, vitamin B-6, vitamin C, vitamin E, and K (Chen et al., 2009). Avocado is a rich source of bioactive phytochemicals including carotenoids, phenols, and sterols, among others. Avocados can reduce LDL cholesterol and triglycerides, and control the weight of subjects, which impact the lipid profile (Pieterse et al., 2005 & Fulgoni et al. 2013). The bright green-yellow color of the avocado, indicates high carotenoid content, and has been associated with reductions of many common forms of cancer including prostate cancer (Lu et al., 2005).

The range of total lipids is about 15-30% of fresh weight of avocado (Takenaga et al., 2008). In most avocado varieties, oleic acid is the predominate FA found in the mesocarp. In addition to oleic acid, palmitic, linoleic, palmitoleic, and alpha-linolenic acid are present in the avocado. The FA types in avocados differ slightly depending on origin, maturity, growing season, variety, and ripening process. These factors also affect quantity and spatial location of the individual FA throughout the mesocarp. Also, the overall distribution of FA changes during postharvest ripening and storage.

Avocado was first introduced to Hawaii in the early 19th century. Today, the fruit approximately makes up 27% of Hawaii’s market share in total pounds of fruits annually (Chan-Halbrendt et al., 2007). Many Hawaiian cultivars are a mixture of Mexican,
West-Indian, and Guatemalan varieties. Hundreds of varieties are grown within Hawaii alone as a result of many years of cultivation. The top avocado cultivars grown in Hawaii are Sharwill, Malama, Kahaluu, Linda, and Hass varieties (Chan-Halbrendt et al., 2007). The versatility of Hawaii’s avocado industry is predicated on the production of many varieties. The wide selection of varieties allows for a year-round supply of avocados.

In 2007, test panel surveys were developed for chefs and avocado consumers to determine buyer’s preference within Hawaii. The results showed that both consumers and chefs significantly preferred Hawaii-grown avocados compared to the imported mainland “Hass” variety (Chan-Halbrendt et al., 2007).

According to the Hawaii Avocado Association (HAA), a lack of research, lack of marketing information, and a lack of collaboration between consumers and growers limit the expansion of Hawaii’s avocado industry (Barber et al., 2008). Despite the demand for locally grown avocados, there is no nutritional information provided on local avocados for consumers. In this project, we aimed to measure the FA content in Hawaii grown avocados (Kahaluu, Linda, Malama, and Sharwill) to provide the research needed to drive Hawaiian avocado industry. Second, moisture, dietary fiber, protein, total mineral content, and carbohydrate by difference were analyzed to provide a more complete nutritional composition of Hawai’i grown avocados. This data will be a foundation for marketing and expanding the Hawaii avocado industry.
Material and Methods

Avocados were obtained from local farmers in Kealakekua, in the Kona district, on the Big Island of Hawaii. The Malama variety was grown at approximately 1,000 feet elevation. Whereas Kahaluu, Linda, and Sharwill variety was grown at an elevation of approximately 1,900 ft. Fruits were harvested at peak season and shipped overnight to the University of Hawaii at Manoa in Honolulu, Hawaii, on the island of Oahu. Upon arrival at the laboratory, fruits were considered to be unripe, confirmed by initial color and firmness measurements. Fruits were allowed to ripen at room temperature for 5 to 7 days, until the flesh made a slight indentation after pressure was applied to the skin surface. Four varieties, Kahaluu (n=4), Linda (n=4), Malama (n=4), and Sharwill (n=4), were prepared for nutrient analysis. All chemicals were obtained from Restek Corporation (Bellefonte, PA) and Sigma-Aldrich (St. Louis, MO).

Sample preparation

Each entire fruit was weighed. The fruit was then cut vertically into two equal sections. The seed and peel of the avocado were removed and placed into a “refuse” container. The mesocarp of the avocado was placed into the “edible portion” container and later used for analysis. The remaining mesocarp was cut horizontally from the stem end to allow the avocado to be placed on a planar surface 1 cm thick. Once two trays were filled with the 1 cm thick slices, the remaining mesocarp was homogenized, labeled, and placed into containers for freezing. The 1 cm slices totaling 30-50 g of avocado were placed on a weigh boat and were frozen at -15°C prior to lyophilization. Samples were lyophilized using a 36-hour drying cycle at -40°C at 720 Torr (VirTis Virtual 50xl, SP
Scientific). A temperature probe was placed into one representative sample during the lyophilization process to confirm complete dryness. Moisture content of each avocado sample was calculated. Samples were pooled together and sealed in jars for further use.

*Extraction of fatty acids*

Oil was extracted through the AOAC 969.33 method with minor modifications. Lyophilized mesocarp tissue was ground to a fine powder using a mortar and pestle. Ground sample was weighed (0.200 g) and placed into filter paper and folded and placed in the soxhlet apparatus. One hundred twenty milliliters of solvent (2:1 CHCl₃/MeOH) was poured in a round bottom flask (RBF) with boiling beads. The sample was refluxed for approximately 2 hrs with the heat adjusted to run at approximately 55°C. The flask was removed and solvent was evaporated using a rotary evaporator (IKA RV 10 Rotovap). The temperature of the rotary evaporator was kept at <50°C at 50 RPM.

The recovered oil was washed in 15 mL of solvent (2:1 CHCl₃/MeOH) and placed into a Teflon centrifuge tube. Three milliliters of 0.1 M KCl was added to the solution and avocado oil. The sample was spun in a centrifuge at 5000rpm for 5 minutes. The aqueous layer containing the oil was decanted into a pear-shaped separatory glass funnel and allowed to separate. The bottom aqueous layer was decanted through a sintered glass funnel containing ≈ 1 cm of Na₂SO₄ into a preweighed RBF. The remaining top layer was placed into a Teflon centrifuge tube. Three milliliters of 2:1 CHCl₃/MeOH was added to the remaining top layer (organic) in the Teflon centrifuge tube. Sample was centrifuged at 5,000 RPM (2990 x g) for 5 minutes. Steps were repeated, aliquoting the aqueous layer into the RBF containing sample. Four pastured
pipettes of CHCl₃/MeOH solution were used to remove residue on the separatory funnel. Solution was rotary evaporated again at 50 °C until only washed oil remained. The RBF was dried and weight was determined as crude lipid amount.

*Saponification and methylation*

Boiling beads containing oil extracts for FAME determination were connected to a condenser. A Teflon sleeve was placed between the RBF and the condenser. Four milliliters of 0.5 M NaOH in MeOH were placed into RBF through condenser. Four milliliters of 0.5 M NaOH were added and refluxed for 15 minutes. BF₃MeOH was added and refluxed for 2 minutes. The heat source for the condenser was turned off and 3 mL of heptane were added and refluxed. Heptane was chosen as the preferred solvent due to improved peak resolution on the gas chromatogram. An ice bath was placed under the condenser to cool the apparatus until refluxing stopped. The solution containing the heptane was poured into a clean Teflon tube. A one centimeter layer of saturated NaCl solution was added to help separate the mixtures. The mixture was centrifuged at 5,000 rpm (2990 x g) for 5 minutes. Following centrifugation, the mixture was decanted leaving the aqueous bottom layer in the Teflon centrifuge tube. The top organic layer containing the heptane and FA were decanted into a clean sintered glass funnel containing approximately 1 cm of Na₂SO₄. Two milliliters of heptane were added to the aqueous layer in the Teflon centrifuge tube and spun at 5,000 rpm (2990 x g) for 5 minutes. Once spun, the mixture was placed into a separatory funnel and the top layer was decanted through sintered glass funnel containing ≈ 1 cm of Na₂SO₄. The Na₂SO₄ layer was rinsed with 3 pipettes full of heptane. The heptane containing the methyl esters
were placed in a scintillation vial and the internal standard decane was added so that there was 10 mg/sample. The scintillation vile was kept for no more than 12 hrs at 5°C.

**Fatty acid methyl ester analysis**

The analysis of fatty acid in avocado was carried out by gas chromatography (GC) through a HP 5890 equipped with a column injector and a FID detector. The identification and quantification selective FAME were detected on a RT-2560 (bisyanopropyl polysiloxane) capillary column (100 meter, 0.25 ID, 0.2 μm df). Column temperature was programmed to start at 100°C and then raised to (250°C) at 1.5°C/min. The injector volume was 1 μl with an inlet zone temperature 250°C and detector temperature 250°C. The carrier gas was He at a constant flow rate of 40 mL/min. Hydrogen was kept at a flow rate of 40 mL/min. Finally purified air was set a flow rate of 440 mL/min. A 1 μl sample was injected using a HP 7673 auto-sampler injector with a 10 μl syringe. Individual FA found within the avocado sample were indentified and quantified by comparison of their retention times and peak areas based on standard curves. A representative chromatograph can be seen in (Appendix 2a-c) Results were expressed as grams of FA per 100 g of fresh weight.

**Protein analysis**

Lyophilized mesocarp tissue was ground to a fine powder using a mortar and pestle and 0.5 g was weighed out. Avocado powder was placed into a pre-weighed filter paper and folded into a digestion tube. Boiling beads were added and samples were weighed and run in duplicate. One blue “kjeltab” (K₂SO₄ + Se) were added along with
25 mL of concentrated H₂SO₄. Protein was digested using an automated digestion block (Tecator DS-20, Eden Prairie, MN). Samples were digested for 2 hours until the contents within the tube were clear. After digestion was allowed to cool, flasks were diluted with 300 mL of distilled water at 100 mL intervals along the side of the distillation flask.

Twenty 600 mL beakers were filled with 100 mL of boric acid and 8 drops of blue indicator (bromo-cresol green). Titration beakers were placed under each burner and 300 mL of distilled water was filled into six beakers. Zinc (3-4 pieces) was placed into the distillation flask along with running 80 mL of NaOH (40%) solution. Once the flame was lit, the contents of the flask were allowed to boil. The distillation continued until the receiver flask reached a total volume of 300 mL for each sample.

The contents of the receiver flask containing the boric acid indicator solution was titrated with sulfuric acid (N=0.0963) until solution turned from blue to green. The calculation was as follows: \( \text{Nitrogen (g/kg)} = \left( 14 \times \text{Molarity of the Acid} \right) \times \left( \text{Titre value} - \text{blank} \right) / \text{Sample Weight} \). Crude protein was calculated as followed: \( \text{Nitrogen} \times 6.25 = \text{crude protein} \).

**Crude lipid analysis**

Crude lipid was determined through soxhlet extraction with petroleum ether. Dried samples (2 g) were weighed onto dry pre-weighed filter paper. Filter paper was folded to contain the sample and placed into soxhlet apparatus. Samples were extracted 24 hours until ether drained from soxhlet apparatus was clear. Samples were dried in fume hood overnight and then transferred to 100°C oven for 24 hours. Crude lipid was
calculated by subtracting the weight of the dry, extracted sample from the original sample weight.

*Dietary fiber analysis*

Fiber analysis was done according to the method AOAC 991.43. Samples were analyzed for soluble and insoluble dietary fiber fractions, through the enzymatic-gravimetric procedure. In 200 mL beakers 1.00±0.0005 g of sample was added. Twenty milliliters of MES-TRIS (pH 8.2) was used to suspend the sample. Samples were digested using 25 µl of α-amylase solution while stirring at low speed at 95-100°C for 35 minutes. Samples were placed at 60°C and 50 µl of protease was added to each sample and allowed to agitate for 30 minutes. In order to assure the sample’s pH to 4.1-4.8, 2 mL of 0.561 N HCL solution was added. If solution needed to be adjusted it was with 5% NaOH solution or 5% HCl solution. The final enzymatic digestion used 100 µL of amylglucosidase while stirring for 30 minutes.

A dried, pre-weighed filter paper was placed into a vacuum Buchner funnel. The sample was poured into a Buchner funnel and filtered with the assistance of a vacuum. Filters were rinsed with 5 mL in the distilled water preheated for 70°C. The filtrate was saved and transferred into a pre-weighed 600 mL tall-for beaker. The insoluble fiber was washed twice with 10 mL of: 95% EtOH and acetone in that specific order, and dried over night in a 103°C oven.

Filtrates plus washings from the insoluble fiber assay were mixed with 4x volume of preheated 95% EtOH (60°C) to precipitate the soluble fiber in the digestates. After 1hr., precipitates were materials filtered through a tarred filter paper in a Buchner funnel.
A vacuum suction was applied to assist the filtration process. Fifteen milliliters of 78% EtOH, 15 mL 95% EtOH, and 15 mL acetone were added in that order for two washes. Soluble fiber samples were dried overnight in a 103°C oven and weighed.

One of each set of duplicate insoluble fiber residues and soluble fiber residues were ashed at 650°C for 16 hrs. The other set was used to determine the protein content using the method previously described. Insoluble and soluble fiber residues (% Original minus % ash and % crude protein) determined the respective insoluble and soluble fiber contents. The sum of insoluble and soluble residues represented the total dietary fiber.

**Mineral content**

Total mineral content was determined by placing 0.5 g of samples into ceramic crucibles. Samples were heated to 650°C, and the temperature was held for 16 hours. When samples were cooled and difference between residue loss and initial sample weight was used to calculate the % of the crude mineral content.

**Carbohydrate calculation**

Carbohydrate content was determined by difference. Remaining sample weight after protein, crude lipid, DF, and mineral content were subtracted was determined to be carbohydrate.

**Caloric calculation**

Caloric amount of avocado was determined through the Atwater factor calculation. Carbohydrates and protein were each given a value of 4 kcal/g of fresh
avocado. Whereas, lipids determined through previous methods were given a value of 9 kcal/g of fresh avocado to determine the total available energy of avocados.

Statistical analysis

Results were collected as mean ± standard deviation. Significant differences between means were calculated by a one-way analysis of variance (ANOVA). Differences were held at a 95% confidence interval (P<0.05) using Tukey’s range test. All analyses were performed using the SAS version 9.1.3.

Results

Fatty acid composition

The fatty acid composition of the four selected avocado varieties and specific FA are shown in Table 1. Oleic acid was the major fatty acid in all four avocados, representing 40-46% of all fatty acids quantified within the mesocarp. Palmitic acid content significantly greater in the Kahaluu variety (4.79 g/100 g fresh weight) than the Malama variety (2.17 g/100 g fresh weight, p=0.0412) (Table 1). Sharwill, Linda, and Malama showed no significant difference of palmitic acid amongst the three. Palmitoleic acid was not significantly different amongst the four varieties (p=0.0718).

Kahaluu had a significantly greater oleic acid content (10.53 g/100 g fresh weight) than both Linda and Malama varieties (p=0.0004). Secondly, Sharwill (8.95 g/100 g fresh weight) was significantly greater than the Malama variety.

Among all four varieties both linoleic and alpha-linolenic acid showed no significant difference (p = 0.0944, p = 0.1049). Out of the four varieties Kahaluu had
both the highest amount of total lipid (16.39 g/100 g fresh weight of avocado) (Table 2). Malama and Sharwill had the second and third highest values (12.90 and 13.91 g/100 g fresh weight, respectively), but were not significantly different from one another. Linda had the lowest lipid content (11.38 g/100 g fresh weight)

*Moisture, dietary fiber, protein, mineral content, and carbohydrate, and caloric values*

Dietary fiber, protein, and mineral content were also examined in the four varieties of avocado as shown in Table 2. A significant difference of insoluble DF was found amongst the four varieties (p=0.0457), the trend led Kahaluu to have the highest amount of insoluble fiber (6.0867 g/100 g fresh weight). Additionally, Kahaluu had significantly greater soluble fiber than Linda (p=0.0265) while other samples were not different from one another. Kahaluu had significantly greater TDF than Malama and Linda, but not Sharwill (p=0.019). Sharwill, Linda, and Malama were not significantly different from one another.

Linda (2.14 g/100 g fresh weight) had significantly greater mineral content than Kahaluu and Malama but not Sharwill (p=0.002). Sharwill variety had significant greater mineral content than Malama variety.

Protein content of the avocado fruit was found to be significantly greater in Sharwill variety (2.62 g/100 g fresh weight) than both Malama and Kahaluu (p=0.0002). Linda was significantly greater than Kahaluu while other samples were not different from one another.
Malama (11.31 g/100 g fresh weight) had significantly greater carbohydrate content than Kahaluu and Sharwill but not Linda (p=0.0001). Linda was also shown to be significantly greater than Sharwill variety.

Finally, through the Atwater factor calculation are shown in Table 2. Kahaluu variety had a significantly greater caloric amount with 193.92 ± 11.27 kcal/100 g fresh weight as compared to Sharwill (162.21 ± 16.14 kcal/100 g fresh wt.), Linda (139.25 ± 18.68 kcal/100 g fresh wt.) and Malama (132.41 ± 11.40 kcal/100 g fresh wt.).

**Discussion**

Foods such as avocado are a biological mixture of many nutrient components. When dealing with food components such as avocado, any sample deemed a “representative sample” still may show variation in overall nutrient composition. The oil content and dry matter of avocado determine its ripeness. Its overall oil quality is determined by its FA composition (Meyer et al., 2008). The FA and oils collected from avocado differ and vary depending on variety of avocado, harvest time, elevation, and post harvest ripening. The average total FA of the Kahaluu, Linda, Malama, and Sharwill variety from this study are in general agreement with previous findings ranging from 14-15.4 g / 100 g fresh weight (Meyer et al., 2008, USDA, 2011, Plaza et al., 2009, and Pieterse et al., 2005).

The most abundant FA in avocado was oleic acid. In the Kahaluu variety, oleic acid was 10.53 g /100 g fresh weight, which was ≈ 40% of the total lipid. This is slightly lower than the study published by Meyer et al. (2008), which reported oleic acid to be about 55-58% of the FA composition. In addition, the oleic acid amount in the Kahaluu
variety in this study was higher than the Hass variety avocado oleic acid amount of 9.80 g/100 g fresh weight (USDA, 2011). Palmitic acid amount in the Kahaluu variety of this study (4.79/100 g fresh wt.) was almost double previous findings of 2.08 -2.85 g /100g fresh weight) (Landahl et al., 2009; USDA, 2011). The current study showed that the Kahaluu variety contained an average of 5.75 g / 100 g was much higher compared to 1.39 g / 100 g fresh weight (USDA, 2011) and 0.84 g /100 g fresh weight (Landahl et al., 2009). Linoleic acid and alpha-linolenic acid were scarce but found highest in the Kahaluu variety (3.61 g, 2.80 g /100 g fresh weight, respectively), and higher than previously reported values (1.67 g, 0.13 g / 100 g fresh weight, respectively) reported by USDA on Hass variety (2011).

A factor that may affect the FA composition of Hawaii avocados is the growing region that Hawaii avocados are grown in. In one study, domestic avocados from Japan were compared to imported avocados from California (Takenaga et al., 2008). The Japanese avocados had higher lipid content than the imported California avocados. In addition when looking at domestic avocados, orchard elevation may also be a factor in nutritional quality of the avocado (Chen et al., 2009). Fruit grown at a higher elevation (610 m) were generally larger, ripened slower, and had higher oil content than those grown at lower elevations (427 m) within Hawaii. These variables were not considered in this study but are an area for future research.

The harvest period effects nutrient content in avocados. In the present study, all avocados were obtained during peak harvest (November-February), depending on the variety. The effect of harvest period was examined in a recent study of California-grown avocados (Meyer et al. 2008). When evaluating the impact of four different harvest
periods (Jan., Apr., Jul., and Oct.) from four different locations (San Luis Obispo, Riverside, Ventura, and San Diego, CA), as the season progressed from January to October in all locations, the total fat and carotenoid content increased. It was suggested that as avocado matures, cellular degradation occurs and allows triglycerides from cells to become more bioavailable (Meyer et al., 2008, Landahl et al., 2009). This concept suggests that fat content of avocados is highly variable, even within a variety and within a growing region. Because the consumer does not know when an avocado was harvested, this information may be needed for nutrient information of the avocado variety. Spatial variability is another factor that affects the nutritional content. Landahl et al. (2009) looked at the spatial distribution of FA in avocados. Between Spanish, Chilean, and Peruvian avocado the greatest variability was at the basal and apical end. This type of article provides insight to the relationship between biochemical and physical properties. Significant differences between nutrient content values in the current literature may be due to the spatial and temporal variability between each type of avocado. If an avocado is homogenized prior to consumption, as in the case of making guacamole or dip, the variable is less important. In this current study the entire avocado sample was homogenized prior to analysis.

For distribution of avocados from Hawaii, exporting brings the factor of storage and its affect on nutrient content is important. In general, after chilled storage (8°C for 8 days) there was a decrease in overall FA in the avocado (Plaza et al., 2009). This was due to the oxidative degradation of the FA within the avocado. Second, Plaza et al. (2009) looked at storage in air, nitrogen, and vacuumed packaging. The vacuum-stored sample best retained its FA the best in the storage. Cutting of the avocado also released
antioxidants, which helped in providing the stability of the FA. In relation to the current study, the process of storage is important for both export from Hawaii and to Hawaii. Important for both export from Hawaii and in order to preserve the avocados nutritional quality, avocados imported

Dietary fiber consumption is recommended due to its recommended health benefits including improving the health of the large intestine, reducing CVD, diabetes, and obesity (Naveh et al., 2002). The fiber values of the Ettinger variety of avocado was 5.2 g/100 g fresh weight with approximately 75% being insoluble, and 25% being soluble. In the current study, fiber values ranged from 5.6-9.59 g/100 g fresh weight with roughly 2/3 of the sample being insoluble and 1/3 being soluble fiber. The values of fiber were in the Kahaluu variety. Naveh et al. (2002), showed that consumption of avocado pulp in diets reduced weight gain in human subjects. However, in order to equal the same amount of fiber as the cellulose control, subjects ate 1.3 times more avocado pulp. Despite eating more quantity of avocado, the study found that avocado diets were less energy dense. Subjects also reported feeling more satiated after eating avocado compared to cellulose.

Protein levels in the Hass variety avocado were reported to be 1.96 g/100 g fresh weight for the Hass variety of avocado (USDA, 2011). However, in the current study the protein values ranged from 1.1-2.62 g/100 g fresh wt., which was consistent with values reported by the USDA (2011). The highest protein amount was found in the Sharwill variety. In the current study, specific proteins were not determined. Spatial and temporal evaluation of protein is also something that should also be further explored.
Mineral content of avocados in the current study ranged from 1.2-2.1 g/100 g fresh weight. The Linda variety had the highest amount of mineral. The mineral values slightly higher that of expected for avocado and agreed with the previous literature (USDA, 2011). The main minerals in avocados are potassium (K) and magnesium (Mg), which have values of 507 and 29 mg, respectively (USDA, 2011). Evidence shows that sufficient levels of potassium are beneficial in blood pressure control within adults (Dreher et al., 2013). Magnesium in the body acts as a cofactor in many cellular enzymatic reactions (Dreher et al., 2013). Avocados contain approximately 29 mg Mg/100 g fresh weight (Dreher et al., 2013). The present study identified total minerals, not individual minerals, which would be an area for further research.

Total carbohydrate in the current study was from 4.32-8.34 g/100 g fresh weight. The Linda variety contained the highest amount 8.34 g/100 g fresh wt. Previous literature reported that the sugars in avocado are mostly known as D-mannoheptulose. The sugars within avocado play a role in the ripening process and decline during the ripening season. Nevertheless, the values found in this current study were in agreement with previous values (8.64 g/100 g fresh weight) (USDA, 2011).

The nutritional value of avocados may be beneficial, when consumed as part of a habitual diet. An analysis of NHANES data from 2001 to 2008 showed the health benefits of avocado consumption (Fulgoni et al., 2013). Individuals who were identified as “avocado consumers” had higher serum HDL cholesterol levels compared with “non avocado consumers,” as well as lower body weight and lower BMI. Dreher et al. (2013) reported that the HDL levels in avocado consumers are higher than non consumers and thus a lower risk of metabolic syndrome. In a clinical trial, subjects consumed 200 g
avocado/per day in place of mixed oils for 6 weeks (Pieterse et al, 2005). The diet was energy restricted to promote weight loss. At the end of the 6 weeks, the avocado group lost a significant amount of weight compared to baseline (2.13-2.65 kg), while the control group did not lose a significantly amount of weight. Serum lipid values and other biomarkers of chronic disease did not change.

In conclusion, the data from this study will be used to promote Hawaii grown avocados in the market. The lack of information on Hawaii grown avocados does not meet the increasing overall market demand. Once nutritional values of the different varieties of avocado are provided, farmers and consumers can make informed decisions. In addition, Hawaii avocado farmers will have the ability to increase consumer awareness on the nutrient properties of their avocado products, thus enhancing sales. Data suggest that Hawaii grown avocados (Kahaluu) contain oleic acid (10.52 g/100 g fresh wt.), linoleic acid (3.60 g/100 g fresh wt.), and linolenic acid (2.79 g/100 g fresh wt.). Both MUFA and PUFA have been associated with potential cardiovascular benefits and improved lipid profiles. In addition to nutritional values, the potential health benefits of avocados can also be used in the marketing strategy of Hawaii grown avocados. For example, consumers may be looking for both a great-tasting snack that also provides MUFA and PUFA.

**Strengths, limitations, and future work**

The strengths of this study was that it provided the first in-depth analysis of the fatty acid content of Kahaluu, Linda, Malama, and Sharwill varieties grown in Hawaii. The avocados sampled in this study were a representative sample of the main four
avocado produced in Hawaii. Besides profiling the FA, other nutrient qualities including fiber, protein, carbohydrate, and mineral were all analyzed.

The main limitation of this study was the low number of varieties sampled. Over 100 varieties of avocados are currently grown in Hawaii. This preliminary study only examined four varieties of Hawaii grown avocado, which can lead to further exploration of the many varieties grown in Hawaii. Another limitation in the study is that factors such as harvesting practices were not collected prior to running avocado samples. Finally, a weakness of this particular study is lack of running a Hass variety to compare. Future work may include carotenoid analysis of the local varieties of avocados, nutrient content of the seed of the avocado for oil use.

Acknowledgements

This research was supported through the research grants: USDA-NIFA Agricultural Diversification Grant Hawaii Tropical Specialty Fruits R&D award 2010-34172-2163.
Table 1. Grams of FAME/100 g fresh weight of Kahaluu, Malama, Sharwill, and Linda varieties of Hawaii-grown avocados.

<table>
<thead>
<tr>
<th>Fatty acid</th>
<th>Kahaluu</th>
<th>Malama</th>
<th>Sharwill</th>
<th>Linda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmitic</td>
<td>4.79 ± 0.9\textsuperscript{A}</td>
<td>2.17 ± 0.01\textsuperscript{B}</td>
<td>3.20 ± 0.7\textsuperscript{AB}</td>
<td>2.66 ± 0.1\textsuperscript{AB}</td>
</tr>
<tr>
<td>Palmitoleic</td>
<td>5.75 ± 2.1</td>
<td>1.17 ± 0.01</td>
<td>2.96 ± 0.5</td>
<td>2.36 ± 0.3</td>
</tr>
<tr>
<td>Oleic</td>
<td>10.52 ± 1.0\textsuperscript{A}</td>
<td>5.28 ± 0.1\textsuperscript{B}</td>
<td>8.95 ± 0.4\textsuperscript{AC}</td>
<td>6.53 ± 0.4\textsuperscript{BC}</td>
</tr>
<tr>
<td>Linoleic</td>
<td>3.60 ± 0.9</td>
<td>1.68 ± 0.1</td>
<td>2.06 ± 0.1</td>
<td>2.01 ± 0.3</td>
</tr>
<tr>
<td>Alpha-linolenic</td>
<td>2.79 ± 0.4</td>
<td>1.64 ± 0.1</td>
<td>2.15 ± 0.2</td>
<td>1.63 ± 0.1</td>
</tr>
</tbody>
</table>

Data are mean ± standard error. Values are based on percent of total lipid as determined by gas chromatography.

Mean values in each row followed by a different superscript letter are significantly different using Tukey’s range test using 4 samples per mean. (p≤0.05)
Table 2. Nutrient content of Kahaluu, Malama, Sharwill, Linda variety of avocado (100 g fresh weight).

<table>
<thead>
<tr>
<th></th>
<th>Kahaluu</th>
<th>Malama</th>
<th>Sharwill</th>
<th>Linda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>66.09</td>
<td>67.37</td>
<td>70.3</td>
<td>70.57</td>
</tr>
<tr>
<td>Total Lipid (g)</td>
<td>16.39 ± 0.01(^A)</td>
<td>12.90 ± 0.53(^B)</td>
<td>13.91 ± 0.18(^B)</td>
<td>11.38 ± 0.34(^C)</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>1.29± 0.07(^A)</td>
<td>1.10 ± 0.08(^BA)</td>
<td>2.62 ± 0.13(^C)</td>
<td>2.07 ± 0.27(^BC)</td>
</tr>
<tr>
<td>Carbohydrate (g)</td>
<td>5.38 ± 0.87(^AC)</td>
<td>11.31 ± 0.82(^B)</td>
<td>4.32 ± 0.46(^C)</td>
<td>8.35 ± 0.65(^AB)</td>
</tr>
<tr>
<td>Total Dietary Fiber (g)</td>
<td>9.60 ± 0.86(^A)</td>
<td>5.69 ± 0.74(^B)</td>
<td>7.03 ± 0.41(^AB)</td>
<td>5.49 ± 0.74(^B)</td>
</tr>
<tr>
<td>Insoluble Fiber (g)</td>
<td>6.09 ± 0.24(^A)</td>
<td>4.25 ± 0.26(^B)</td>
<td>4.71 ± 0.29(^B)</td>
<td>4.39 ± 0.75(^C)</td>
</tr>
<tr>
<td>Soluble Fiber (g)</td>
<td>3.51 ± 0.86(^A)</td>
<td>1.44 ± 0.24(^AB)</td>
<td>2.31 ± 0.28(^AB)</td>
<td>1.10 ± 0.88(^B)</td>
</tr>
<tr>
<td>Mineral (g)</td>
<td>1.44 ± 0.03(^AC)</td>
<td>1.20 ± 0.14(^C)</td>
<td>1.81 ± 0.13(^AB)</td>
<td>2.14 ± 0.03(^B)</td>
</tr>
<tr>
<td>Energy (kcal)</td>
<td>193.92 ± 5.63(^A)</td>
<td>132.41 ± 5.70(^B)</td>
<td>162.21 ± 8.07(^B)</td>
<td>139.25 ± 9.34(^B)</td>
</tr>
</tbody>
</table>

Data are mean ± standard error.

Mean values in each row followed by a different superscript letter are significantly different using Tukey’s range test using 4 samples per mean. (p≤0.05)
References


Appendix
Table A1. Fatty acid composition from previous published literature.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Avocado Type</th>
<th>Unit</th>
<th>Total FA</th>
<th>Palmitic acid (16:1 cis)</th>
<th>Palmitoleic acid (16:1 trans)</th>
<th>Oleic acid (18:1 cis)</th>
<th>Linoleic acid (18:2 cis n6)</th>
<th>Linolenic acid (18:3 trans n3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moreno et al. (2003)</td>
<td>Mexican Variety</td>
<td>g/100 g oil</td>
<td>15.8% of proximal analysis.</td>
<td>21.1 g</td>
<td>8.9 g</td>
<td>52.04 g</td>
<td>14.89 g</td>
<td>1.83 g</td>
</tr>
<tr>
<td>Pieterse et al. (2005)</td>
<td>Hass</td>
<td>% of total FA</td>
<td>15.23/100 g FW.</td>
<td>16.79%</td>
<td>10.65%</td>
<td>47.48%</td>
<td>14.64%</td>
<td>1.29%</td>
</tr>
<tr>
<td>Pacetti et al. (2007)</td>
<td>Hass Reed</td>
<td>% of TL</td>
<td>17.4 ± 0.3%</td>
<td>6.3 ± 0.0%</td>
<td>65.8 ± 0.3%</td>
<td>9.3 ± 0.2%</td>
<td>0.5 ± 0.0%</td>
<td>0.5 ± 0.0%</td>
</tr>
<tr>
<td>Takenaga et al. (2008)</td>
<td>Fuerte Bacon Hass</td>
<td>Area % in GC</td>
<td>19.9%</td>
<td>5.7%</td>
<td>54.4%</td>
<td>11.6%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Meyer et al. (2008)</td>
<td>Hass</td>
<td>% total FA mg/ g DW mg/g oil</td>
<td>20.85%</td>
<td>8.89%</td>
<td>56.95%</td>
<td>12.20%</td>
<td>1.14%</td>
<td>0.94 mg</td>
</tr>
<tr>
<td>Plaza et al. (2009)</td>
<td>Hass</td>
<td>% total FA</td>
<td>15%</td>
<td>6%</td>
<td>57%</td>
<td>12%</td>
<td>n/d</td>
<td></td>
</tr>
<tr>
<td>Landahl et al. (2009)</td>
<td>Spanish/Chilean variety</td>
<td>% total FA</td>
<td>16%</td>
<td>6%</td>
<td>63%</td>
<td>11%</td>
<td>1%</td>
<td></td>
</tr>
<tr>
<td>Peruvian variety</td>
<td>Hass</td>
<td>Area percentage ± STDV</td>
<td>28%</td>
<td>13%</td>
<td>43%</td>
<td>15%</td>
<td>1.2%</td>
<td></td>
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</tr>
<tr>
<td>Reddy et al. (2012)</td>
<td>63.67 ± 0.20 g/ 100 g</td>
<td>24.33 ± 0.88</td>
<td>18.03 ± 0.18</td>
<td>13.01 ± 0.1</td>
<td>48.75 ± 0.08</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>Dreher et al. (2013)</td>
<td>15.4 g</td>
<td>2.08 g</td>
<td>0.05 g</td>
<td>9.80 g</td>
<td>1.67 g</td>
<td>0.13 g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Legend:

1. **Y axis**: Units are given arbitrary units generated by the FID.
2. **Time**: Given in minutes which indentifies the FA.
3. **Retention times**: Retention times are as follows for the FA:
   a. Palmitic acid \( \approx 67 \) min.
   b. Palmitoleic acid \( \approx 71 \) min.
   c. Oleic acid \( \approx 80 \) min.
   d. Linoleic acid \( \approx 84 \) min.
   e. Linolenic acid \( \approx 89 \) min.
4. **Peak Area (PA)**: Quantities of FA were determined based on these equations (\( y = \text{Peak area values}, \ x = \text{total amount in mg} \)):
   a. Palmitic acid: \( y = 7.6714x - 1.1812 \)
   b. Palmitoleic acid: \( y = 2.8581x + 0.685 \)
   c. Oleic acid: \( y = 7.3916x - 0.9924 \)
   d. Linoleic acid: \( y = 9.0257x - 2.1092 \)
   e. Linolenic acid: \( y = 9.0257x - 2.1092 \)
Oleic acid is shown in the figure zoomed in to show the peak area and retention time of oleic acid.

Figure A2: Oleate zoomed in from previous chromatogram
Figure A3. Kahaluu sample 10 C chromatogram
<table>
<thead>
<tr>
<th>Title</th>
<th>Author</th>
<th>Year</th>
<th>Journal</th>
<th>Type of Study</th>
<th>Topic</th>
<th>Results</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development of a rapid method for the sequential extraction of fatty acids and sugars from avocado mesocarp.</td>
<td>Meyer et al.</td>
<td>2008</td>
<td>J. Agric. Food Chem</td>
<td>Soxhlet and GC.</td>
<td>Extraction from avocado for analysis of FA and sugars.</td>
<td>Soxhlet extracted 0.61 g/g of mesocarp tissue. Oleic acid (56.93%), palmitic (20.92%), linoleic (12.165) palmitoleic (8.88%) and linoleic (1.12%)</td>
<td>Oil recovery improved as fruit ripened. Oil content didn’t change post-harvest.</td>
</tr>
<tr>
<td>Spatial and temporal analysis of textural and biochemical changes of imported avocado during avocado fruit ripening</td>
<td>Landahl et al.</td>
<td>2009</td>
<td>J Agric. Food Chem.</td>
<td>Research</td>
<td>Examined different origin and temporal analysis of avocado</td>
<td>Composition of FA in dry matter content varied significantly according to origin. Palmitic, palmitoleic, and oleic acid were all found most in various parts of avocado.</td>
<td>FA ranges was consistent with values reported by others. Stress from shipping and storage also affects fruit quality.</td>
</tr>
<tr>
<td>Fatty acid profile and elemental content of avocado oil effect of extraction methods.</td>
<td>Reddy et al.</td>
<td>2012</td>
<td>J. of Env. Health Science s.</td>
<td>Research</td>
<td>Soxhlet extraction of avocado FA.</td>
<td>64.76 ± 0.24 g oil / 100g dry weight for Hass variety. Microwave extraction had wider range of FA content but not as reproducible. Hass: palmitic (23.33± 0.08%), palmitoleic acid(13.01± - 0.17%), oleic (48.75±0.08%).</td>
<td>Soxhlet method more consistent.</td>
</tr>
<tr>
<td>Lipid and FA composition of Mesocarp and seed of Avocado fruits harvested at northern range in Japan.</td>
<td>Takenaga et al.</td>
<td>2008</td>
<td>J. Oleo Science s</td>
<td>Research</td>
<td>FA composition of Japanese avocados compared with imported variety</td>
<td>Comparison b/t Japanese and Mexico saw no significant difference b/t the two. TL was 20% of mesocarp. Oleic acid accounted for 50% of MUFA.</td>
<td>No significant difference between Japanese and Mexican variety of avocado.</td>
</tr>
<tr>
<td>Study Title</td>
<td>Authors</td>
<td>Year</td>
<td>Journal/Media Type</td>
<td>Research Area/Method</td>
<td>Key Findings/Results</td>
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<tr>
<td>Non-destructive prediction of ‘Hass’ avocado dry matter via FT-NIR spectroscopy.</td>
<td>Wedding et al.</td>
<td>2010</td>
<td>J. Sci Food Agric.</td>
<td>Research</td>
<td>Found DM % to be in a range of Hass avocado to be 21-31.2 % of avocado. Pilot study to examine a non-invasive way to detect %DM.</td>
<td></td>
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<tr>
<td>N-6 Fatty acid and CVD health: a review of the evidence for dietary intake recommendation</td>
<td>Czernichow et al.</td>
<td>2010</td>
<td>British Journal of Nutr</td>
<td>Review article</td>
<td>Epi studies showed that n-6 PUFA dietary intake significantly lowers LDL. Prospective cohort showed n-6 PUFA showed a protective role of n-6 (linoleic acid) towards CVD especially when SFA are reduced.</td>
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<tr>
<td>Tracing the geographic Origins of major avocado cultivars</td>
<td>Chen et al.</td>
<td>2009</td>
<td>Journal of Heredity</td>
<td>Research</td>
<td>Used nucleotide and model based clustering program to examine 21 wild avocado from the origins of 33 cultivars. Used to prevent bottlenecking affect of domesticated avocado.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit and vegetable intake and risk of major chronic diseases</td>
<td>Hung et al.</td>
<td>2004</td>
<td>J. of the national Cancer Institute</td>
<td>Research</td>
<td>NHANES study cohort study</td>
<td>Total fruit and vegetable intake was inversely associated with risk of CVD. Benefits appeared to be primarily for CVD and not for cancer.</td>
<td></td>
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<tr>
<td>Hawai‘i avocado industry analysis, part 1: Supply Focus</td>
<td>Chan-Halbrendt et al.</td>
<td>2007</td>
<td>CTAHR Economic issues</td>
<td>Research</td>
<td>Economic issues of avocado production in Hawaii.</td>
<td>Avocados rank 7th in tropical fruits of agricultural sales in HI. Imports rose from 700,000 lbs in 1999 to 2,130,000 lbs. in 2005. Lack of information is a major reason why it accounts for only 30% of local demand. Producers need to increase efficiency. Need to meet consumer preference in order to succeed. There is a desire for consumes to buy local.</td>
<td></td>
</tr>
<tr>
<td>Study Title</td>
<td>Authors</td>
<td>Year</td>
<td>Journal/Document</td>
<td>Study Focus</td>
<td>Summaryhoria</td>
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<tr>
<td>Hawaii avocado industry analysis, part 2: Buyer Preference Focus</td>
<td>Barber et al.</td>
<td>2008</td>
<td>CTAHR economic issues</td>
<td>Research</td>
<td>Buyer preference Local Kahaluu, Malama, Linda, and Sharwill varieties preferred over Hass. Sharwill is the most cultivated (45%), Malama (21%), Can’t produce desirable avocados year round. Stated that for avg. consumer Sharwill doesn’t stand out from Hass. Seasonality of local avocados also limits production.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fatty acids, sterols, and antioxidant activity in minimally processed avocados during refrigerated storage.</td>
<td>Plaza et al.</td>
<td>2009</td>
<td>J. Agric Food Chem.</td>
<td>Research</td>
<td>Phytosterol and FA In general after refrigeration there was a decrease in FA. In general phytosterols were not affected. Oleic acid found to be the highest (57%). Cutting also showed to release both anti and FA. Minimal processing could be a good option to preserve the potentially health promoting attribute. Need to clarify the effects he bioavailability of bioactive compounds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defatted avocado pulp reduces body weight and total hepatic fat but increases plasma cholesterol in male rats fed in male rats fed diets with cholesterol.</td>
<td>Naveh et al.</td>
<td>2002</td>
<td>American Soc. For NS.</td>
<td>Research</td>
<td>Dietary Fiber within avocado The metabolic effect of avocado in male rats fed normal and hypercholesteromic diets. Rats fed either avocado or cellulose (control). Showed that avocado fed rats had lower hepatic fat levels. Avocado intake increased showed a decrease in total food intake. Lowering plasma cholesterol is due to the DF in the avocado.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pigments in Avocado Tissue and Oil</td>
<td>Ashton et al.</td>
<td>2006</td>
<td>J. Agric. Food Chem</td>
<td>Research</td>
<td>Carotenoids Carotenoids indentified were lutein, a-carotene, b-carotene, neoxanthin, violaxanthin, zeaxanthin, antheraxanthin, chlophylls, and pheophytins. Total carotenoid concentration in oils declined as the fruit ripened. Over ripening period lutein did not vary significantly. Lutein were highest in the avocado oils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substitution of high MUFA avocado for mixed dietary fats during an energy restricted diet effects on weight loss, serum lipids, fibrinogen and vascular function</td>
<td>Pieterse et al.</td>
<td>2005</td>
<td>J. of Nutrition</td>
<td>Research</td>
<td>CVD through clinical trial The consumption of 200g/d of avocado within a energy restricted dieted does not compromise weight loss when sub for 30g mixed DF. In summary, study dispels the myth that avocados are fattening and should not be included in diets.</td>
<td></td>
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<tr>
<td>Topic</td>
<td>Author(s)</td>
<td>Year</td>
<td>Journal</td>
<td>Data/Methodology</td>
<td>Summary</td>
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<td>Variation in ‘Sharwill’ avocado maturity during the harvest season and resistance to fruit fly infestation</td>
<td>Chen et al.</td>
<td>2009</td>
<td>J. Hort Science Research</td>
<td>Dry matter, maturity, oil content</td>
<td>Hawaii avocado cultivars oil content varied from 5-30%. Mean dry matter content as from 32-38 depending on season. Percentage of oil content ranged from 21-25% in 2007 and 18-28% in 2008. Dry matter and oil contents increase as the season progressed. The texture of ripe fruit was negatively correlated with the initial firmness and skin color at harvest. Dry matter and oil content of Sharwill avocado were correlated through linear regression. Fruit with a minimum mean oil content of 18% had a 29% dry matter sensory quality.</td>
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<td>Simultaneous analysis of glycolipids and phospholipids molecular species in avocado (Persea americana)</td>
<td>Pacetti et al.</td>
<td>2007</td>
<td>J. of Chromatography Research</td>
<td>HPLC and Avocado</td>
<td>The lipid fraction of the pulp is rich of polar lipids, such as glycolipids and phosphopholipids. Little is known on the polar lipid composition of the almond, which is not taken in consideration for the oil extraction. Showed that it isn’t acceptable to claim avocado and olive oil have similar oil properties.</td>
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<td>Phenolic Compound Profiles and Antioxidant Capacity of Persea americana Mill. Peels and Seeds of Two Varieties</td>
<td>Agnieszka Kosinski et al.</td>
<td>2012</td>
<td>J. Agric Food Chem Research</td>
<td>Phenolic compound and Avocado</td>
<td>Article examined seed phenolic compounds mainly in the form of catachin galate (105.4 μg/g), The peel extracts had a higher total phenolic compound content and antioxidant activity when compared to the seed extracts. Looked at Hass and Sheppard variety of avocado.</td>
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<td>Title</td>
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<td>Research Area</td>
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<td>Metabolism of the flavonoid Epicatechin by laccase of Colletorichium gloeosporioides and its effect on patogenicity on avocado fruits.</td>
<td>Guetsky et al.</td>
<td>2005</td>
<td>J. of Biochemistry and Cell Biology</td>
<td>Research</td>
<td>During avocado ripening, levels of flavonoid epicatechin modulate the metabolism of preformed antifungal compounds. Laccase activity is important factor in inducing ripening by modulating levels of epicatechin.</td>
<td>J. of Biochemistry and Cell Biology</td>
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<td>Effect of an avocado oil-rich diet over an angiotensin II-induced blood pressure response.</td>
<td>Salazar et al.</td>
<td>2005</td>
<td>J. of Ethanolop harmocology</td>
<td>Research</td>
<td>Avocado oil-rich diet induced in a slightly higher Ang II BP response. Avocado rich diet modifies the FA content and renal membranes in a tissue specific manner. Avocado rich diet had no effect on body weight but increased oleic acid content. Not oil that effects CVD but perhaps other active substances.</td>
<td>J. of Ethanolop harmocology</td>
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<td>Hass Avocado Composition and Potential Health Effects</td>
<td>Dreher et al.</td>
<td>2013</td>
<td>Clinical Review s in Food Science and Nutritio n</td>
<td>Clinical Trial Review</td>
<td>Health research related to avocado. The avocado consist of 71% MUFA, 13% PUFA, and 16% SFA which help aid in the bioavailability of fat soluble vitamins and phytochemicals. Avocado’s low SFA and high (MUFA and PUFA) unsaturated FA, along with phytosterols may play secondary CVD lowering roles. Also explored it’s role in anti-cancer activity.</td>
<td>Clinical Review s in Food Science and Nutritio n</td>
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