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Hass Avocado Composition and Potential Health Effects

MARK L. DREHER[1] and ADRIENNE J. DAVENPORT[2]

[1]Nutrition Science Solutions, LLC, Wimberly, TX 78676, USA
[2]No affiliation

Hass avocados, the most common commercial avocado cultivars in the world, contain a variety of essential nutrients and important phytochemicals. Although the official avocado serving is one-fifth of a fruit (30 g), according to NHANES analysis the average consumption is one-half an avocado (68 g), which provides a nutrient and phytochemical dense food consisting of the following: dietary fiber (4.6 g), total sugar (0.2 g), potassium (345 mg), sodium (5.5 mg), magnesium (19.5 mg), vitamin A (43 μg), vitamin C (6.0 mg), vitamin E (1.3 mg), vitamin K_1 (14 μg), folate (60 mg), vitamin B-6 (0.2 mg), niacin (1.3 mg), pantothenic acid (1.0 mg), riboflavin (0.1 mg), choline (10 mg), lutein/zeaxanthin (185 μg), phytosterols (57 mg), and high-monounsaturated fatty acids (6.7 g) and 114 kcals or 1.7 kcal/g. The avocado oil consists of 71% monounsaturated fatty acids (MUFA), 13% polyunsaturated fatty acids (PUFA), and 16% saturated fatty acids (SFA), which helps to promote healthy blood lipid profiles and enhance the bioavailability of fat soluble vitamins and phytochemicals from the avocado or other fruits and vegetables, naturally low in fat, which are consumed with avocados. There are eight preliminary clinical studies showing that avocado consumption helps support cardiovascular health. Exploratory studies suggest that avocados may support weight management and healthy aging.

Keywords Fruit, monounsaturated fat, cardiovascular health, normal blood glucose, weight control, healthy aging

INTRODUCTION

The avocado (*Persea americana*) originated in Mexico, Central or South America, and was first cultivated in Mexico as early as 500 BC (Duester, 2000; Rainey et al., 1994; California Avocado Commission, 2011). The first English language mention of avocado was in 1696. In 1871, avocados were first introduced to the United States in Santa Barbara, California, with trees from Mexico. By the 1950s, there were over 25 avocado varieties commercially packed and shipped in California, with Fuerte accounting for about two-thirds of the production. As the large-scale expansion of the avocado industry occurred in the 1970s, the Hass avocado cultivar replaced Fuerte as the leading California variety and subsequently became the primary global variety. The Hass avocado contains about 136 g of pleasant, creamy, smooth texture edible fruit covered by a thick dark green, purplish black, and bumpy skin. The avocado seed and skin comprise about 33% of the total whole fruit weight (USDA, 2011). Avocados are a farm-to-market food; they require no processing, preservatives or taste enhancers. The avocado's natural skin eliminates the need for packaging and offers some disease and insect resistance, which allows them to be grown in environmentally sustainable ways. This review provides the first comprehensive literature summary of the published nutrition and health research related to the avocado and its major components.

Address correspondence to Dr. Mark Dreher, PhD, Nutrition Science Solutions LLC, 900 S. Rainbow Ranch Road, Wimberley, TX 78676, USA. E-mail: nss3@sbeglobal.net

HASS AVOCADO COMPOSITION

Avocado consumers tend to consume significantly more of key shortfall nutrients—dietary fiber, vitamins K, and E, potassium, and magnesium—in their diet than non-avocado consumers (Fulgoni et al., 2010a). Although the U.S. Nutrition Labeling and Education Act (NLEA) defines the serving size of an avocado as one-fifth of a fruit, or 30 g (1 ounce), the National Health and Nutrition Examination Survey (NHANES) 2001–2006 finds that the average consumption is one-half an avocado (approximately 68 g) (Fulgoni et al., 2010a; 2010b). The nutrition and phytochemical composition of Hass avocados is summarized in Table 1. One-half an avocado is a nutrient and phytochemical dense food consisting of the following: dietary fiber (4.6 g), total sugar (0.2 g), potassium (345 mg), sodium

Table 1 Hass avocados (Persea americana) composition of edible portion (USDA, 2011)

Nutrient/phytochemical	Value per 100 g	1 fruit, 136 g	1/2 fruit, 68 g (NHANES eating occasion)	1 serving, 30 g (NLEA serving)
Proximates				
Water (g)	72.3	98.4	49.2	21.7
Energy (kcal)	167	227	114	50.0
Energy (kcal) (insoluble fiber adjusted)	148	201	101	44.0
Protein (g)	1.96	2.67	1.34	0.59
Total lipid (fat) (g)	15.4	21.0	10.5	4.62
Ash, g	1.66	2.26	1.13	0.50
Carbohydrate, by difference (g)	8.64	11.8	5.90	2.59
Fiber, total dietary (g)	6.80	9.20	4.60	2.00
Sugars, total (g)	0.30	0.41	0.21	0.09
Starch (g)	0.11	0.15	0.08	0.03
Minerals				
Calcium (mg)	13.0	18.0	9.0	4.0
Iron (mg)	0.61	0.83	0.42	0.18
Magnesium (mg)	29.0	39.0	19.5	9.0
Phosphorus (mg)	54.0	73.0	36.5	16.0
Potassium (mg)	507	690	345	152
Sodium (mg)	8.0	11.0	5.5	2.0
Zinc (mg)	0.68	0.92	0.46	0.20
Copper (mg)	0.17	0.23	0.12	0.05
Manganese (mg)	0.15	0.20	0.10	0.05
Selenium (ug)	0.40	0.50	0.25	0.10
Vitamins and Phytochemicals				
Vitamin C (mg)	8.80	12.0	6.0	2.60
Thiamin (mg)	0.08	0.10	0.05	0.02
Riboflavin (mg)	0.14	0.19	0.09	0.04
Niacin (mg)	1.91	2.60	1.30	0.57
Pantothenic acid (mg)	1.46	2.00	1.00	0.44
Vitamin B-6 (mg)	0.29	0.39	0.19	0.09
Folate, food (μg)	89.0	121	60.5	27.0
Choline, total (mg)	14.2	19.3	9.65	4.30
Betaine (mg)	0.7	1.0	0.5	0.2
Vitamin B-12 (μg)	0.0	0.0	0.0	0.0
Vitamin A (μg RAE)	7.0	10.0	5.0	2.0
Carotene, beta (μg)	63.0	86.0	43.0	19.0
Carotene, alpha (μg)	24.0	33.0	16.5	7.0
Cryptoxanthin, beta (μg)	27.0	37.0	18.5	8.0
Lutein + zeaxanthin (μg)	271	369	185	81.0
Vitamin E (alpha-tocopherol),mg	1.97	2.68	1.34	0.59
Tocopherol, beta (mg)	0.04	0.05	0.03	0.01
Tocopherol, gamma (mg)	0.32	0.44	0.22	0.10
Tocopherol, delta (mg)	0.02	0.03	0.02	0.01
Vitamin K_1 (phylloquinone) (μg)	21.0	28.6	14.3	6.30
Lipids				
Fatty acids, total saturated (g)	2.13	2.90	1.45	0.64
16:0 (g)	2.08	2.82	1.41	0.62
Fatty acids, total monounsaturated (g)	9.80	13.3	6.65	2.94
18:1 (g)	9.07	12.3	6.15	2.71
Fatty acids, total polyunsaturated (g)	1.82	2.47	1.24	0.55
18:2 (g)	1.67	2.28	1.14	0.50
18:3 (g)	0.13	0.17	0.09	0.04
Cholesterol (mg)	0	0	0	0
Stigmasterol (mg)	2.0	3.0	1.5	1.0
Campesterol (mg)	5.0	7.0	3.5	2.0
Beta-sitosterol (mg)	76.0	103	51.5	23.0

(5.5 mg), magnesium (19.5 mg), vitamin A (5.0 μg RAE), vitamin C (6.0 mg), vitamin E (1.3 mg), vitamin K_1 (14 μg), folate (60 mg), vitamin B-6 (0.2 mg), niacin (1.3 mg), pantothenic acid (1.0 mg), riboflavin (0.1 mg), choline (10 mg), lutein/zeaxanthin (185 μg), cryptoxanthin (18.5 μg), phytosterols (57 mg), and high-monounsaturated fatty acids (6.7 g) and 114 kcals or 1.7 kcal/g (after adjusting for insoluble dietary fiber), which may support a wide range of potential health effects (USDA, 2011;

Table 2 Composition: Avocado compared to tree nut qualified health claims reference amount (edible portion) (USDA, 2011)

Nutrient	Hass avocado 1 fruit (136 g)	Almonds 1.5 oz (42.5 g)	Pistachios 1.5 oz (42.5 g)	Walnuts 1.5 oz (42.5 g)
Water (g)	98.4	1.1	0.8	1.7
Calories (kcal)	227	254	240	278
Calories (kcal) (insoluble fiber adjusted)	201	239	235	269
Total fat (g)	21.0	22.1	19.1	27.7
Monounsaturated fat (g)	13.3	13.8	10.1	3.8
Polyunsaturated fat (g)	2.5	5.5	5.7	20
Saturated fat (g)	2.9	1.7	2.3	2.6
Protein (g)	2.7	9.0	9.0	6.5
Total Carbohydrate (g)	11.8	9.0	12.2	5.8
Dietary fiber (g)	9.2	4.6	4.2	2.9
Potassium (mg)	690	303	450	188
Magnesium (mg)	39.0	120	48	68
Vitamin C (mg)	12.0	0.0	1.4	0.6
Folate (mcg)	121	23	21	42
Vitamin B-6 (mg)	0.4	0.05	0.5	0.2
Niacin (mg)	2.6	1.5	0.6	0.5
Riboflavin (mg)	0.2	0.4	0.1	0.06
Thiamin (mg)	0.1	0.04	0.3	0.15
Pantothenic acid (mg)	2.0	0.1	0.2	0.2
Vitamin K (ug)	28.6	0.0	6.3	1.2
Vitamin E (α-Tocopherol) (mg)	2.7	10.1	0.9	0.3
γ-Tocopherol (mg)	0.44	0.3	9.0	8.9
Lutein + zeaxanthin (ug)	369	0.0	494	4.5
Total phytosterols (mg)	113	54	123	30

ADA, 2009). Avocados contain an oil rich in monounsaturated fatty acids (MUFA) in a water based matrix, which appears to enhance nutrient and phytochemical bioavailability and masks the taste and texture of the dietary fiber (USDA, 2011; Unlu et al., 2005). Avocados' are a medium energy dense fruit because about 80% of the avocado edible fruit consists of water (72%) and dietary fiber (6.8%) and has been shown to have similar effects on weight control as low-fat fruits and vegetables (USDA, 2011; Bes-Rastrollo et al., 2008). An analysis of adult data from the NHANES 2001–2006 suggests that avocado consumers have higher HDL-cholesterol, lower risk of metabolic syndrome, and lower weight, BMI, and waist circumference than nonconsumers (Fulgoni et al., 2010b). One avocado fruit (136 g) has nutrient and phytochemical profiles similar to 1.5 ounces (42.5 g) of tree nuts (almonds, pistachios, or walnuts), which have qualified heart health claims (FDA, 2003; 2004; USDA, 2011; and USDA and HHS, 2010b) (Table 2).

THE ROLE OF AVOCADO IN CARDIOVASCULAR HEALTH

Avocado Clinical Studies

There are eight preliminary avocado cardiovascular clinical trials summarized in Table 3 (Grant, 1960; Colquhoun et al., 1992; Alvizouri-Munoz et al., 1992; Lerman-Garber et al., 1994; Carranza et al., 1995; Lopez-Ledesma et al., 1996; Carranza-Madrigal et al., 1997; Pieterse et al., 2005).

The first exploratory avocado clinical study demonstrated that the consumption of 0.5–1.5 avocados per day may help to maintain normal serum total cholesterol in men (Grant, 1960). Half the subjects experienced a 9–43% reduction in serum total cholesterol and the other subjects (either diabetic or very hypercholesterolemic) experienced a neutral effect, but none of the subjects showed increased total cholesterol. Also, the subjects did not gain weight when the avocados were added to their habitual diet.

In the 1990s, a number of avocado clinical trials consistently showed positive effects on blood lipids in a wide variety of diets in studies on healthy, hypercholesterolemic, and type 2 diabetes subjects (Colquhoun et al., 1992; Alvizouri-Munoz et al., 1992; Lerman-Garber et al., 1994; Carranza et al., 1995; Lopez-Ledesma et al., 1996; Carranza-Madrigal et al., 1997). In hypercholesterolemic subjects, avocado enriched diets improved blood lipid profiles by lowering LDL-cholesterol and triglycerides and increasing HDL-cholesterol compared to high carbohydrate diets or other diets without avocado. In normolipidemic subjects, avocado enriched diets improved lipid profiles by lowering LDL-cholesterol without raising triglycerides or lowering HDL-cholesterol. These studies suggest that avocado enriched diets have a positive effect on blood lipids compared to low-fat, high carbohydrate diets or the typical American diet. However, since all these trials were of a small number of subjects (13–37 subjects) and limited duration (1–4 weeks), larger and longer term trials are needed to confirm avocado blood lipid lowering and beyond cholesterol health effects.

In a randomized crossover study of 12 women with type 2 diabetes, a monounsaturated fat diet rich in avocado was

Table 3 Avocado cardiovascular health clinical overview

Conclusions	Methods	Results	References
Daily addition of California avocados to the habitual diet showed a beneficial effect on total cholesterol (TC) and body weight control (Preliminary, uncontrolled study)	- Open label study for 4 weeks ($n = 16$) - Normal/hypercholesterolemic male patients in Veteran's Administration Hospital - 27–72 yrs old - 0.5–1.5 California avocados per day in addition to habitual diet	- 1/2 subjects had significantly lowered total cholesterol (TC) by 9–43% - 1/2 subjects had unchanged TC - No subjects had increased TC - 3/4 of subjects lost weight or remained weight stable despite an increase intake of calories and fat - Generally the subjects had a more regular bowel movement pattern	Grant, 1960
An avocado enriched diet (AE) was more effective than the AHA III diet in promoting heart healthy lipid profiles in women (Limited number of subjects and short duration)	- Randomized, crossover study for 3 weeks ($n = 15$) - Females w/ baseline total cholesterol (4–8 mm/L) - 37–58 years old - 66.8 ± 0.8 kg body weight - Two diets: (1) High MUFA primarily avocado diet (AE) or (2) High in complex carbohydrates low-fat diet (AHA III)	- Both diets decreased total cholesterol (TC) compared to baseline - Avocado diets were more effective in decreasing TC 8.2% vs. 4.9% - LDL-C decreased ($p < 0.05$) on AE but not AHA III diet - HDL-C did not change on AE but decreased by 13.9% on the AHA III ($p < 0.01$)	Colquhoun et al., 1992
Avocado enriched diets can help avoid potential adverse effects of low-fat diets on HDL-C and triglycerides (Well designed study but limited number of subjects and short duration)	- Randomized, crossover study for 2 weeks ($n = 16$) - Healthy subjects baseline total cholesterol 4.2 ± 0.68 mm/L; mean age 26 years; mean BMI 22.9 - Four diets: (1) Control, typical diet (2) MUFA fat diets with avocado (75% from Hass Avocados) (RMF) (3) Habitual diet plus same level of Hass avocados as (2) (FME) (4) Low-saturated diet (LSF)	- Both RMF and LSF diets had similar reductions in total cholesterol (TC) and LDL-C - Both FME and LSF diets had significantly lower TC, LDL-C and HDL-C ($p < 0.05$) - RMF and FME diets lowered triglycerides (TG) and the LSF diet had significantly increased TG levels ($p < 0.05$)	Alvizouri-Munoz et al., 1992
Partial replacement of avocados for other dietary fats in patients with type 2 diabetes favorably affected serum lipid profile and maintained adequate glycemic control (Well designed study but limited number of subjects)	- Randomized, crossover study for 4 weeks ($n = 12$) - Women with type 2 diabetes; mean 56 ± 8 years; BMI 28 ± 4 - Three diets (1) Control, American Diabetes Diet plan; 30% kcal from fat (ADA) (2) High MUFA diet with 1 avocado (Hass) and 4 teaspoons of olive oil; 40% kcal from fat (HMUFA) (3) High in complex carbohydrates 20% Kcal from fat (High-CHO)	- Both HMUFA and High-CHO diets had a minor hypo-cholesterolemic effect with no changes in HDL-C - HMUFA diet was associated with a greater decrease in triglycerides (20 vs. 7% for High-CHO) - Glycemic control was similar for both HMUFA and High CHO diets	Lerman-Garber et al., 1994
Diets rich in avocados appear to help manage hyper-cholesterolemia (Well designed study but limited number of subjects and level of avocado consumption very high)	- Randomized crossover for study 4 weeks with a controlled diet ($n = 16$) - Hyper-cholesterolemic subjects with phenotype II and IV dyslipidemias - Two diets: (1) Avocado rich diet (75% fat from avocado) diet (2) Low-saturated fat diet	The Avocado diet had significantly lowered total cholesterol, LDL-C levels, and increased HDL-C with a mild decrease in triglycerides compared the low-saturated fat diet plan	Carranza et al., 1995
Avocado-enriched diets had significantly improved lipoprotein and/or triglyceride profiles in normal and hyper-cholesterolemic subjects (Complex clinical design and very short duration)	- Randomized, controlled study for 7 days ($n = 67$) (1) Healthy normo-lipidemic subjects (<200 mg/dL) (2) Mild hyper-cholesterolemia and type 2 diabetic patients (201–400 mg/dL) - Enriched avocado diet vs. isocaloric non-avocado diets. 300 g Hass Avocado substituted for other lipid sources (both diets contained about 50% kcal from fat	- Subjects with normal cholesterol had a 16% decrease in serum total cholesterol following avocado diets vs. an increase in total cholesterol with the control ($p < 0.001$) - Subjects with elevated cholesterol had significant decrease ($p < 0.001$) total serum cholesterol (17%), LDL-C (22%), triglycerides (22%), and a slight increase in HDL-C - No changes with the non-avocado habitual diet	Lopez-Ledesma et al., 1996

(Continued on next page)

Table 3 Avocado cardiovascular health clinical overview *(Continued)*

Conclusions	Methods	Results	References
Vegetarian diets with avocados promote healthier lipoprotein profiles compared to low-fat and vegetarian diets without avocados (Preliminary study with limited number of subjects)	- Randomized, prospective, transversal and comparative 4 week study and controlled diet ($n = 13$) - Dyslipidemic subjects with high blood pressure - Three vegetarian diets: (1) 70% carbohydrate, 10% protein and 20% lipids (2) 60% carbohydrates, 10% protein and 30% lipids (75% of the fat from Hass avocados) (3) Diet 2 w/o avocado	The avocado diet significantly reduced LDL-C, whereas high carbohydrate and non-avocado diets did not change LDL-C	Carranza-Madrigal et al., 1997
The consumption of as much as 1 1/2 avocados within an energy-restricted diet does not compromise weight loss or lipoproteins or vascular function (Well designed study)	- Randomized, controlled, parallel study, free-living ($n = 61$) - Male ($n = 13$) and female ($n = 48$) adults with a age 40.8 ± 8.9 years; BMI 32 ± 3.9 - Energy restricted diet for 6 weeks at the rate of 30% kcal from fat - 200 g avocado/day (30.6 g fat) substituted for 30 g of mixed fat (e.g., margarine and vegetable oil) compared to a control diet without avocado	- There was no difference in body weight, BMI, and% body fat when avocados were substituted for mixed fats in an energy restricted diet - There was also no difference in serum lipids (total cholesterol, LDL-C, HDL-C, and triglycerides), fibrinogen, blood pressure, or blood flow when avocados were substituted for mixed fats in an energy-restricted diet	Pieterse et al., 2005

compared with a low-fat complex-carbohydrate-rich diet for effects on blood lipids (Lerman-Garber et al., 1994). After 4 weeks, the avocado rich diet resulted in significantly lowered plasma triglycerides and both diets maintained similar blood lipids and glycemic controls. Additionally, a preclinical study found that avocados can modify the HDL-C structure by increasing paraoxonase 1 activity (PON-1), which can enhance lipophilic antioxidant capacity and help convert oxidized LDL-C back to its nonoxidized form (Mendez and Hernandez, 2007).

Avocado Components Related to Cardiovascular Health

The following section is an assessment of avocado's many nutrients and phytochemicals (Table 1) with potential cardiovascular health benefits. Avocados have a similar composition profile to that of tree nuts, which have a heart health claim, with less than half the calories (USDA, 2011) (Table 2).

Fatty Acids

Avocados can fit into a heart healthy dietary pattern such as the DASH diet plan (USDA and HHS, 2010a; Jakobsen et al., 2009; de Souza et al., 2008; Appel et al., 2005). Avocados contain a monounsaturated fatty acids (MUFA)-rich fruit oil with 71% MUFA, 13% polyunsaturated fatty acids (PUFA), and 16% saturated fatty acids (SFA). As the avocado fruit ripens, the saturated fat decreases and the monounsaturated oleic acid increases (Lu et al., 2009; Slater et al., 1975; Moreno et al., 1980). The use of avocado dips and spreads as an alternative to more traditional hard, SFA rich spreads or dips can assist in lowering dietary SFA intake (Avocado Central, 2012).

Carbohydrates

Dietary Fiber

Avocado fruit carbohydrates are composed of about 80% dietary fiber, consisting of 70% insoluble and 30% soluble fiber (Marlett and Cheung, 1997). Avocados contain 2.0 g and 4.6 g of dietary fiber per 30 g and one-half fruit, respectively (USDA, 2011). Thus, moderate avocado consumption can help to achieve the adequate intake of 14 g dietary fiber per 1000 kcal as about one-third this fiber level can be met by consuming one-half an avocado.

Sugars

Compared to other fruits, avocados contain very little sugar (USDA, 2011). One-half an avocado contains only about 0.2 g sugar (e.g., sucrose, glucose, and fructose). The primary sugar found in avocados is a unique seven-carbon sugar called D-mannoheptulose and its reduced form, perseitol, contributes about 2.0 g per one-half fruit but this is not accounted for as sugar in compositional database as it does not behave nutritionally as conventional sugar and is more of a unique phytochemical to avocados (Meyer and Terry, 2008; Shaw et al., 1980). Preliminary D-mannoheptulose research suggests that it may support blood glucose control and weight management (Roth, 2009). The glycemic index and load of an avocado is expected to be about zero.

Minerals

Potassium

Clinical evidence suggests that adequate potassium intake may promote blood pressure control in adults (USDA and HHS, 2010b). The mean intake of potassium by adults in the United States was approximately 3200 mg per day in men and 2400 mg per day in women, which is lower than the 4700 mg per day recommended intake (USDA and HHS, 2010b; IOM, 2005). Avocados contain about 152 mg and 345 mg of potassium per 30 g and one-half fruit, respectively. Also, avocados are naturally very low in sodium with just 2 mg and 5.5 mg sodium per 30 g and one-half fruit, respectively (USDA, 2011). The health claim for blood pressure identifies foods containing 350 mg potassium and less than 140 mg of sodium per serving as potentially appropriate for this claim (FDA, 2000).

Magnesium

Magnesium acts as a cofactor for many cellular enzymes required in energy metabolism, and it may help support normal vascular tone and insulin sensitivity (IOM, 1997). Preliminary preclinical and clinical researches suggest that low magnesium may play a role in cardiac ischemia (IOM, 1997). In the Health Professionals Follow-up Study, the results suggested that the intake of magnesium had a modest inverse association with risk of coronary heart disease in men (Al-Delaimy et al., 2004). Magnesium was shown to inhibit fat absorption to improve postprandial hyperlipidemia in healthy subjects (Kishimoto et al., 2009). Avocados contain about 9 and 20 mg magnesium per 30 g and one-half fruit, respectively (USDA, 2011).

Vitamins

Antioxidant Vitamins

Avocados are one of the few foods that contain significant levels of both vitamins C and E. Vitamin C plays an important role in recycling vitamin E to maintain circulatory antioxidant protection such as potentially slowing the rate of LDL-cholesterol oxidation. Evidence suggests that vitamin C may contribute to vascular health and arterial plaque stabilization (IOM, 2000). According to a recent review article, vitamin C might have greater CVD protective effects on specific populations such as smokers, obese, and overweight people; people with elevated cholesterol, hypertension, and type 2 diabetics; and people over 55 years of age (Honarbakhsh and Schachter, 2009). Avocado fruit contains 2.6 mg and 6.0 mg vitamin C per 30 g and one-half fruit, respectively (USDA, 2011). Avocados contain 0.59 mg and 1.34 mg vitamin E (α-tocopherol) per 30 g and one-half avocado, respectively (USDA, 2011). One randomized clinical study suggested that a combination of vitamin C and E may slow atherosclerotic progression in hypercholesterolemic persons (Salonen et al., 2003).

Vitamin K_1 (phylloquinone)

Vitamin K_1 functions as a coenzyme during synthesis of the biologically active form of a number of proteins involved in blood coagulation and bone metabolism (IOM, 2001). Phylloquinone (K_1) from plant-based foods is considered to be the primary source of vitamin K in the human diet. Vitamin K_1 in its reduced form is a cofactor for the enzymes that facilitate activity for coagulation (McCann and Ames, 2009). The amount of vitamin K_1 found in avocados is 6.3 μg and 14.3 μg per 30 g and one-half fruit, respectively (USDA, 2011). Some people on anticoagulant medications are concerned about vitamin K intake; however, the avocado level of vitamin K_1 per ounce is 150 times lower than the 1000 μg of K_1 expected to potentially interfere with the anticoagulant effect of drugs such as warfarin (Coumadin) (Crowther et al., 1998; Dismore et al., 2003).

B-vitamins

Deficiencies in B-vitamins such as folate and B-6 may increase homocysteine levels, which could reduce vascular endothelial health and increase CVD risk (IOM, 1998; Antoniades et al., 2009). Avocados contain 27 μg folate and 0.09 mg vitamin B-6 per 30 g and 61 μg folate, respectively, and 0.20 mg vitamin B-6 per one-half fruit (USDA, 2011).

Phytochemicals

Carotenoids

The primary avocado carotenoids are a subclass known as xanthophylls, oxygen-containing fat-soluble antioxidants (Voutilainen et al., 2006) (USDA, 2011) (Table 1). Xanthophylls, such as lutein, are more polar than carotenes (the other carotenoid subclasses including β-carotene), so they have a much lower propensity for pro-oxidant activity (McNulty et al., 2008). Avocados have the highest lipophilic total antioxidant capacity among fruits and vegetables (Wu et al., 2004). In a relatively healthy population, the DASH diet pattern clinical study reported reduced oxidative stress (blood ORAC and urinary isoprostanes) compared to a typical American diet (Miller et al., 2005), which appears primarily due to the DASH diet providing significantly more serum carotenoids, especially the xanthophyll carotenoids lutein, β-cryptoxanthin, and zeaxanthin, as a result of increased fruit and vegetable consumption. Xanthophylls appear to reduce circulating oxidized LDL-C, a preliminary biomarker for the initiation and progression of vascular damage (Hozawa et al., 2007). The Los Angeles Atherosclerosis Study, a prospective study, findings suggest that higher levels of plasma xanthophylls were inversely related to the progression of carotid intima-media thickness, which may be protective against early atherosclerosis (Dwyer et al., 2001, 2004). Although this research is encouraging, more clinical studies are needed to understand the cardiovascular health benefits associated with avocado carotenoids.

The consumption of avocados can be an important dietary source of xanthophyll carotenoids (Lu et al., 2005; 2009). Hass avocado carotenoid levels tend to significantly increase as the harvest season progresses from January to September (Lu et al., 2009). In Hass avocados, xanthophylls lutein and cryptoxanthin predominate over the carotenes, contributing about 90% of the total carotenoids (Lu et al., 2009). USDA reports lutein and zeaxanthin at 81 μg and 185 μg per 30 g and one half fruit, respectively, and cryptoxanthin at 44 μg and 100 μg per 30 g and one-half fruit, respectively (USDA, 2011). However, a more comprehensive analysis of avocados including xanthophylls has found much higher levels ranging from 350–500 μg per 30 g to 800–1100 μg per one-half fruit at time of harvest (Lu et al., 2009). The color of avocado flesh varies from dark green just under the skin to pale green in the middle section of the flesh to yellow near the seed (Lu et al., 2009). The total carotenoid concentrations were found to be greatest in the dark green flesh close to peel (Lu et al., 2005).

The intestinal absorption of carotenoids depends on the presence of dietary fat to solubilize and release carotenoids for transfer into the gastrointestinal fat micelle and then the circulatory system (Reboul et al., 2007; Ashton et al., 2006). Avocado fruit has a unique unsaturated oil and water matrix naturally designed to enhance carotenoid absorption. For salads, a significant source of carotenoids, reduced fat or fat free salad dressings are common in the marketplace and these dressings have been shown to significantly reduce carotenoid absorption compared to full fat dressings (Brown et al., 2004). Similar clinical research has demonstrated that adding avocado to salad without dressing, or with reduced fat/fat free dressing and serving avocados with salsa increases carotenoid bioavailability by 2–5 times (Unlu et al., 2005).

Phenolics

Preliminary evidence suggests beneficial effects of fruit phenolics on reducing CVD risk by reducing oxidative and inflammatory stress, enhancing blood flow and arterial endothelial health, and inhibiting platelet aggregation to help maintain vascular health (Chong et al., 2010; Arts and Hollman, 2005; Ghosh and Scheepens, 2009; Victor et al., 2009). Avocados contain a moderate level of phenolic compounds contributing 60 mg and 140 mg gallic acid equivalents (GAE) per 30 g and one-half fruit, respectively. The avocado also has a total antioxidant capacity of 600 μmol Trolox Equilvalent (TE) per 30 g or 1350 μmol TE per one-half fruit (Wu et al., 2004; 2007). This places avocados in the mid-range of fruit phenolic levels. Avocados have the highest fruit lipophilic antioxidant capacity, which may be one factor in helping to reduce serum lipid peroxidation and promoting vascular health (Wu et al., 2007).

Phytosterols

Avocados are the richest known fruit source of phytosterols (Duester, 2001) with about 26 mg and 57 mg per 30 g and one half fruit, respectively (USDA, 2011). Other fruits contain substantially less phytosterols at about 3 mg per serving (Duester, 2001). Although the avocado's phytosterol content is lower than that of fortified foods and dietary supplements, its unique emulsified fat matrix and natural phytosterol glycosides may help promote stronger intestinal cholesterol blocking activity than fortified foods and supplements (Lin et al., 2009). A recent economic valuation in Canada of the potential health benefits from foods with phytosterols suggests that they may play a role in enhancing cardiovascular health and reducing associated health costs (Gyles et al., 2010).

WEIGHT MANAGEMENT

The availability and consumption of healthy foods, including vegetables and fruits, is associated with lower weight (Bes-Rastrollo et al., 2008) and body mass index (BMI) (de Oliveira et al., 2008). Over the last several decades, there has been the general perception that consuming foods rich in fat can lead to weight gain, and low-fat diets would more effectively promote weight control and reduce chronic disease risk (Walker and O'Dea, 2001). However, a key large, randomized, long-term clinical trial found that a moderate fat diet can be an effective part of a weight loss plan and the reduction of chronic disease risk (Sacks et al., 2009). "Strong and consistent evidence indicates that dietary patterns that are relatively low in energy density improve weight loss and weight maintenance among adults" (USDA and HHS, 2010c). Three randomized controlled weight loss trials found that lowering food-based energy density by increasing fruit and/or vegetable intake is associated with significant weight loss (de Oliveira et al., 2008; Saquib et al., 2008; Ello-Martin et al., 2007). The energy density of an entire dietary pattern is estimated by dividing the total amount of calories by the total weight of food consumed; low, medium, and high energy density diets contain 1.3 kcal, 1.7 kcal, and 2.1 kcal per g, respectively (Savage et al., 2008). Avocados have both a medium energy density of 1.7 kcal/g and a viscose water, dietary fiber and fruit oil matrix that appears to enhance satiety (Wien et al., 2011). This is consistent with research by Bes-Rastrollo et al. (2008), which suggests that avocados support weight control similar to other fruits.

Several preliminary clinical studies suggest that avocados can support weight control. The first trial studied the effect of including one and a half avocados (200 g) in a weight loss diet plan. In this study, sixty-one healthy free-living, overweight, and obese subjects were randomly assigned into either a group consuming 200 g/d of avocados (30.6 g fat) substituted for 30 g of mixed fats, such as margarine and oil, or a control group excluding avocados for 6 weeks (Pieterse et al., 2005). Both groups lost similar levels of weight, body mass index (BMI), and percentage of body fat ($p < 0.001$) to confirm that avocados can fit into a weight loss diet plan. A randomized single blinded, crossover postprandial study of 26 healthy overweight adults suggested that one-half an avocado consumed at lunch significantly reduced self-reported hunger and desire to eat, and increased satiation as compared to the control meal ($p < 0.002$) (Wien et al., 2011). Additionally, several exploratory trials suggest that MUFA rich diets help protect against abdominal fat accumulation and diabetic health complications (Tentolouris et al., 2008; Paniagua et al., 2007a; 2007b).

HEATHY AGING

DNA Damage Protection

Several clinical studies suggest that xanthophylls, similar to those found in avocados, may have antioxidant and DNA protective effects with possible healthy aging protective effects. One study was conducted involving 82 male airline pilots and frequent air travelers who are exposed to high levels of cosmic ionizing radiation known to damage DNA, potentially accelerating the aging process (Yong et al., 2009). There was a significant and inverse association between intake of vitamin C, beta-carotene, β-cryptoxanthin, and lutein-zeaxanthin from fruits and vegetables and the frequency of chromosome translocation, a biomarker of cumulative DNA damage ($p < 0.05$). In another trial, lipid peroxidation (8-epiprostaglandin F2a) was correlated inversely with plasma xanthophyll levels (Haegele et al., 2000). In other studies, inverse correlations were found between lutein and oxidative DNA damage as measured by the comet assay, and in contrast to beta-carotene (Hughes et al., 2009; Thomson et al., 2007). NHANES analysis suggests that xanthophylls intake decreases with aging (Johnson et al., 2010).

Osteoarthritis

Osteoarthritis (OA) is characterized by progressive deterioration of joint cartilage and function with associated impairment, and this affects most people as they age or become overweight or obese (Dinubile, 2010; Helmick et al., 2008). This joint deterioration may be triggered by oxidative and inflammation stress, which can cause an imbalance in biosynthesis and degradation of the joint extracellular matrix leading to loss of function (Dinubile, 2010; Gabay et al., 2008; Jacques et al., 2006; Goldring and Berenbaum, 2004; van der Kraan and van den Berg, 2000; Lotz et al., 1995). A cross-sectional study reported that fruits and vegetables rich in lutein and zeaxanthin (the primary carotenoids in avocados) are associated with decreased risk of cartilage defects (early indicator of OA)(Wang et al., 2007).

Avocado and soy unsaponifiables (ASU) is a mixture of fat soluble extracts in a ratio of about 1(avocado):2(soy). The major components of ASU are considered anti-inflammatory compounds with both antioxidant and analgesic activities (Dinubile, 2010; Lipiello et al., 2008; Au et al., 2007; Henroitin et al., 2006; Berenbaum, 2004; Ernst, 2003; Blotman et al., 1997). In vitro studies found that pretreatment of chondrocytes with ASU blocked the activation of COX-2 transcripts and secretion of prostaglandin E_2 (PGE_2) to baseline levels after activation with lipopolysaccharide (LPS). Further study revealed that ASU can also block tumor necrosis factor-α (TNF-α), IL-1β, and iNOS expression to levels similar to those in nonactivated control cultures. Additional laboratory studies suggest that ASU may facilitate repair of OA cartilage through its effect on osteoblasts (Dinubile, 2010).

Clinical support for ASU in the management of hip and knee OA comes from four randomized controlled trials (Lequesne et al., 2002; Appelboom et al., 2001; Maheu et al., 1998; Blotman et al., 1997) and one meta-analysis (Christensen et al., 2008). All studies used 300 mg per day. The clinical trials were generally positive with three providing OA support and one study showing no joint cartilage improvement compared to placebo.

Eye Health

Lutein and zeaxanthin are selectively taken up into the macula of the eye (the portion of the eye where light is focused on the lens) (Caepentier et al., 2009). Relative intakes of lutein and zeaxanthin decrease with age and the levels are lower in females than males (Johnson et al., 2010). Mexican Americans have the highest intake of lutein and zeaxanthin than any other ethnicity and they are among the highest consumers of avocados in the United States. Observational studies show that low dietary intake and plasma concentration of lutein may increase age-related eye dysfunction ((Ma et al., 2009; Parekh et al., 2009; Chong et al., 2009; Moeller et al., 2008; Cho et al., 2008; Wang et al., 2007). Research from the Women's Health Initiative Observation Study found that MUFA rich diets were protective of age-related eye dysfunction (Chong et al., 2009; Moeller et al., 2008). Avocados may contribute to eye health since they contain a combination of MUFA and lutein/zeaxanthin and help improve carotenoid absorption from other fruits and vegetables (Unlu et al., 2005). Avocados contain 185 μg of lutein/zeaxanthin per one-half fruit, which is expected to be more highly bioavailable than most other fruit and vegetable sources.

Skin Health

Skin often shows the first visible indication of aging. Topical application or consumption of some fruits and vegetables or their extracts such as avocado has been recommended for skin health (Roberts et al., 2009; Morganti et al., 2002; 2004). The facial skin is frequently subjected to ongoing oxidative and inflammatory damage by exposure to ultraviolet (UV) and visible radiation and carotenoids may be able to combat this damage. A clinical study found that the concentration of carotenoids in the skin is directly related to the level of fruit and vegetable intake (Rerksuppaphol and Rerksuppaphol, 2006). Avocado's highly bioavailable lutein and zeaxanthin may help to protect the skin from damage from both UV and visible radiation (Roberts et al., 2009). Several small studies suggest that topical or oral lutein can provide photo-protective activity (Puizina, 2008; Palombo et al., 2007; Morganti et al., 2002).

A cross-sectional study examined the relationship between skin anti-aging and diet choices in 716 Japanese women (Nagata et al., 2010). After controlling for covariates including age, smoking status, BMI, and lifetime sun exposure, the results showed that higher intakes of total dietary fat were significantly associated with more skin elasticity. A higher intake of green and yellow vegetables was significantly associated with fewer wrinkles (Nagata et al., 2010). Several preclinical studies suggest that avocado components may protect skin health by enhancing wound healing activity and reducing UV damage (Nayak et al., 2008; Rosenblat et al., 2011).

Cancer

Avocados contain a number of bioactive phytochemicals including carotenoids, terpenoids, D-mannoheptulose, persenone A and B, phenols, and glutathione that have been reported to have anti-carcinogenic properties (Ding et al., 2009; Jones et al., 1992; Ames, 1983). The concentrations of some of these phytochemicals in the avocado may be potentially efficacious (Jones et al., 1992). Currently, direct avocado anti-cancer activity is very preliminary with all data based on in vitro studies on human cancer cell lines.

Cancer of the larynx, pharynx, and oral cavity are the primary area of avocado cancer investigation. Glutathione, a tripeptide composed of three amino acids (glutamic acid, cysteine, and glycine) functions as an antioxidant (Flagg et al., 1994). The National Cancer Institute found that avocado's glutathione levels of 8.4 mg per 30 g or 19 mg per one-half fruit is several fold higher than that of other fruits (Flagg et al., 1994). Even though the body digests glutathione down to individual amino acids when foods are consumed, a large population-based case controlled study showed a significant correlation between increased glutathione intakes and decreased risk of oral and pharyngeal cancer (Castillo-Juarez et al., 2009). One clinical study found that plasma lutein and total xanthophylls but not individual carotenes or total carotenes reduced biomarkers of oxidative stress (urinary concentrations of both total F2-isoprostanes and 8-epi-prostaglandin) in patients with early-stage (in situ, stage I, or stage II) cancer of larynx, pharynx, or oral cavity (Hughes et al., 2009). Xanthophyll rich avocado extracts have been shown in preclinical studies to have anti-Helicobacter pylori activity for a potential effect on gastritis ulcers, which may be associated with gastric cancer risk (Castillo-Juarez et al., 2009).

Dietary carotenoids show potential breast cancer protective biological activities, including antioxidant activity, induction of apoptosis, and inhibition of mammary cell proliferation (Thomson et al., 2007). Studies examining the role of fruits and vegetables and carotenoid consumption in relation to breast cancer recurrence are limited and report mixed results (Thomson et al., 2007). In preclinical studies, total carotenoids and lutein appear to reduce oxidative stress, a potential trigger for breast cancer (Ding et al., 2007). In women previously treated for breast cancer, a significant inverse association was found between total plasma carotenoid concentrations and oxidative stress (Thomson et al., 2007), but more clinical research is needed to confirm this finding.

Mammographic density is one of the strongest predictors of breast cancer risk (Tamimi et al., 2009). The association between carotenoids and breast cancer risk as a function of mammographic density was conducted in a nested, case-control study consisting of 604 breast cancer cases and 626 controls with prospectively measured circulating carotenoid levels and mammographic density in the Nurses' Health Study (Tamimi et al., 2009). Overall, circulating total carotenoids were inversely associated with breast cancer risk ($p = 0.01$). Among women in the highest tertile of mammographic density, elevated levels α-carotene, β-cryptoxanthin, lycopene, and lutein/zeaxanthin in the blood were associated with a 40–50% reduction in breast cancer risk ($p < 0.05$). In contrast, there was no inverse association between carotenoids and breast cancer risk among women with low-mammographic density. These results suggest that plasma levels of carotenoids may play a role in reducing breast cancer risk, particularly among women with high mammographic density. There are no direct avocado breast cancer clinical studies.

Exploratory studies in prostate cancer cell lines suggest antiproliferative and antitumor effects of avocado lipid extracts (Lu et al., 2005). Lutein is one of the active components identified. There are currently no human studies to confirm this potential lutein and prostate cancer relationship.

CONCLUSIONS

In the context of a healthy diet, consumption of avocados can fit into a full range of healthy eating plans (e.g., DASH diet plan). According to NHANES data, the average avocado consumption is one-half fruit, which provides for a nutrient and phytochemical dense food consisting of significant levels of the following: dietary fiber, potassium, magnesium, vitamin A, vitamin C, vitamin E, vitamin K_1, folate, vitamin B-6, niacin, pantothenic acid, riboflavin, choline, lutein/zeaxanthin, phytosterols, and MUFA rich oil at 1.7 kcal/g. This caloric density is medium-low because an avocado is about 80% by weight is water (72%) and dietary fiber (6.8%). Unlike the typical fruit, avocados contain a very low sugar content with only about 0.2 g sugar per one-half fruit. There are eight preliminary avocado cardiovascular health clinical studies that have consistently demonstrated positive heart healthy effects on blood lipids profiles. This is primarily because of avocado's low SFA and high-unsaturated fatty acids (MUFA and PUFA) content, but its natural phytosterols and dietary fiber may play potential secondary cholesterol lowering roles. Avocados also have a diverse range of other nutrients and phytochemicals that may have beyond cholesterol vascular health benefits. In particular, avocado's potassium and lutein may help promote normal blood pressure and help to control oxidative/inflammatory stress, respectfully. The consumption of avocados with salads or salsa increases the bioavailability of carotenoids multi-fold, which may add to the potential health benefits. More comprehensive avocado clinical research is underway to significantly expand the scientific understanding of avocados in cardiovascular health, weight management, blood glucose control and healthy living.

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