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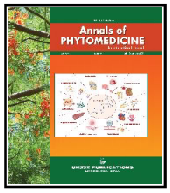

Review Article : Open Access

Exploring the bioactive components and their pharmacological prospects in Avocado (*Persea americana* Mill.)

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Abstract

Avocado (*Persea americana* Mill.) has had considerable attention in recent years due to the presence of valuable bioactive compounds with potential health benefits. The bioactive constituents of avocados encompass a diverse range of compounds, including monounsaturated fatty acids (MUFA), polyphenols, vitamins, and minerals. These constituents have been studied for their antioxidant, anti-inflammatory, antimicrobial, and cardioprotective properties. Notably, fatty acid (oleic, linoleic, palmitic, palmitoleic, linolenic), the primary MUFA in avocado, has been linked to improved cardiovascular health and lipid metabolism. Polyphenols, such as flavonoids and phenolic acids (coumaric acid, epicatechin, quercetin), contribute significantly to the antioxidant capacity of avocados. These compounds exhibit potential anticancer properties by modulating cell signaling pathways and inhibiting tumor growth. Moreover, avocado-derived phytosterols (sitosterol, campesterol, avenasterol, stigmasterol) and phytosterols (cycloartenol, sitostanol, campestanol) have shown promising effects in mitigating inflammatory responses and oxidative stress, thereby offering therapeutic potential in inflammatory diseases and age-related disorders. Avocado also serves as a rich source of vitamins, particularly vitamin E and vitamin C, which play crucial roles in immune function and skin health. Additionally, minerals like potassium and magnesium contribute to the regulation of blood pressure and muscle function, highlighting the multifaceted pharmacological benefits of avocado consumption. This review aims to provide a comprehensive exploration of the bioactive components in avocados and their pharmacological prospects.

1. Introduction

Avocado (*Persea americana* Mill.), a widely known fruit appreciated for its smooth texture and flavorful taste, has become incredibly popular. Besides its culinary qualities, people also value the excellent nutrition and potential health advantages of avocado. It is originated from Central and South America and has been grown for many years. Throughout history, different cultures have used avocados for their health benefits (Popenoe, 1935; Smith, 1966). This has increased the interest primarily from the presence of various beneficial bioactive compounds in avocados (Kosinìska *et al.,* 2012; Lu *et al.,* 2009; Wang *et al.,* 2010). It have been well studied and have demonstrated exceptional antioxidant qualities that are advantageous for the therapeutic effect in reducing a number of medical ailments (Chellammal, 2022).

However, it is primarily known for its high lipid content, consisting mostly of unsaturated fatty acids, which are linked to various health benefits (Yahia and Woolf, 2011). Additionally, the avocado contains polar lipids like glycolipids and essential phospholipids, particularly found in cell membranes (Araújo *et al.,* 2018).The avocado seed is often discarded during the processing of the fruit pulp, posing potential ecological concerns. However, it also gives an opportunity for the industry as a source of valuable bioactive compounds. Chemical compounds of avocado seeds includes, phytosterols, fatty acids, triterpenes, and two newly discovered glucosides of abscisic acid. The avocado seed has been found to exhibit various biological activities, including antihypertensive, antioxidant, fungicidal, hypolipidemic, larvicidal, and more recently, giardicidal and amoebicidal activities (Noorul *et al.,* 2016).

The avocado seed and peel contain significant amounts of extractable bioactive compounds, such as polyphenols. These compounds are well-known for their bioactivity and have potential applications in various fields (Calderón-Oliver *et al.,* 2016; Rodríguez-Carpena *et al.,* 2011; Wang *et al.,* 2010), found that the avocado peel and seed have much higher phenolic content compared to the pulp. Hence, these by-products hold promise as cost-effective sources for extracting phenolic compounds, which could be utilized in pharmaceuticals, cosmetics and food industries as bioactive ingredients.

Avocado oil, renowned for its abundance in omega fatty acids beneficial for human health, particularly in preventing cardiovascular diseases, is increasingly favored for incorporation into human food products (Salgado *et al.,* 2008). Nevertheless, in Brazil, a small portion of avocado oil is utilized in its raw, unsaponifiable form by the pharmaceutical and cosmetic industries due to its notable epidermal regenerative properties (Duarte *et al.,* 2016). Avocado by-products contains significant amounts of carbohydrates, lipids, proteins, fibers, minerals, and various bioactive compounds (Araújo *et al.,* 2018).

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These include hydroxycinnamic acids, hydroxybenzoic acids, organic acids, phenolic-alcohol derivatives, flavonoids, proanthocyanidins, terpenoids, alkaloids, saponins, acetogenins, phytosterols, and other polar and non-polar compounds that have been identified. Meta-analysis of the polyphenols, carotenoids, fatty acids, and vitamins present in different avocado portions provided detailed information about the distribution and changes in these chemicals between avocado kinds and regions. This allows us to quickly determine whether avocados have their bioactive component, their possible health benefits, and recommendations for future research and nutrition. Understanding the presence and pharmacological potential of bioactive compounds in avocados, it is crucial for exploring their therapeutic applications (Mahmassani, 2018). The health benefits of avocado are shown in the Figure 1.

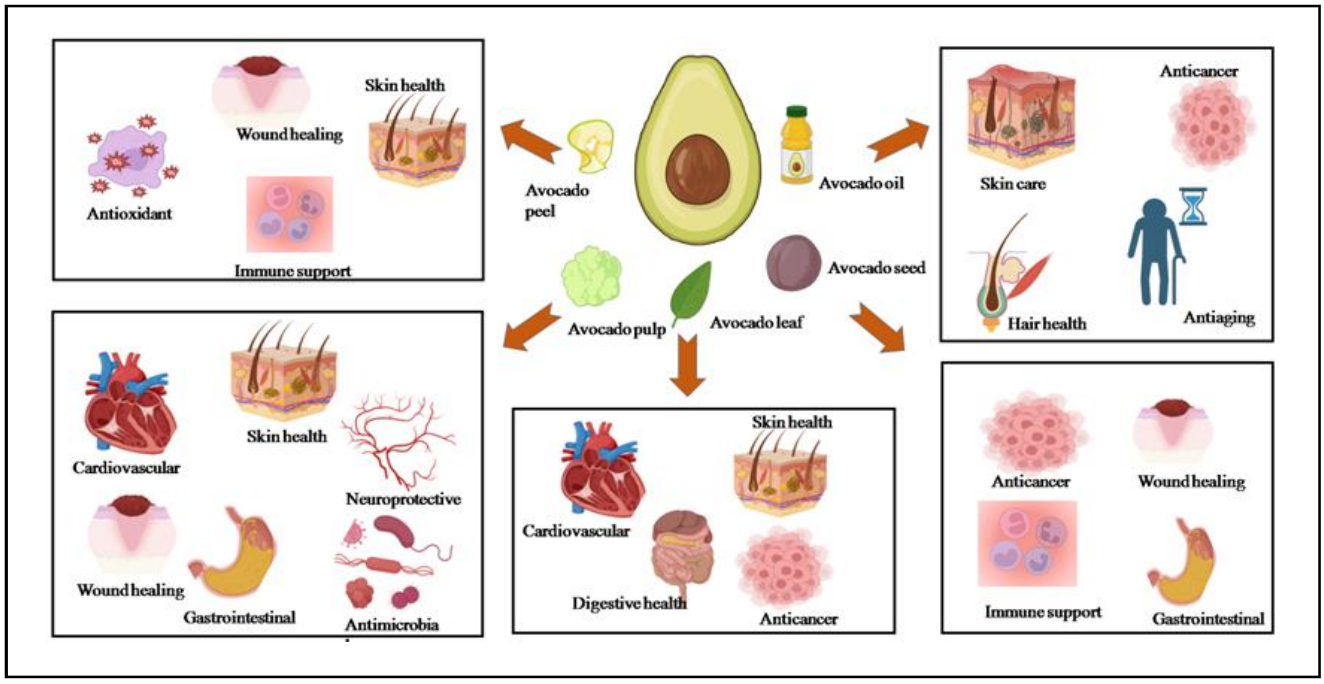


Figure 1: Health benefits of avocado.

2. Geographical distribution of avocado

The avocado tree originally comes from Central America and southern Mexico. Its center of origin is in central Mexico, extending through Guatemala into Central America, where it was first cultivated around 500 B.C. Avocados are tropical fruits known for their pear shape, blackish-green color, creamy texture, and high nutritional value (Smith, 1966). There are three main types of avocados: Mexican, Guatemalan and West Indian. The Mexican type, found in Mexico and mountains of Central America, produces small fruits (75 to 300 g) with thin, smooth skin and high oil content. The Guatemalan type, native to highlands of Central America, has larger fruits (500 to 600 g) with thick, brittle skin and moderate oil content, but it does not tolerate cold temperatures as the Mexican type. The West Indian type, from the lowlands of Central America and northern South America, has fruits of intermediate size with smooth, leathery, and sometimes glossy skin and lower oil content.

Avocado trees do not go dormant, but their activity slows down in winter compared to spring and summer. Frost can damage the fruit, buds, and leaves, with temperatures near or below freezing being particularly harmful. Among the three types, the West Indian avocado is most sensitive to cold, while the Mexican avocado is the most cold-tolerant. Apart from the three land races, hybrids between two races also available for commercial cultivation and being cultivated in many parts of the globe especially in the warm humid tropics.

3. Biochemical composition of avocado

Avocado pulp and seed contains minerals such as oxygen (76.88-78.45 mg/100 g), sodium (51.47-52.56 mg/100 g), magnesium (40.77-42.60 mg/100 g), potassium (28.02-30.23 mg/100 g), calcium (27.13-29.97 mg/100 g), phosphorus (31.63-35.50 mg/100 g), carbon (17.29-17.90 mg/100 g), iron (12.01-12.07 mg/100 g), nitrogen (4.13-5.25 mg/100 g), zinc (7.23-7.25 mg/100 g), hydrogen (0.65-0.70 mg/100 g), sulphur (0.04-0.06 mg/100 g) while silicon, aluminum and chlorine was not detected. Proximate composition analysis revealed that, the seed of avocado are high in carbohydrate (49.01-49.05 g/100 g), lipid (17.76-18.04 g/100 g), protein (15.19-15.91 g/100 g), moisture (15.00-15.24 g/100 g), and ash (2.03-2.49 g /100 g). The seed also contain total oxalate (14.95-15.01mg/100 g) Figures 2, 3. Levels of tannin (6.94-7.02 mg/100 g) and phytic acid (3.02-3.34 mg/100 g) are low (Ejiofor *et al.,* 2018).

Oleic acid contains 50 and 65% of the total fatty acids. A study of the unsaponifiable fraction revealed that avocado oil has 113.13–332.17 mg/kg tocopherols and 3259.9-5378.8 mg/kg sterols. High percentage of oleic acid (61.18%) in oil was obtained from the variety Reed; besides, a higher content of tocopherol (332.17 mg/kg) and sterol (5378.80 mg/kg) was obtained from the variety Fuerte (Nasri *et al.,* 2021).

The main components of the peel and stone were acid-insoluble lignin (35.0% and 15.3%, respectively), aqueous extractives (15.5% and 16.9%, respectively) and polymeric sugars (23.6% and 43.9%,

respectively). Both contains lipids and protein, but in lesser proportion (<6%). The valorization of lignin and sugars is of interest given the high content; stones are a rich source of glucose (93.2% of the polymeric fraction), which could be used to obtain biofuels or derivatives of interest. The extractive fraction of the peel contained the highest number of phenolic compounds (4.7 g/100 g biomass), mainly concentrated in the aqueous fraction (*i.e.,* 87%) compared to the ethanol, which was subsequently extracted (García-Vargas *et al.,* 2020). Biochemical and proximate composition present in different avocado varieties are expressed in Table 1 and Figure 2, respectively.

Table 1: Biochemical composition of different varieties of avocado

Avocado variety	Crude fiber (%)	Crude protein (%)	Lipid (%)	MU FA (%)	PUFA (%)	Beta carotene (mg/100 g)	Reference
Hass	6.60	2.67	15.41	12.00	2.00	0.02	Dreher and Davenport, 2013
Fuerte	6.70	2.54	14.66	13.00	2.50	1.02	Jimenez *et al.,* 2021
Reed	6.50	2.79	16.47	12.50	3.00	0.02	
Bacon	6.90	2.35	14.66	13.00	2.30	0.02	
Zutano	6.60	2.78	14.21	12.50	2.80	0.02	
Ouro Verde	5.01	2.78	13.14	10.50	2.00	0.68	Mardigan *et al.,* 2018
Breda	5.12	2.80	13.65	9.50	1.80	0.28	
Quintal	5.20	2.08	13.71	11.00	2.00	0.56	
Margarida	5.70	2.86	13.35	11.50	2.20	0.61	
Choquette	5.45	2.08	13.11	10.00	1.90	0.28	

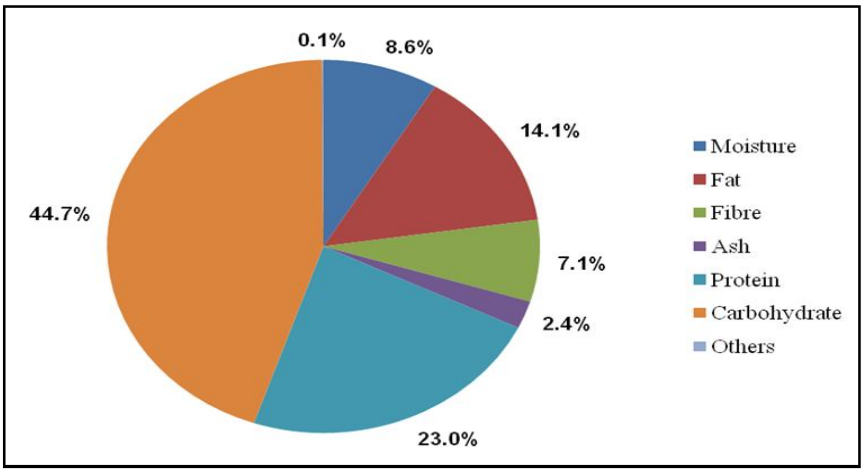


Figure 2: Composition of proximate in avocado seed.

4. Bioactive compounds of avocado

The main bioactive compounds found in avocado are carotenoids, polyphenols, tocopherols and tocotrienols, phytosterols and phytostanols, fatty acid, vitamins, fiber, acetogenins, organic acid and sugars (Mardigan *et al.,* 2018). The bioactive compounds of avocado and their structures are sourced from PubChem (PubChem, 2024) Table 2 .

4.1 Carotenoids

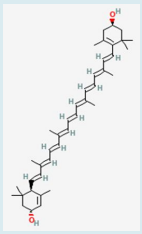
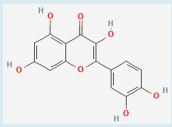
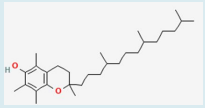
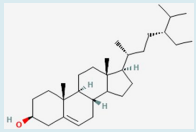
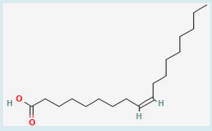
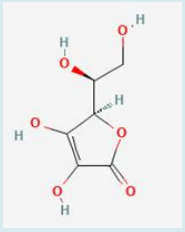
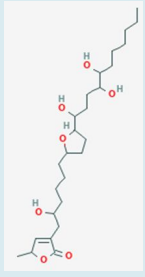
Lutein is the main yellow pigment found in avocado pulp, along with other carotenoids like β-cryptoxanthin, zeaxanthin, β-carotene, and β-carotene. Lutein, part of the xanthophyll family of carotenoids, is famous for its role in keeping our eyes healthy by shielding them from age-related macular degeneration and cataracts. Avocados are a good source of lutein (0.001-0.004 g/kg), especially in the dark green part of the flesh closest to the peel (Scott *et al.,* 2017). Zeaxanthin contains (0.0002 g/kg), another carotenoid like lutein, also helps maintain eye health by blocking harmful blue light and guarding against oxidative stress. Both lutein and zeaxanthin help to protect the eyes from issues like cataracts and age-related macular degeneration. Carotenoids also shield the skin from damage caused by the sun, and some of them (like β-carotene (0.0005-0.0008 g/kg), β-carotene (0.0002-0.0003 g/kg), and γ-cryptoxanthin (0.0002-0.0003 g/kg)) are converted into vitamin A, which is good for our overall health (Ramos-Aguilar *et al.,* 2019). The composition of carotenoids in avocado pulp is expressed in Figure 3.

4.2 Polyphenols

Avocados have various polyphenols, which are special nutrients found in plants with antioxidant properties. Among these are flavonoids like quercetin, kaempferol, and myricetin, which help fight against harmful free radicals in the body, reducing inflammation and oxidative stress (Mustarichie and Runadi, 2021). Avocados also contain phenolic acids such as caffeic acid and ferulic acid, which

may lower inflammation, protect the heart and promote overall health (Fan *et al.,* 2022). Additionally, avocados contain procyanidins, another type of flavonoid known for their antioxidant properties, which may improve heart health and lower the risk of chronic diseases (Wang *et al.,* 2010). Avocados are unique because they contain a specific kind of polyphenol called polyhydroxylated fatty alcohols (PFAs). These are found in the avocado seed and are being researched for their potential to reduce inflammation and support heart health (Rosenblat *et al.,* 2011). The composition of phytochemicals in avocado seed is expressed in Figure 4.

Table 2: Structure of bioactive compounds in avocado

Bioactive compounds	Molecular formula	Structure
Carotenoids (Lutein)	$C_{40}H_{56}O_2$	
Flavnoids (Quercetin)	$C_{15}H_{10}O_7$	
α - tocopherol	$C_{29}H_{50}O_2$	
Phytosterols	$C_{29}H_{50}O$	
Oleic acid	$C_{18}H_{34}O_2$	
Vitamin C	$C_6H_8O_6$	
Acetogenins	$C_{26}H_{46}O_7$	

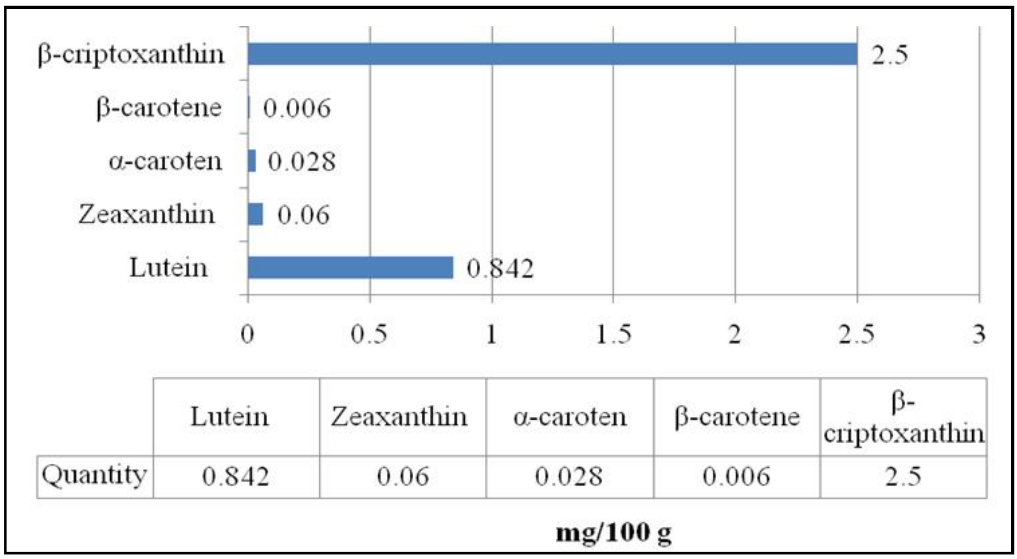


Figure 3: Composition of carotenoids in avocado pulp.

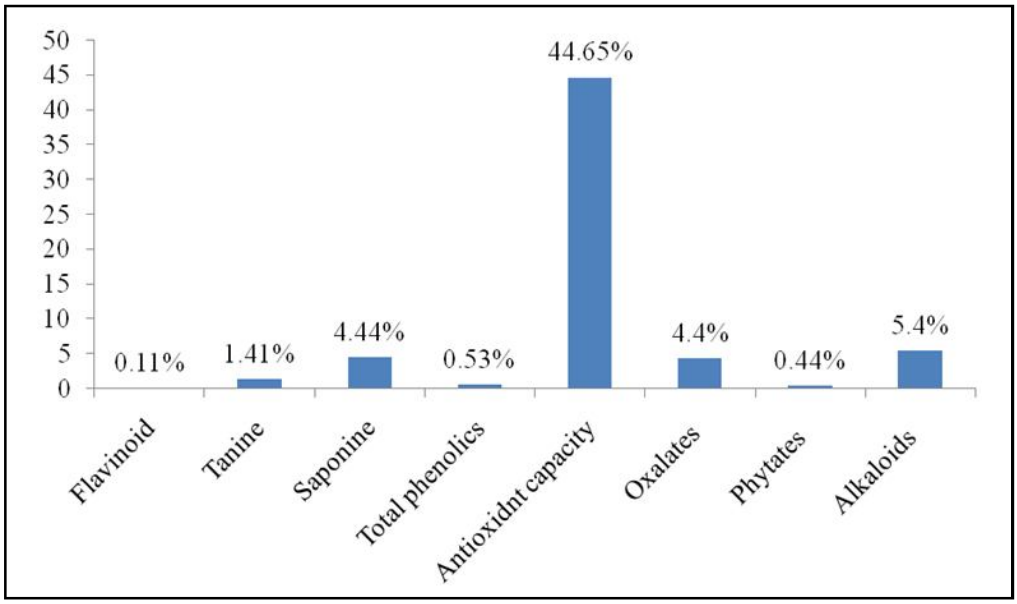


Figure 4: Composition of phytochemicals in avocado seed.

4.3 Tocopherols and tocotrienols

Tocopherols and tocotrienols are fat-soluble compounds. The avocado pulp is rich in α-tocopherol but also contains small concentrations of γ- tocopherol (0.006-0.067 g/kg) and γ-tocopherol (0.012-0.024 g/kg). The α-tocopherol is one of the most potent antioxidants that exist in the nature. Tocopherols and tocotrienols reduce the risk of several cancer forms (lung, esophagus, stomach, skin and large intestine). Tocopherols and tocotrienols strengthen the immune system, relieve inflammatory diseases (arthritis, rheumatoid arthritis and osteoarthritis) symptoms, and prevent cataracts and age-related macular degeneration. This group of compounds can protect against neurological disorders (Alzheimer's and Parkinson's) and aging (Manaf *et al.,* 2018).

4.4 Phytosterols and phytostanols

Avocado pulp contains phytosterols such as β-sitosterol (0.62-0.76 g/kg), campesterol (0.04-0.05 g/kg), and stigmasterol (0.003-0.004 g/kg). Phytosterols and phytostanols lower the absorption of cholesterol in the intestines, which reduces the level of cholesterol in the bloodstream (Ramos-Aguilar *et al.,* 2021). β-sitosterol also disrupts the reabsorption of bile acids during digestion, which further lowers cholesterol absorption by affecting cholesterol micellarization. This helps reduce the risk of heart attacks, atherosclerosis, blood clots, and other heart diseases (Calderón-Oliver *et al.,* 2016). Stigmasterol can decrease levels of triiodothyronine, thyroxine, and glucose in the blood, as well as the activity of glucose-6-phosphatase in the liver, while increasing insulin levels (Ramos-Aguilar *et al.,* 2019). Campesterol may have an anti-angiogenic effect, which could aid in cancer treatment (Salau, 2020).

4.5 Monounsaturated fatty acids (MUFA'S)

Monounsaturated fatty acids (MUFAs), which are healthy fats, are abundant in avocados. In all native Mexican avocado varieties, monounsaturated fatty acids like oleic (2.42-2.98 g/kg), linoleic (0.37-0.50 g/kg), and linolenic acids (0.07-0.12 g/kg) are the most common (Méndez-Zúñiga *et al.,* 2019). These fats are good for the heart as they lower bad cholesterol levels while increasing good cholesterol levels. Avocados are especially rich in oleic acid, a type of monounsaturated fatty acid, which brings various health benefits like better heart health and less inflammation (Weschenfelder *et al.,* 2015). Eating foods high in MUFAs, such as avocados, can improve overall health and lower the risk of chronic diseases like heart disease and diabetes (Wang, 2015). The composition of fatty acid in avocado pulp is expressed in Figure 5.

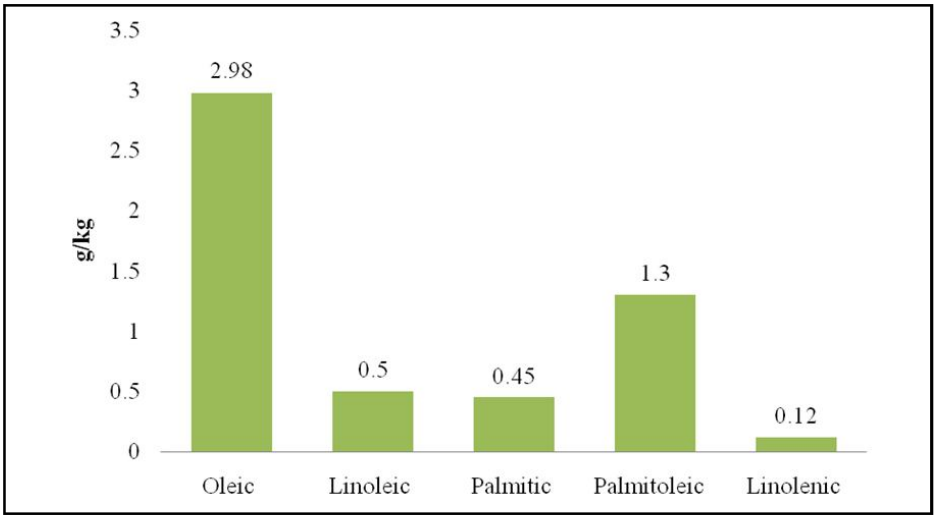


Figure 5: Composition of fatty acid in avocado pulp.

4.6 Fiber

Fiber in avocados plays a vital role in weight management by making you feel full and satisfied after meals, which helps reduce hunger and prevents overeating (Zhu *et al.,* 2019), avocados are rich in both soluble and insoluble fiber, which work together to regulate bowel movements and prevent constipation. Soluble fiber forms a gel-like substance when mixed with water, softening stools and promoting regularity, while insoluble fiber adds bulk to stools, speeding up the passage of food through the digestive tract (Paturi *et al.,* 2017). Additionally, the fiber in avocados helps lower cholesterol levels by binding to cholesterol in the digestive tract, preventing its absorption into the bloodstream. This reduces the risk of heart disease and stroke (Mahmassani, 2018).

4.7 Vitamin E

Vitamin E is well-known for its wide-ranging benefits, especially for the skin, immune system, eye health, and heart health. It protects the skin from pollution, UV rays and other environmental factors while improving moisture levels and elasticity for a youthful appearance. Additionally, by combating free radicals, vitamin E strengthens the immune system, helping to fend off infections and diseases (Negm and Abo-Raya, 2018). It also shield eye cells from oxidative damage, potentially reducing the risk of age-related eye conditions like macular degeneration and cataracts. Moreover, vitamin E assists in preventing the oxidation of LDL cholesterol, which reduces the chances of plaque buildup in arteries and supports heart health (Weschenfelder *et al.,* 2015).

4.8 Acetogenins

Acetogenins are substances made from fatty acids. Avocado fruit makes acetogenins in special parts called idioblasts, where oil is stored, using triglycerides as starting materials (Rodríguez-López *et al.,* 2017). The most common acetogenins in avocados are persenone A (0.2-4.6 g/kg) and persenin (0.05-1.3 g/kg), which are part of the persenin group. The amount of acetogenins varies depending on the type of avocado and its tissue. Persenone A is found most in the peel and pulp of avocados, making up 46% and 48% of all acetogenins in those parts. However, some studies have shown that persin can be the most common acetogenin in certain avocado types (Rodríguez-López *et al.,* 2015). Acetogenins are known for their strong antioxidant properties, mainly by stopping the production of nitric oxide and superoxide in cells. They can also make cancer cells die, which is called pro-apoptotic activity, and they protect against acute myeloid leukemia (Rodríguez-López *et al.,* 2015).

4.9 Organic acid

Avocado pulp contains organic acids like succinic (0.01-0.18 g/kg), citric (0.0090-0.0095 g/kg), quinic (0.0002-0.06 g/kg), and ascorbic acid (0.11-0.13 g/kg), which play important roles in the body's metabolism. Succinic acid helps the body absorb iron, which is especially important for preventing anemia. Ascorbic acid (AA), also known as vitamin C, is well-known for its protective effects. Studies have shown that ascorbic acid helps protect against diseases caused by oxidative stress, as well as age-related conditions like coronary heart disease, cataracts, and certain cancers. Additionally, ascorbic acid is crucial for making collagen and carnitine, and it supports processes like neuronal development, learning, memory, and movement (Wei *et al.,* 2018).

4.10 Sugars

Avocado pulp has small amounts of sugars like glucose (0.46-2.48 g/kg), fructose (0.15-2.48 g/kg), and sucrose (1.00-4.94 g/kg), making

it a good choice for people with diabetes. One unique thing about avocados is that they contain high levels of seven-carbon sugars, with D-mannoheptulose (0.31 6.55 g/kg) and perseitol (0.13-7.48 g/kg) being the most common. Eating D-mannoheptulose can lower insulin secretion and promote gluconeogenesis, which helps protect against diabetes. D-mannoheptulose also acts like calorie restriction, which can slow down aging and related health issues (Saraswat and Rizvi, 2017). Avocado extracts that are rich in D-mannoheptulose and perseitol can also help stop the fungus *Malassezia furfur* from growing on the skin, which is what causes dandruff (Donnarumma *et al.,* 2007).

5. Pharmacological uses of avocado

Pharmacological uses refer to the medicinal applications, in preventing, treating, or managing various health conditions which include antimicrobial property, antioxidant property, anti-inflammatory property, anticancer property, antidiabetic activity, antilithiasis activity, antiulcer activity, antithrombic and antiplatelet effect, neurological effects, wound healing properties, cardiovascular disease prevention, hypercholesterolemia, osteoarthritis, weight management, ameliorative effect, dermatological effects and also in traditional medicine. The Presence of bioactive compounds in avocado pulp and their pharmaceutical uses is given in Table 3.

Table 3: Presence of bioactive compounds and their pharmaceutical uses in avocado pulp

Bioactive compounds	Pharmaceutical use	Quantity (g/100 g)	References
Monounsaturated fatty acids (*e.g.,* oleic acid)	Cardiovascular health	9.0-10.0	Weschenfelder *et al.,* 2015
Polyunsaturated fatty acids (*e.g.,* linoleic acid)		1.0-2.0	
Antioxidants (*e.g.,* vitamin E)		0.002-0.003	
Polyphenols	Anti-inflammatory	0.014-0.020	Hassan *et al.,* 2022
Flavonoids		0.005-0.010	
Vitamin C	Skin health	0.008-0.010	Dreher and Davenport, 2013
Vitamin E		-	
Beta-carotene	Wound healing	0.0001-0.0003	Gupta *et al.,* 2018
Omega-3 fatty acids		0.0001-0.0002	
Dietary fiber	Gastrointestinal health	6.0-7.0	Salazar-López *et al.,* 2021
Glutamine		-	
Soluble fiber	Antidiabetic		Jimenez *et al.,* 2021.
Lutein	Anticancer	0.0001-0.0003	Cuevas-Cianca *et al.,* 2023
Zeaxanthin		0.0001-0.0002	
Omega-3 fatty acids	Neuroprotective	0.0001-0.0002	Da Silva *et al.,* 2022
Vitamin E		-	
Phenolic compounds	Antimicrobial	-	Rodríguez-Carpena *et al.,* 2011
Lauric acid		-	
Omega-9 fatty acids	Analgesic	0.5-1.0	Opiyo *et al.,* 2023
Vitamin B6		0.0001-0.0002	

5.1 Antimicrobial property

Avocado has been shown to have strong antibacterial qualities, perhaps because of its high flavonoid, procyanidin, and catechin content. Due to the antibacterial and antifungal properties of these chemicals, avocados are an excellent natural resource for treating a wide range of microbial illnesses. Additionally, studies have demonstrated the potential of avocado extracts as a natural antibacterial agent by efficiently inhibiting the growth of specific pathogenic bacteria and fungi. Many researchers studying the antibacterial properties of plants would benefit from the oil extracted from the avocado also, the oil is suggested for the treatment of skin problems caused by these organisms (Ilesanmi *et al.,* 2022). According to recent research, antibacterial components of avocado powder are effective against a wide range of bacteria, including Gram-positive and Gram-negative ones (Nguyen *et al.,* 2021). This is as a result of the secondary metabolites that avocado leaves contain flavonoids, alkaloids, and other secondary metabolites have the ability to suppress microorganisms (Wijaya, 2020).

5.2 Antioxidant property

Avocados are known for its strong antioxidant qualities. It has a range of antioxidants, such as flavonoids, tocopherols, and

carotenoids, which aid in shielding the body from oxidative stress and harm from free radicals. According to Tahsin *et al.* (2023), avocado fruit oil has inherent antioxidants that act as scavengers or inhibitors of free radicals. Avacado peel which is seen as waste, include flavonoids, saponins, and tannins that have been shown to have beneficial effects as antioxidants (Rahman *et al.,* 2022). Hass avocado pulp was found to contain the highest levels of quercetin, epicatechin, and chlorogenic acid, all of which have use in the pharmaceutical and food industries. These antioxidants play a crucial role in reducing the likelihood of chronic illnesses such as heart disease, cancer, and degenerative eye problems (Fan *et al.,* 2022).

5.3 Anti-inflammatory property

The present focus of medical research is on using fruit peels as a source of useful chemicals to treat various metabolic problems (Saiharini and Padmaja, 2022). Avocado contains several compounds known for their anti-inflammatory properties, including phytosterols, carotenoids, and omega-3 fatty acids. These substances can help alleviate inflammation in the body, offering potential benefits for conditions such as arthritis, heart disease, and other inflammatory disorders. A study by Dabas *et al.* (2019) examined the *in vitro* anti-inflammatory effects of a colored extract derived from avocado seeds. They found that the extract reduced the production of pro-inflammatory mediators by stimulated macrophage cells, indicating its potential to combat inflammation. Another investigation by Aprilianto *et al.* (2019) checking the anti-inflammatory activity of avocado peel against carrageenan-induced inflammation in mice. They observed a significant reduction in paw edema with all doses of avocado peel infusion, decoction, and extract, highlighting its potential as a natural anti-inflammatory agent. The presence of bioactive compounds and their pharmaceutical uses in avocado peel is given in Table 4.

Table 4: Presence of bioactive compounds and their pharmaceutical uses in avocado peel

Pharmaceutical use	Bioactive compounds	Quantity (g/100 g)	References
Antioxidant	Polyphenols	0.05-0.10	Lyu *et al.,* 2023
	Carotenoids	0.0005-0.002	
Anti-inflammatory	Flavonoids	0.10-0.30	Hassan *et al.,* 2022
	Procyanidins	0.005-0.10	
Skin health	Vitamin C	0.005-0.10	Dreher and Davenport, 2013
	Vitamin E	0.001-0.002	
Wound healing	Essential oils	-	Gupta *et al.,* 2018
	Tannins	0.005-0.10	
Antimicrobial	Terpenoids	-	Rodríguez-Carpena *et al.,* 2011
	Alkaloids	-	
Antiageing	Saponins	0.001-0.005	Lister *et al.,* 2021
	Phytosterols	0.01-0.02	
Digestive health	Dietary Fiber	0.02-0.03	Salazar-López *et al.,* 2021
	Pectin	0.001-0.002	
Immune support	Beta-glucans	-	Farheen *et al.,* 2022
	Immunomodulatory peptides	-	

5.4 Anticancer property

The ICMR's 2020 data for India projects 1,392,179 cancer patients, with the most common five main locations being mouth, throat, cervix, tongue, and breast cancer (Khan and Ahmad, 2021). Avocados are healthy fruits with high nutritional content that may be used to treat cancer cells through immunotherapy. Avocados are beneficial for curing cancer and lowering blood pressure, among other things (Chatterjee, 2021; Pal and Raj, 2023) reported that, avocados include unsaturated fatty acids like oleic acid, linolenic acid, *etc.*, they also contain sugars, carotenoids, phenols, β-sitosterol, daucosterol, campesterol, lutein, persenone A and persenin and other compounds that help prevent some types of cancer like breast, colon, and prostate cancer. Avocado pulp extract has high acetogenins which has potential applications as a complementary therapy for rheumatoid arthritis and cancer prevention or treatment (Hassan *et al.,* 2022).

5.5 Antidiabetic activity

According to a research released in 2019 by the International Diabetes Federation (IDF), diabetes is the health emergency with the fastest rate of growth in the 21st Century everywhere in the world. Based on the IDF report, 463 million people worldwide are estimated to have diabetes, a condition that will multiply several times by 2045 (Ain *et al.,* 2022). The avocado fruit pulp extract having various phytochemical classes including saponins, tannins, alkaloids, and steroids. Avocado extract significantly lowered blood glucose levels (Umoh *et al.,* 2019). Recent research by Nardi *et al.* (2020) highlighted that, ethanol extract from avocado seeds contains triterpenoids, polyphenols, flavonoids, tannins, monoterpenoids, sesquiterpenoids, quinones. Among these compounds, flavonoids have displayed beneficial effects in managing diabetes mellitus. The presence of bioactive compounds and their pharmaceutical uses in avocado seed is given in Table 5.

Table 5: Presence of bioactive compounds and their pharmaceutical uses in avocado seed

Pharmaceutical use	Bioactive compounds	Quantity (g/100 g)	References
Antioxidant	Polyphenols	0.05-0.10	Lyu *et al.*, 2023
	Flavonoids	0.01-0.02	
Anti-inflammatory	Tannins	0.01-0.02	Hassan *et al.*, 2022
	Sterols	0.05-0.10	
Skin health	Vitamin E	0.002-0.005	Fulgoni *et al.*, 2013
	Unsaturated fatty acids	0.01-0.020	
Wound healing	Essential oils	-	Gupta *et al.*, 2018
	Phytosterols	0.02-0.05	
Digestive health	Dietary fiber	0.02-0.03	Salazar-López *et al.*, 2021
	Saponins	0.005-0.01	
Antidiabetic	Insoluble fiber	0.015-0.020	Jimenez *et al.*, 2021
	Alkaloids	-	
Anticancer	Procyanidins	0.005-0.01	Dabas, Elias, *et al.*, 2019
	Catechins	0.005-0.01	
Immune support	Beta-glucans	-	Farheen *et al.*, 2022
	Immunomodulatory peptides	-	

5.6 Antilithiasis activity

Urolithiasis happens when crystals in the urine become too concentrated and start to gather and crystallize within the kidney, forming stones. Avocado leaf extract had significantly lower levels of calcium in their kidneys compared to rats treated with a solution containing ethylene glycol and ammonium chloride. This suggests that avocado leaf extract could be a useful herbal remedy, particularly for preventing urolithiasis (Wientarsih *et al.*, 2012). The presence of bioactive compounds and their pharmaceutical uses in avocado leaf is given in Table 6.

Table 6: Presence of bioactive compounds and their pharmaceutical uses in avocado leaf

Pharmaceutical use	Bioactive compounds	Quantity(g/100 g)	References
Antioxidant	Polyphenols	0.1-0.30	Lyu *et al.*, 2023
	Flavonoids	0.02-0.05	
Anti-inflammatory	Triterpenoids	0.005-0.010	Hassan *et al.*, 2022
	Saponins	0.01-0.02	
Digestive health	Tannins	0.01-0.03	Salazar-López *et al.*, 2021
	Dietary fiber	0.01-0.015	
Immune support	Vitamins (*e.g.* vitamin C)	0.015-0.03	Farheen *et al.*, 2022
	Alkaloids	-	
Antidiabetic	Quercetin	0.005-0.01	Jimenez *et al.*, 2021
	Kaempferol	0.002-0.005	
Skin health	Anthocyanins	-	Dreher and Davenport, 2013
	Luteolin	0.002-0.005	
Wound healing	Essential oils	-	Gupta *et al.*, 2018
	Phytosterols	0.01-0.02	
Cardiovascular health	Oleuropein	-	Weschenfelder *et al.*, 2015
	Beta-sitosterol	0.005-0.01	
Anticancer	Catechins	-	Dabas, Elias, *et al.*, 2019
	Procyanidins	-	

5.7 Antiulcer activity

Avocado seed extract contains beneficial phenolic compounds like caffeoylquinic acid, flavonoids, phenylpropanoids, and tannins, which help prevent and treat gastric ulcers by inhibiting pathways involved in their formation (Athaydes *et al.,* 2019). Research by Salawu *et al.* (2020) found that, the aqueous seed extract significantly reduced malondialdehyde levels and increased the activities of antioxidants like reduced glutathione, catalase, and superoxide dismutase in gastric tissues, indicating its protective effect against aspirin-induced gastric ulceration.

5.8 Antithrombic and antiplatelet effects

Eating avocado as part of your diet can make it a functional food. It contains certain compounds called acetogenins that can stop blood cells from sticking together, which might help prevent dangerous blood clots. These clots, known as thrombus, can cause serious health issues like heart attacks and strokes. Also, the fatty acids in avocados are thought to reduce the risk of blood clotting by making blood cells less likely to stick together (Rodriguez-Sanchez *et al.,* 2015).

5.9 Neurological effects

Feeding the adult rats with avocado oil and pulp influences the development of the nervous system of their babies in the short and long term, by improving the memory (Melo *et al.,* 2019). Recent findings were achieved plausibly through the cytoprotective antioxidant efficacy of the peels of avocado. It is thus worth pursuing avocado peel as a natural treatment due to its anxiolytic effect and improvement of learning and memory in starvation and re-feeding in wistar rats (Ilochi and Chuemere, 2019).

5.10 Wound healing properties

Polyphenols are found in many plants, and they function as antioxidants, antibacterial, and wound-healing agents that help wounds heal quickly (Jayakumari *et al.,* 2023). Hayati *et al.* (2021) found that avocado leaf compounds like alkaloids, flavonoids, saponins, and tannins aid wound healing. Their study showed that a 5% extract gel was notably effective, achieving a 90% wound healing rate. Another study on Wistar rats indicated that avocado oil boosts collagen production, reduces inflammation, accelerates clotting, and speeds up skin cell regeneration, suggesting its potential as a treatment for skin wounds (Ebad Sichani *et al.,* 2021). Additionally, Yang *et al.* (2021) demonstrated that, ointments prepared from avocado peel can be used to treat the wounds that are caused by burnt.

5.11 Cardiovascular disease prevention

Avocado seeds might protect the heart from damage caused by toxins, likely due to their antioxidant properties. Also, consuming avocado pulp before aerobic exercise improves various heart and nervous system functions during recovery in healthy women. These results suggest that eating avocado before working out can be beneficial for overall health (Sousa *et al.,* 2020). Mexican varieties have high level of Omega-9, Omega-6 and Omega-3 fatty acid which protect against heart diseases (Méndez-Zúñiga *et al.,* 2019).

5.12 Hypercholesterolemia

Hypercholesterolemia, or high cholesterol, occurs when there are elevated levels of cholesterol in the bloodstream. It is a type of condition where there's too much fat in the blood, including high levels of lipoproteins (Durrington, 2003). Tan *et al.* (2018) conducted a study using male Sprague-Dawley rats which fed a high-cholesterol diet for four weeks to induce hypercholesterolemia. Once the hypercholesterolemia model was confirmed, they administered virgin avocado oil (at doses of 450 and 900 mg per kilogram of body weight per day) and simvastatin (at a dose of 10 mg per kilogram of body weight per day) orally while continuing the high-cholesterol diet for another four weeks. The results indicated that the disease was prevented. The presence of bioactive compounds and their pharmaceutical uses in avocado oil is given in Table 7.

Table 7: Presence of bioactive compounds and their pharmaceutical uses in avocado oil

Pharmaceutical use	Bioactive compounds	Quantity (g/100 g)	References
Skin health	Vitamin E	0.01-0.02	Dreher and Davenport, 2013
	Beta-carotene	-	
Wound healing	Omega-3 fatty acids	0.5-1.0	Gupta *et al.,* 2018
	Omega-6 fatty acids	10-15	
Anti-inflammatory	Oleic acid	60-70	Hassan *et al.,* 2022
	Linoleic acid	10-15	
Cardiovascular health	Monounsaturated fatty acids	60-70	Weschenfelder *et al.,* 2015
	Polyunsaturated fatty acids	10-15	
Antiageing	Phytosterols	0.1-0.15	Jimenez *et al.,* 2021
	Squalene	0.07-0.10	
Hair health	Oleic acid	60-70	Park *et al.,* 2021
	Vitamin D	-	
Immune support	Lutein	-	Farheen *et al.,* 2022
	Zeaxanthin	-	
Anticancer	Polyphenols	-	Dabas, Elias, *et al.,* 2019
	Carotenoids	-	
Digestive health	Dietary fiber	-	Salazar-López *et al.,* 2021
	Glutamine	-	

5.13 Osteoarthritis

Avocado extract along with vitamin D and Calcium has shown to be effective in reducing pain severity, osteoarthritis symptoms, and knee discomfort, leading to an improvement in quality of life for patients with osteoarthritis (Atabati *et al.,* 2021). Chandra *et al.* (2019) reported that, avocado oil is also being used as a food supplement, but does not have any side effects unlike NSAIDs, glucosamine sulfate, chondroitin sulfate, sulfasalazine, *etc.* Therefore, avocado oil can be safely used for a long duration in the management of osteoarthritis.

5.14 Weight management

Keeping your weight steady involves eating the right amount of food and burning enough energy. Processed and high-calorie foods, especially those eaten between meals, make people eat more and move less, which causes obesity (Sharma and Sarwat, 2022). Avocados are packed with fiber, lutein, and vitamin E, and they're a great source of healthy MUFA. Eating Hass avocados every day as part of a low-calorie diet helped people lose weight, reduce levels of Hepatocyte Growth Factor (HGF) in their blood, and increase the presence of beneficial bacteria that break down plant fibers (Henning *et al.,* 2019). According to Heskey *et al.* (2019), regular eating avocados is linked to a lower risk of being overweight and can help prevent weight gain in people of healthy weight over time. People who eat more avocados on a regular basis are less likely to become overweight or obese, although the effect is influenced by their initial BMI.

5.15 Ameliorative effect

The medicinal properties of avocado leaf extract suggest its potential as a natural remedy for treating lead poisoning. Research indicates that the extract can alleviate histomorphological distortions caused by lead acetate toxicity in the brain, leading to moderate regeneration of cerebellar tissue. This provides a more favorable and satisfactory approach to managing lead poisoning (Isaac, 2020).

5.16 Dermatological effects

The avocado pulp is commonly utilized in various dermatological formulations, including cosmetic products designed for dry skin, protective agents against ultraviolet radiation, and antiageing products. A recent study focused on the development and assessment of the safety and effectiveness of a topical cream containing saffron extract and avocado oil for combating wrinkles. Throughout the study, no allergic reactions were reported, and there were no observable changes in skin hydration levels. The findings demonstrated that the saffron extract and avocado oil-based anti-wrinkle cream proved to be both effective and safe for rejuvenating facial skin (Naeimifar *et al.,* 2020). Moreover, avocado seed extract, known to contain catechin, exhibits potential as a skin lightening agent by inhibiting tyrosinase activity (Laksmiani *et al.,* 2020).

6. Use of avocado in traditional medicine

For a long time, people in places where avocado trees grow naturally have used different parts of the tree as herbal medicine. Avocado tea made from its leaves is used to treat diarrhea, bloating, and gas issues. Some believe it helps with coughs and gout by getting rid of uric acid in the body. The tea is also thought to cleanse the liver and reduce blood pressure (Gupta *et al.,* 2018). In Mexico, it's been used for a long time to help with menstrual problems and as a contraceptive because it's believed to speed up menstruation. Avocado leaf extracts have been shown in labs to stop herpes simplex viruses, which cause cold sores and genital herpes (Araújo *et al.,* 2018). Avocado seeds are known to fight bacteria and fungi and have traditionally been used to treat diarrhea. The peel of the fruit is sometimes used to get rid of intestinal worms, and the pulp is believed to have aphrodisiac effects (Duarte *et al.,* 2016).

7. Conclusion

It is concluded that, avocado is considered a super fruit, because it is packed with nutrients and special immune protective compounds that are really good for human health. Eating avocados regularly can help to maintain healthy heart, make your immune system stronger, help you manage your weight, and lower your chances of getting chronic diseases. Avocado has antioxidants and anti-inflammatory stuff that can protect cells and reduce swelling in body, which is good for overall health.

Future prospects

In the future, researchers should conduct more thorough studies on avocados to uncover their individual phenolic components and discover new compounds using improved extraction and analysis techniques. Additionally, there is a need for further exploration into the health benefits and potential applications of these avocado-derived compounds. Moreover, the development of novel avocado-based products, such as skincare items utilizing avocado oil, could create new market opportunities. Research based on avocado bark and roots should be examined to find out the bioactive compounds present in it.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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