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Chemical Contents, Plant Diseases and Biopharmaceutical Applications of *Persea americana* Mill.: Total Phenolic and Flavonoid Values

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ABSTRACT: The discovery of active substances in plants has positioned pharmacology as one of the most rapidly developing fields. The fundamental reason for the widespread use of plants lies in the human fascination with natural products. This study compiles the traditional uses, biological activities, cosmetic industry applications, plant diseases, chemical composition, phenolic content, and total phenolic and total flavonoid values of *Persea americana*. In traditional usage, the fruit portion of the avocado has been predominantly favored. Its applications, particularly in the realm of skincare, are widespread within the cosmetic industry. A primary factor contributing to this prevalence is the avocado's high vitamin E content. Evaluations of biological activity studies indicate a significant value in terms of antioxidant and antimicrobial properties. Literature reviews reveal that the majority of research on plant diseases focuses on fungal conditions, which are also noted to cause substantial economic losses. It has been observed that the major components in the chemical content of the leaf part of the avocado plant are estragole, β-caryophyllene, 2-(8Z,11Z)-8,11-heptadecadiene-furan, and methyl eugenol. A review of the literature reveals that the common phenolic compounds found in the seed, fruit, and leaf parts of the avocado plant include rutin, procyanidin, catechin, caffeic acid, epicatechin, ferulic acid, sinapic acid, quercetin, apigenin, kaempferol, gallic acid, protocatechuic acid, chlorogenic acid, syringic acid, and vanillic acid. It is believed that our study will contribute to future research on avocado and other tropical products, particularly in the field of pharmacology.

Keywords: *Persea americana*, Plant disease, Biological activity, Pharmacology.

INTRODUCTION

Throughout history, plants have been used as an indispensable resource in different areas of human life. In the early ages, plants played an important role in meeting basic needs such as shelter, nutrition and clothing, and over time, they began to be evaluated for medical purposes (Pehlivan et al., 2021). Today, the pharmacological potential of plants has come to the forefront with the discovery of bioactive compounds in their content (Uysal et al., 2021). The biological effects of these natural components, such as antioxidant, antimicrobial, anti-inflammatory and anticancer, contribute to the development of new drugs in modern medicine and enable the synthesis of traditional knowledge and scientific data (Uysal et al., 2023a; Sevindik et al., 2024a). Pharmacological studies have indicated its potential effects, including antioxidant, anticancer, antiviral, antimicrobial, anti-inflammatory, DNA-protective, hepatoprotective, and anti-aging properties (Akgul et al., 2020; Kına et al., 2021; Mohammed et al., 2023a; Mohammed et al., 2024; Seğmenoğlu et al., 2024; Sevindik et al., 2024b; Sevindik et al., 2025).

This study compiles the traditional uses, biological activities, cosmetic industry applications, plant diseases, chemical composition, phenolic content, and total phenolic and total flavonoid values of *P. americana*.

GENERAL CHARACTERISTICS AND USAGE AREA OF AVOCADO

Persea americana Mill. is a member of the Lauraceae family. *P. americana*, **Amharic**: avocado; **Burmese**: htaw bat, kyese; **Creole**: zaboka; **English**: alligator pear, avocado, avocado-pear, butter fruit; **Filipino**: avocado; **French**: avocat, avocatier, zabelbok, zaboka; **German**: Alligatorbirne, Avocadobirne; **Indonesian**: adpukat, avokad; **Khmer**: avôkaa; **Malay**: apukado, avokado; **Mandinka**: avacado; **Pidgin English**: bata; **Spanish**: aguacate, pagua; **Swahili**: mparachichi, mpea, mwembe mafuta; **Thai**: awokado; **Trade name**: medang and **Vietnamese**: bo, lê dâù it is known as. Originating in South America, the avocado is a tropical or subtropical fruit that's considered extremely nutritious. It has a green, rectangular shape and grows on trees that can reach about 20 meters. Its flowers are greenish-yellow, and its leaves are oval or lance-shaped, measuring 7-41 cm. The pear-

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shaped fruit is 7-20 cm long and only ripens after being harvested. Avocados are unique because they contain a lot of healthy fats (Yasir et al., 2010; Yahia and Woolf, 2011; Hurtado-Fernández et al., 2018).

The nutritional composition of avocado is characterized by significant levels of protein, lipids, riboflavin, carbohydrates, ascorbic acid, crude fiber, provitamin A (as carotene), niacin, and thiamine. This species is extensively cultivated in regions including Mexico, Colombia, the Dominican Republic, Peru, Indonesia, Kenya, Brazil, and Ethiopia, representing a commercially significant crop with high economic returns for these nations. *P. americana* exhibits adaptability to a broad spectrum of soil types; however, it demonstrates sensitivity to conditions of inadequate soil drainage. Optimal growth is observed within a soil pH range of 5 to 7. The species thrives in tropical and semi-tropical climates experiencing moderate summer precipitation, as well as in humid subtropical zones with summer rainfall patterns. The typical period for field establishment of avocado seedlings is during June and July. Nutritional management, particularly nitrogen supplementation, is crucial for avocado cultivation. Fertilizer application is conducted at a distance from the tree trunk, with the application rate adjusted based on tree age and canopy diameter. Fertilizers are incorporated into the soil via shallow trenches (15-20 cm width, 5 cm depth) encircling the base of the trees. Furthermore, the application of micronutrients is employed to enhance fruit yield. Notable cultivars include Pinkerton, Sharwil, Choquette, Fuerte, Reed, Hass, Bacon, Gwen, Brogden, Lula, Ettinger, Arka Supreme, Monroe, Zutano, TKD-1, CHESPA-XIII-1, and Propagation (Whiley et al., 2002; Tripathi et al., 2014; Bhore et al., 2021).

The avocado fruit is documented to possess aphrodisiac qualities and is employed in managing intestinal parasites, lowering cholesterol, and addressing conditions like atherosclerosis, angina pectoris, and Alzheimer's disease. It also aids in digestion, regulates blood sugar, and finds applications in cosmetics and dermatological care. The leaves of the avocado tree are utilized to treat herpes simplex, diarrhea, and liver detoxification, reduce blood pressure, alleviate coughs and gout, relieve bloating and flatulence, manage menstrual irregularities, and serve as a contraceptive. The seeds, conversely, are used in the treatment of diarrhea and dysentery (Dabas et al., 2013; Ranade and Thiagarajan, 2015; Ameer, 2016; Duarte et al., 2016; Kendir and Köroğlu, 2018; Paniagua-Zambrana et al., 2020; Wang et al., 2020; Stephen and Radhakrishnan, 2022).

AVOCADO IN COSMETICS INDUSTRY

Characterized by its high content of monounsaturated fatty acids, carotenoids, and phenolic compounds, the avocado is a valuable nutritional resource. Clinical trials have provided evidence that oral carotenoid intake can ameliorate the effects of skin aging (Henning et al., 2022). The senescence of skin is a complex physiological phenomenon subject to modulation by both endogenous (genetic, hormonal, cellular metabolic, and systemic metabolic factors) and exogenous influences (chronic exposure to ultraviolet radiation, environmental pollutants, ionizing radiation, chemical agents, and toxins). The monounsaturated fatty acid composition of avocado oil, with a notable abundance of oleic acid, confers advantageous properties concerning wound cicatrization, cutaneous hydration, and the mitigation of aging effects (Dewi et al., 2024). A member of the Lauraceae family, the avocado is a fruit with a single seed that is grown in all tropical and subtropical regions of the world, as well as Turkey's southern coastal region. Inflammation can be triggered by oxidative damage, particularly that caused by ultraviolet (UV) radiation, which can lead to major inflammatory skin disorders such as eczema, seborrheic dermatitis, hyperpigmentation, and aging. Tyrosinase, an enzyme inhibitor involved in melanogenesis, is one of the enzymes that has recently been used in cosmetic products to treat hyperpigmentation and skin diseases (Hürkul et al., 2021). Over the years, the cosmeceutical industry has witnessed substantial growth, leading to a critical need for safe and effective options. Bioactive compounds extracted from fruits are increasingly recognized as viable alternatives for human health, characterized by their safety profile and reduced incidence of adverse effects. Notably, avocado a tropical fruit is abundant in phytonutrients and lipid-soluble bioactive compounds, which have demonstrated potential in promoting diverse health benefits, particularly in improving skin health (Yeoh et al., 2024). Numerous studies have shown that avocados display a variety of salutary effects, such as antioxidant, anticancer, and lipid-reducing characteristics (Myung et al., 2019). Avocado oil is obtained from the mesocarp of the avocado fruit. Due to its stability and significant α-tocopherol content, its dominant use is in the cosmetics sector. Conventional extraction processes involve relatively severe methods, including high-temperature and solvent extraction, often accompanied by standard refining steps. The final market influences the required fruit quality. Optimal cold-pressed oil necessitates relatively undamaged fruit, often those deemed cosmetically imperfect or undersized for direct sales. Cold-pressed avocado oil represents a novel product, with substantial production and commercialization emerging in the 21st century. Avocado oil exhibits superior properties for both culinary and cosmetic uses (Woolf et al., 2009). Given that a cosmeceutical contains bioactive constituents that elicit enhanced dermal pharmacological activity relative to inert cosmetics, it is differentiated from the latter. Avocado oil has been employed within the cosmeceutical sector historically, attributable to its inherent stability, elevated α-tocopherol concentration, dermal regenerative capabilities, and significant transdermal uptake. Nevertheless, the exploration of avocado-derived peel fractions as potential cosmeceutical agents necessitates further research to facilitate the creation of innovative, value-added formulations (Avalos-Viveros et al., 2023).

The versatile biological activities that avocado exhibits with both its fruit pulp and oil have made it a remarkable natural resource not only in terms of nutrition but also in terms of pharmacological and dermocosmetic applications. The phenolic compounds, carotenoids and tocopherols in its content suppress the formation of free radicals and prevent cellular damage caused by oxidative stress, thus preventing skin-related problems such as inflammation, hyperpigmentation and aging. In particular, the strong antioxidant effect of α-tocopherol and the role of oleic acid in strengthening the skin barrier make avocado oil an effective agent that supports dermal healing. In addition, it is thought that parts that are often considered waste, such as avocado peel, also have rich phenolic content and therefore may constitute an important research area in terms of sustainable cosmeceutical product development in the future. In this direction, advanced research on topics such as bioavailability of different fractions of avocado, molecular mechanisms of action and formulation stability will contribute to the development of natural and effective skin care products.

BIOLOGICAL ACTIVITIES

The literature reveals that in investigations concerning the in vitro and in vivo biological activities of *P. americana*, various extracts, namely aqueous, ethanol, hydroethanol, chloroform, ethyl acetate, butanol, n-hexane, acetone, methanol, dichloromethane, water, petroleum ether, and hydroalcoholic extracts, have been utilized. Biological activity studies pertaining to *P. americana* are detailed in Table 1.

Table 1. *Biological activity of Persea americana.*

Biological activities	**Solvents**	**Used parts**	**Geographic regions**	**References**
Antioxidant, antimicrobial, anticancer, antıtumor, cytotoxic, α-amylase inhibitory activity, antiprotozoal, antiproliferative, antidiabetic, antilarvicidal, anti-inflammatory, anti-cholinesterase	Aqueous, ethanol, hydroethanol, chloroform, ethyl acetate, butanol, n-hexane, acetone, methanol, dichloromethane, water, petroleum ether, hydroalcoholic	Pulp, skin, seed, leaf, fruit, peel, stem bark, root, bark, exocarp, mesocarp	Portugal Saudi Arabia, Brazil, Slovenia, Nigeria, Cameroon, Indonesia, Mexico, Vietnam, Zimbabwe, Egypt, Chile	Idris et al., 2009; Leite et al., 2009; Nwaoguikpe et al., 2011; Ferreira da Vinha et al., 2013; Jiménez-Arellanes et al., 2013; Ogundare and Oladejo, 2014; Adaramola et al., 2016; Folasade et al., 2016; Rotta et al., 2016; Ajayi et al., 2017; Egbuonu et al., 2018; Amado et al., 2019; Dang et al., 2019; Deuschle et al., 2019; Vo and Le, 2019; Makopa et al., 2020; Ovalle Marín et al., 2020; Tessalonica and Roeslan, 2020; Dibacto et al., 2021; Abd Elkader et al., 2022; Ekom and Kuete, 2022; Rahman et al., 2022; Rahwawati et al., 2022; Kupnik et al., 2023; Isah et al., 2024; Ukwubile and Makinde, 2024

Antioxidant Activity

Oxidative stress caused by free radicals is a harmful condition that can cause serious damage to cellular structures. These reactive molecules can play a role in the development of many chronic diseases, especially cancer, by creating destructive effects on cell membranes, proteins, and DNA (Sevindik et al., 2018). Antioxidants, which act as a defense mechanism against this process, react with oxidizing agents and restore balance at the cellular level (Gürgen and Sevindik, 2022). In addition to endogenously synthesized antioxidants, natural antioxidants of plant origin also play an important role in preventing biological damage caused by oxidative stress by neutralizing free radicals (Sevindik et al., 2023). Therefore, the use of compounds with high antioxidant capacity is increasingly gaining importance in both preventive health practices and therapeutic strategies (Mohammed et al., 2023b; El-Chaghaby et al., 2024). In a Portuguese study, the antioxidant capacity of aqueous extracts from the pulp, skin, and seed of Persea americana was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. The study demonstrated that the DPPH inhibition percentages were 43% for the seed, 35% for the skin, and 23% for the pulp (Ferreira da Vinha et al., 2013). Researchers in Saudi Arabia explored the α-amylase inhibition potential of ethanol extracts derived from *P. americana* fruit and leaf. The fruit extract displayed a stronger inhibition capacity than the leaf extract, achieving inhibition percentages of 92.13% and 88.95% at 1000 µg/ml, respectively (Abd Elkader et al., 2022). A Brazilian study assessed the antioxidant properties of crude *P. americana* extract via DPPH and FRAP assays. The findings revealed DPPH values of 16.10 µmol for in natura avocado peel (INAP) and 763.02 µmol for dehydrated avocado peel (DAP), with corresponding FRAP values of 9.56 µmol (INAP) and 422.77 µmol (DAP) (Rotta et al., 2016). The antioxidant capacity of an ethanolic extract derived from the seed of *P. americana* was assessed via the DPPH assay in a Slovenian study. The extract demonstrated a DPPH radical scavenging activity of 67.49% (Kupnik et al., 2023). A Brazilian study explored the antioxidant capacity of the ethanol extract from *P. americana* fruit, utilizing DPPH, ABTS, and FRAP assays. The findings revealed DPPH values spanning 21.28-482.65 µmol, ABTS values spanning 2.34-497.53 µmol, and FRAP values spanning 3.62-546.49 µmol (Amado et al., 2019). A separate investigation in Brazil examined the impact of hydroethanolic, chloroform, ethyl acetate, and butanol extracts, derived from the leaves of *P. americana*, on DPPH. The findings indicated that the ethyl acetate extract exhibited the most potent inhibitory activity, with an IC50 value of 19.7 µg/mL (Deuschle et al., 2019). In a Nigerian study, the influence of n-hexane extract, derived from the seed of *P. americana*, on DPPH and reducing power was examined. The findings indicated a DPPH inhibition of 51.54%, with an IC50 of 4.68 mg/mL, and a reducing power IC50 of 0.001 mg/mL (Adaramola et al., 2016). The Total Antioxidant Capacity (TAC) of aqueous, hydroethanolic, and ethanolic extracts derived from the fruit of *P. americana* was assessed in a Cameroonian study. The findings revealed that the maximum TAC values were as follows: 129.32 mg/g for the aqueous extract, 132.87 mg/g for the hydroethanolic extract, and 129.63 mg/g for the ethanolic extract (Dibacto et al., 2021). A

Nigerian study explored the antioxidant capacity of *P. americana* seed extracts (acetone, ethanol, water, and ethyl acetate) via FRAP and DPPH analyses. Findings indicated that acetone extracts exhibited the strongest antioxidant activity, yielding FRAP and DPPH values of 0.85 mg/mL and 89.15%, respectively (Folasade et al., 2016). The antioxidant capacities of aqueous and ethanolic extracts from *P. americana* leaf, stem bark, seed, and root were evaluated in a Nigerian-based study. The DPPH radical scavenging activity was found to be between 8.65% and 39.90% for leaf extracts, 2.21% and 36.85% for stem bark extracts, 7.12% and 40.21% for seed extracts, and 5.46% and 34.84% for root extracts (Isah et al., 2024). It was reported from a study carried out in Indonesia that the methanol extract derived from the fruit portion of *P. americana* exhibited a DPPH IC50 value of 185.891 ppm (Rahman et al., 2022). In a study performed in Vietnam, the antioxidant activities of ethanol, water, dichloromethane, and ethyl acetate extracts, derived from the seed of *P. americana*, were evaluated using DPPH and ABTS assays. The study reported that the dichloromethane extract yielded the lowest DPPH IC50 value (48.0 µg/mL), signifying the highest scavenging activity, and the ethyl acetate extract displayed the lowest ABTS IC50 value (22.0 µg/mL), indicating the strongest radical-scavenging potential (Vo and Le, 2019). The antioxidant activity of ethanol, ethyl acetate, and petroleum ether extracts from *P. americana* leaf samples was evaluated in an Egyptian study using DPPH and ABTS assays. The ethanol extract yielded the highest inhibition percentages: 95.80% for DPPH and 96.47% for ABTS. The standard, ascorbic acid, exhibited inhibition percentages ranging from 96.49% to 99.14% for DPPH and 96.97% to 99.60% for ABTS (Awaad et al., 2023). A review of the literature reveals that various parts of the *P. americana* specimen have been utilized in antioxidant studies. Common assays employed in these investigations include DPPH, FRAP, and ABTS tests. Furthermore, the literature suggests that the avocado plant is a significant source of antioxidants.

Antimicrobial Activity

The increase observed in microbial diseases in recent years has led to the more widespread use of antimicrobial drugs in treatment processes (Mohammed et al., 2023c). However, the resistance developing against existing drugs has made the discovery of new and effective antimicrobial sources mandatory (Krupodorova et al., 2022). In this direction, research has focused on natural sources; especially plant-based products have been at the top of the list of attractive alternatives due to their strong biological activities (Gürgen et al., 2024). Various secondary metabolites found in plants have broad-spectrum antimicrobial effects and have the potential to both inhibit the growth of pathogens and protect against infections (Uysal et al., 2023b). A study conducted in Slovenia investigated the effects of an ethanol extract obtained from the seed portion of *P. americana* on *Escherichia coli*, *Pseudomonas aeruginosa*, *P. fluorescens*, *Bacillus cereus*, *Staphylococcus aureus*, *Streptomyces platensis*, *Streptococcus pyogenes*, *Aspergillus brasiliensis*, *A. flavus*, *A. fumigatus*, *A. niger*, *Candida albicans*, *Penicillium cyclopium*, *Saccharomyces cerevisiae*, and *Trichoderma viride*. The results of the study indicated that the highest inhibition zone value among bacterial strains was observed in *P. fluorescens* at 18 mm, while the highest zone value among fungal strains was observed in *P. cyclopium* at 13 mm (Kupnik et al., 2023). A study conducted in Brazil investigated the effects of hydroethanolic, chloroform, ethyl acetate, and butanol extracts obtained from the leaves of *P. americana* on *C. tropicalis*, *C. parapsilosis*, *C. guilliermondii*, *C. glabrata*, *C. dubliniensis*, *C. albicans*, *Cryptococcus neoformans*, *S. cerevisiae*, *A. fumigatus*, and *A. flavus*. The study reported that the lowest minimum inhibitory concentration (MIC) value of 128 µg/ml was observed in ethyl acetate and butanol extracts against *C. parapsilosis*, *C. neoformans*, and *S. cerevisiae* strains (Deuschle et al., 2019). In a Mexican study, researchers examined how chloroform and ethanol extracts, derived from the seeds of *P. americana*, affected certain bacteria. They found that the chloroform extract stopped the growth of several types of *Mycobacterium*, including drug-resistant tuberculosis, at low concentrations (MIC ≤50 µg/ml). The ethanol extract was less effective, only inhibiting two strains (Jiménez-Arellanes et al., 2013). A study conducted in Nigeria evaluated the effects of petroleum ether, chloroform, ethyl acetate, and methanol extracts obtained from the seed portion of *P. americana* on *E. coli*, *Klebsiella pneumoniae*, *B. subtilis*, *S. pyogenes*, *P. aeruginosa*, *S. aureus*, *Corynebacterium ulcerans*, *Salmonella typhi*, *Neisseria gonorrhoeae*, and *C. albicans*. The results of the study indicated that the highest inhibition zone value among the tested strains was observed for *C. albicans*, with a diameter of 42 mm. Furthermore, the zone diameter range for the standard antibiotic Streptomycin was reported to be 22-27 mm (Idris et al., 2009). A study conducted in Nigeria investigated the effects of hot water, cold water, methanol, and ethanol extracts, derived from the seed portion of *P. americana,* on *E. coli*, *P. aeruginosa*, *S. aureus*, and *K. pneumoniae*. The results indicated that the highest inhibition zone value was observed with the *P. aeruginosa* strain, measuring 30 mm (Nwaoguikpe et al., 2011). In a separate study conducted in Nigeria, the effect of the methanol extract obtained from the leaf and bark of *P. americana* on *S. pyogenes*, *Proteus mirabilis*, *S. typhi*, *K. pneumoniae*, *E. coli*, *B. subtilis*, and *S. aureus* was investigated. The study reported that the highest inhibition zone value was 12 mm for the *S. aureus* strain, observed in the extract obtained from the bark (Ogundare and Oladejo, 2014). In a separate study conducted in Nigeria, the effect of the crude extract obtained from the seed portion of the *P. americana* specimen on *P. mirabilis*, *S. aureus*, *P. aeruginosa*, *A. niger*, *C. albicans*, and *P. notatum* was investigated. The study revealed that the highest inhibition zone value was observed with the *C. albicans* strain, measuring 32 mm. Additionally, the inhibition zone ranges for Ciprofloxacin and Ketoconazole, used as standards, were reported to be 33-45 mm and 6-48 mm, respectively (Egbuonu et al., 2018). A distinct study conducted in Nigeria investigated the effects of acetone and methanol extracts, derived from the leaf portion of *P. americana*, on *B. cereus*, *B. subtilis*, *P. aeruginosa*, *S. typhi*, *S. aureus*, *Shigella flexneri*, *E. coli*, *C. albicans*, *A. fumigatus*, *A. niger*, and *A. flavus*. The results of this study indicated that the highest inhibition zone value, measuring 34.20 mm, was observed with the methanol extract against the *S. aureus* strain. Furthermore, the range of values for the standard antibiotics Ciprofloxacin, Rocephin, Gentamicin, Pefloxacin, and Erythromycin were reported as follows: 11.20-15.43 mm, 12.50-49.97 mm, 0.00-18.50 mm, 0.00-15.40 mm, and 0.00-16.47 mm, respectively (Ajayi et al., 2017). A study conducted in Zimbabwe investigated the effects of acetone, ethanol:water, dichloromethane, and methanol extracts obtained from the leaf portion of *P. americana* on *K. pneumoniae*, *S. epidermidis*, *C. albicans*, and *C. tropicalis*. The study reported that the best minimum inhibitory concentration (MIC) value was 50 µg/mL for the acetone extract against *S. epidermidis* (Makopa et al., 2020). In a study conducted in Brazil, the effect of hexane and methanol extracts obtained from the seed portion of *P. americana* on *Candida spp.*, *C. neoformans,* and *Malassezia pachydermatis* was investigated. The results indicated that the hexane extract exhibited the most potent minimum inhibitory concentration (MIC) values, ranging from 0.625 to 1.25 mg/mL for *Candida spp.*, 0.312 to 0.625 mg/mL for *C. neoformans*, and 0.031 to 0.625 mg/mL for *M. pachydermatis* strains (Leite et al., 2009). The antimicrobial activity of a methanol extract from the seeds of *P. americana* against *S. aureus* was evaluated in a Cameroonian study. The findings indicated a minimum inhibitory concentration (MIC) range of 64 to 128 µg/mL for the extract (Ekom and Kuete, 2022). In an Egyptian study, researchers looked at how extracts from the leaves of *P. americana* (using ethanol, ethyl acetate, and petroleum ether) affected various microorganisms: *B. subtilis*, *A. fumigatus*, *C. albicans*, *Enterococcus faecalis*, *P. aeruginosa,* and *E. coli*. They found the ethanol extract worked best against *B. subtilis*, with a 30 mm inhibition zone. For comparison, the standard antibiotic Gentamicin had zones between 15-25 mm (Awaad et al., 2023). A review of the literature indicates that the most frequently used bacterial strains in antimicrobial studies of the avocado plant are *S. aureus*, *B. cereus*, *B. subtilis*, *P. aeruginosa*, and *E. coli*, while the most commonly studied fungal strains are *Candida spp.* and *Aspergillus* spp. Furthermore, literature research suggests that the avocado plant is a significant source of antimicrobial compounds.

Anticancer and Cytotoxic Activity

The heterogeneous structure of cancer necessitates various treatment approaches due to the biological properties that vary between different types and stages of the disease. In order to respond to this diversity, versatile and targeted therapeutic strategies are needed (Ni et al., 2019; Mohammed et al., 2023d). In this context, the use of active pharmaceutical substances obtained from natural compounds of plant origin is gaining more and more importance (Çömlekçioğlu et al., 2024). Phytochemicals are often considered as both alternative and complementary treatments to classical chemotherapy due to their ability to affect multiple biological targets (Şabik et al., 2024). These compounds derived from natural sources can show anticancer effects through various mechanisms such as stopping cancer progression, inhibiting cell proliferation and inducing apoptosis, with a less side effect profile (Uysal et al., 2024). The anticancer potential of ethanol, water, dichloromethane, and ethyl acetate extracts from *P. americana* seeds was evaluated in a Vietnamese study. Results indicated that avocado seed extracts, particularly hexane (81%) and dichloromethane (75%) fractions, markedly suppressed the growth of human lung (A549) and gastric (BGC823) cancer cells at a concentration of 200 µg/mL (Vo and Le, 2019). This research, carried out in Egypt, examined the impact of ethanol, ethyl acetate, and petroleum ether extracts, derived from the leaves of *P. americana,* on human lung normal fibroblast (WI38), human lung carcinoma (A549), and human liver carcinoma (HepG2) cell lines, utilizing the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide tetrazolium (MTT) assay. The study revealed that the ethyl acetate extract demonstrated the most potent anticancer effects against the A549, HepG2, and WI38 cell lines, with IC50 values recorded as 44.28, 88.91, and 90.52 µg/ml, respectively (Awaad et al., 2023). This research, performed in Nigeria, examined the impact of a methanol extract derived from the seed of *P. americana* on the MCF-7 human breast cancer cell line and the HMVII human vaginal melanoma cell line. The findings indicated IC50 values of 16.51 µg/mL against MCF-7 cells and 31.71 µg/mL against HMVII cells for the tested extract (Ukwubile and Makinde, 2024). This research, performed in Indonesia, examined the impact of *P. americana* leaf-derived ethanolic extract on the HSC-3 human squamous carcinoma cell line. Utilizing the MTT assay, results indicated that a 100% concentration of the extract exhibited the highest efficacy among the tested concentrations (100%, 50%, 25%, and 10%) (Tessalonica and Roeslan, 2020). Researchers in Indonesia examined the effects of ethanol, n-hexane, chloroform, and ethyl acetate extracts from *P. americana* seed on MCF-7 cells. The n-hexane extract showed the most potent effect, with an IC50 value of 211.2 µg/mL (Rahwawati et al., 2022). Examination of the existing literature reveals that the avocado plant could serve as a natural anticancer agent.

Other Activity

The antiprotozoal properties of chloroform and ethanol extracts from *P. americana* seeds were evaluated in a study performed in Mexico. The study revealed that these extracts demonstrated substantial activity against *Entamoeba histolytica*, *Giardia lamblia*, and *Trichomonas vaginalis*, as evidenced by IC50 values of less than 0.634 µg/mL (Jiménez-Arellanes et al., 2013). The α-glucosidase inhibitory activity of acetone, ethanol:water, dichloromethane, and methanol extracts of *P. americana* leaves was assessed. Spectrophotometric analysis of p-nitrophenol production from p-nitrophenol-glucopyranoside revealed that the methanol extract exhibited the most significant time- and dose-dependent inhibition. The K_i and K_{inact} values for the methanol extract were determined to be 1.4 mg/mL and 2.4 U/min, respectively, following a 1-hour incubation (Makopa et al., 2020). In a Brazilian study, researchers analyzed how hexane and methanol extracts from avocado seeds affected *Aedes aegypti*. They found that the IC50 values for the larvae were 16.7 mg/mL for the hexane extract and 8.87 mg/mL for the methanol extrac (Leite et al., 2009). Scientists in Chile looked at extracts from the avocado plant (*P. americana*) to see if they could reduce inflammation. They used two types of extracts: one with alcohol and one with water, from both the peel and the leaves. The alcohol-based extract from the leaves worked best to lower NO levels ($p < 0.001$). Both types of extracts lowered TNF-α levels ($p < 0.05$), and the alcohol extract also lowered TNF-α gene activity ($p < 0.01$) (Ovalle Marín et al., 2020). The anti-cholinesterase (AChE) activity of n-hexane, ethyl acetate, and n-butanol extracts, procured from the leaf, seed, exocarp, and mesocarp of *P. americana*, was assessed in a Vietnamese study. The n-butanol seed extract demonstrated the highest efficacy, yielding an IC50 value of 15.24 µg/mL (Dang et al., 2019).

PLANT DISEASES OF AVOCADO

The economic importance of avocado cultivation in many regions is significantly challenged by a broad spectrum of pests and diseases. These biotic factors, encompassing pathogenic oomycetes, fungi, bacteria, and viroids, alongside a range of arthropod pests, pose a considerable risk to avocado production. Their capacity to affect all parts of the avocado tree, from the roots to the fruit, results in diverse modes of damage that can substantially diminish both the quantitative and qualitative aspects of fruit yield, thereby impacting the overall productivity and economic sustainability of avocado orchards (Dann et al., 2013; Peterson and Orden, 2008).

Phytophthora Root Rot

This disease, caused by the oomycete *Phytophthora cinnamomi*, has a broad host range, affecting nearly 5000 plant species, including avocado (Jung et al., 2013). *P. cinnamomi* can act as a saprophyte or parasite, infecting avocado feeder roots and potentially causing tree death and substantial economic losses (Farooq et al., 2023). The pathogen thrives in warm, saturated soil conditions, which promote sporangium and zoospore development, leading to root tip infection and rapid mycelial growth. Root damage impairs water and nutrient uptake, resulting in canopy decline (chlorosis, small leaves, dieback), and potentially malformed fruit (Salgadoe et al., 2018; Dann and Gazis, 2024). Symptoms can range from wilting to chlorosis, with variable disease progression. The pathogen's long-term survival is aided by saprophytic growth, latent infections, and resistant structures, complicating eradication efforts. Management strategies include preventing pathogen spread, chemical treatments, soil amendments, and the use of resistant cultivars (D'Souza et al., 2005). Integrated approaches, incorporating tolerant varieties, organic amendments, biological control, nutritional management, optimized irrigation, and targeted fungicide use, are crucial for sustainable disease management (Wolstenholme and Sheard, 2010; Belisle et al., 2019; Ramírez-Gil and Morales-Osorio, 2020; Farooq et al., 2023).

Anthracnose

Anthracnose is a widespread fungal disease affecting numerous crops, including avocado, almond, coffee, and others, causing significant economic losses. While the specific causal organisms are still being researched (Sharma and Kulshrestha, 2015; Kimura et al., 2020), *Colletotrichum* spp. (e.g., *C. gloeosporioides*, *C. acutatum*) and *Pestalotiopsis versicolor* have been identified as key pathogens in avocado (Velázquez-del Valle et al., 2016; Valencia et al., 2011). The disease cycle involves the dispersal of fungal propagules by rain or irrigation, leading to infection of leaves (brown necrosis), blossoms, and fruits (lesions) (Willingham et al., 2000; Silva-Rojas and Ávila-Quezada, 2011). Effective control integrates pre-harvest strategies (pruning, resistant cultivars, fungicides) with post-harvest treatments and potential biological agents (Perkins et al., 2019; Kimura et al., 2020) to maintain fruit marketability.

Avocado Scab

Avocado scab, caused by the fungus *Elsinoe perseae* (syn. *Sphaceloma perseae*), is a significant disease in humid avocado production areas, reducing fruit marketability due to cosmetic damage (Dann et al., 2013). Fruit damage appears as rough, brown to purple-brown spots that enlarge and coalesce into corky regions. Leaf lesions are smaller, brown to black, vein-associated, and can lead to stunted, distorted foliage. Lesions may also occur on twigs and pedicels (Fischer and Firmino, 2023; Belizaire et al., 2024). Recent research suggests a more complex etiology, with symptom overlap and other fungal species (e.g., *Colletotrichum* spp.) potentially contributing to scab-like symptoms (Morales-García et al., 2023). As avocado is the sole known host, disease establishment in new regions is limited to avocado trees. Control relies on integrated management, including resistant cultivars and timed fungicide applications (copper or benomyl) (Marais, 2004; Fischer et al., 2023).

Verticillium Wilt

Verticillium albo-atrum and *V. dahliae*, soilborne fungal pathogens, cause wilt diseases in various countries (Ramírez-Gil and Morales-Osorio, 2020). These pathogens have a broad host range, infecting over 200 plant species (Agrios, 2005), including economically important crops (Haberman et al., 2020). The disease is characterized by rapid wilting and browning of leaves that remain attached to the plant. Vascular tissue exhibits brown to grey-brown streaking. Older trees may show branch symptoms, while younger trees are often systemically affected. Symptom recurrence is common, even with compensatory shoot growth (Dann et al., 2013). Effective management is challenging, with inconsistent results from biological control, beneficial microorganisms, heat treatments, and chemical applications (Haberman et al., 2020; Ramírez-Gil and Morales-Osorio, 2021).

Armillaria Root Rot

Armillaria mellea is the primary fungal pathogen causing Armillaria root rot, a lethal and slow-progressing disease in avocado. This pathogen has a broad host range, infecting over 600 species (including oak and indigenous species). *A. mellea* colonizes roots and woody debris, which are essential for its survival. Infection occurs through direct root contact or rhizomorph invasion (Marais, 2004; Dann et al., 2013). Symptoms include chronic chlorosis and gradual decline or rapid wilt (without leaf drop). Internal examination reveals brown to black decay in root, cambium, and wood tissues (Marais, 2004). Diagnostic features include mycelial plaques, pseudosclerotia, and rhizomorphs. Advanced wood degradation leads to brittleness, and basidiocarps may be observed (Michua-Cedillo et al., 2024). Management is difficult due to the pathogen's persistence in soil and debris. Sanitation and soil fumigation have limited control, and eradication is often unattainable. Fungicide injection and composting have shown some efficacy (Pérez-Jiménez, 2008).

Dothiorella Canker: Branch Canker and Dieback

Branch canker and dieback, often associated with Botryosphaeriaceae fungi, are significant diseases in avocado orchards. A diverse array of Botryosphaeriaceae, including *Botryosphaeria dothidea*, *Diplodia* spp., and *Neofusicoccum* spp. (Valencia et al., 2022), are etiological agents, affecting woody tissues and fruit. Management focuses on preventing pathogen establishment and spread through sanitation of grafting tools, minimizing plant stress (especially drought), and pruning/harvesting during dry periods. Inoculum reduction is achieved by removing dead organic material. Prophylactic treatments (e.g., copper fungicide) are crucial in high-density plantings (Dann et al., 2013; Möller et al., 2025).

White Root Rot

White root rot, caused by *Rosellinia necatrix* (syn. *Dematophora necatrix*), is a critical disease in avocado cultivation. The pathogen has a broad host range, infecting 170 plant species in 63 genera (Ten Hoopen and Krauss, 2006), impacting various crops (Ten Hoopen and Krauss, 2006; Arjona-López et al., 2020). Progression to tree death occurs over 1-3 years, with initial symptoms including growth decline, yellowing foliage, and shriveled fruit, culminating in defoliation. Root examination reveals white mycelial growth progressing to darker structures (Marais, 2004; Dann et al., 2013). Management requires a multi-pronged approach: removal of infected material, physical containment, and preventative measures. Soil disinfection (chemical/physical) and biological control agents (e.g., *Trichoderma* spp., *Entoleuca* sp.) have shown potential (Dann et al., 2013; Arjona-Girona et al., 2014; Arjona-Girona and López-Herrera, 2018; Arjona-López et al., 2020).

Cercospora Spot

Pseudocercospora purpurea causes Cercospora spot, a disease prevalent in warm, humid climates (Schoeman and Kallideen, 2018). The disease affects leaves, fruits, and stems/pedicels, leading to lesions and potential fruit drop (Fischer and Firmino, 2023). Management involves timely fungicide applications, biological control (*Bacillus subtilis*), insect and root rot management, and orchard sanitation (Dann et al., 2013).

Bacterial Canker

Bacterial canker, caused by *Pseudomonas syringae* pv. *syringae*, *Pantoea agglomerans*, or *Xanthomonas campestris*, is generally a minor disease of avocado (Marais, 2004). Symptoms include sunken, dark lesions on the trunk, often with exudation and a white powdery substance. Internal necrotic tissue can lead to tree decline (Dann et al., 2013). Management emphasizes preventative measures, such as disease-free planting material and removal of infected trees (Korsten and Kotzé 1985, Marais, 2004).

Avocado Sunblotch Viroid (ASBVd)

Avocado sunblotch disease is caused by ASBVd, a circular single-stranded RNA viroid (Roberts et al., 2023). The viroid is primarily spread through infected nursery stock, with significant seed transmission from asymptomatic trees (Marais, 2004). While pollen and mechanical transmission are possible experimentally, insect vectors are not involved. ASBVd has a limited host range, mainly affecting avocado (Kuhn et al., 2017), and causes yield and quality reductions (Saucedo Carabez et al., 2019). Symptoms include leaf distortion, twig streaking, fruit discoloration, and trunk cracking (Dann et al., 2013; Kibwage, 2023). Infected trees may also exhibit stunted growth and reduced yields.

Common Avocado Pests

Avocado cultivation is susceptible to various arthropod pests that can significantly impact tree health and fruit yield. These pests, including insects and mites, have diverse feeding strategies and life cycles, causing different types of damage (Kendra et al., 2011). Sap-feeding insects (e.g., thrips, scale insects) cause leaf distortion, reduced vigor, and honeydew production, potentially leading to sooty mold (Hoddle et al., 2005; Jones et al., 2019; Bara and Laing, 2020). Foliage feeders (e.g., lepidopteran larvae, coleopteran adults) can defoliate trees, impacting photosynthesis (Torres et al., 2023). Fruit pests (e.g., weevils, fruit flies) directly reduce crop quality and quantity (Márquez-Santos et al., 2020). Effective pest management requires accurate species identification and understanding their ecological roles within the agroecosystem. In conclusion, avocado production is constrained by a complex interaction of diseases and pests, encompassing a range of fungal, oomycete, and viroid pathogens, as well as various arthropod species. These biotic factors can cause significant economic losses through reduced yield and diminished fruit quality. Especially within these effects, fungal effects stand out more than other effects. Effective management strategies require a comprehensive understanding of the etiology and epidemiology of each threat, often necessitating integrated approaches that combine cultural practices, biological control, and judicious use of chemical interventions to ensure sustainable avocado production.

CHEMICAL CONTENTS

This study compiles the chemical contents of *P. americana* as documented in the existing literature. The results are summarized in Table 2.

Table 2. *Chemical contents of Persea americana.*

Used part	Chemical contents	References
Leaf	estragole (9.0-78.12%), β-caryophyllene (1.1-47.6%), valencene (16.0%), germacrene-D (3.0-5.9%), α-humulene (0-25.2%), δ-cadinene (0.48-4.8%), β-cubebene (0.5-11.3%), caryophyllene oxide (3.6-5.66%), spathulenol (3.2%), β-pinene (0.42-22.04%), α-pinene (0.9-14.25%), sabinene (0.7-15.16%), α-cubebene (0-13.0%), cis-γ-cadinene (3.0%), methyl eugenol (0.75-31.2%), 2-(8Z,11Z)-8,11-heptadeca dienyl-furan (9.89-67.37%), α-copaene (1.9-23.6%), trans-nerolidol (8.28%), eucalyptol (0.31-3.49%)	Sagrero-Nieves et al., 1995; Ogunbinu et al., 2007; Larijani et al., 2010; Niogret et al., 2013; Granados-Echegoyen et al., 2015; García-Rodríguez et al. 2016; Elosaily et al., 2021; Nasri et al., 2022

Literature reviews indicate that the leaf portion of *P. americana* has been reported to contain the following compounds: estragole (9.0-78.12%), β-caryophyllene (1.1-47.6%), valencene (16.0%), germacrene-D (3.0-5.9%), α-humulene (0-25.2%), δ-cadinene (0.48-4.8%), β-cubebene (0.5-11.3%), caryophyllene oxide (3.6-5.66%), spathulenol (3.2%), β-pinene (0.42-22.04%), α-pinene (0.9-14.25%), sabinene (0.7-15.16%), α-cubebene (0-13.0%), cis-γ-cadinene (3.0%), methyl eugenol (0.75-31.2%), 2-(8Z,11Z)-8,11-heptadeca dienyl-furan (9.89-67.37%), α-copaene (1.9-23.6%), trans-nerolidol (8.28%), and eucalyptol (0.31-3.49%) (Sagrero-Nieves et al., 1995; Ogunbinu et al., 2007; Larijani et al., 2010; Niogret et al., 2013; Granados-Echegoyen et al., 2015; García-Rodríguez et al. 2016; Elosaily et al., 2021; Nasri et al., 2022). Phytochemical analysis of avocado leaves identified estragole, β-caryophyllene, 2-(8Z,11Z)-8,11-heptadecadienyl-furan, and methyl eugenol as major constituents. While various parts of the avocado plant have been studied, leaf-based analyses are more prevalent. Given the limited overall data on the plant's chemical profile, these findings provide a valuable reference for future research.

PHENOLIC CONTENTS

Secondary metabolites do not possess direct nutritional value; however, they play crucial roles in plant defense and exhibit significant pharmacological activities, including antimicrobial, antioxidant, and anticancer effects (Mohammed et al., 2022; Uysal, 2023). The phenolic compounds present in *P. americana* are shown in Table 3.

Table 3. *Phenolic compounds of Persea americana.*

Used parts	Phenolic compounds	References
Seed	3-O-caffeoylquinic acid, 3-O-p-coumaroylquinic acid, procyanidin, quinic acid, citric acid, procyanidin dimer, catechin, 5-O-caffeoylquinic acid, caffeic acid, epicatechin, vanillin, p-coumaric acid, ferulic acid, sinapic acid, rutin, quercetin-3-O-glucoside, phloridzin, quercetin, apigenin, kaempferol, cis 3-O-caffeoylquinic acid, trans 3-O-caffeoylquinic acid, epicatechin dimer, cis 3-p-coumarouylquinic acid, isorhametin-glucuronide, protocatechuic acid, kaempferidclorogenic acid, syringic acid, gallc acid, 4-hydroxybenzoic acid, vanillic acid	Kosińska et al., 2012; Pahua-Ramos et al., 2012; Melgar et al., 2018; Soldera-Silva et al., 2018; Deuschle et al., 2019; Rosero et al., 2019; Weremfo et al., 2020
Fruit	3-O-caffeoylquinic acid, 3-O-p-coumaroylquinic acid, procyanidin, catechin, procyanidin dimer, quinic acid, citric acid, syringic acid, 5-O-caffeoyl-quinic acid, caffeic acid, epicatechin, vanillin, p-coumaric acid, ferulic acid, sinapic acid, rutin, quercetin-3-O-glucoside, phloridzin, quercetin, apigenin, kaempferol, 4-O-caffeoylquinic acid, epicatechin dimer, quercetin-dihexoside, epicatechin hexamer, quercetin-pentoside-hexoside, quercetin-glucoronide, quercetin-hexoside, quercetin-rhamnoside-hexoside, quercetin-rhamnoside-pentoside, isorhametin-glucuronide, naringenin, catechin hydrate, naringin, rutin hydrate, hesperidin, cynnamic acid, protocatechuic acid, gallic acid, gentisic acid, 4-hydroxybenzoic acid, chlorogenic acid, homovanillic acid, vanillic acid, benzoic acid, taxifolin, narirutin, isorhamnetin, myricetin, neohesperidin, luteolin, trans-cinnamic acid, poncirin, galangin, chrysin	Kosińska et al., 2012; Di Stefano et al., 2017; Melgar et al., 2018; Deuschle et al., 2019; Rosero et al., 2019; Trujillo-Mayol et al., 2020
Leaf	rutin, quercetin, chlorogenic acid, caffeic acid 4-O-glucoside, medioresinol, 3-hydroxyphloretin 2′-O-glucoside, cyanidin 3-O-glucosyl-rutinoside, sinensitin, cinnamoyl glucose, caffeoyl tartaric acid, cyanidin 3-O-(6″-malonyl-3″-glucosyl-glucoside), esculin, kaempferide, tangeretin, jaceosidin, 3,7-dimethylquercetin, resveratrol, kaempferol 3-O-(2″-rhamnosyl-galactoside) 7-O-rhamnoside, 5-5′-dehydrodiferulic acid, 6″-O-acetylglycitin, p-coumaroyl tyrosine, p-coumaric acid 4-O-glucoside, caffeic acid, coumaric, ferulic acid, gallic acid, hydroxybenzoic, protocatechuic, pyrocatechuic, resorcylic, sinapic, syringic, vanillic acid, apigenin, isorhamnetin, kaempferol 3-O-arabinopyranoside, kaempferol 3-O-b-glucopyranoside, kaempferol 3-O-rhamnopyranoside, luteolin, luteolin 7-O-glucoside, quercetin 3-O-arapyranoside, quercetin 3-O-b-glucopyranoside, quercetin 3-O-b-D-glucoside, catechin, epicatechin, procyanidin, trimeric procyanidin, luteolin-8-C-glucoside, tri-glycosylated kaempferol, quercetin-3-O-(Rha-Glc)-7-rhamnoside, peltatoside hyperoside, isoquercitrin, avicularin, quercitrin, astragalin, afzelin	Ding et al., 2007; Owolabi et al., 2010; Yamassaki et al., 2017; Loh and Lim, 2018; Deuschle et al., 2019; Solís-Salas et al., 2021

Literature reviews indicate that studies on *P. americana* have focused on the phenolic compounds found in its seeds, fruit, and leaves. The seed portion has been reported to contain the following phenolic constituents: 3-O-caffeoylquinic acid, 3-O-p-coumaroylquinic acid, procyanidin, quinic acid, citric acid, procyanidin dimer, catechin, 5-O-caffeoylquinic acid, caffeic acid, epicatechin, vanillin, p-coumaric acid, ferulic acid, sinapic acid, rutin, quercetin-3-O-glucoside, phloridzin, quercetin, apigenin, kaempferol, cis 3-O-caffeoylquinic acid, trans 3-O-caffeoylquinic acid, epicatechin dimer, cis 3-p-coumarouylquinic acid, isorhametin-glucuronide, protocatechuic acid, kaempferide, chlorogenic acid, syringic acid, gallic acid, 4-hydroxybenzoic acid, and vanillic acid (Kosińska et al., 2012; Pahua-Ramos et al., 2012; Melgar et al., 2018; Soldera-Silva et al., 2018; Deuschle et al., 2019; Rosero et al., 2019; Weremfo et al., 2020). The phenolic content of the fruit portion has been reported to include 3-O-caffeoylquinic acid, 3-O-p-coumaroylquinic acid, procyanidin, catechin, procyanidin dimer, quinic acid, citric acid, syringic acid, 5-O-caffeoyl-quinic acid, caffeic acid, epicatechin, vanillin, p-coumaric acid, ferulic acid, sinapic acid, rutin, quercetin-3-O-glucoside, phloridzin, quercetin, apigenin, kaempferol, 4-O-caffeoylquinic acid, epicatechin dimer, quercetin-dihexoside, epicatechin hexamer, quercetin-pentoside-hexoside, quercetin-glucuronide, quercetin-hexoside, quercetin-rhamnoside-hexoside, quercetin-rhamnoside-pentoside, isorhametin-glucuronide, naringenin, catechin hydrate, naringin, rutin hydrate, hesperidin, cinnamic acid, protocatechuic acid, gallic acid, gentisic acid, 4-hydroxybenzoic acid, chlorogenic acid, homovanillic acid, vanillic acid, benzoic acid, taxifolin, narirutin, isorhamnetin, myricetin, neohesperidin, luteolin, trans-cinnamic acid, poncirin, galangin, and chrysin (Kosińska et al., 2012; Di Stefano et al., 2017; Melgar et al., 2018; Deuschle et al., 2019; Rosero et al., 2019; Trujillo-Mayol et al., 2020). The phenolic content of the leaf portion has been reported to include rutin, quercetin, chlorogenic acid, caffeic acid 4-O-glucoside, medioresinol, 3-hydroxyphloretin 2′-O-glucoside, cyanidin 3-O-glucosyl-rutinoside, sinensitin, cinnamoyl glucose, caffeoyl tartaric acid, cyanidin 3-O-(6″-malonyl-3″-glucosyl-glucoside), esculin, kaempferide, tangeretin, jaceosidin, 3,7-dimethylquercetin, resveratrol, kaempferol 3-O-(2″-rhamnosyl-galactoside) 7-O-rhamnoside, 5-5′-dehydrodiferulic acid, 6″-O-acetylglycitin, p-coumaroyl tyrosine, p-coumaric acid 4-O-glucoside, caffeic acid, coumaric acid, ferulic acid, gallic acid, hydroxybenzoic acid, protocatechuic acid, pyrocatechuic acid, resorcylic acid, sinapic acid, syringic acid, vanillic acid, apigenin, isorhamnetin, kaempferol 3-O-arabinopyranoside, kaempferol 3-O-b-glucopyranoside, kaempferol 3-O-rhamnopyranoside, luteolin, luteolin 7-O-glucoside, quercetin 3-O-arapyranoside, quercetin 3-O-b-glucopyranoside, quercetin 3-O-b-D-glucoside, catechin, epicatechin, procyanidin, trimeric procyanidin, luteolin-8-C-glucoside, tri-glycosylated kaempferol, quercetin-3-O-(Rha-Glc)-7-rhamnoside, peltatoside, hyperoside, isoquercitrin, avicularin, quercitrin, astragalin, and afzelin (Ding et al., 2007; Owolabi et al., 2010; Yamassaki et al., 2017; Loh and Lim, 2018; Deuschle et al., 2019; Solís-Salas et al., 2021). A review of the existing literature reveals that rutin, procyanidin, catechin, caffeic acid, epicatechin, ferulic acid, sinapic acid, quercetin, apigenin, kaempferol, gallic acid, protocatechuic acid, chlorogenic acid, syringic acid, and vanillic acid are common phenolic compounds found in the seed, fruit, and leaf components of the avocado plant.

TOTAL PHENOLIC AND FLAVONOID CONTENTS

In this study, the total phenolic and flavonoid content of *P. americana,* as reported in the literature, is presented in Table 4.

Table 4. *Total phenolic and flavonoid contents of Persea americana*.

Total phenolic value	Used part	References	Total flavonoid value	Used part	References
0.20-2.407 mg/g	Leaf, pulp, peel, skin, seed, fruit	Pahua-Ramos et al., 2012; Ferreira da Vinha et al., 2013; Adaramola et al., 2016; Kamagate et al., 2016; Di Stefano et al., 2017; Yamassaki et al., 2017; Loh and Lim, 2018; Soldera-Silva et al., 2018; Chaiyasut et al., 2019; Deuschle et al., 2019; Kavaz and Ogbonna, 2019; Vo et al., 2019; Che-Galicia et al., 2020; Trujillo-Mayol et al., 2020; Weremfo et al., 2020; Dibacto et al., 2021; Dal-Bó and Freire, 2022; Fan et al., 2022; Sulistyani et al., 2022; Lyu et al., 2023; Munthe et al., 2023	0.01-5.552 mg/g	Leaf, pulp, peel, skin, seed, fruit, stem bark	Ferreira da Vinha et al., 2013; Adaramola et al., 2016; Kamagate et al., 2016; Soldera-Silva et al., 2018; Deuschle et al., 2019; Kavaz and Ogbonna, 2019; Trujillo-Mayol et al., 2020; Weremfo et al., 2020; Dibacto et al., 2021; Fan et al., 2022; Isromarina et al., 2022; Lyu et al., 2023; Munthe et al., 2023; Risnata and Hidayati, 2024

P. americana has been studied for its total phenolic and flavonoid content, with common use of leaf, pulp, peel, skin, seed, fruit, and stem bark portions. The total phenolic content has been reported to range from 0.20 to 2.407 mg/g (Pahua-Ramos et al., 2012; Ferreira da Vinha et al., 2013; Adaramola et al., 2016; Kamagate et al., 2016; Di Stefano et al., 2017; Yamassaki et al., 2017; Loh and Lim, 2018; Soldera-Silva et al., 2018; Chaiyasut et al., 2019; Deuschle et al., 2019; Kavaz and Ogbonna, 2019; Vo et al., 2019; Che-Galicia et al., 2020; Trujillo-Mayol et al., 2020; Weremfo et al., 2020; Dibacto et al., 2021; Dal-Bó and Freire, 2022; Fan et al., 2022; Sulistyani et al., 2022; Lyu et al., 2023; Munthe et al., 2023). Total flavonoid content was reported to range from 0.01 to 5.552 mg/g (Ferreira da Vinha et al., 2013; Adaramola et al., 2016; Kamagate et al., 2016; Soldera-

Silva et al., 2018; Deuschle et al., 2019; Kavaz and Ogbonna, 2019; Trujillo-Mayol et al., 2020; Weremfo et al., 2020; Dibacto et al., 2021; Fan et al., 2022; Isromarina et al., 2022; Lyu et al., 2023; Munthe et al., 2023; Risnata and Hidayati, 2024).

CONCLUSION

Avocado has recently become one of the fruits with high export and import rates in terms of both nutritional and health aspects. This study compiles the traditional uses, biological activities, cosmetic industry applications, plant diseases, chemical composition, phenolic content, and total phenolic and total flavonoid values of *P. americana*. The significant vitamin E concentration within the fruit has notably augmented its usage in cosmetic formulations, particularly for dermal applications. An analysis of studies concerning its biological activity reveals its substantial antioxidant and antimicrobial properties. Furthermore, a literature survey indicates that fungal infections constitute the predominant area of research in plant pathology related to this species, resulting in significant economic repercussions. The major components identified in the chemical composition of the avocado plant's leaf portion were determined to be estragole, β-caryophyllene, 2-(8Z,11Z)-8,11-heptadecadienyl-furan, and methyl eugenol. A review of the literature revealed that the phenolic compounds commonly found in the seed, fruit, and leaf portions of the avocado plant include rutin, procyanidin, catechin, caffeic acid, epicatechin, ferulic acid, sinapic acid, quercetin, apigenin, kaempferol, gallic acid, protocatechuic acid, chlorogenic acid, syringic acid, and vanillic acid. It is believed that our study will contribute to future research on avocado and other tropical products, particularly in the field of pharmacology. Furthermore, this study is anticipated to facilitate the utilization of natural products in the advancement of pharmacology.

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CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

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