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Traditional use, phytoconstituents, and pharmacological effects of *Persea americana*: A recent review

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ABSTRACT

Persea americana is a native American plant most known as avocado, aguacate, abacate, or palta. It is considered a commercially valuable fruit tree cultivated worldwide for its rich oil content. It has various medicinal properties throughout the plant, including fruits, roots, leaves, and seeds. Conventionally, it has been used to treat malaria, obesity, urinary incontinence, and anemia, and protect against sunlight and skin diseases. However, as avocado is a plant species with worldwide knowledge, it is necessary to constantly review recently published articles, according to the topic of interest. Therefore, the objective of this review is to compile and discuss recent studies (2010–2024) on ethnomedicinal, pharmacological, and chemical information of *P. americana*. Articles were searched from the following electronic databases: Scopus (n = 62), ScienceDirect (n = 70), and PubMed (n = 194). Regarding the *in vivo* pharmacological effects, studies suggest potential benefits for diabetes, gastric ulcers, and others, likely due to reduced glucose levels. *In vitro* studies mainly focused on antioxidant/anti-inflammatory and anticancer activities. These findings demonstrate a high diversity of pharmacological activities achievable with *P. americana* extracts through various administration forms (decoction, juice extract, and infusion) and plant parts. Overall, *P. americana* shows promise as an effective alternative treatment for various health issues.

1. INTRODUCTION

Persea americana, commonly known as avocado, is a versatile fruit tree native to Central and South America. Beyond its culinary value, avocado boasts a rich history of traditional medicinal use in various cultures. It is represented worldwide by several varieties, mainly the Mexican (*P. americana* var. *drymifolia*), Antillean (*P. americana* var. *americana*), and Guatemalan (*P. americana* var. *guatemalensis*) [1-4]. African descriptions of *P. Americana* include other names such as Alligator pear, avocado, butter, avokado (Afrikaans and English), mparachichi, mpea, mwembe, mafuta (Swahili), Maluma (Zulu), Paya (Ghana-Twi), and Pia (Yoruba). Other common names in the world are include htaw bat and kyese (Burmese), zaboka (Creole), avocat, avocatier, zabelbok and zaboka (French), alligatorbirne, avocadobirne (German), adpukat, avocado (Indonesian), avôkaa (Khmer), apukado, avocado (Malay), avocado (Mandinka), bata (Pidgin English), awokado (Thai), medang (Trade name), and bo, lê dâù (Vietnamese) [5]. It is botanically classified as belonging to the Plantae Kingdom; *Laurales* Order; Family *Lauraceae*; Genus *Persea*; and species *Americana*. It is commonly grown in tropical and subtropical regions of the world. The leaf of the plant is shiny and green, with a bell-shaped (green/brown) fruit [6]. The morphological characteristics of *P. americana* include the woody and green stem with an approximate size of 3–5 meters in height, in addition to elliptical and elongated leaves and the obovate-narrow/ellipsoid shape of the fruit, with an average peel thickness equal to 1.11 mm average. Morpho–anatomy studies also report the following average values: 118.48 cm^2 leaf area, 458.59 g fruit weight, 84.34 mm fruit diameter, 117.74 mm fruit length, 261.36 g pulp weight, and 58.0 g seed weight [7-9].

Regarding its traditional use, in South America, the seed extract is used as a hypocholesterolemic, hypotensive, antidiabetic, and anti-inflammatory, while avocado oil (seeds) is used for dermatological applications and it is reported that its unsaponifiable portion has

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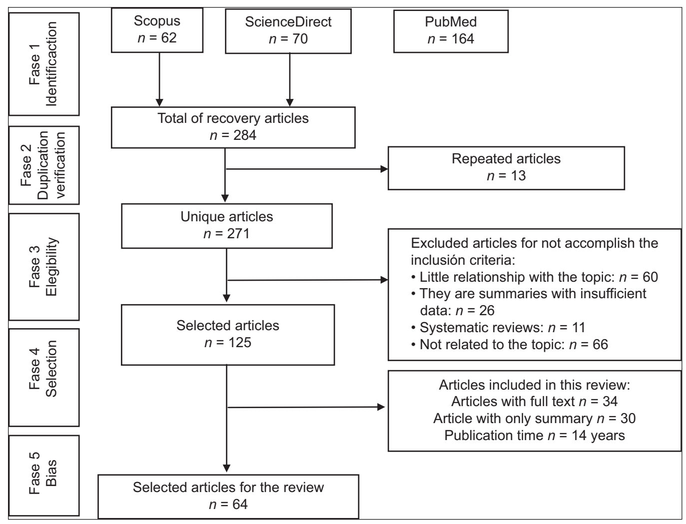
beneficial effects against osteoarthritis [10]. On the other hand, in the African continent, leaf extracts are commonly used in ethnomedicinal practices by local communities in the management of diabetes, hypertension, malaria, and other diseases, without any documented side effects except for dizziness and in alone cases of malaria treatment in Ivory Coast. In addition, the leaves are used for hypertension, diabetes, malaria, thyroid, diarrhea, cough, sedative, and antibacterial, the seeds and bark for tooth pain, stem bark and leaves for malaria, the seeds for skin diseases, while the leaves and fruits are indicated for constipation, kidney disorders and various types of pain, and the bark is used for syphilis [6].

Due to the nutritional composition, its antioxidants, and biochemical profile, avocado is considered a superfood that has gained substantial popularity and acceptance, so it presents important health benefits [1,11]. Furthermore, avocado fruits are rich in bioactive compounds that can be used in functional food applications [12]. Avocado pulp is widely consumed as a primary food source, while the seed is often discarded. However, the seed exhibits high antioxidant activity and inhibits metabolic changes induced by oxidative stress in endothelial cells, suggesting that avocado seed extracts have vasoprotective actions [13]. Furthermore, it was evaluated the use of avocado seed as a possible therapeutic agent in diabetes treatment, enhancing insulin sensitivity and regulating glycolipid metabolism, in addition to showing activity as a putative treatment of pancreatic dysfunction in diabetic patients, with a reduction in serum insulin [14]. Moreover, the whole fruit is rich in biocompounds (pulp, seed, and peel) and has antimicrobial, antioxidant, and anticancer activities, as well as dermatological and other uses [1], in addition to being a plant food rich in nutrients, whose chemicals are of great importance in the food, cosmetic, and pharmaceutical industries [12]. For example, avocado fatty acids have beneficial effects on risk factors for cardiovascular diseases (CVD), whereas the high content of carotenoids and phenolic compounds exhibit antifungal, anticancer, antioxidant, and anti-inflammatory activities [2]. Still notably, the seven-carbon sugars D-mannoheptulose and perseitol are chemical markers of avocado [15] and present anti-inflammatory, antimicrobial, and immunomodulatory activity [16,17]. Moreover, works from previous reviews report various types of pharmacological activities, such as antimicrobial, including activity against *Bacillus cereus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Salmonella flexneri*, *Staphylococcus aureus*, *Escherichia coli,* and *Candida albicans*, in addition to antidiabetic action by inhibiting enzymes alpha-amylase and alpha-glucosidase through the administration of the seeds aqueous extract and the phenolic extracts from the leaves and fruits, as well as the protective effect on the liver and kidneys through the administration of the aqueous extract of *P. americana* leaf, by reducing oxidative stress, and which also include antihypertensive and cholesterol-regulating effects [5].

Overall, *P. americana* is a fruit crop of economic importance throughout the world, in addition to being a highly studied plant species responsible for pharmacological, antioxidant, dermatological, and anti-cancer effects [1]. The fruit also guarantees biological functions thanks to the considerable amounts of vitamins and other phytonutrients [18], so the global demand for avocados has led to the planting of millions of young plants each year [19]. However, due to the large number of studies on the chemical and medicinal aspects of avocado in a short space of time, periodic compilation and integrated discussion of their contents are necessary, therefore the objective of this work is to chronologically summarize and discuss the recent literary review on studies that report the chemical, pharmacological, and ethnomedicinal activities of *P. americana* extracts from different ways of preparation and parts of the plant.

2. METHODOLOGY

A comprehensive search of scientific databases was conducted to compile and summarize ethnomedicinal, phytochemical, and pharmacological knowledge on *P. americana* and its various parts. This included Scopus (n = 62), ScienceDirect (n = 70), and PubMed (n = 194). The search terms focused on the medicinal properties of *P. americana*, using keywords such as "*P. americana*" combined with "chemical composition," or "pharmacological effects," or "Ethnomedicinal uses," so that only articles that focused on the topic related to the title of this review were included. Articles published between 2010 and 2024 were included in the study. Some articles in the introduction section, to provide additional information, were included without taking into account the search parameters.



3. RESULTS AND DISCUSSION

3.1. Traditional Uses and Ethnomedicinal Applications

Table 1 presents the ethnomedicinal use of *P. americana*, which has various traditional purposes due to its therapeutic properties [20]. The results report that the main route of administration is oral, likewise, they indicate that the leaves, stem, or fruit prepared by decoction are used to treat urinary incontinence [21] and nervousness [22], as well as analgesics [23], in addition to treat malaria [24]. On the other hand, the fruit is consumed fresh or in a salad to treat obesity [25], whereas the topical administration of the fruit in powder form or as maceration helps to treat skin diseases [26] or soften it, in addition to changing its texture, protecting it from sunlight, treating pimples and eliminating spots [27]. Moreover, the infusion of the leaves is used to treat anemia or increase energy [28].

3.2. Chemical Composition

Table 2 shows the chemical composition of *P. americana*, observing that the fruit contains procyanidin B2 [29], naringenin, rutin [30], and 60% monounsaturated fatty acids, presenting the oleic acid as the major fatty acid [31]. In addition, it was found that 16 to 32% of oil from the pulp [32,33]. The lineoic acid, palmitoleic acid [33], besides omega-6 and omega-3 acids also have been identified as major

Table 1: Traditional use of *Persea americana* depending on route of administration

Route of administration	Traditional use	Plant organ	Way of preparation	Country	Reference
Oral	Malaria treatment	Leaves and barks	Decoction/juice extract	Nigeria	[24]
	Urinary incontinence	Leaves or fruit	Raw or decoction consumed daily	Algeria	[21]
	Central nervous system disorders, nervous problems	Leaves, seeds and stem	NR	Central America	[22]
	Against nervousness and are used as analgesics	Leaves and bark	Decoction	Central America	[23]
	To treat or prevent anemia and increase energy	Leaves	Infusion	Zambia	[28]
	Obesity treatment	Leaves and Fruits	It is consumed fresh, in a salad after having let it ferment	Central America	[25]
Topical	Skin diseases	Fruit	Powder	Morocco	[26]
	Soften skin, change skin texture, protection from sunlight, treating pimples, removing spots	Fruit	Maceration	South Africa	[27]

compounds in the fruit. The results indicate that fruit pulp is a good source of useful vegetable oil that can be used in the food industry [34]. On the other hand, the presence of phenolic acid, condensed tannins, alkaloids, flavonoids [35], and sterols [36] are also representative in the fruit, so that 65.55 mg of total polyphenols have been quantified in the seed [29]. Furthermore, the phenolic and carotenoid profile in seeds powder was evaluated, so that benzoic acid, chlorogenic acid, caffeic acid, gallic acid, quercetin, and catechin were the most abundant compounds [37]. These results indicate that the seed could be used as a source of phenolic compounds for the manufacture of foods to improve their antioxidant and nutraceutical capacity [29,35]. In its turn, the starch extracted from the seed can be applied for the preparation of edible or biodegradable films, in the same way as the fruit peel [38]. Still, the volatile profile of raw and roasted avocado kernels presented ester as major compounds, while high molecular weight alcohols, aldehydes, ketones, and saturated aliphatic hydrocarbons also were important in their composition, so that the nutritional and organoleptic characteristics have been maintained after the roasting process [39]. Furthermore, anthocyanins as well as procyanidins, flavonols, hydroxybenzoic, and hydroxycinnamic acids have been also identified [36,40]. The study of Miñón–Hernández *et al*. also identified the following bioactive phenols in the peel: Quercetin, naringenin, catechin, cyanidin 3-glucoside, pelargonidin 3-glucoside, pelargonidin 3-rhamnoside, hydroxydelphinidin, eugenol, and estragole [41]. In a phytochemical and pharmacological study of *P. americana* collected in Nigeria, the leaves used in local ethnomedicine for tumor-related problems contain alkaloids, tannins, flavonoids, cardiac glycosides, saponins, terpenes, and steroids [42], while other study from the same country also demonstrated phlobatannins and anthraquinones in the leaves [43]. Other study on leaves chemical composition showed that the hexane fraction from leaves reports steroids and saponins, whereas the ethyl acetate fraction presents the hyperoside (quercetin-3-galactoside), quercetin-3-O-galactoside, quercetin-3-O-rhamnoside, cyclopenol, and cytosporin as main phytochemicals [44]. The essential oil composition from leaves according to some cultivars was also evaluated Elosaily *et al*. described the α-copaene, β-copaene, and β-caryophyllene are common major compounds in the unripe leaves from three analyzed cultivars (Mexican, Fuerte, and Hass), while estragole was the most abundant in Mexican, being found in traces in Fuerte and not found in Hass cultivar [45]. In mature leaves, estragole, 2-(8Z,11Z)-8, 11-heptadecadienyl-furan, or caryophyllene were found as major compounds in seven cultivars [46]. Moreover, it was suggested that ripening significantly increased the content of fats, alkaloids, and saponins, but reduced the carbohydrate content of the seeds, indicating that ripe ones may be a better source of antioxidant compounds due to their higher phytochemical content [47]. Hence, these results confirm the potential of avocado peel as an important source of bioactives applicable in the food, cosmetic, or pharmaceutical sectors [40].

3.3. Pharmacological Effects

Table 3 presents the *in vivo* pharmacological effects of *P. americana* administered orally. It was found that the main form of preparations is as an extract. One of these studies demonstrated that the avocado peel extract reduces fasting glucose levels, characterizing a hypoglycemic effect [48], and reverses or attenuates the metabolic effects caused by a diet high in sucrose [41]. This occurs due to the polyphenolic compounds that act as antidiabetics [48] such as quercetin, pelargonidin 3-glucoside, hydroxydelphinidin, eugenol, estragole, and especially avocatin B, among others [41]. *P. americana* is used in natural medicine for the treatment of patients with diabetes mellitus, acting on the enzymes involved in the capture of glucose in the small intestine, and also on the liver enzymes of carbohydrate metabolism. It was observed that the lipid avocatin B have the ability to prevent mitochondria from oxidizing the fatty acids of pancreatic beta cells (lipotoxicity), preventing the death of pancreatic cells [49]. This effect contributes to ensuring that insulin is not lacking and that insulin resistance is reduced and even avoided so that by inhibiting the fatty oxidation, the sensitivity of insulin uptake is improved. Avocatin B also achieves the same effect on skeletal muscle cells, which improves insulin uptake and decreases cellular lipotoxicity [50]. In addition, it could be useful as a remedy for the management of kidney dysfunction associated with Type 2 diabetes [51].

On the other hand, the seed has properties of antioxidants and antidiabetics [14,52], so that the effects have also been related to

Table 2: *Persea americana* chemical composition

Plant organ	Chemical composition	Technique used in its determination	Reference
Fruit (peel)	Fibers (53.14%), lipids (35.22%), carbohydrates (7.98%) and proteins (0.25%)	Enzymatic-gravimetric method (AOAC 991.43)	[67]
fruit (pulp)	Oleic, palmitic, palmitolenic, docosadienoic, tricosanoic, linoleic and palmitoleic acids	NR	[32]
Fruit	Monounsaturated fatty acids (60%)	Gas chromatography	[31]
Fruit (pulp)	Oleic acid, omega-6/omega-3 ratios	Gas chromatography	[34]
Fruit (seed and peel)	Tocopherol	Method of Freitas *et al*.	
Fruit (seed)	Phenolic acid, condensing tannins, alkaloids and flavonoids, fatty acids	Liquid chromatography with mass spectrometry	[29]
Fruit	Procyanidin B2	High pressure liquid chromatography	[35]
Fruit (seed)	Total polyphenol content 65.55 mg gallic acid equivalents/g	Folin– Ciocalteu test	
Fruit (peel)	Bioactive polyphenols (flavanol quercetin, flavanone naringenin, flavan 3 - Ol catechin, cyanidin 3-glucoside, pelargonidin 3-glucoside, pelargonidin 3-rhamnoside, hydroxydelphinidin, eugenol and estragole)	Liquid chromatography with mass spectrometry	[41]
Fruit	Naringenin and routine	High pressure liquid chromatography	[30]
Fruit (pulp)	Oil content 16.2%–32.3% pulp (unsaturated fatty acids: Oleic, linoleic, and palmitoleic)	Gas chromatography	[33]
Fruit (peel)	Anthocyanins (between 0.64 and 47 mg/g fresh weight)	Gas chromatography	
Fruit (peel)	Procyanidins, flavonols, hydroxybenzoic, and hydroxycinnamic acids	Liquid chromatography coupled to precise ultra-high definition mass spectrometry	[38]
Fruit (seed and pulp)	Unsaturated fatty acid (oleic acid)	Gas chromatography	[36]
Fruit (seed)	Sterols	Gas chromatography	
Fruit (seed)	Starch (Amylose 39.56%)	Loos method	[38]
Fruit (seed powder)	Lutein (0.323 mg/100 g), gallic acid (8.82), chlorogenic acid (33.65), p-hydroxybenzoic acid (10.74), caffeic acid (4.42), benzoic acid (138.12), catechin (2.60), epigallocatechin (0.82), rrutinoside-3-O-quercetin (0.40), glycoside-3-O-kaempferol (0.90), quercetin (2.81)	Liquid chromatography coupled to precise ultra-high definition mass spectrometry	[37]
Fruit (raw and roasted kernel)	Raw Kernel: (*E*)-hex-2-en-1-ol (7.34%), (*E*)-hept-2-enal (5.36%), pentadecane (5.33%), cyclohex-3-ene-1-carbaldehyde (4.92%), and decan-2-one (4.67%), esters (27.53%). Roasted Kernel: 3,7,11, trimethyl-8,10-dodecedienylacetate (6.28%), 2-methylbutan-1-ol (5.89%), 2-decanone, O-methyloxime (3.73%), 2-methyl-pyrazine (3.62%), and n-hexane (3.51%), esters (20.36%)	Gas chromatography coupled with mass espectrometry	[39]
Leaves	Alkaloids, tannins, flavonoids, saponins, phlobatannins, phenols, anthraquinones, and triterpenes	Thin layer liquid chromatography	[42]
Leaves	Alkaloids, tannins, flavonoids, cardiac glycosides, saponins, terpenes, and steroids	Thin layer liquid chromatography	[43]
Leaves	Saponins and steroids (hexane fraction), hyperoside (quercetin-3-galactoside), quercetin-3-O-galactoside, quercetin-3-O-rhamnoside, cyclopenol and cytosporin (ethyl acetate fraction)	Thin layer liquid chromatography; high performance liquid chromatography coupled with diode array detector	[44]
Leaves (unripe)	α-copaene, β-copaene and β-caryophyllene (Mexican, Fuerte, and Hass cultivars), estragole (62.61% in Mexican cultivar)	Gas chromatography coupled with mass espectrometry	[45]
Leaves	Estragole (30.04% in Ettinger cultivar and 36.74% in Fuerte), 2-(8Z, 11Z)-8,11-heptadecadienyl-furan (67.37%, 43.61% and 59.9% in Hass, Bacon, and Maluma Hass cultivars, respectively), caryophyllene (36.61% 17.68% in Reed and Zutano cultivars, respectively)	Gas chromatography coupled with mass espectrometry	[46]

the presence of ascorbic acid, myricetin, luteolin, avocatin B, and gallic acid [14]. According to another study, a natural alternative to control glucose levels by a diet considers that *P. americana* is included in the daily meals of patients with DM2, helping to reduce the consumption of antidiabetic drugs, in addition to promoting weight loss and reducing the lipid and glycemic profile [53]. Moreover, in

Table 3: *In vivo* pharmacological properties of *Persea americana* administered orally

Plant organ	Way of preparation	Identified substances	Pharmacological effect	Reference
Fruit (peel)	Ethanolic extract	Polyphenolic compounds	Hypoglycemic	[48]
Fruit (peel)	Ethanolic extract	Bioactive polyphenols (flavanol quercetin, flavanone naringenin, flavan 3- Ol catechin, cyanidin 3-glucoside, pelargonidin 3-glucoside, pelargonidin 3-rhamnoside, hydroxydelphinidin, eugenol and estragole)	Reverses or attenuates the metabolic effects caused by a high sucrose diet. It is hypoglycemic	[41]
Fruit (seed)	Aqueous extract	Avocatin B	Protects against cadmium-induced inflammation and kidney toxicity	[52]
Fruit (seed)	Aqueous extract	NR	Antioxidant properties and is hypoglycemic	[14]
Fruit (seed)	Ethanol-water extract	Flavonoid (myricetin, luteolin), gallic acid, and ascorbic acid	Improves glomerular filtration rate, with antihemorrhagic effect and erythropoiesis rate in diabetic complications due to streptozotocin toxicity	[51]
Leaves	Ethanolic extract	Avocatin B	Reduction of uric acid concentration in blood from 12.3% to 4.3%, great potential as antihyperuricemia	[52]
Fruit	Ethanolic extract	Ferulic acid, polyphenols, alkaloids and flavonoid	Anti-inflammatory effect may mitigate cyclophosphamide-induced toxicity	[56]
Fruit (seed)	Ethyl acetate fraction of extract	NR	Prevention and treatment of gastric ulcer and cardiovascular diseases	[54]
Fruit (seed)	Ethanolic extract	Terpenes, alkaloids, flavonoids, tannins, saponins, sterols, and glycosides	Depressant action on the CNS	[55]
Fruit (pulp)	Diluted pulp	Lauric acid, linoleic acid, myristic acid, oleic acid, palmitic acid	Anti-inflammatory activity in rat model induced by TNBS	[57]
Leaves	Ethanolic extract	Saponins, steroids hyperoside (quercetin-3-galactoside), quercetin-3-O-galactoside, quercetin-3-O-rhamnoside, cyclopenol, and cytosporin	Antimalaric activity in mice model	[44]
Leaves	Ethanolic extract	Isorhamnetin, luteolin, rutin, quercetin, and apigenin	Antihyperlipemic activity	[62]

addition to having cardiovascular effects, *P. americana* has effects on cholesterol control where oleic fatty acid is rescued, reducing the plasma concentration of low-density lipoprotein cholesterol (LDL-C), without causing its oxidation. This fatty acid is the main substrate for acyl-CoA: Cholesterol acyltransferase, a liver enzyme that catalyzes the formation of cholesterol esters from cholesterol. Therefore, the presence of excess cholesterol in its free form is rapidly esterified and does not lead to the suppression of LDL-C receptors and contributes to the absorption of LDL-C, producing a decrease in its plasma concentration. In addition, the avocado seed is used for the treatment or prevention of gastric ulcers, due to the presence of caffeoylquinic acid, flavonoids, phenylpropanoids, and tannins [54].

Furthermore, noteworthy is the depressant action on the central nervous system through its seed ethanolic extract in mice, so that the extract at 250–1000 mg/kg dose-dependently leads to a significant reduction in rearing and locomotor activities [55]. Likewise, the reducing effect of the seed against inflammation and renal toxicity induced by cadmium has been reported [48], whereas the fruit has an anti-inflammatory effect that can mitigate the toxicity induced by cyclophosphamide [56]. Besides this, the work of de Oliveira *et al.* evaluated the anti-inflammatory activity of avocado fruit pulp (5, 10 or 20%) incorporated in the diet of rats, for 21 days before and 7 days after trinitrobenzene sulfonic acid-induced intestinal inflammation. Dietary intervention with avocado fruit pulp (20%) decreased the extension of colonic lesions and weight/length colon ratio, as well as inhibited myeloperoxidase activity, reduced tumor necrosis factor-α, interleukin-1β and interferon-gamma levels, and prevented colonic glutathione depletion. Still, the consumption of an enriched diet with 20% avocado pulp by 28 days did not promote any alterations in the biochemical or behavioral parameters evaluated [57]. Furthermore, the reduction of the concentration of uric acid in the blood from 12.3% to 4.3% according to the treatment with avocado leaves demonstrated its great potential as anti-hyperuricemic [58]. Although the molecule involved in these effects has not been determined, this activity could be associated with the presence of bioactive polyphenols present in the fruit [41]. *P. americana* consists of different phytochemicals and nutrients that have been related to cardiovascular benefits, which is why it is recommended to substitute monounsaturated fatty acids instead of trans fatty acids to prevent both primary and secondary CVD [59,60]. The results presented expand the understanding of avocado for its application as a nutraceutical or biological products due to its beneficial properties for human health [54,14]. This effect is also related to the presence of soluble fibers, which are approximately 30% of the fiber content of avocado, so that they increase the synthesis of bile acids and reduces absorption of cholesterol, reducing cholesterol in the blood [59,61]. Still, the crude ethanolic extract from *P. americana* leaves demonstrated significant maximal plasmodial inhibition in mice as 52.16 ± 2.77%, and chemo suppression of parasitemia at 64.01 ± 0.08%. In this study, it was also observed that

Table 4: *In vitro* pharmacological activities of *Persea americana*

Plant organ	Way of preparation	Identified substance	Pharmacological/biological activity	Reference
Fruit (seed and peel)	Ethanolic extract	Polyphenol content	Antioxidant	[29]
Fruit	Ethanolic extract	NR	Antimicrobial, especially against methicillin-resistant *S. aureus* (MIC=7.81 µg/mL)	[30]
Fruit (peel)	Ethanolic extract	NR	Antioxidant 53.3–307.3 mmol g/fresh weight)	[33]
Fruit (seed)	Ethanolic extract	NR	Anti-inflammatory and anticancer against colon cancer cell line (HCT116) and liver cancer cell line (HePG2) and antioxidant activity	[36]
Leaves	Ethanolic extract	Hydrocarbons, sterols and unsaturated fatty acids ("oleic acid")	Antioxidant	[63]
Fruit (pulp and seed)	Ethanolic and aqueous extracts	Phenolic acids and flavonoids	Ethanolic extract: Antimicrobial (104.2–416.7 µg/mL) against Gram-positive and Gram-negative bacteria (except *Escherichia coli*), Aqueous extract: *Listeria monocytogenes* (93.8–375.0 µg/mL) and *Staphylococcus epidermidis* (354.2 µg/mL). mL)	[65]
Fruit	Ethanolic extract	Tannins, catechin flavones and polyphenolic compounds	They function as a pro-apoptotic compound and its therapeutic action on leukemia	[64]
Fruit (seed)	Extract	Polyphenols, steroids, tripertenoids, tannins	Antioxidant and inhibited metabolomic changes induced by oxidative stress in endothelial cells	[13]
Fruit (peel)	Methanolic extract	NR	Larvicide against mosquitoes of the order *Anopheles stephensi* followed by *Aedes aegypti* and *Culex quinquefasciatus* in the third larval stage	[66]

the extracts and fractions of the plants prolonged the survival time of the infected mice, so that the more polar fractions displayed the most active antimalarial effect, corroborating the ethnomedicinal studies in Nigeria, which in turn is a country heavily affected by malaria [44]. Finally, the combination of leaf ethanolic extracts from *Annona squamosa* L. (EEAS) and *P. americana* M. (EEPA) has been shown to have antihyperlipidemic activity, which should guarantee the accuracy and consistency of the combination of EEAS and EEPA as antihyperlipidemic treatments, although it is necessary to characterize the secondary metabolites of the plant [62].

Table 4 presents the *in vitro* pharmacological effects of *P. americana*. It was found that the leaf has a prominent antioxidant capacity [63] associated with its content of polyphenols [35], mainly flavonoids and phenolic [63]. In addition, the leaves displayed anti-inflammatory and anti-cancer activity against the colon cancer cell line (HCT116) and the liver cancer cell line (HePG2), which may be related to its high content of hydrocarbons, sterols, and unsaturated fatty acids [36]. In addition, the ethanolic extract of the fruit evidenced apoptotic activity and therapeutic action on leukemia, which may be related to the content of polyphenols, steroids, triterpenoids, and tannins [64]. Besides this, it was proved that the seed extract inhibits the metabolomic changes induced in endothelial cells, which suggests that it has good vasoprotective actions [13], whereas the pulp and seed have reported antimicrobial activity [30], which may be related to their content of tannins, catechin flavones, and polyphenolic compounds [65]. Finally, the peel methanolic extract displayed notable larvicidal activity against *Aedes aegypti*, *Culex quinquefasciatus,* and *Anopheles stephensi*. These findings may indicate that avocado can be considered a promising alternative for combating the transmission of tropical diseases such as dengue, filariasis, and malaria, respectively [66]. The results presented to provide us with information about avocado and its application in the field of medicine [63], but more *in vivo* investigations are required to confirm the *in vitro* results described above, in addition to isolation and identification of the molecules in the extracts [64], to optimize their extraction [13].

4. CONCLUSION

P. americana emerges as a plant with a rich historical and scientific basis for its medicinal applications. From traditional uses to contemporary research, evidence suggests a diverse range of health benefits associated with its various bioactive compounds. Further investigations are warranted to fully explore the potential of *P. americana* for therapeutic applications and its possible inclusion as a functional food to promote human health.

5. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be author as per the International Committee of Medical Journal Editors requirements/guidelines.

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7. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

8. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

9. DATA AVAILABILITY

All the data is available with the authors and shall be provided upon request.

10. PUBLISHER'S NOTE

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11. USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declares that they have not used artificial intelligence (AI)-tools for writing and editing of the manuscript, and no images were manipulated using AI.

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