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Therapeutic Bio-Compounds from Avocado Residual Biomass †

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Abstract: Since ancient times, plants have been used as preservatives, spices, flavorings and as natural remedies to prevent or treat diseases owing to the biological activity correlated with the bioactive compounds they contain. The avocado fruit (*Persea americana*), native to Mexico and Guatemala, has been traditionally used for its pleasant organoleptic characteristics, high nutritional value and health benefits, but its residual biomass (seeds, skin and tree leaves) is also valuable in therapeutic terms. For this reason, the present investigation reviews the pharmacological potential of avocado waste. It can serve as a source of antioxidants, as well as hypotensive, anti-analgesic, photoprotective, antibacterial, and anti-inflammatory agents, and can be used to treat skin disorders. The main active components seem to be phenolic compounds. The content of phenolic compounds in waste extracts varied from 6 to 307 g/kg dry weight, depending on the waste type and extraction conditions, among others. In particular, our results suggested that using water as a solvent, a high amount of phenolic compounds can be obtained from the peel (266 g/kg dry weight), and this was correlated with major antioxidant activity. Therefore, the peels can be applied to obtain antioxidants, and water can be used as an environmentally friendly extraction solvent to obtain various valuable compounds of its chemical composition for food and pharmacological applications.

Keywords: avocado seed; avocado peel; *Persea americana* extracts; anti-inflammatory

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1. Introduction

Since ancient times, plants have been used as spices, preservatives, flavorings and as natural remedies to prevent or treat diseases owing to the biological activity correlated with the active compounds they contain. The use of natural extracts with pharmacological activity is of great interest because they have therapeutic potential in the treatment of different diseases with fewer side effects. The avocado is a fruit that has become fashionable for its attractive organoleptic characteristics, high nutritional value and health benefits. It is consumed as a fresh product and is also processed to obtain salad oil and guacamole. In both cases, the only usable portion is the pulp. However, the inedible parts have been consumed as remedies, for example, by the Mayans and Aztecs. In particular, the leaf has been used for expelling intestinal parasites, in gynecological and gastrointestinal problems, etc. [1,2]. Currently, a large number of studies are being carried out on the properties not only of the avocado pulp but also of the fruit seed, the fruit peel and the tree's leaves. Pharmacological actions such as antioxidant activity; hypotensive, anti-analgesic and anti-inflammatory effects; skin disorder treatment; photoprotective

effects against UVB radiation; antiviral, antifungal and antioxidant actions, etc. are being related to their bioactive compounds, such as phenolic compounds [3,4]. Therefore, besides avocado fruit and oil, avocado waste extracts could promote the development of functional ingredients for applications in the food, nutraceutical, pharmaceutical and cosmetic sectors.

2. Methods

Bibliographic research was carried out for finding and accessing reviews, articles in academic journals, institutional repositories, archives using databases and search engines. Most recent literature was selected (mainly since the last five years).

Additionally, experimental research was performed: avocado residues were obtained from the fruit cultivar "Hass". The peel and stones were dried at room temperature and exposed to crushing by a 1.0 mm material at Retsch ZM200 Mill (Hann, Germany). The samples were subjected to Soxhlet extraction for 24 h with water, and then the residual solid fraction was extracted with ethanol. Aqueous and ethanolic extracts were filtered before analysis (nylon filters of 0.45 μm pore size) (SinerLab Group, Madrid, Spain). The total phenolic content (TPC) was measured using the Folin–Ciocalteu colorimetric assay, its absorbance was measured with a microplate reader (Bio-Rad iMark™, Hercules, CA, USA) at 655 nm. The TPC was reported as g gallic acid equivalent (GAE)/kg of extract by using a gallic acid calibration curve. The total flavonoid content (TFC) was determined using the aluminum chloride colorimetric method; absorbance was measured with the aforementioned microplate reader at 510 nm. The total flavonoid content was calculated from a calibration curve built with rutin, and the results were expressed as g rutin equivalent (RE) per kg of extract.

The antioxidant activity was appraised by the antioxidant ability of avocado peel and stones to reduce the cation $ABTS^{\bullet+}$ and Fe^{3+} using the ABTS™ (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) radical scavenging and ferric reducing antioxidant power (FRAP) assays. The absorbance was measured with Bio-Rad iMarkTM at 734 nm for TEAC. Absorbance readings of the antioxidant extracts were compared to standard calibration curves of the hydrophilic vitamin E analog, Trolox (6−330 μM), and the results were expressed as g Trolox equivalents (TE) per kg of extract.

3. Results and Discussion

3.1. Bioactive Properties

An excellent opportunity to take advantage of the rich sources of natural compounds for therapeutic purposes is agro-industrial waste. In recent years, the number of studies characterizing the composition of avocado peel, stones and leaves has increased in order to explore the possibility of using them as a value-added product in the pharmaceutical industry. Some of the pharmacological actions that have been published are cancer inhibitory activity; moderate activity against epimastigotes and trypomastigotes; as an inhibitor of the growth of fungi, yeasts, bacteria and viruses; as a potential antidiabetic agent, etc. Table 1 depicts a summary of these biological properties.

Table 1. Pharmacological properties of avocado peel, stone and leaf extracts.

Avocado Part	Pharmacological Action	Bio-Compound	Study Type [a]	Ref.
Stone	Antioxidant and cancer inhibitory activity	Polyphenols	IVT	[5]
Stone	Moderate activity against epimastigotes and trypomastigotes	trihydroxyheptadecane and trihydroxy-nonadecane derivatives	IVT	[6]
Stone and leaf	Pro-apoptotic effect on Jurkat lymphoblastic leukemia cells that are eliminated through an oxidative stress mechanism	NR	IVT	[7]
Peel	Antibacterial activity against a wide range of infectious agents	Phenolic compounds Alkaloids	IVT	[8]

Leaf	Anti-oxidative properties Antimicrobial properties, including fungi, yeasts, bacteria, and viruses Antinociceptive effect on UVB radiation-induced skin injury in mice. Treatment of the pain associated with sunburn	Phenolic compounds such as (+)-catechin, chlorogenic acid and rutin	IVV	[9]
Leaf	Antioxidant activity	Phenolic compounds, including phenolic acids and flavonoids	IVT	[10]
Stone	Anti-inflammatory activity	Perseorangin	IVT	[11]

[a] In vitro (IVT), in vivo (IVV), and in humans (H).

Most of the in vitro investigations consulted in this work agree that avocado stones, peel and leaves have antioxidant properties, owing to the phenolic compounds present in their constitution. Owing to these biocompounds, they are capable of reducing or inhibiting oxidation reactions. Although antioxidants can be obtained synthetically, the trend is to obtain them from natural sources to avoid possible toxic effects in humans. Table 2 shows a summary of studies that have reported the antioxidant properties of the avocado waste extracts. It also highlights that there is a high variability between the antioxidant activity values reported, even for the same cultivar, and depending on the extraction method and plant part. Among the solvents applied, water can be applied to recover antioxidant compounds from the peel. Our preliminary results show that it was possible to extract around 87% of the total content when water and ethanol were sequentially applied. Moreover, microwave-assisted extraction using aqueous solutions of acetone and ethanol showed high TPC and antioxidant activity.

Table 2. Total phenolic content (TPC), total flavonoid content (TFC) and antioxidant activity determined by the ABTS and ferric reducing antioxidant power (FRAP) assays.

Part	Extraction Method	Solvent	TPC (g GAE/kg)	TFC (g RE/kg)	ABTS (g TE/kg)	FRAP (g TE/kg)	Ref.
Peel	Soxhlet extraction	Water	266	342	281	245	This study
	Boiling	Water	20	11	ND	23	[12]
	Ultrasound-assisted extraction	80% Ethanol	64	ND	198	ND	[13]
	Homogenization	70% Acetone	90	ND	ND	ND	[14]
	Homogenization	70% Acetone	51	ND	ND	ND	[15]
	Stirring in bath	50% Ethanol	31	ND	66	110	[16]
	Homogenization	50% Methanol and 70% acetone	137	ND	ND	137	[17]
	Heated and filtered	Water	52	2	ND	ND	[8]
Stone	Soxhlet extraction	Water	18	27	25	19	This study
	Boiling	Water	6	3	ND	10	[12]
	Ultrasound-assisted extraction	80% Ethanol	57	ND	162	ND	[13]
	Acelerated solvent extraction	50% Ethanol	ND	ND	88	ND	[18]
	Homogenization	70% Acetone	61	ND	ND	ND	[19]
	Homogenization	70% Acetone	41	ND	ND	ND	[15]
	Homogenization	50% methanol and 70% acetone	81		ND	77	[17]
	Microwave-assisted extraction	70% Acetone	307	ND	607	ND	[20]
	Microwave-assisted extraction	58.5% Ethanol	254	ND	516	ND	[20]

GAE, gallic acid equivalents; RE, rutin equivalents; TE, Trolox equivalents.

3.2. Phytochemicals

Phenolic compounds are some of the active components of avocado waste (Tables 1 and 2). The chemical structure of these natural compounds found in avocado is summarized in Figure 1.

In addition, the structure of a natural colorant (glycosylated benzotropolone) has recently been identified in the stones, and it showed anti-inflammatory activity [3,11,21] (Figure 2). The active fractions with trypanocidal activity against *Trypanosoma cruzi*, the etiological agent for Chagas' diseases, included 1,2,4-trihydroxyheptadecane and 1,2,4-trihydroxynonadecane derivatives [6] (Figure 2).

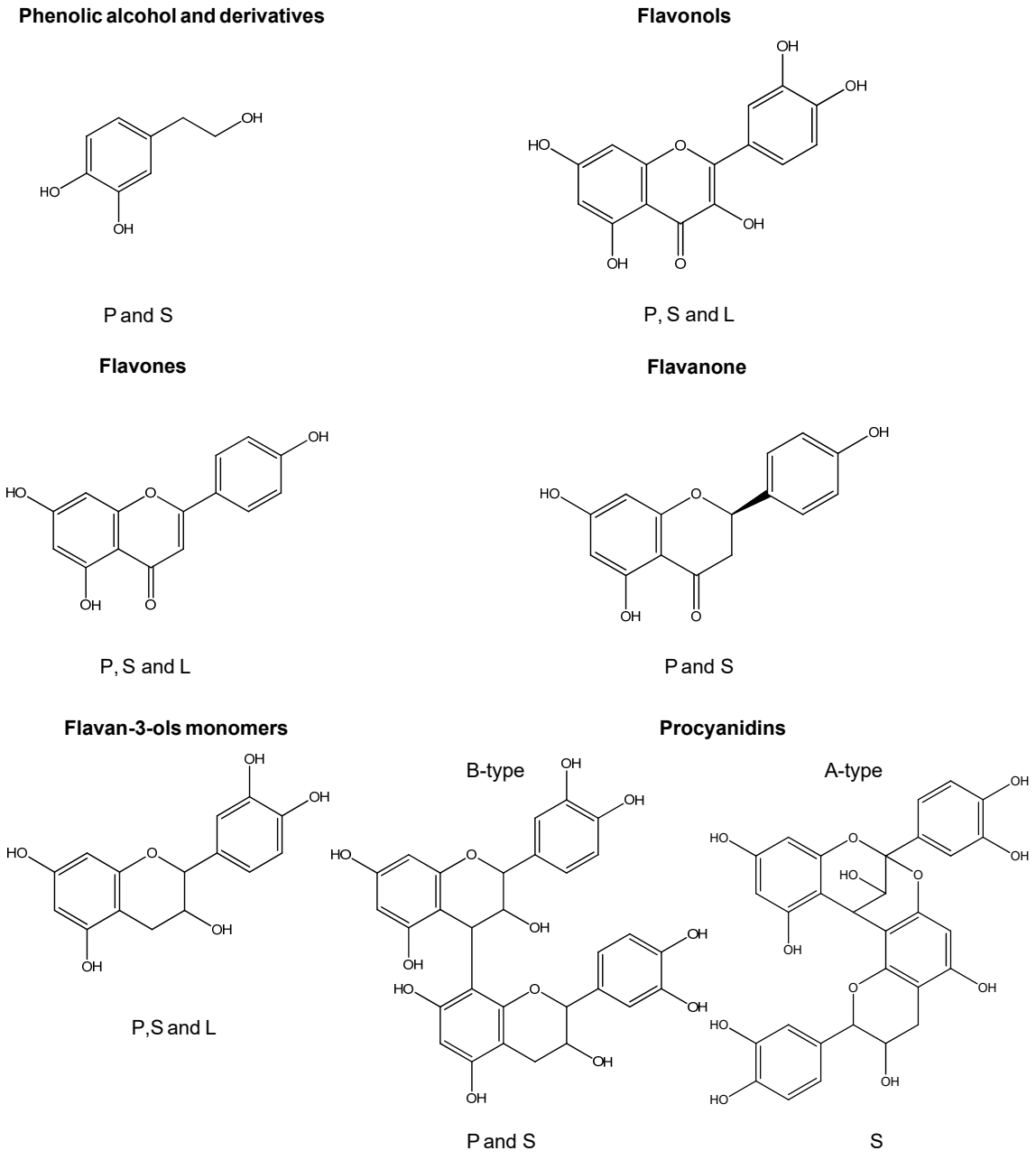

Figure 1. Phenolic classes found in avocado waste, peel (P), stone (S), leaf (L) and example of the structures: hydroxytyrosol (phenolic alcohol), quercetin (flavonol), apigenin (flavone), naringenin (flavanone), (epi)catechin (flavan-3-ols monomer), and B- and A-type flavan-3-ols dimers (procyanidins).

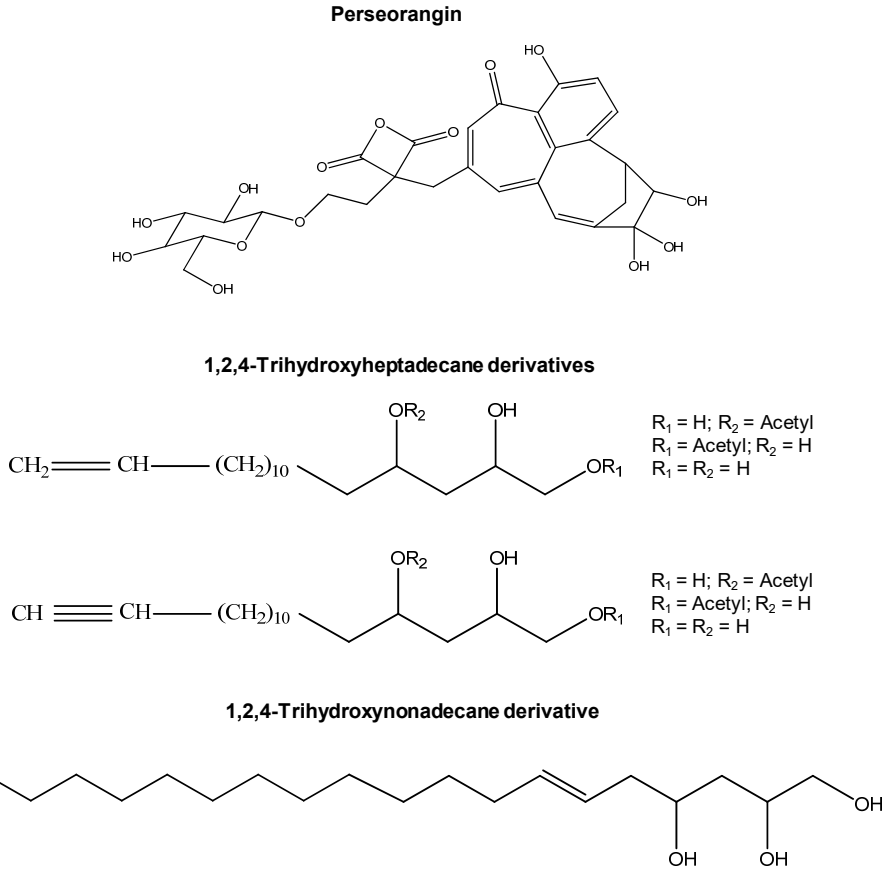

Figure 2. Other phytochemicals characterized in the avocado stone extracts with bioactive properties.

4. Conclusions

In vitro and in vivo studies suggest that avocado waste possesses bioactive properties. Phenolic compounds are generally the antioxidant compounds found in the extracts, but other phytochemicals have been identified in active extracts with anti-inflammatory and trypanocidal activity, including a glycosylated benzotropolone and trihydroxyheptadecane and trihydroxynonadecane derivatives. Nonetheless, further in vivo and clinical studies are required to confirm these studies.

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