









## Comprehensive Approach Of Avocado Fruit (*Persea Americana*; Mill.): A Review Of Its Potential Application In Food Formulations.

### Aprovechamiento Integral Del Fruto Del Aguacate (*Persea Americana*; Mill.), Una Revisión De Su Potencial Aplicación En Formulaciones Alimentarias.

**Ortega-Barbosa Jenny Paola<sup>1,2,3</sup>, Moreno Caballero Michael Ernesto<sup>1,2</sup>, Palomeque-Forero Liliam Alexandra<sup>2</sup>, Miranda-Lasprilla Diego<sup>3</sup>, Rodríguez-Varela Luis Ignacio<sup>1,2</sup>, \*Parada-Alfonso Fabian<sup>1,2\*</sup>**

<sup>1</sup> High Pressure Laboratory, Department of Chemistry, Faculty of Science, Universidad, Nacional de Colombia, Bogotá, Colombia;

<sup>2</sup> Grupo de Investigación en Química de Alimentos, Universidad Nacional de Colombia,

<sup>3</sup> Faculty of Agricultural Sciences, Universidad Nacional de Colombia.  ORCID: <https://orcid.org/0009-0001-4659-8111>;  ORCID: <https://orcid.org/0009-0002-5227-5463>;  ORCID: <https://orcid.org/0000-0001-9398-080X>;  ORCID: <https://orcid.org/0000-0001-9861-6935>;  ORCID: <https://orcid.org/0000-0001-8943-7185>;  ORCID: <https://orcid.org/0000-0003-0896-4114>

✉ Correo electrónico: [jportegab@unal.edu.co](mailto:jportegab@unal.edu.co); [micmorenoca@unal.edu.co](mailto:micmorenoca@unal.edu.co); [lapalomequef@unal.edu.co](mailto:lapalomequef@unal.edu.co); [dmirandal@unal.edu.co](mailto:dmirandal@unal.edu.co); [lirodriguezv@unal.edu.co](mailto:lirodriguezv@unal.edu.co); [fparadaa@unal.edu.co](mailto:fparadaa@unal.edu.co); Tel: 3114750329, Ciudad Universitaria, edificio 451, Bogotá. Colombia

Recibido: 20/febrero/2026/ Aprobado: 18 abril/2026; Publicado: 30/mayo/2026

## RESUMEN

El fruto de aguacate (*Persea americana*, Mill) ha despertado interés dada su importancia nutricional, el cual se ha catalizado debido a los usos y aplicaciones dados a la pulpa del fruto. Adicionalmente, se han realizado varios estudios mediante los cuales se plantea que el consumo de fruto fresco, así como de la pulpa, trae beneficios sobre la salud humana, lo cual permite categorizarlo como un alimento funcional. Por otra parte, bajo la mirada de los ODS y de la química verde, se plantea la necesidad de lograr un mejor aprovechamiento de los subproductos del fruto, a saber,

epicarpio, semilla y residuo de la pulpa. El presente documento analiza de manera crítica y sistemática la información disponible sobre las aplicaciones como ingredientes y formulaciones alimentarias del fruto del aguacate y sus subproductos, centrándonos en la variedad Lorena, la cual es la más consumida en Colombia, dicho estado del arte se contrasta contra los desarrollos y estudios realizados en la variedad Hass, de la cual se cuenta con mayor información, dado que es la variedad más comercializada en el mundo.

\*Autor a quien debe dirigirse la correspondencia \*Parada-Alfonso

Fabian<sup>1</sup> Correo electrónico: ;  
[fparadaa@unal.edu.co](mailto:fparadaa@unal.edu.co)



**Palabras clave:** Aguacate, variedad Lorena, subproductos, compuestos bioactivos, nuevos alimentos.

## ABSTRACT

The fruit of the avocado (*Persea americana*, Mill) has attracted considerable interest due to its nutritional importance, which has been further by the diverse uses and applications of its pulp. Moreover, several studies have suggested that the consumption of fresh fruit, as well as its pulp, provides health benefits, thereby allowing it to be categorized as a functional food. From the perspective of the Sustainable Development Goals (SDGs) and green chemistry, there is an increasing need to achieve better utilization of the fruit's by-products—namely, the peel, seed, and pulp residue. This document dissert critically and systematically the available information on the applications of avocado fruit and its by-products as ingredients and components in food formulations, with a particular focus on the Lorena variety, which is the most widely consumed in Colombia. This state-of-the-art review is contrasted with the developments and studies

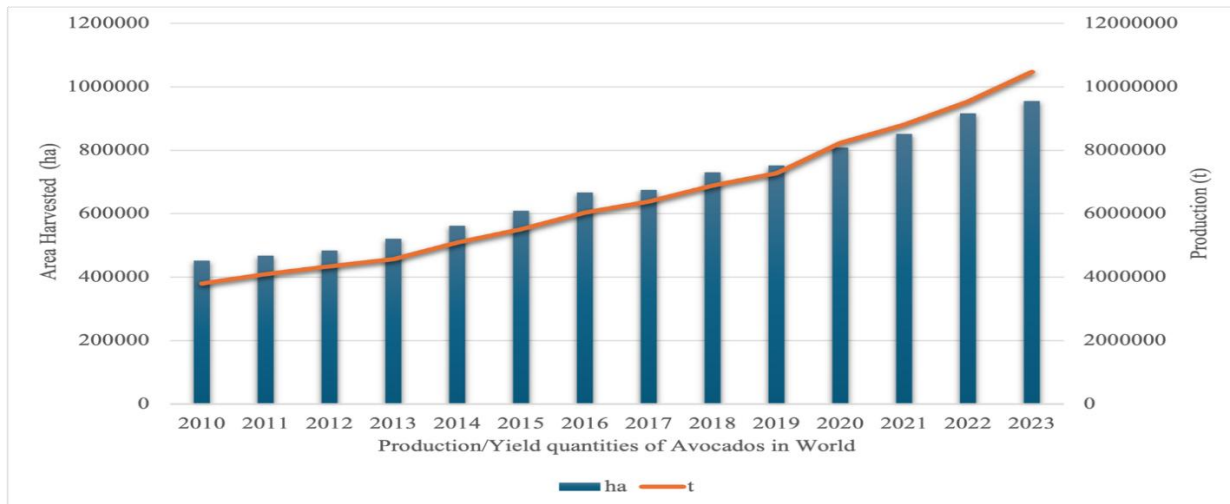
conducted on the Hass variety, for which more information is available, as it is the most commercially distributed avocado variety worldwide.

**Key words:** Avocado, Lorena variety, by-products, bioactive compounds, novel foods.

## INTRODUCTION

The avocado is a tree cultivated in subtropical and tropical regions, native to Mexico and Central America, belonging to the family Lauraceae and the genus *Persea*. Currently, approximately 150 varieties are known (Salazar-López et al., 2020a). The fruits—also referred to as palta, palto, or aguacatero—typically weigh between 150 and 1,400 g, depending on the variety. This weight is approximately distributed as follows: pulp, around 73%; seed, about 16%; and peel, nearly 11% (Salazar-López et al., 2020a). Due to its nutritional quality and the optimization of its cultivation practices, the avocado has become an increasingly important agricultural product. According to production records from the Food and Agriculture Organization of the United Nations (FAO), global avocado production doubled over the past decade, rising from approximately 4 to 8 million tons (Figure 1). The same report indicated that, by 2020, the

main avocado-producing countries were Mexico (33.0%), the Dominican Republic (10.5%), Peru (7.8%), Indonesia (5.7%), and Colombia (5.1%) (Food and Agriculture Organization of the United Nations & Agriculture, 2020). Global avocado production is projected to reach 6.5 million tons, with an annual growth rate of 2.9% over the next decade (F, 2020). It is estimated that 28% of total avocado production is not commercialized due to failure to meet quality standards or deterioration (Contreras et al., 2022). Considering that marketable fruits account for approximately 70% of production, it is currently estimated that around two million tons of waste—comprising seeds, peel, and other post-harvest residues—are generated annually worldwide (Salazar-López et al., 2020b). Production is expected to slightly exceed 11 million tons by 2029, representing more than two and a half times the level recorded in 2009 (FAO, 2020).



**Figure 1.** Global annual avocado production between 2010 and 2023, adapted from (FAOSTAT, 2025)

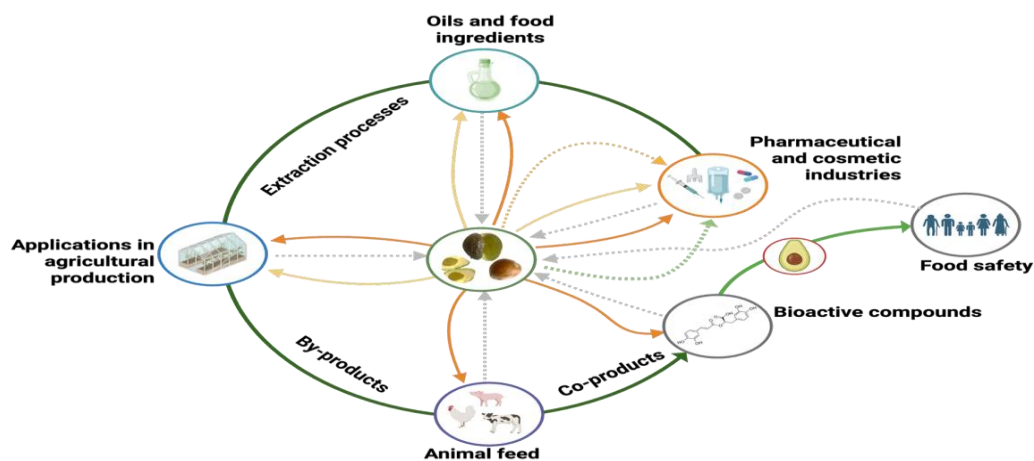
Considering that by 2020 Colombia ranked as the fifth-largest avocado producer worldwide (FAO, 2020), and that its production has been growing at a remarkable rate, it is expected that the country is currently among the top three producers of this fruit. According to the latest report from the Ministry of Agriculture and Rural Development (Agronet, 2025), which includes all avocado varieties, it is estimated that Colombia’s avocado production could exceed one million tons per year, a figure that contrasts with the approximately 600,000 tons produced in 2019. Thus, what was achieved globally over the past decade—namely, the doubling of avocado production—has been accomplished in

Colombia within the last five years, reflecting an almost 100% increase in production between 2019 and 2024. This agricultural activity directly benefits approximately 62,000 Colombians, with the departments of Antioquia, Caldas, and Tolima being the main production regions (Agronet, 2025).

The national and global expansion of avocado cultivation raises concerns about how this monoculture can be practiced responsibly and sustainably, without causing harm to the environment. Many monocultures contribute to the loss of native forests and deforestation in the regions where they are established—an issue of particular relevance given that avocado is intensively produced in some of the most

biodiverse countries on the planet (Denvir, 2023). Furthermore, since both the avocado fruit and its by-products or residues (peel and seed) serve as sources of protein, fiber, fat, and other bioactive compounds of interest to the food industry (Luna-García et al., 2024; Gutiérrez-Zambrano, et al., 2022; Melgar et al., 2018), it becomes necessary to develop strategies for the production and commercialization of high-value products while minimizing impacts on ecosystems. To achieve this goal, it is proposed to establish a circular bioeconomy for the avocado, as a

sustainable process aimed at generating products and services based on the production, use, and conservation of this resource, grounded in knowledge from science, technology, and innovation (Castellanos-González et al., 2023; Calicioglu & Bogdanski, 2020; Almanza, et al., 2019). From this perspective, the present article provides a review of the alternative and promising uses of certain avocado by-products and their potential applications in the food industry. This strategy illustrated in Figure 2.



**Figure 2.** Avocado biorefinery, by-products and co-products. Created using <https://BioRender.com>

**1. Pulp:** The most commercially significant and representative part of the avocado fruit is the pulp, which, depending on the variety, can account for between 25.9% and 81.3%

of the total fruit weight. According to proximate analyses, the pulp contains between 67% and 78% moisture, 13.5% to 24.0% lipids, 0.8% to 4.8% carbohydrates,

1.0% to 3.0% protein, and 1.4% to 3.0% fiber, with an ash content ranging from 0.8% to 1.5%. Additionally, avocado pulp has been identified as a source of vitamins A, B2, K, and B9 (folic acid), coenzyme Q10, monounsaturated fatty acids (MUFAs), and bioactive compounds of interest such as ascorbic acid (Jimenez et al., 2021). The consumption of fresh pulp, or with minimal processing—such as in juices, salads, or ice creams—has been the most common form of avocado commercialization (Salazar-López et al., 2020b).

Given the lipid content of the pulp, one of its main uses in the food industry has been the extraction of oil, which can be regarded as an ingredient suitable for incorporation into various food preparations. This ingredient is considered a product that promotes human health (Parada et al., 2020; Arancibia et al., 2017), particularly due to the quantity and composition of fatty acids that constitute the saponifiable fat fraction, as well as the presence of other non-saponifiable lipids with antioxidant activity. Various extraction methods have been employed for obtaining avocado oil, with the most representative ones summarized in Table 1.

**Table 1.** Common extraction methods used for obtaining avocado oil from the pulp. Adapted from (Marcos et al., 2019).

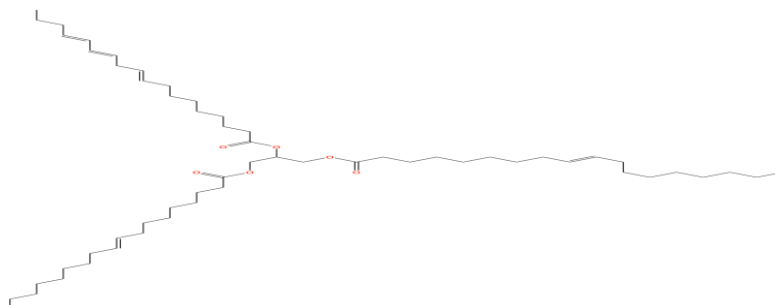
Method	Sample	Conditions	Yield (%)
Cold pressing	Fresh pulp	Mechanical process by pressing or extrusion. The obtained oil is purified through washing, filtration, sedimentation, or centrifugation.	18 - 23
Ultrasound-assisted aqueous extraction	Mashed pulp	The pulp is suspended in water and subjected to ultrasound treatment (0.4–2 MHz) for 5 minutes at temperatures close to 50°C.	12 - 19
CO <sub>2</sub> Supercritical	Freeze-dried pulp	Pressure conditions: 200–400 bar, temperature: 45–50°C, under static mode. There is the possibility of using co-solvents to increase yield or to enrich the oil with constituents exhibiting antioxidant activity.	10-13
Solvent extraction	Dried pulp	The most commonly used solvents are n-hexane, petroleum ether, and acetone. A Soxhlet-type extraction system is employed, which may be assisted by ultrasound or microwaves, with extraction times ranging from 24 hours to 11 minutes, depending on the applied methodology, and operating at temperatures between 30 and 60°C.	15 - 18

The extraction process occurs when a set of compounds (analytes or metabolites) is preferentially or selectively transferred from a matrix or biomass into an extracting phase or solvent, thereby enabling the recovery and eventual separation of the compounds (To et al., 2019). To perform this process, various extraction techniques are available, which differ in the technological systems employed and, in their potential, to optimize the experimental conditions inherent to the process—such as the nature of the solvent, extraction time, temperature, and pressure, among others. These extraction techniques can be classified as classical or emerging. The classical techniques include maceration, Soxhlet distillation, and ultrasound-assisted extraction, among others; whereas the emerging techniques comprise supercritical fluid extraction (SFE), pressurized liquid extraction (PLE), and microwave-assisted extraction (MAE), among others (Rudke et al., 2019).

In the particular case of oil extraction, although all extraction methods differ in yield (Table 1), the most widely accepted method in the oil industry is cold pressing. However,

supercritical CO<sub>2</sub> extraction, despite producing the lowest fat yield, allows the recovery of high-quality oils enriched in tocopherols, owing to the low temperatures employed in this technique (Barros et al., 2017). Furthermore, when ethanol is used as a co-solvent, the oil composition can be enriched with compounds exhibiting antioxidant activity (Domínguez-Ávila et al., 2020).

With respect to the composition of oils obtained from the pulps of the most cultivated avocado varieties, it is noteworthy that these oils consist predominantly of neutral fats, mainly in the form of triacylglycerols (TAGs), in figure 3, the OOLn TAG (Oleic–Oleic–Linolenic) can be observed, which is one of the most common triacylglycerols present in avocado oil (Fernandes et al., 2018). These neutral fats are rich in monounsaturated fatty acids (MUFAs), particularly oleic acid, which is associated with numerous health benefits. Neutral lipids, mainly TAGs, account for 95–96% of the total lipid content of avocado pulp, while the remaining fraction consists of minor polar lipids, such as phospholipids and glycolipids (Neves et al., 2024).



**Figure 3.** OOLn TAG

The predominant fatty acid in these neutral fats is oleic acid (C18:1), typically representing 50–72% of total fatty acids, followed by palmitic acid (C16:0), linoleic acid (C18:2), and palmitoleic acid (C16:1) (Wang et al., 2020; Gonçalves et al., 2024). The exact proportions may vary depending on the

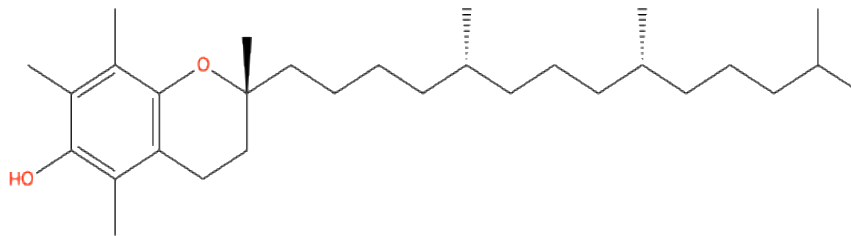
variety, region, and harvest season (Gonçalves et al., 2024). In addition, avocado oil contains compounds with antioxidant activity that are part of the unsaponifiable lipid fraction. Marcos and collaborators reported the fatty acid composition of the saponifiable lipid fraction in various avocado varieties (see Table 2).

**Table 2.** Fatty acid content (percentage %) in the saponifiable lipid fraction of avocado oil from the most widely cultivated varieties. Adapted from Marcos et al. (2019a) and olive oil from Lucci et al. (2020).

Variety	Palmitic 16:0	Stearic 18:0	Palmitoleic 16:1 □7	Oleic 18:1 □□	Linoleic 18:2 □□	□-Linoleic 18:3 □□
Hass	18,17 ± 0,02	0,37 ± 0,01	4,03 ± 0,01	51,76 ± 0,04	11,12 ± 0,01	0,59 ± 0,01
Bacon	12,16 ± 0,04	0,38 ± 0,01	6,57 ± 0,01	61,17 ± 0,02	8,30 ± 0,02	0,44 ± 0,01
Pinkerton	16,93 ± 0,03	0,43 ± 0,01	7,33 ± 0,05	57,39 ± 0,18	8,25 ± 0,02	0,56 ± 0,01
Fuerte	21,31 ± 0,55	0,76 ± 0,02	2,39 ± 0,19	64,44 ± 0,67	9,15 ± 0,03	0,47 ± 0,02
Antillana	18,87 ± 0,06	0,59 ± 0,01	4,16 ± 0,01	63,07 ± 0,10	11,83 ± 0,01	1,32 ± 0,01
Olive oil	7,5-20,0	0,5-5,0	0,3-3,5	55,0-83,0	3,5-21,0	0,0-0,9

An examination of the fatty acid content reveals that, across all avocado varieties, the proportion of unsaturated fatty acids is close to or greater than 70%, making the oil highly desirable for fresh consumption or for its incorporation as an ingredient in various food preparations. Furthermore, the predominant fatty acids in these varieties, in descending order of concentration, are oleic acid,

followed by palmitic, linoleic, and palmitoleic acids, respectively. Variations in both oil yield and fatty acid profile are influenced by the degree of fruit maturity—with optimal results achieved when the fruit ripens on the tree after the climacteric phase (Marcos et al., 2019a; Peñaloza y Hernández, 2018)—as well as by climatic conditions and cultivation management practices (Permal et al., 2020).



**Figure 4.**  $\alpha$ -tocopherol

Additionally, avocado oil contains unsaponifiable lipophilic compounds, some of which possess antioxidant activity, such as  $\alpha$ - and  $\gamma$ -tocopherol (vitamin E), figure 4. In contrast to olive oil, the phytosterol content in avocado oil can be up to 10% higher (Nasri et al., 2021). This characteristic provides avocado oil with greater oxidative stability compared to olive oil (Berasategi et al., 2012).

highlighting that  $\beta$ -sitosterol is present across all varieties. Regarding vitamin E-related compounds (tocopherols), the Hass, Fuerte, and Bacon varieties exhibit the highest concentrations of these bioactive components.

Table 3 presents selected antioxidant compounds identified in avocado oil,

**Table 3.** Content of antioxidant compounds (mg/kg) in avocado oil from the most widely cultivated varieties. Adapted from Marcos et al. (2019a) and olive oil from Lucci et al. (2020).

Variety	sitosterol	tocopherol	□□tocopherol	Campesterol	Stigmasterol	Campestanol
Hass	82,95 ± 0,06	86,75 ± 0,04	9,02 ± 0,09	5,88 ± 0,01	-	0,04 ± 0,01
Bacon	82,60 ± 0,03	51,90 ± 0,04	71,61 ± 0,57	3,71 ± 0,01	0,40 ± 0,01	0,05 ± 0,01
Fuerte	80,56 ± 0,08	103,11 ± 6,87	20,35 ± 1,22	4,62 ± 0,02	0,15 ± 0,01	0,04 ± 0,01
Antillana	98,30 ± 0,08	-	-	10,60 ± 0,01	-	-
Olive oil	1-3	98-370	2-29	-	-	-

Avocado oil has been studied for its potential health benefits through both in vitro and in vivo experiments. These studies have demonstrated reductions in triglyceride levels in rats, as well as improvements in insulin resistance in genetically modified rodents (Cervantes-Paz & Yahia, 2021; Del Toro-Equihua et al., 2016; Torres-Isidro et al., 2025; Velderrain-Rodríguez et al., 2021).

In light of these findings, a relevant and promising application for avocado pulp is the production of avocado oil, a high-value ingredient for the food industry whose qualities and composition may surpass those of olive oil. As such, it can serve as a substitute for lipid ingredients in other food products, offering significant health benefits for consumers (Machado et al., 2025; Marcos et al., 2019).

The profile and reported benefits of avocado oil have been examined from a foodomics perspective by Torres and colleagues. They analyzed the composition of avocado oil—specifically its PUFAs, phytosterols, chlorophylls, xanthonenes, xanthines, and carotenoids—in relation to its antioxidant potential and its role in mitigating age-related conditions such as hypertension, insulin resistance, diabetes, liver damage, and cognitive decline (Torres-Isidro et al., 2025). It is worth noting that foodomics integrates advanced analytical techniques to characterize the nutritional, chemical, and bioactive components of foods (Tarón Dunoyer et al., 2022; Alvarez-Rivera et al., 2020). Recent research has provided detailed knowledge of the fatty acid composition, minor compounds, and quality markers of avocado oil, supporting its value

in food, nutrition, and health (King-Loeza et al., 2023). These studies reveal that avocado oil is a nutrient-rich oil with a distinctive fatty acid profile, high levels of bioactive compounds, and strong quality indicators. Such characteristics support its use in health-promoting foods and underscore the importance of advanced analytical methodologies to ensure its authenticity and nutritional value (Nasri et al., 2023).

During the oil extraction process, among other by-products, avocado cake (or defatted pulp) is generated. Recent studies highlight the potential of this by-product for diverse applications in the food, cosmetic, energy, and environmental sectors (Cheikhyoussef & Cheikhyoussef, 2022). For instance, the use of spray-dried avocado cake powder has been explored to prevent lipid oxidation in meat products, offering a natural alternative to synthetic preservatives (Guzmán, 2022). Extracts derived from avocado cake have been characterized as rich in antioxidants and phenolic compounds and have been employed as sources of natural preservatives and functional ingredients, supporting their use in food formulations to extend shelf life and enhance nutritional value (García-Ramón et al., 2025).

The integration of by-products and co-products, viewing them not as waste but as starting materials for new or complementary processes (Rațu et al., 2023), exemplifies a circular bioeconomy approach. In the specific case of avocado pulp utilization, this approach relies on green chemistry principles to promote sustainable development (Muscat et al., 2021), aiming to reduce waste and maximize resource efficiency within food and industrial systems. Ultimately, this aligns with the concept of a biorefinery, in which all co-products are effectively used (Ahmad et al., 2024).

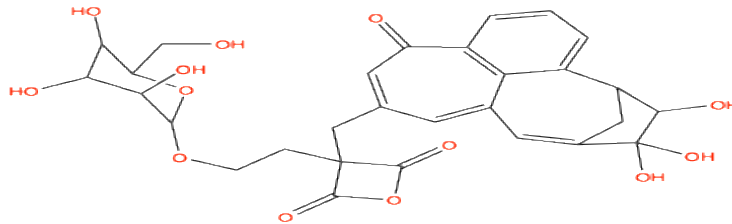
**2. Seed:** The avocado seed represents between 10% and 25% of the total fruit weight, depending on the variety. This residue or by-product has a proximate composition of 52.7–54.1% moisture, 34.8% fiber, 2.4–2.5% protein, 0.5% lipids, and 1.2% ash. Compared to the pulp, the seed contains less lipid and more fiber (Navarro et al., 2017). The fat content generally ranges from 1.1% to 3.4% of seed weight. Of the total lipids, neutral fats (mainly triacylglycerols) account for approximately 77–80%, which is lower than in the pulp but still significant for a by-product. Within the fatty acid profile, linoleic acid (an omega-6 polyunsaturated fatty acid) is the most

abundant, representing 35–38%, followed by oleic acid (22–24%, monounsaturated) and palmitic acid (17–19%, saturated) (Surin et al., 2025).

Coutinho and collaborators (Coutinho et al., 2022) proposed an alternative use for avocado seeds by subjecting them to drying, grinding, and sieving to obtain avocado seed powder. This powder has been investigated as a means of valuing this by-product, with potential use as an ingredient in food formulations. To obtain the powder, crushed seeds are dried at approximately 60°C until reaching less than 11% moisture. The dried material is then milled to achieve a uniform particle size (<300 µm). The resulting flour was used in various proportions to protect and stabilize reconstituted avocado pulp powder. The optimal ratio for spray-drying was achieved by adding 3% seed flour, resulting in a 50% process yield with lower moisture content. This finding suggests that avocado seed flour could serve as a substitute for maltodextrin and may be considered a high-fiber ingredient suitable for use in confectionery and bakery products due to its suitable physicochemical properties (Coutinho et al., 2022).

Owing to its high content of polyphenolic compounds (such as quercetin, catechin,

chlorogenic acid, and caffeic acid), as well as glycolipids and phospholipids, the seed may also be utilized as a source of natural pigments through pH-modifying treatments. Under this premise, Dabas et al. evaluated the formation of a yellow pigment in methanolic extracts of avocado seeds adjusted to pH values between 7.5 and 11.0, observing a color shift from yellow to red in the presence of oxygen. The pigment solution remained stable for two months when stored at –18°C (Punia et al., 2022). Furthermore, Hatzakis et al. (2019) identified through analytical techniques that the major compound responsible for the red color in seed extracts is perseoragin, figure 5, a glycosylated benzotropone pigment recognized as the primary coloring compound in avocado seed extracts. Its formation is linked to polyphenol oxidase activity, which produces the yellow-orange hue observed in processed seed extracts. This pigment is of particular interest as a natural colorant for use in food and cosmetic applications due to its stability and distinctive coloration (Sánchez-Rosario et al., 2025).



**Figure 5.** Structure proposed by NMR analysis for perseoragin, (Hatzakis et al., 2019)

Another technofunctional compound of interest isolated from the avocado seed is starch. The starch content varies depending on variety and extraction method, generally ranging from 10% to over 40% of the seed's dry weight, with some optimized methods achieving up to 64% yield (Frasson et al., 2023). Extraction efficiency is influenced by factors such as solvent type, temperature, and processing technique (Martins et al., 2022). The physicochemical properties of avocado seed starch include a high amylose content (15–49%), greater than that of many common starches, which contributes to its excellent gelling and film-forming capacity. Additionally, its type-B crystallinity and oval/spherical granule morphology imply greater resistance to digestion, improved water-holding capacity, and enhanced stability at low temperatures, which would result in desirable rheological behaviors and potential food applications, furthermore, gelatinization temperatures between 56 and 76°C, high thermal stability, and a high resistant starch content (often >60%),

making it beneficial for gut health and suitable as a functional food ingredient, as resistant starch acts as a dietary fiber with prebiotic activity in the intestinal microbiota (Martins et al., 2025).

With this in mind, Salazar-Irrazabal et al. (2023) studied starches isolated from the seeds of three avocado varieties (Criolla, Fuerte, and Hass). To extract starch, seed powder was suspended in sodium bisulphite solution, filtered, and allowed to settle for 24 h at room temperature and then 2 h at 4°C. The supernatant was decanted, and the sediment, corresponding to the starch fraction, was washed, filtered, and dried. The isolated starches were characterized in terms of morphology, particle size distribution, thermal and pasting properties, Fourier-transform infrared (FTIR) spectra, amylopectin chain-length distribution, and digestibility. The starch granules were oval to spherical in shape. The Criolla variety had the largest granule size (24.55 µm), followed by Hass and Fuerte (21.37 µm). Regarding thermal properties, the Fuerte starch

exhibited the highest gelatinization enthalpy (8.55 J/g), gelatinization temperature (75.28°C), and pasting temperature (75.57°C). The Hass starch showed the highest peak (836.27 mPa·s), final (1407.37 mPa·s), setback (588.78 mPa·s), and breakdown viscosity (17.68 mPa·s) values, these rheological values indicate that the starch under study exhibits strong thickening capacity, stability at low temperatures, and the ability to form firm and structured gels, as well as good thermal stability. Therefore, when applied in food formulation, it would be expected to enhance texture and yield, providing dense, stable, and creamy textures, which are particularly useful in cold or structured food products. All starches exhibited high resistant starch contents (60.1–68.9%). Variations in amylose content

among the starches were also observed, influencing gel formation, retrogradation, and digestibility. The Hass starch showed the highest final viscosity, associated with its higher amylose content, while the Criolla starch exhibited a greater proportion of short amylopectin chains, which may relate to its resistant starch content (Salazar-Irrazabal et al., 2023).

Another promising application of avocado seed powder is its incorporation into snack-type products. Permal et al. (2023) prepared snacks using three biomass sources—brown rice, barley, and avocado seed—and compared their physical properties (lateral expansion ratio, bulk density, apparent density, porosity, and texture) (see Table 4).

**Table 4.** Relationship between the characteristics of prepared snacks and their physical parameters. Adapted from Permal et al. (2023).

Sample	Lateral expansion %	Unit density (g/cm <sup>3</sup> )	Bulk density (g/cm <sup>3</sup> )	Porosity %	Hardness (N/cm <sup>2</sup> )	Crispness (N/mm)	Fracturability (MPa)	Flexibility (MPa)
Avocado Seed	14 ± 6	0,30 ±0,02	0,598 ± 0,002	63,8 ± 1,3	4,34 ± 0,9	1,4 ± 0,3	0,75 ± 0,18	62 ± 16
Brown rice	118 ± 6	0,19 ±0,02	0,796 ± 0,015	74, 7 ± 2,2	12,2 ± 1,9	8,7 ± 1,9	1,13 ± 0,18	34 ± 10
Barley	65 ± 7	0,37 ± 0,04	0,614 ± 0,022	40,4 ± 3,8	10,7 ± 1,7	7,9 ± 1,7	1,32 ± 0,33	94 ± 36

In addition, snacks prepared with avocado flours obtained from different treatments—freeze-dried seeds, oven-dried seeds, and extruded seeds—as well as those made with extruded brown rice and barley flours, were

chemically characterized. The analyses determined the total phenolic content (TPC) and antioxidant capacity using the FRAP, CUPRAC, and phosphomolybdenum assays (see Table 5).

**Table 5.** Summary of antioxidant activity measurements (total phenolic content) for prepared snack samples. Adapted from Permal et al. (2023).

Sample	FRAP (mg ET/g)	CUPRAC (mg ET/g)	Phosphomolybdenum (mg ET/g)	TPC (mg EAG/L)
Freeze-dried seed	57,6 ± 4,1	186,1 ± 2,8	313 ± 26	31,2 ± 2,9
Oven-dried seed	22,7 ± 1,2	58,0 ± 1,9	140,6 ± 1,2	16,9 ± 0,5
Extruded seed	15,4 ± 1,8	39,2 ± 0,4	105 ± 12	12,9 ± 1,1
Extruded Brown rice	0,9 ± 0,2	4,3 ± 1,0	21 ± 14	0,7 ± 0,1
Extruded Barley	4,04 ± 0,2	10,1 ± 1,2	52,6 ± 9,7	3,4 ± 0,2

Considering the previous results, avocado seed flour can be incorporated into the formulation of snack-type products (crunchy bites). Although the resulting product is less crispy, harder, and more brittle than other reference snacks, those made with avocado seed flour exhibit a higher antioxidant capacity. To date, however, this product has not undergone consumer acceptance testing.

Regarding the potential use of avocado seeds, their value lies in the production of starch-rich flours, which may partially or

completely replace some of the flours traditionally used in the baking and bakery industry (Siol et al., 2023).

**3. Peel:** The avocado peel is considered an important by-product of avocado processing, rich in nutrients and bioactive compounds, making it a promising material for food and industrial applications. Its composition and functional properties support its use as a source of dietary fiber, antioxidants, and natural additives (Ramos-Aguilar et al., 2021). This by-product typically represents 11.0–15.0% of the total fruit weight,

depending on the variety, and has a proximate composition of 65.7–76.9% moisture, 6.8–56.9% fiber, 2.9–11.0% total lipids, 1.51–6.3% protein, and 0.8–1.6% ash (Jimenez et al., 2021).

Recent studies have identified the avocado peel as a source of bioactive compounds, due to its high polyphenol content (>120 mg/g), as well as its richness in flavonoids, carotenoids, and tocopherols, which contribute to its potential antioxidant and anti-inflammatory properties (Lyu et al., 2023; Figueroa et al., 2021). This composition highlights the peel as a potential natural food additive, owing to its high polyphenol and fiber content (Arango et al., 2025). Building on this potential, Pino et al. (2021) evaluated the antioxidant activity and matrix metalloproteinase (MMP) inhibitory activity of extracts obtained from Hass avocado peel. MMP inhibition consists of blocking the activity of enzymes involved in the degradation of the extracellular matrix; compounds exhibiting this property are used in treatments for cancer, osteoarthritis, periodontal disease, and wound healing. Pino and collaborators designed a microwave-assisted extraction process using hydroalcoholic solvent systems, considering the effects of temperature (50–130°C), time

(5–45 min), ethanol concentration (0–100%), and solvent-to-sample ratio (10–50 mL/g). The response variables measured included antioxidant capacity—evaluated by ABTS, FRAP, and ORAC methods—and MMP inhibitory activity. The optimal extract was obtained at 130°C for 39 minutes, using 39% ethanol as the extraction solvent and a solvent-to-sample ratio of 44 mL/g. This extract exhibited antioxidant capacities of  $1.34 \pm 0.01$  mmol ET/g DE (ABTS),  $2.66 \pm 0.13$  mmol Fe(II)/g DE (FRAP), and  $3.02 \pm 0.05$  mmol ET/g DE (ORAC). At low concentrations, the extract demonstrated MMP inhibition values between  $14.6 \pm 2.5\%$  and  $59.6 \pm 5.0\%$  IC. These findings suggest a promising application for Hass avocado peel extracts, given their high antioxidant capacity and MMP-inhibitory activity. Consequently, this by-product is a potential candidate for the food industry as a natural antioxidant ingredient, suitable for preservative purposes or for the formulation of functional and nutraceutical foods with antioxidant and anti-aging properties. Moreover, an initial identification of fifty-three polar compounds was achieved, among which procyanidin dimers and trimers (types A and B) were the most abundant phenolic compounds (Pino-García et al., 2021).

Considering the phenolic compounds with potential antioxidant contributions found in avocado peel, Rotta et al. (2016) developed a tea formulation using this matrix—both fresh and after 45 days of storage—and

compared it with other commonly used ingredients such as apple, yerba mate, and green tea. The results of total phenolic content (TPC) and antioxidant activity are presented in Table 6.

**Table 6.** Relationship between total phenolic content (TPC) and antioxidant activity in tea beverages prepared with dehydrated avocado peel and other commonly consumed matrices. Adapted from Rotta et al. (2016).

Sample	TPC (mg EAG/L)	FLAV (mg EQ/L)	FRAP ( $\mu\text{mol Fe}_2\text{SO}_4 \cdot 7\text{H}_2\text{O/L}$ )	DPPH ( $\mu\text{mol ET/L}$ )
APT 0	123,57 $\pm$ 4,64	14,09 $\pm$ 2,71	2 166,09 $\pm$ 35,48	1 954,24 $\pm$ 87,92
APT 45	110,20 $\pm$ 2,55	10,38 $\pm$ 1,64	1 900,90 $\pm$ 90,99	2 518,27 $\pm$ 192,59
Apple tea	20,72 $\pm$ 0,92	25,78 $\pm$ 2,66	2 777,88 $\pm$ 106,34	13 497,51 $\pm$ 696,55
Mate tea	176,68 $\pm$ 6,12	83,42 $\pm$ 3,14	3 477,18 $\pm$ 169,63	2 858,84 $\pm$ 14,87
Green tea	493,81 $\pm$ 10,23	134,21 $\pm$ 2,01	12 341,55 $\pm$ 344,19	2 409,50 $\pm$ 86,10

The results reveal that the teas prepared from the peels exhibit similar results to those of mate tea, with the tea produced from the fresh peel (day 0) demonstrating the best result. Furthermore, a sensory acceptance test conducted with 40 panelists showed that 66% expressed liking for the tea and an intention to purchase the new product (Rotta et al., 2016).

From this perspective, avocado peel is a promising source of functional ingredients that can be used in the food industry as

additives, preservatives, or ingredients (Figueroa et al., 2021).

**4. Pruning residues (leaves):** Avocado leaves constitute an important by-product of avocado cultivation, not only because defoliation and foliage loss may occur naturally throughout the production process, but also due to pruning practices, which are part of good agricultural practices aimed at promoting fruit growth (Minagricultura, 2019). This by-product is rich in nutrients and bioactive compounds, making it a promising ingredient for the development of functional foods and nutraceuticals. Its unique

composition supports both nutritional and therapeutic applications (Precious et al., 2025). Regarding its proximate composition, avocado leaves have been reported to contain  $38.40 \pm 5.12\%$  fiber,  $25.54 \pm 2.52\%$  protein,  $7.34 \pm 0.41\%$  carbohydrates,  $5.33 \pm 0.62\%$  moisture,  $4.01 \pm 0.16\%$  fat, and  $19.38 \pm 4.34\%$  ash (Precious et al., 2025), these researchers evaluated aqueous extracts, protein isolates, and protein hydrolysates with respect to their micronutrient content, such as magnesium, as well as compounds serving as sources of vitamin A, in the same way, the protein isolate and aqueous extract

exhibited high levels of total phenols and flavonoids. It is worth noting that avocado leaves have traditionally been used in herbal infusions and teas due to their diuretic and therapeutic effects (Jimenez et al., 2020).

Extracts obtained from avocado leaves exhibit total phenolic contents ranging between 1,700 and 4,382 mg GAE/100 g, with epicatechin, caffeic acid, p-coumaric acid, ferulic acid, and kaempferol identified as the most frequently reported polyphenols (Permal et al., 2023).

**Table 7.** Summary of extracts obtained from avocado leaves by maceration and their biological activity. Adapted from Kumar Gupta et al. (2018a).

Method	Biological activity
Aqueous maceration	Anti-inflammatory
	Analgesic
	Anticonvulsant
	Vaso relaxant
Ethanol: water maceration	Antidiabetic

The biological activities reported for avocado leaves are attributed to their high content of polyphenolic compounds present in the corresponding (polar) extracts. In light of these findings, pruning residues, when subjected to various extraction and purification methods, may be utilized as additives, preservatives, or ingredients in

food products and phytotherapeutic formulations (Kumar Gupta et al., 2018b).

From another perspective, Öncel et al. (2025) incorporated avocado leaves powder into gluten-free noodles, which resulted in an increased content of proteins, fiber, minerals, and antioxidants in the final product, while also enhancing its sensory properties.

Moreover, the developed product was associated with a reduction in glycemic index (Öncel et al., 2025).

Additionally, avocado leaves have been identified as a source of carotenoids—including  $\alpha$ -carotene,  $\beta$ -carotene, and

lutein—and contain significant amounts of essential minerals such as sodium, potassium, and magnesium. Therefore, this by-product demonstrates promising potential as a natural additive in food products (Ayodeji et al., 2025).

## CONCLUSION

This review confirmed that the avocado is a tropical fruit crop experiencing significant growth, which calls for the development of innovative technological strategies to facilitate and stimulate the commercialization of the fruit, its derived products, and corresponding by-products, within the framework of green chemistry and the Sustainable Development Goals (SDGs). Furthermore, it was identified that the avocado fruit and its by-products or co-products represent an excellent source of bioactive compounds. Their comprehensive and sustainable utilization would enable the avocado production chain to adopt the perspective of a Circular Bioeconomy,

promoting strategies for the development of new and promising additives, ingredients, and products of great interest for the advancement of functional and nutraceutical foods. Finally, although information related to by-products such as pruning residues (leaves) from avocado cultivation has been reported, it is noteworthy that the potential techno-functional applications of avocado flowers remain largely unexplored. Investigating this by-product could yield valuable insights, contributing to the completion of the avocado by-product cycle and its potential applications under a circular bioeconomy approach.

## ACKNOWLEDGMENT

To the General System of Royalties project: “Development, validation, and implementation of innovative technologies for the comprehensive management and

cultivation of avocado systems in the municipalities of Monterrey, Sabanalarga, and Tauramena, in the department of Casanare” (BPIN 2021000100308).

## AUTHOR STATEMENT

*Principal author Ortega-Barbosa Jenny Paola:* the first author, responsible for conducting the research, drafting the manuscript, and coordinating communication with the co-authors.

*Co-authors Moreno Caballero Michael Ernesto, Palomeque-Forero Liliam, Miranda-Delaspriella Diego, Rodríguez-Varela Luis*

*Corresponding author Parada-Alfonso Fabián:* responsible for correspondence with the journal and for managing communication with the co-authors and the journal editor.

*Ignacio:* contribute to the work presented in the manuscript by collaborating with the principal author.

## REFERENCES

Agronet. (2025). *Agricultural database 2019-2025*. Agricultural Statistics System; Ministry of Agriculture-Government of Colombia.

<https://www.agronet.gov.co/estadistica/Paginas/home.aspx?cod=1>

Ahmad, T., Esposito, F., & Cirillo, T. (2024). Valorization of agro-food by-products: Advancing sustainability and sustainable development goals 2030 through functional compounds recovery. *Food Bioscience*, 62, Article 105194. <https://doi.org/10.1016/j.fbio.2024.105194>

[4](#)

Almanza, K., Navarro, M., & Ruiz, J. (2019). Dye powder extraction from avocado seeds in Hass and Fuerte varieties.

*Revista @limentech, Ciencia y Tecnología Alimentaria*, 17(1), 5–14. <https://doi.org/10.24054/limentech.v17i1.336>

Álvarez-Rivera, G., Ballesteros-Vivas, D., Ibáñez, E., Parada-Alfonso, F., & Cifuentes, A. (2020). Foodomics of bioactive compounds from tropical fruits by-products. In *Reference Module in Food Science*. Elsevier. <https://doi.org/10.1016/B978-0-08-100596-5.22882-5>

Arancibia, C., Riquelme, N., Zúñiga, R., & Matiacevich, S. (2017). Comparing the effectiveness of natural and synthetic emulsifiers on oxidative and physical stability of avocado oil-based

- nanoemulsions. *Innovative Food Science & Emerging Technologies*, 44, 159–166. <https://doi.org/10.1016/j.ifset.2017.06.009>
- Barros, H. D. F. Q., Grimaldi, R., & Cabral, F. A. (2017). Lycopene-rich avocado oil obtained by simultaneous supercritical extraction from avocado pulp and tomato pomace. *The Journal of Supercritical Fluids*, 120, 1–6. <https://doi.org/10.1016/j.supflu.2016.09.021>
- Calicioglu, O., & Bogdanski, A. (2020). Linking the bioeconomy to the 2030 Sustainable Development Agenda: Can SDG indicators be used to monitor progress towards a sustainable bioeconomy? *New Biotechnology*, 59, 13–21. <https://doi.org/10.1016/j.nbt.2020.10.010>
- Castellanos-González, L., Vera-Peña, M. S., & Calderón-Gutiérrez, J. A. (2023). Fungal diseases in blackberry (*Rubus* spp.) in the municipalities of Pamplona and Pamplonita, North of Santander. *Revista @limentech, Ciencia y Tecnología Alimentaria*, 21(2), 69–84. <https://doi.org/10.24054/limentech.v21i2.2628>
- Cervantes-Paz, B., & Yahia, E. M. (2021). Avocado oil: Production and market demand, bioactive components, implications in health, and tendencies and potential uses. *Comprehensive Reviews in Food Science and Food Safety*, 20(4), 4120–4158. <https://doi.org/10.1111/1541-4337.12784>
- Cheikhoussef, N., & Cheikhoussef, A. (2022). Avocado (*Persea americana*) wastes: Chemical composition, biological activities and industrial applications. In *Mediterranean Fruits Bio-wastes: Chemistry, Functionality and Technological Applications* (pp. 699–719). Springer International Publishing. [https://doi.org/10.1007/978-3-030-84436-3\\_30](https://doi.org/10.1007/978-3-030-84436-3_30)
- Contreras, J., Hoyos-Arbeláez, J., & Gómez, F. (2022). Valorization of avocado waste. In *Agro-industrial by-products and indigenous resources*. INTA.
- Coutinho, I. B., Quezadas, M. B., Franquelin, L., Souza, G. de, Nitz, M., & Andreola, K. (2022). Spray drying of avocado pulp using the seed as an adjuvant. *Powder Technology*, 408, Article 117738. <https://doi.org/10.1016/j.powtec.2022.117738>

- Del Toro-Equihua, M., Velasco-Rodríguez, R., López-Ascencio, R., & Vásquez, C. (2016). Effect of an avocado oil-enhanced diet (*Persea americana*) on sucrose-induced insulin resistance in Wistar rats. *Journal of Food and Drug Analysis*, 24(2), 350–357.  
<https://doi.org/10.1016/j.jfda.2015.11.005>
- Denvir, A. (2023). Avocado expansion and the threat of forest loss in Michoacán, Mexico under climate change scenarios. *Applied Geography*, 151, Article 102856.  
<https://doi.org/10.1016/j.apgeog.2022.102856>
- Domínguez-Avila, J. A., Yahia, E. M., & Salazar-López, N. J. (2020). Avocado fruit and by-products as potential sources of bioactive compounds. *Food Research International*, 138, Article 109774.  
<https://doi.org/10.1016/j.foodres.2020.109774>
- FAOSTAT. (2025). *World avocado production*. Food and Agriculture Organization of the United Nations.  
<https://www.fao.org/faostat/es/#data/QCL/visualize>
- Fernandes, G. D., Gómez-Coca, R. B., Pérez-Camino, M. C., Moreda, W., & Barrera-Arellano, D. (2018). Chemical characterization of commercial and single-variety avocado oils. *Grasas y Aceites*, 69(2), Article e243.  
<https://doi.org/10.3989/gya.0110181>
- Food and Agriculture Organization of United Nations. (2020). *FAOSTAT – Food and Agriculture Organization of the United Nations*. FAOSTAT.  
<http://www.fao.org/faostat/en/#data/QC>
- García-Ramón, D. F., Cios, J., Soares, M. E. M., de Sant’Ana, J. P. F., Viganó, J., da Costa Rodrigues, C. E., West, C., & de Oliveira, A. L. (2025). Sustainable aqueous extraction of Brazilian varieties avocado oil: Effects on yield, physical and chemical properties, fatty acids and Triacylglycerols. *Food Chemistry*, 493, Article 145693.  
<https://doi.org/10.1016/j.foodchem.2025.145693>
- Gutiérrez-Zambrano, M., Garnica-Mayorga, N. R., & Maldonado-Mateus, L. Y. (2022). Factors influencing the nutritional quality of life of female inmates at the Bucaramanga penitentiary and prison center. *Revista @limentech, Ciencia y Tecnología Alimentaria*, 20(1), 92–110.

<https://doi.org/10.24054/limentech.v20i1.2308>

Hatzakis, E., Mazzola, E. P., Shegog, R. M., Ziegler, G. R., & Lambert, J. D. (2019). Perseoragin: A natural pigment from avocado (*Persea americana*) seed. *Food Chemistry*, 293, 15–22. <https://doi.org/10.1016/j.foodchem.2019.04.064>

Jiménez, P., García, P., Quitral, V., Vásquez, K., Parra, C., Reyes-Farias, M., García-Díaz, D. F., Robert, P., & Encina, C. (2021). Pulp, leaf, peel and seed of avocado fruit: A review of bioactive compounds and healthy benefits. *Food Reviews International*, 37(6), 619–655. <https://doi.org/10.1080/87559129.2020.1717520>

King-Loeza, Y., Ciprián-Macías, D. A., Cardador-Martínez, A., Martín-del-Campo, S. T., Castañeda-Saucedo, M. C., & Ramírez-Anaya, J. del P. (2023). Functional composition of avocado (*Persea americana* Mill. var. Hass) pulp, extra virgin oil, and residues is affected by fruit commercial classification. *Journal of Agriculture and Food Research*, 12, Article 100573. <https://doi.org/10.1016/j.jafr.2023.100573>

Krumreich, F. D., Borges, C. D., Mendonça, C. R. B., Jansen-Alves, C., & Zambiasi, R. C. (2018). Bioactive compounds and quality parameters of avocado oil obtained by different processes. *Food Chemistry*, 257, 376–381. <https://doi.org/10.1016/j.foodchem.2018.03.048>

Kumar Gupta, S., Singhal, P., Singh, A., Chauhan, R., & Kumar, B. (2018). Nutritional and pharmaceutical benefits of avocado plant. *Journal of Advanced Scientific Research*, 9(2), 4–11. <https://doi.org/10.55218/JASR.20189202>

Lucci, P., Bertoz, V., Pacetti, D., Moret, S., & Conte, L. (2020). Effect of the refining process on total hydroxytyrosol, tyrosol, and tocopherol contents of olive oil. *Foods*, 9(3), Article 292. <https://doi.org/10.3390/foods9030292>

Luna-García, N., Rueda-Páez, E., & Rodríguez-N., A. (2024). Determination of nutritional, physicochemical and sensory properties of light jam made from gulupa sweetened with stevia. *Revista @limentech, Ciencia y Tecnología Alimentaria*, 22(2), 5–17. <https://doi.org/10.24054/limentech.v22i2.3195>



- Machado, M., Costa, E. M., Silva, S., Gomes, A. M., & Pintado, M. (2025). Exploring the therapeutic potential of avocado oil: Insights into obesity metabolism and immune regulation through in vitro models. *Biocatalysis and Agricultural Biotechnology*, 63, Article 103464. <https://doi.org/10.1016/j.bcab.2024.103464>
- Marcos, F., Saravia, C., Vergara, C. E., Ávila, F., Valdés, H., & Ortiz-Viedma, J. (2019). Avocado oil: Characteristics, properties, and applications. *Molecules*, 24(11), Article 2121. <https://doi.org/10.3390/molecules24112121>
- Melgar, B., Dias, M. I., Ciric, A., Sokovic, M., Garcia-Castello, E. M., Rodriguez-Lopez, A. D., Barros, L., & Ferreira, I. C. R. F. (2018). Bioactive characterization of *Persea americana* Mill. by-products: A rich source of inherent antioxidants. *Industrial Crops and Products*, 111, 212–218. <https://doi.org/10.1016/j.indcrop.2017.10.024>
- Minagricultura. (2019). *Avocado supply chain: Indicators and instruments*. Ministry of Agriculture and Rural Development of Colombia.
- Nasri, C., Halabi, Y., Hajib, A., Choukri, H., Harhar, H., Lee, L. H., Mani, V., Ming, L. C., Goh, K. W., Bouyahya, A., & Tabyaoui, M. (2023). Proximate composition, lipid and elemental profiling of eight varieties of avocado (*Persea americana*). *Scientific Reports*, 13(1), Article 22971. <https://doi.org/10.1038/s41598-023-50119-y>
- Nasri, C., Halabi, Y., Harhar, H., Mohammed, F., Bellaouchou, A., Guenbour, A., & Tabyaoui, M. (2021). Chemical characterization of oil from four avocado varieties cultivated in Morocco. *OCL - Oilseeds and fats, Crops and Lipids*, 28, Article 8. <https://doi.org/10.1051/ocl/2021008>
- Navarro, R., Díaz-Calderón, P., Saavedra, J., Fuentealba, C., Astudillo-Castro, C., Toledo, L., Enrione, J., & Gálvez, L. (2017). Industrial avocado waste: Functional compounds preservation by convective drying process. *Journal of Food Engineering*, 198, 44–53. <https://doi.org/10.1016/j.jfoodeng.2016.11.018>
- Öncel, B., & Eryilmaz, N. (2025). Valorization of avocado leaf as a by-product of the avocado fruit: Nutritional, textural, and

- sensory properties of gluten-free erişte (Turkish noodles). *Food Science & Nutrition*, 13(7), Article e70615. <https://doi.org/10.1002/fsn3.70615>
- Parada-O., M., Caballero-P., L., & Rivera, M. (2020). Selection and training of coffee cupping judges. *Revista @limentech, Ciencia y Tecnología Alimentaria*, 18(2), 104–124. <https://doi.org/10.24054/limentech.v18i2.996>
- Peñaloza, R., & Hernández, M. (2018). Preservation of cape gooseberry (*Physalis peruviana* L.) through the application of an edible coating based on *Aloe barbadensis* Miller gel. *Revista @limentech, Ciencia y Tecnología Alimentaria*, 16(2), 50–67. <https://doi.org/10.24054/16927125.v16.i2.2018.3228>
- Permal, R., Leong, W., Seale, B., Hamid, N., & Kam, R. (2020). Converting industrial organic waste from the cold-pressed avocado oil production line into a potential food preservative. *Food Chemistry*, 306, Article 125635. <https://doi.org/10.1016/j.foodchem.2019.125635>
- Pino-García, R. del, Figueroa, J. G., Borrás, I., & Segura-Carretero, A. (2021). Functional ingredient from avocado peel: Microwave-assisted extraction, characterization and potential applications for the food industry. *Food Chemistry*, 352, Article 129300. <https://doi.org/10.1016/j.foodchem.2021.129300>
- Precious Adesola, A., Sunday Abiodun, M., & Oluwole Steve, I. (2025). Nutritional, phytochemical and functional properties of avocado (*Persea americana* Mill) leaf: Evaluation of its derivative extraction. *Food Chemistry Advances*, 6, Article 100869. <https://doi.org/10.1016/j.focha.2024.100869>
- Rațu, R. N., Veleșcu, I. D., Stoica, F., Usturoi, A., Arsenoaia, V. N., Crivei, I. C., Postolache, A. N., Lipșa, F. D., Filipov, F., Florea, A. M., Chițea, M. A., & Brumă, I. S. (2023). Application of agri-food by-products in the food industry. *Agriculture*, 13(8), Article 1559. <https://doi.org/10.3390/agriculture13081559>
- Rotta, E. M., Morais, D. R. de, Batoqui, P., Biondo, F., Santos, J., Matsushita, M., &

- Visentainer, J. V. (2016). Use of avocado peel (*Persea americana*) in tea formulation: A functional product containing phenolic compounds with antioxidant activity. *Acta Scientiarum. Technology*, 38(1), 23–29. <https://doi.org/10.4025/actascitechnol.v38i1.27397>
- Rudke, A. R., Mazzutti, S., Andrade, K. S., Vitali, L., & Ferreira, S. R. S. (2019). Optimization of green PLE method applied for the recovery of antioxidant compounds from buriti (*Mauritia flexuosa* L.) shell. *Food Chemistry*, 298, Article 125061. <https://doi.org/10.1016/j.foodchem.2019.125061>
- Salazar-Irrazabal, M. D., Ramírez-Tixe, E. E., & Velasquez-Barreto, F. F. (2023). Avocado seed starch: Effect of the variety on molecular, physicochemical, and digestibility characteristics. *International Journal of Biological Macromolecules*, 247, Article 125746. <https://doi.org/10.1016/j.ijbiomac.2023.125746>
- Salazar-López, N. J., Domínguez-Avila, J. A., Yahia, E. M., Belmonte-Herrera, B. H., Wall-Medrano, A., Montalvo-González, E., & González-Aguilar, G. A. (2020). Avocado fruit and by-products as potential sources of bioactive compounds. *Food Research International*, 138, Article 109774. <https://doi.org/10.1016/j.foodres.2020.109774>
- Siol, M., & Sadowska, A. (2023). Chemical composition, physicochemical and bioactive properties of avocado (*Persea americana*) seed and its potential use in functional food design. *Agriculture*, 13(2), Article 316. <https://doi.org/10.3390/agriculture13020316>
- Tarón-Dunoyer, A., Barros-Portnoy, I., & Mercado-Camargo, J. (2022). Characterization of fatty acids and total phenols with antioxidant activity from peach seed (*Prunus persica*). *Revista @limentech, Ciencia y Tecnología Alimentaria*, 20(1), 77–91. <https://doi.org/10.24054/limentech.v20i1.1667>
- Teixeira-Chia, T., Arena, G., Fleming, C., Chen, J., Chen, T., Leong, W., Seale, B., Hamid, N., & Kam, R. (2023). Converting avocado seeds into a ready to eat snack and analysing for persin and amygdalin. *Food Chemistry*, 399, Article 134011.



<https://doi.org/10.1016/j.foodchem.2022.134011>

Torres-Isidro, O., González-Montoya, M., Vargas-Vargas, M. A., Florian-Rodriguez, U., García-Berumen, C. I., Montoya-Pérez, R., Saavedra-Molina, A., Calderón-Cortés, E., Rodríguez-Orozco, A. R., & Cortés-Rojo, C. (2025). Anti-aging potential of avocado oil via its antioxidant effects. *Pharmaceuticals*, 18(2), Article 246. <https://doi.org/10.3390/ph18020246>

Velderrain-Rodríguez, G. R., Salvia-Trujillo, L., & Martín-Belloso, O. (2021). Oil-in-water emulsions containing avocado peel and seed extracts as affected by the presence of low methoxyl pectin. *Food Research International*, 150, Article 110781. <https://doi.org/10.1016/j.foodres.2021.110781>