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Avocado production in Kenya in relation to the world, Avocado by-products (seeds and peels) functionality and utilization in food products

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ABSTRACT

Globally, about 8.06 million tonnes of avocado are produced annually. According to Food and Agricultural Oorganisation Corporate Statistical Database, 2020, Kenya was ranked the 6th highest avocado producer globally. The processing of avocado leads to the production of large quantities of peels and seeds that are typically disposed off as waste without any further application. Avocado peels and seeds are claimed to contain high amounts of phytochemicals that offer therapeutic and other nutritional benefits. These compounds can be used to produce economically high-value products. The amounts of phenols present vary with different factors such as the varieties of avocado, level of ripening, maturation, growing conditions, and climatic conditions. Studies have shown that phenolics found in avocado peels and seeds exhibit antioxidant, anti-inflammatory and antimicrobial properties and contain related health benefits. Despite findings, that these by-products contain high-value functional properties that are beneficial to human health, pharmaceutical and food industry, they still remain underutilized. Avocado seeds and peels are currently being used traditionally in the production of soaps, pharmaceuticals, and food products, including beverage products. This review, therefore, focuses on the avocado production trend in Kenya from the year 2011 to 2020 compared to other parts of the world, with emphasis on the composition of avocado seeds and peels and their utilization in food products.

1. Introduction

The avocado (*Persea americana*) is a well-known fruit containing high bioactive compounds. Because of its health benefits, its consumption has increased globally over the past years (Araújo et al., 2018; Migliore et al., 2018). The avocado fruit is consumed in different forms and has varying commercial applications in various products, including frozen products, ice cream, avocado oil, guacamole, and cosmetic products (Colombo & Papetti, 2019; Palma et al., 2016; Saavedra et al., 2017). Currently, the interest in applying avocado as a functional ingredient in foods has remarkably increased (Colombo & Papetti, 2019; Saavedra et al., 2017). This is majorly due to the avocado's association with a high concentration of bioactive compounds such as unsaturated fatty acids, vitamins C, B and E, dietary fiber, lutein, phenolic compounds and pigments (chlorophylls, anthocyanins, and carotenoids) (Kosińska et al., 2012; Lu et al., 2005; Saavedra et al., 2017; Wang et al., 2010).

The market for processed avocados is projected to increase from US $ 1.70 billion recorded in 2018 to US $ 2.70 billion by 2024 (Ramos-Aguilar et al., 2021). Processing avocados generates approximately 2.42 million tonnes of by-products (peels and seeds) which are released into the environment. According to Araújo et al. (2018), these by-products account for approximately 30% of the fresh weight of the avocado fruit. Therefore, avocado production and processing generate large amounts of waste that lead to environmental challenges since they take long periods to degrade (Araújo et al., 2018; Figueroa et al., 2018; Kosińska et al., 2012).

Colombo and Papetti (2019) reported that avocado by-products (peels and seeds) contain relatively significant amounts of carbohydrates, proteins, lipids, fibers and high amounts of bioactive compounds. The avocado peel has been reported to contain by high phenolic content and antioxidant activity of up to 527 mg GAE/g and IC_{50} value of 9.5, respectively (Rosero et al., 2019). Furthermore, avocado peels have been reported to contain effectual antibiotic, antimicrobial and anti-inflammatory properties (Morais et al., 2015). With this significance, avocado wastes are promising materials that can be used to produce functional foods and pharmaceutical products. On the other hand, Antasionasti et al. (2017) argue that avocado by-products can be effectively utilized as a bio-source for the production of eco-friendly adsor-

Abbreviations: FAOSTAT, Food and Agriculture Organization Corporate Statistical Database.

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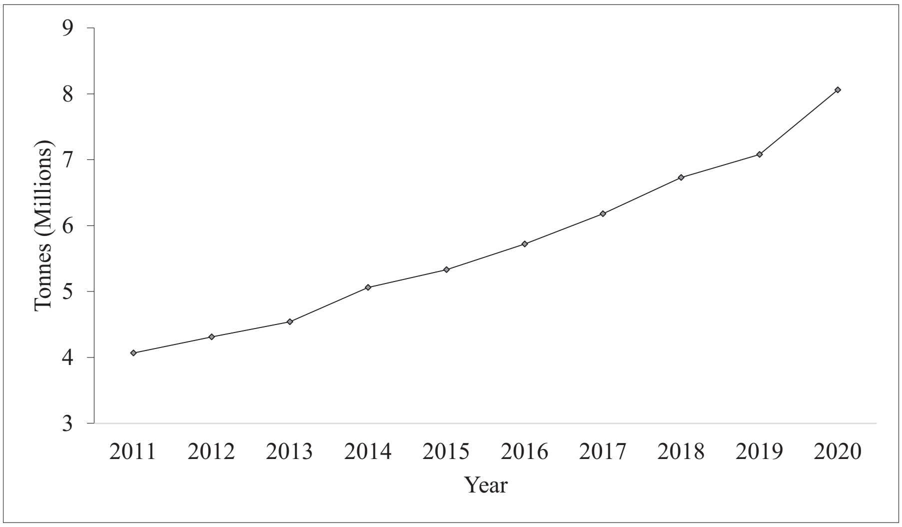

Fig. 1. The production of avocado globally between 2011 and 2020 Source: (FAOSTAT, 2020).

bents. Hence, there is a need to utilize avocado by-products to mitigate the negative impacts brought about by their release to the environment.

Therefore, this review discusses the literature on avocado production trends in Kenya from the year 2011 to 2020 compared to the other parts of the world, avocado varieties, with emphasis on composition of avocado peels and seeds and their utilization in food products.

2. Avocado production in Kenya in relation to the world

2.1. Avocado production trends

According to Araújo et al. (2018), avocado is believed to have originated in Mexico and Central America. Studies reckon the presence of evidence that avocado has been consumed in Mexico for the past 10,000 years (Gutiérrez-Contreras et al., 2010). Typically, avocado is known as butter pear because of its shape as well as the smooth texture of its pulp. According to Zafar and Sidhu (2011) avocado belongs to the kingdom *Plantae*, family *Lauraceae*, order *Laurales*, genus *Persea*, and species *P. americana*. Botanically, avocado is known as *Persea americana* Mill., which contains three ecological races, including the Guatemalan, Mexican, and west Indian which are named based on the areas of origin and traits of the fruit (Carr, 2013)

The production of avocado has been on the rise globally for the last decade. According to reports published by FAOSTAT (2020), over the past decade, avocado production has doubled from 4.07 million tonnes in 2011 to about 8.06 million tonnes in 2020 (Fig. 1). This represents approximately 50.46% increase in avocado production since 2011. Therefore, this signals a massive increase to an estimated 2.46 million tonnes (30%) of avocado wastes globally due to the release of avocado by-products into the environment if not utilized or reused.

The avocado fruit is adapted to the various tropical ecological zones, making it possible for the fruit to be cultivated in over 60 countries worldwide (Araújo et al., 2018). Based on production per country, Mexico is the highest producer and exporter of avocado fruits and has remained so at least for the past decade, followed by Colombia and Peru as the second and third producers with a production capacity of 2,393,849, 829,147 and 672,232 tonnes, respectively (FAOSTAT, 2020) (Table 1). The world's top eleven avocado-producing countries are Mexico, Colombia, Peru, Dominican Republic, Indonesia, Kenya, Brazil, Ethiopia, United States of America, Haiti, and Chile (FAOSTAT, 2020) (Table 1). The leading producers of avocado fruits in Africa include Kenya, Ethiopia, Malawi, South Africa, Cameroon and Morocco, with an annual production of 322,556, 245,336, 93,565, 84,775, 74,871, and 69,940 tonnes respectively (FAOSTAT, 2020).

Table 1
Avocado production among the top producing countries in 2020 (Source: (FAOSTAT, 2020)).

No.	Country	Production (Tonnes)
1	Mexico	2393,849
2	Colombia	829,147
3	Peru	672,232
4	Dominican Republic	620,087
5	Indonesia	609,049
6	Kenya	322,556
7	Brazil	266,784
8	Ethiopia	245,336
9	United States of America	187,433
10	Haiti	179,333
11	Chile	161,210

According to FAOSTAT (2020), Kenya produced 322,556 tonnes of avocado in 2020 (Table 1). Over the past decade, avocado production in Kenya has been increasing steadily from 149,241 tonnes in 2011 to 322,556 tonnes in 2020 (Fig. 2). This represents about a 216.13% increase in avocado production since 2011.

However, the production of avocados declined by 37.62% in 2015 to 136,420 tonnes compared to 218,692 tonnes in 2014 (Fig. 2). This decline in the production of avocados between 2014 and 2015 could be attributed to the persistent drought in major production areas and the reduced avocado production area (Gonzalez, 2016).

2.2. Avocado varieties

Avocado fruit varies in size, shape and weight based on their varieties, climatic conditions as well as agricultural practices applied during the production and cultivation processes (Kathula, 2021). Today, studies report over 500 varieties of avocado that have been identified (Araújo et al., 2018; de la Cruz & Ramirez, 2020; Naamani, 2007). Some of the avocado varieties include Hass, Lamb Hass, Shepard, Reed, Wurtz, Fuerte, Sharwil, Zutano, Ettinger, and Edranol, among others (Araújo et al., 2018; de la Cruz & Ramirez, 2020; Naamani, 2007). However, most of these varieties are not commercially produced due to diverse problems, including production time, quality in terms of protein and fat contents, resistance to environmental challenges and post-harvest damages. Numerous differences exist between avocados namely; form, weight, size, and flavor. However, the most renown difference involves the color of the skin/peel during avocado ripening (Araújo et al., 2018; Cheikhyoussef & Cheikhyoussef, 2022).

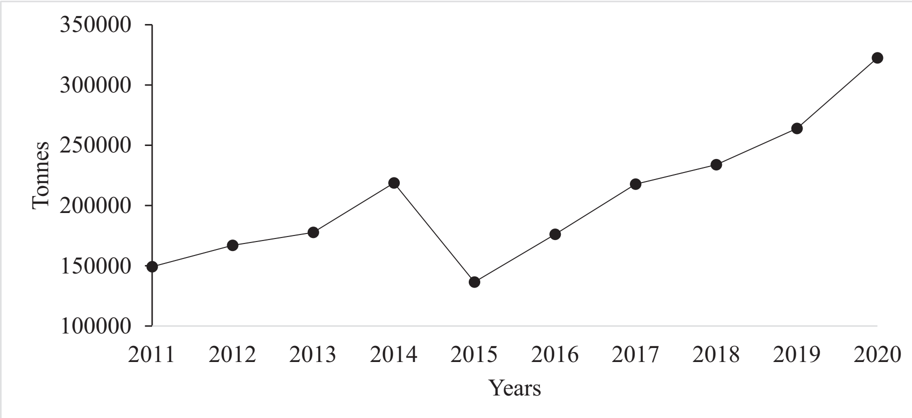

Fig. 2. Production of avocado in Kenya since 2011 (Source: (FAOSTAT, 2020)).

2.3. Avocado varieties in Kenya

In Kenya, there are more than 40 varieties of avocados. According to Wasilwa et al. (2018), Hass avocado is the main export variety and Fuerte is preferred for processing. Other varieties of avocado include Keitt, Reed, Booth 8, Simmonds, Pinkerton, Nabal, Puebla, Tonnage, Ettinger, Hayes, G6 and G7. Varieties used as rootstocks include Puebla, Fuerte, Duke, G6, and G7 (Wasilwa et al., 2018).

The skin color of Hass avocados typically turn black or black with green spots when ripened. Typically the ripeness of the avocado is determined by applying a gentle squeeze (Amare et al., 2019). Hass avocado is served when the flesh is yellowish-green. Hass avocado is characterized by intense flavor and creamy flesh, making it a perfect candidate for the production of guacamole. Hass avocado takes relatively lesser time to mature and has been shown to produce more yield per acre (Wanjiku et al., 2020).

On the other hand, Fuerte avocados have a characteristic elongated form containing glossy and thin skin. They are known to have bright green, loose, textured skin which is easily peeled (Mahendran et al., 2019). Fuerte avocados do not soften when ripe; hence, it is difficult to determine when they are ripe. Compared to Hass avocados, Fuerte avocados have a relatively low-fat content and calories (Olaeta, Schwartz, Undurraga, & Contreras, 2007; Tremocoldi et al., 2018).

3. Compositional analysis of Hass avocado

Various avocado varieties are cultivated globally, with Hass and Fuerte being the most predominant varieties consumed (Rodríguez-Carpena et al., 2011). Avocado industrial processing produces large amounts of agro-processing by-products, constituting 30% of fruit fresh weight that ends up in the ecosystem (Wang et al., 2010). Therefore, it is essential to reuse these avocado by-products, mainly the peels and seeds to help mitigate the negative impact associated with the disposal on the environment. This can be done through value addition, as these by-products are good sources of phytochemical compounds (Melo et al., 2015; Tehranifar et al., 2011).

Various studies have been conducted on avocado to characterize the chemical composition of the by-products. The studies have shown that the composition of the avocado seeds and peels varies with the avocado cultivar and other factors such as climate, cultivation region, level of maturity, rain patterns, and genetics of the fruit (Araújo et al., 2018). The seeds are rich in nutrients such as carbohydrates, protein, lipids and ash (Ejiofor et al., 2018; Mahawan et al., 2015; Talabi et al., 2016). However, avocado seeds have been of main concern in recent years because it is believed they contain antinutrients such as tannins that are a potential threat to animals and human beings, even though the by-product is rich in nutrients.

The nutritional composition is reported to contain moisture content ranging from 67 –78%, the lipid content of approximately between 12 - 24%, carbohydrate content ranging from 0.8% - 4.8%, fiber content of between 1.4% and 3.1%, and energy content of approximately 140 - 228 kcal per avocado (Duarte et al., 2016; Rodríguez-Carpena et al., 2011). Additionally, the lipid content of avocado is of critical importance as it has elevated amounts of oil compared to other fruits (Ranade & Thiagarajan, 2015) and is considered to contain high levels of polar lipids, including phospholipids and glycolipids. These polar lipids are essential in various cellular processes in cell membranes (Zafar & Sidhu, 2011). Other researchers also found that avocado contains monounsaturated fatty acids that are useful in minimizing the blood vessels of undesirable low-density lipoproteins (LDLs) while increasing the amounts of high-density lipoproteins (HDLs) (Cowan & Wolstenholme, 2016).

Compared to other vegetable oils, oil from avocado pulp has been proven to contain higher amounts of monosaturated fatty acids (palmitoleic and oleic acids) and low levels of polyunsaturated fatty acids (linoleic acid). Besides, Duarte et al. (2016) reported that avocado also has a significant amount of saturated fatty acids (stearic and palmitic acids). Other types of fatty acids found in avocado oils is in small amounts and include linoleic, eicosapentaenoic and myristic acids (Carvalho et al., 2015). Avocado pulp oil has been shown to contain a high amount of tocopherols ranging between 113.13–332.17 mg/kg (Nasri et al., 2021). Various forms of tocopherols have been identified in Hass variety avocado oil (α-tocopherol, β-tocopherol, δ-tocopherol, and γ-tocopherol) (Ghafoor et al., 2021). The tocopherol content of the avocado oil varies with the variety, stage of maturation and the mode of dehydration (air- and microwave-drying). Ghafoor et al. (2021) in a study evaluating the tocopherol content of ripe and unripe Hass avocado, the values ranged between 14.86 mg/100 g to 88 mg/100 g for unripe and 12.71 mg/100 g to 17.40 mg/100 g for ripe under the various dehydration conditions. This signifies that avocado oil is rich in antioxidants.

Avocado products also contain minerals such as magnesium, phosphorous, calcium, potassium, and sodium as well as other minerals such as zinc and iron that are present in amounts less than 1 mg per gram of fresh-weight avocado. According to Cowan and Wolstenholme (2016), high levels of potassium and minimal amounts of sodium are beneficial for persons with low-sodium diets and protect against cardiovascular diseases (CVDs).

Avocado products are also important in nourishing the diet with vitamins, such as β-carotene, Retinol, vitamin E, Ascorbic acid, Riboflavin, Thiamine, Folic acid, Niacin and Pyridoxine (Bahru, Tadele, & Ajebe, 2019; Duarte et al., 2016). These vitamins are of significant importance to human health and well-being (Duarte et al., 2016; Maqbool et al., 2018).

4. The phytochemical composition of Hass avocado seeds and peels

Phytochemicals are bioactive compounds produced by plants to protect plant from invasion by fungi, bacteria and viruses as well as prevent them from being consumed by animals and insects (Setyawan et al., 2021). Studies confirm that plants use phytochemicals as a defense mechanism against potential threats which may involve fungi, viruses, and bacteria (Ferreira da Vinha et al., 2013; Hurtado-Fernández et al., 2018; Setyawan et al., 2021). Through the consumption of these plants or plant products, the protective features of phytochemicals are passed along to humans to strengthen the human immune system and help the body fight potential health threats (Yang, 2022). Avocado extracts have played a role in the management of non-communicable diseases such as type 2 diabetes mellitus, hypertension and hypocholesterolemia (Al-Juhaimi et al., 2021). These medicinal properties are attributed to the polyphenolic composition and antioxidants present within the avocado pulp and it's by products.

Avocado seeds and peels contain high bioactive compounds, including flavonoids, carotenoids, phenolics, vitamin E and Vitamin C (Ferreira da Vinha et al., 2013). Babiker et al. (2021) reported that the ripening stage and the drying method (air drying at 24 °C, microwave drying (720 W), and oven drying at 60 °C) affect the phenolic content of the various parts of the fruit, oven-dried peels and seeds yielded the lowest total phenol content for both ripe and unripe avocado fruits. In a study conducted on Hass, Forte, and Pinkerton avocado varieties, the phenol content for the parts of the unripe fruits was found to be higher than those of ripe ones by 25.82% and 13.32% for the seeds and peels, respectively (Babiker et al., 2021). The phenolic constituents contained in the peels include; 1,2-dihydroxyhenzene, 2,3-dihydroxybenzoic acid, gallic acid, rutin trihydrate, syringic acid, and caffeic acid (Al-Juhaimi et al., 2021; Alkaltham et al., 2021; Babiker et al., 2021). Further, the findings reported by Al-Juhaimi et al. (2021) showed that avocado fruit by-products could be a significant source of phenolic compounds, and to extract the phenols, the best modes of drying that preserves majority of the compounds are microwave and air drying. These methods have been shown to preserve up to 25.86% and 36.42% of phenols respectively when compared to oven drying. Similar findings were also reported in a study conducted on ripe and unripe avocados, whereby the highest phenol content for the peels and the seeds was recorded on samples subjected to air drying (Babiker et al., 2021). The drying temperature affects the phenol content because at a certain temperature, the enzyme polyhenolic oxidase is inactivated, thereby preserving the polyphenols. Once that temperature is exceeded, the thermo-sensitive polyphenols may be denatured (Alkaltham et al., 2021; Babiker et al., 2021). Avocado peels account for 18% of the total fresh weight, and contain higher phenolic concentration and antioxidant activity compared to the reported values of edible avocado pulp (Al-Juhaimi et al., 2021). The total phenolic content of avocado peels ranges from 0.6 to 6.8 mg gallic acid equivalent per gram of sample (mg GAE/g) for the fresh avocado peel. On the other hand, dry avocado peels have been shown to have a total phenolic content of between 4.3 - 120.3 mg GAE/g; across avocado varieties and it varies with the drying conditions (Melgar et al., 2018; Rotta et al., 2016; Tremocoldi et al., 2018). Compared to other tropical fruit peels (passion fruit, pineapple, banana, melon and papaya), avocado dried peels have the highest total phenolic content and the raw peel contains the highest flavonoid content. Besides, (Morais et al., 2015) also confirmed that dried avocado peels contain the highest antioxidant activity (FRAP assay) compared to the peels of other fruits.

The other components of avocado seeds include sugar, starch, protein, fat, and water. However, the phytochemical compounds in avocado seed include saponins (0.00052%), flavonoids (0.0203%), tannins (0.00076%), alkaloids (0.0054%), phytates (0.00044%), and oxalates (0.0044%) (Bahru, Tadele, & Ajebe, 2019; Okoye, 2017). The information concerning the phytochemical properties of avocado seeds and peels is applicable in enhancing product development, especially in the phytopharmaceutical industry.

Several studies show that avocado fruit by-products contain elevated amounts of polyphenolic compounds which are considered to offer therapeutic effects to humans (Rodríguez-Carpena et al., 2011). In fact, studies have shown that these polyphenols exhibit chemoprotective properties against cancer activities (Okoye, 2017), platelet aggregation inhibition properties, anti-allergenic, antihypoglycemic (Cárdenas-Castro et al., 2021), anti-inflammatory, antioxidant properties as well as improving lipid metabolism (Bahru, Tadele, & Ajebe, 2019).

Additionally, avocado by-products (seeds and peels) have been used as raw material in the production of cosmetic products, including the behenyl alcohol in the oil. Therefore, the application of avocado by-products has been increasing in the food, nutraceutical and pharmaceutical industries. The food industry applies the antioxidant properties of phytochemicals from avocado by-products to delay the lipid oxidative damage that aids food rancidity. These biological impacts of avocado by-products are majorly associated with flavanol derivatives and phenolic acids (Henry et al., 2015; Merino et al., 2021).

According to Kosińska et al. (2012), different avocado varieties produce various content of phenolic compounds. The phenolic compound profile of avocado seed is categorized into several groups, such as terpenoid glycosides, alkanols, flavonoids, furan ring-containing derivatives, and coumarin Yasir et al. (2010). In line with these findings, studies have also shown elevated concentrations of phenolic content and higher antioxidant properties of avocado peels which showed several-fold more than the values recorded for raw blue-berries (Kosińska et al., 2012; Olaeta, Schwartz, Undurraga, & Contreras, 2007; Wang et al., 2010).

5. Utilization of phytochemical-rich avocado by-products in foods

5.1. Avocado peels

Avocado fruit is widely consumed and processed all over the world (Colombo & Papetti, 2019). Processing of this fruit leads to the generation of high amounts of peels that are rich in bioactive compounds, including polyphenols which are important for the food industry and pharmaceutical industry (Hurtado-Fernández et al., 2018). In a study comparing the peels of Hass variety and an indigenous avocado, Ramos-Aguilar et al.(2021) reported that the peels of both varieties contained bioactive compounds, including perseitol, β-sitosterol, α-tocopherol, epicatechin, carotenoids and cyaniding-3-glucoside. Even though most of the biological activities of the avocado by-products are related to the seed (Araújo et al., 2018), the avocado peels have also been shown to have a higher phenol content (63.5 mg/g GAE) than the seed (57.3 mg/g GAE) and more than seventy phenolic compounds have been identified in the peel of Hass variety alone (Babiker et al., 2021; Ramos-Aguilar et al., 2021; Tremocoldi et al., 2018), due to this, the peel has been shown to have numerous benefits that can be beneficial to the food industry and the pharmaceutical industry. These residues may provide an abundant and renewable source of bioactive ingredients to the food industry for the formulation of functional foods while promoting the circular economy agenda for zero waste.

The extracts from the avocado peel have been extensively studied with many phenolic compounds, including flavanols, anthocyanins, and phenolic acids already identified (Ramos-Aguilar et al., 2021). The peels, therefore, have been shown to have antioxidant properties and can be used as a preservative in food products (Tremocoldi et al., 2018). Moreover, Figueroa et al. (2021) studied the potential application of avocado peel extracts in food products, and the results indicated that the extract has high antimicrobial activity against both gram-positive and gram-negative bacteria and, therefore can be used in foods as a natural preservative to prevent rapid deterioration.

The application of the peels in the pharmaceutical industry has been studied and several activities, including; antioxidant, anticancer, antibacterial, and insecticidal, have been reported (Dabas et al., 2013; Kamaraj et al., 2020).

Ramos-Aguilar et al. (2021) reported the possibility that Hass avocado peels can be coverted to peel flour to fortify foods to promote good health. Due to the widespread intake of cereal-based products, it is easier to substitute the flour with avocado peel flour, and can be the best vehicle for functional dietary supplements (Dziki et al., 2014). Avocado peels have been used to fortify beverages to make them functional, containing health-promoting properties. Rotta et al. (2016) prepared dried avocado peels tea and noted significant phenol content, which showed improved antioxidant activity in the tea and was acceptable by the sensory panel. Furthermore, the peel extract has been demonstrated to prevent the oxidation of proteins when 5% of the peel extract was added to ground meat (Calderón-Oliver & López-Hernández, 2022). This shows the potential of avocado peels in the food industry.

5.2. Avocado seeds

The avocado seed represents 13–18% of the avocado fruits. With the production of more than 8.06 million tonnes of avocado fruits every year shows that over 1.45 million tonnes of seeds are disposed of annually (Tesfaye et al., 2022).

5.2.1. Application in meat and meat products

Meat and meat products are highly susceptible to microbial spoilage and sensory alterations caused by oxidation of the meat components (Falowo et al., 2014). This characteristic of meat and its products calls for mechanisms to mitigate these changes and extend the shelf life and reduce economic losses. Several strategies have been developed to extend the shelf life of meat using preservatives and synthetic additives. Application of naturally occurring additives in food preservation and fortification has been a subject of research by scientists in recent years. This has necessitated the exploration of fruit and vegetable processing by-products as sources of active ingredients such as polyphenols. Avocado seed extract has been shown to be rich in antioxidants (Boyadzhieva et al., 2018). Antioxidants are important in scavenging the free radicals and reactive oxygen that are responsible for the oxidation of meat components (Calderón-Oliver & López-Hernández, 2022). According to the findings reported by Gómez et al. (2014) on burger meat, results showed that the samples treated with 0.5% avocado seed powder had over 90% protection against oxidation; a similar case was observed when lyophilized (0.1%) extract was used. Avocado seed extract added to porcine meat displayed insignificant changes in lipid oxidation compared to samples that were not treated (Rodríguez-Carpena et al., 2011). These findings show that the seed extracts can be a breakthrough in preserving meat and meat products and add value to the avocado fruit.

5.2.2. Use in baked products

Cereal-based baked products are consumed by the majority of the population on a daily basis, and therefore the processers are finding ways to increase the nutritional value of these products (Garcia & Davidov-Pardo, 2021). Some researchers have resorted to finding new sources of raw material to supplement or substitute the common sources of flour, such as wheat, rye, and barley (Mahawan et al., 2015). Avocado seeds have been a point of focus for most researchers because of the increased consumption of the fruit, which has led to great volumes of discarded seeds. Through the application of the right technology, the utilization of avocado seeds in the baking industry may improve the nutritional and functional properties of the end product. Recently researchers are finding ways to enrich cereal-based products with herbs, spices, and other plant parts (Dziki et al., 2014). Barbosa-Martín et al. (2016) reported the fibrous residues of the avocado seed kernel could be used as additives in the baking industry to increase the softness of the baked products. Mahawan et al. (2015), on the other hand, evaluated the potential use of avocado seed flour in the baking industry. The findings indicated that avocado seed flour had a low protein content and the flour would be desired for tender and crisp products such as biscuits and cakes that are acceptable to the consumer. Avocado seed flour has also been reported to be of good yield (46.28%) and is rich in nutrients, making it a good alternative source of flour in baking cakes, bread, and cookies (Bangar et al., 2022). The substitution of wheat flour for avocado seed flour in baked products cuts baking costs, improves the phytochemical composition, and promotes the circular economy.

5.2.3. Use in beverages

A beverage is a portable drink other than water that is taken for a refreshing or stimulating effect, and they include hot drinks, soft drinks, milk drinks, and alcoholic drinks (Renfrew, 2016). The functional foods industry has been growing recently due to the recognition of the roles food products play beyond basic nutritional requirement (Corbo et al., 2014). In the food industry, beverages have been used as vehicles for bioactive compounds to make functional food products (Marete et al., 2011). Beverages by far, are the most preferred vehicles for functional ingredients because of the ease of distribution and convenience (Corbo et al., 2014). Among other functional ingredient sources, various researchers have investigated avocado seeds as a source of bioactive compounds in the beverage sector. For instance, avocado seed instant drink incorporated with maltodextrin and ginger has been studied as a functional drink (Aretzy & Ansharullah, 2018).

Further, avocado seed tea has been developed and reported the best quality tea after drying the seed at 50 °C for 2 h which was acceptable by the sensory panel (Anwar et al., 2022). The avocado seeds have been exhibited to be rich in starch, about 74.47% of their dry weight (Silva et al., 2017). The seeds can be utilized in the brewing industry to make use of seed starch (Tesfaye et al., 2022). The seed starch is hydrolyzed using enzymes to yield simple sugars, which are then fermented to make alcoholic beverages in the brewing industries. According to Dabas et al. (2011) avocado seeds can be a good source of the natural orange color which can be used in beverages and also come along with the benefits of the avocado seed extracts. In a different study by Pușcaș et al. (2022), avocado seed powder could be valorized in a hot drink, similar to the already existing coffee drinks, produced by infusing the roasted and ground avocado seeds.

5.2.4. Use in various food systems

In a study conducted by Chel-Guerrero et al. (2016), avocado seeds proved to be a potential alternative starch source. The study found that avocado seed starch has a potential use as a thickening, gelling, bioplastic, and an emulsifying agent in food systems as well as a possible ingredient in biodegradable polymers for food packaging (Barbosa-Martín et al., 2016; Charles et al., 2022). In addition, avocado seed powder is also applicable locally in Tanzania as a relief drink in treating diarrhea or dysentery, teeth aches, and skin diseases (Henry et al., 2015).

6. Conclusion

Avocado is a globally recognized cultivated and consumed tropical fruit that is popular following its high nutritious, bioactive content and its association with several health-promoting benefits. Avocado by-products (peels and seeds) form a significant part of the avocado fruit and are normally discarded into the environment without further processing. This problem can be alleviated by producing food ingredients from avocado by-products. As an easily attainable raw material, avocado peels and seeds offer great potential for producing natural food additives, medicines, pharmaceuticals, and nature-friendly adsorbents. Therefore, studies should focus on finding methods and techniques for tapping the beneficial properties of avocado by-products into useful products in the food, cosmetic and pharmaceutical industries.

Declaration of Competing Interest

Authors have no interests to declare.

CRediT authorship contribution statement

Clinton O Nyakang'i: Conceptualization, Investigation, Formal analysis, Writing – review & editing. **Rebecca Ebere:** Supervision, Writing – review & editing. **Eunice Marete:** Conceptualization, Supervision, Funding acquisition, Project administration, Resources, Writing – review & editing. **Joshua M. Arimi:** Conceptualization, Supervision, Formal analysis, Investigation, Writing – review & editing.

Data availability

Data will be made available on request.

Role of the funding source

This research was funded by the National Commission for Science, Technology, and Innovation (NACOSTI) 3rd call for women scientists. However the funding source had no involvement in this research.

Ethical statement

This research work did not involve human and animal subjects and therefore did not have ethical approval.

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