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Status of Avocado Production, Postharvest Handling and Utilization in Kenya

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Abstract

Avocado is an exotic fleshy fruit dicotyledonous plant grown for its fruit though leaves of the plant have also been used for avocado flavored tea production while the seed is known to contain antioxidants. The consumption of avocados is on the increase in Kenya; however, the value chain experiences losses estimated to be around 40% due to inability of the sector players to convert fresh fruits into more shelf stable products due to limited preservation technologies. Limited information exists on the production status of avocado, postharvest handling and consumption pattern of avocado in Kenya. This paper aims at determining the current Kenyan avocado distribution patterns, production volumes, nutrition properties and post-harvest handling practices. A semi systematic literature review approach was used to review research materials relevant available articles. The most current articles published in reputable journals within the last 10 years were considered. From the literature, avocado crop popularity is on the increase and has surpassed traditional cash crops such as coffee and tea. According to the findings, avocados can be converted to various products which include avocado oil, guacamoles, dry avocado powder, dehydrated products and avocado blended ice creams. There are gaps in avocado fruit preservation with an estimated 40% loss occasioned by low technologies in product transformation. In conclusion, the sector is in need of knowledge and technologies in product transformation to enable the sector avert losses occasioned by poor post-harvest handling techniques. This literature review provides information on the current status of avocado production, postharvest handling and utilization in Kenya which is useful to avocado marketers, policy makers, authorities, consumers and other stakeholders as well as avocado production and post-harvest handling researchers.

Keywords: *avocado; consumption patterns; post-harvest handling*

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Introduction

The avocado is an exotic fleshy fruit dicotyledonous plant derived from the same-named tropical tree in the Lauraceae family and the Ranales order (Mpho, 2012). Avocado is known as Palta in some parts of South America (Galindo-Tovar *et al.,* 2007). Before the Spanish conquest, the fruits were first grown in tropical America as individual seedling trees (Galindo-Tovar *et al.,* 2007). However, according to Galindo-Tovar et al. (2007), much of the plant's attention as a horticultural crop came after 1900. Avocado fruits grow on avocado trees, which have elliptic to egg-shaped leaves that grow to be about 10-30 cm long (Chia and Evans, 1987). Notably, Chia and Evans (1987) discovered that avocado trees of the perennial leaf bear fruit for the first time in the fourth or seventh

year. Avocado trees thrive in warm climate zones, particularly in South American countries.

The trees produce small greenish flowers in dense inflorescences devoid of actual petals (Chia and Evans, 1987). The flowers typically have nine stamens organized into three series. According to Chia and Evans (1987), the fruits themselves measure about 5-6 cm in length and weigh about 200-400 grams on average, though some fruits can weigh up to 2 kilograms. Avocado skin is thick and rigid, and the color is green, though the tone may vary depending on the variety (Chia and Evans, 1987). All avocados are classified into two types: A and B, based on their floral behavior (FAO *et al.,* 2004). Group A cultivars perform better when blooming in low temperatures than group B cultivars, which also perform well in these conditions (FAO *et al.,* 2004). According to Hategekimana (2019), there are over 500 varieties of avocados, with differences in texture, shape, size, and maturity rate. Fuerte and Hass are the most common, with Hass being the most common globally (Hategekimana, 2019).

Avocado quality and shelf life is highly affected by the form of handling after harvest, in Kenya avocado for export is handled in a more improved way compared to those meant for local consumption (Chen *et al.,* 2017). According to (Hategekimana, 2019) harvesting activities is done using secateurs or knives or sticks, fruits are then placed in on the ground, in gunny bags or in crates and transported to export companies using open small pickup trucks. Due to absence of refrigeration during the first mile transport approximately 20% of the fruits is lost (Herman et al, 2021) when the quality of fruits starts deteriorating, while 10% of the fruit is lost in subsequent chain movement of fruit that occurs during post packing transport and packaging steps. The more the distance the most the fruit quality is affected.

Utilization of avocado in Kenya is primarily for consumption after ripening, according to (Mwaura, 2021) only 10% of avocado produced in Kenya are exported the reminder is used locally. Most of the avocado used locally is ripened and consumed in salads, transformed into juice and a few quantities converted to oil (Chen *et al.,* 2017). The potential of transformation of avocado to more shelf stable products remain untapped this is partly due to low availability of technology, capital and technical knowledge. This literature review provides information on the current status of avocado production, utilization, postharvest handling and gaps in product transformation leading to losses in Kenya which is useful to avocado marketers, policy makers, authorities, consumers and other stakeholders as well as avocado production and post-harvest handling researchers.

Materials and Methods

Review of literature materials in this paper was done through a semi systematic review of literature materials available online or hard copies of journals at the University of Nairobi department of Food Science, Nutrition and Technology library. The most current materials published in reputable journals within the last ten years were considered. Online literature search involved the search of relevant information by the use of key words that define the scope of the review. Various articles were searched which include Google Scholar, Web of Science and Science direct data. A total of 380 article were identified as primary source of information for the topic, to get better results filtration through the use of attributes such as relevance, scope of study, date of publication among other was done to identify relevant articles. On further screening a total of Forty-four articles were selected for consideration in this review.

Relevant article Searching

The study review considered peer reviewed journals disseminated in English and published within the last ten years. Majority of the search were done through the Google scholar however a few hard copy journals available at the University of Nairobi Kabete campus food science, nutrition and technology library were also reviewed. Some of the key words used to perform the search include avocado production in Kenya, utilization option for avocado, nutritional

value of avocado and value addition of avocado in Kenya. To increase the scope of search alternative words were also used those include avocado oil extraction in Kenya, methods of avocado preservation, HCD reports on avocado production.

Article Screening

To determine appropriate content an including and exclusion metrics (Table 1) was used which was based on five attributes, the criteria involved reading the abstract of the selected articles and using a semi systematic review 380 of articles were selected.

Table 1. Inclusion and exclusion criteria

Metrics	Inclusion aspects	Reason for exclusion
Date	Published within the last 10years those older than 10year but with no current information available	Older than 10years articles
Relevance	Suitability in the filed on avocado crop research in Kenya, detailed information on avocado use.	More focused on central America production
Sector	Avocado crop in Kenya	Other crops apart from avocado
Scope	Theories, book chapters , PhD research work publication if relevant	Articles with inferior quality due to low level of review or publication for profits.
Language	English written articles	Non-English written articles

Results

Extr*action and analysis of screened articles*

The screened Forty-four articles were analyzed through reading the abstract, results, discussion, conclusion and recommendations. The screened articles were grouped into three categories:

(i) Global avocado production and distribution.
(ii) Cultivation, consumption, utilization and main products value addition of avocado in Kenya.
(iii) Postharvest losses of avocado fruit in Kenya.

Table 2. Summary of articles reviewed

Categories	Number of articles reviewed	Search engine	No of websites
Global avocado production and distribution.	Forty-four (44)	Google Scholar, Microsoft big, Meta crawler, Web crawler, Brave search	Sixty-one (61)
Cultivation, consumption, utilization and main products value addition of avocado in Kenya.	Twenty-one (15)	Yahoo, Google scholar, You.com, Smart page	Twenty-two (22)
Postharvest losses of avocado fruit in Kenya.	Ten (10)	Google scholar, Hard copies at UoN Library	Fifteen (15)

Forty-four articles were thoroughly reviewed for evidence and determined to contain valuable information, there were fifteen articles published detailing publication materials from Kenya on avocado. Forty-four publication materials had detailed relevant information but covered global aspects of avocado production. Ten articles reviewed had relevant information on post-harvest losses in Kenya. A total of ninety-eight websites were visited and classified according to the three thematic. The reviewed materials indicated a gap in research work in the field of avocado post-harvest knowledge, utilization and value addition in Kenya similar to publication according to Juma et al, (2019).

Discussion

Review of global avocado production and distribution

There are approximately fifty-seven (57) countries producing avocado globally, with approximately 348,769 Ha of land indicated as the total land in which avocado grows globally, producing approximately 2,538,226 tons on an annual basis (FAO *et al.*, 2020). Mexico is the world's leading producer of avocados (FAO *et al.*, 2020). Avocado is grown in several African countries, including Kenya, which have continued to dominate the market (Chen *et al.*, 2017). The fruits are available all year and are commonly eaten in salads or as a dessert in many parts of the world (Kimaru *et al.*, 2020). Mexico leads in global production of avocado followed by Peru while Kenya is the leading avocado producer in Africa but third in the world (Figure 1, FAOSTAT 2020). Kenya has continuously recorded increased production with actual production volumes in Kenya hitting an impressive volume of 318,000 MT per year in 2018 (Herman *et al.*, 2021),

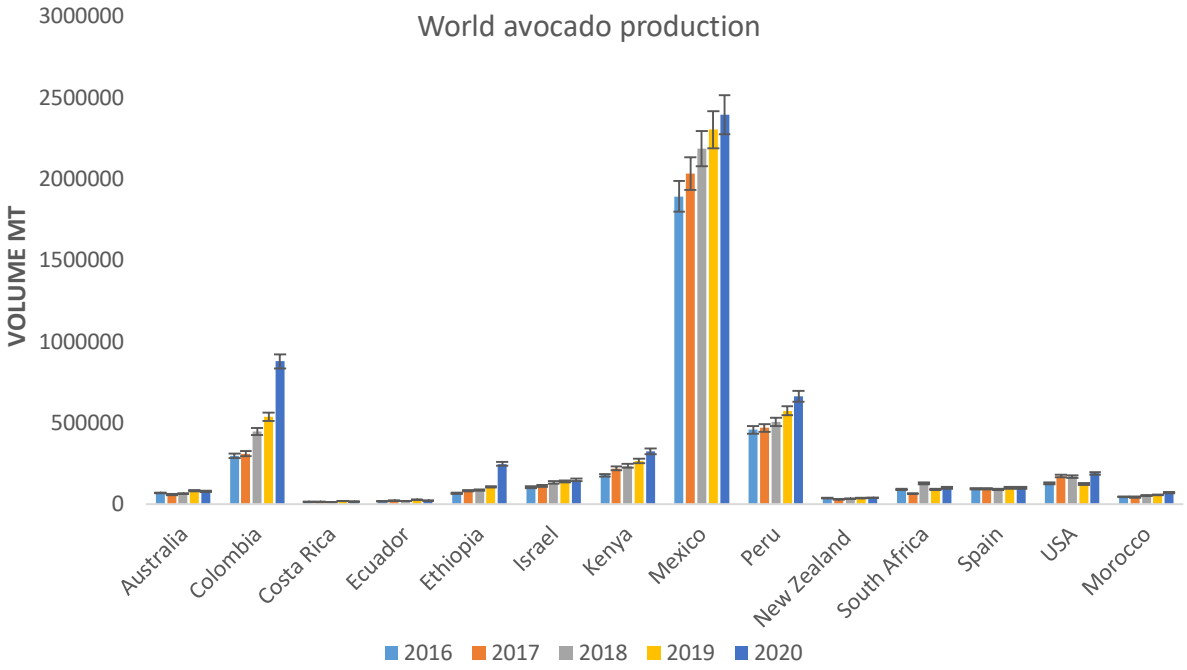

Figure 1. World avocado production trends (FAO*STAT 2020)*

Increased health concerns are a current trend in the world, particularly in developing countries (Benbrook and Davis, 2011), which have resulted in an increase in global demand for avocado fruits. People want to eat healthy foods that will help them maintain a balanced diet and provide their bodies with a variety of nutrients (Benbrook and Davis, 2011). As a result of its ability to provide a variety of essential nutrients, avocado demand has increased significantly.

Avocado cultivation in Kenya

Kenya is a top producer of the avocado crop in Africa, with both exotic and indigenous varieties dominating production (FAOSTAT 2020). However, in recent years, increased production of the Hass variety, which has gained international economic relevance and industrial processing into a variety of industrial products, including oil, which is one of the most commonly used forms of the processed fruit, has occurred (HCD 2020). Kenya, as previously mentioned, is among the top producers in Sub-Saharan Africa (Chen *et al.*, 2017). Kenya has consistently developed avocado production in the East African region

for many years, resulting in almost export monopoly rights, and is ranked third in the world in avocado production (FAOSTART 2020) 2017). Avocados Boom in Kenya (Yanyan, 2018) claims that farmers have recently switched from producing tea to avocado in order to benefit from increased profits in the European market. Production data from the Horticulture Crop Directorate (HCD) as shown in Table 3 show increased production and value of avocado among selected among them Murang'a, Kiambu, Kisii, Meru for the period between 2019-2020.

Table 3. Avocado production in some of the selected counties in Kenya

County	2019			2020			% Of Total Value
	Area (Ha)	Volume (MT)	Value (KES)	Area (Ha)	Volume (MT)	Value (KES)	
Murang'a	4,882	136,080	2,899,048,369	5,890	137,561	2,923,607,824	**31.0**
Kiambu	1,637	49,125	1,204,258,500	1,676	51,584	988,561,000	**10.5**
Kisii	2,294	73,728	1,194,732,344	1,981	80,652	644,000,000	**6.8**
Bomet	672	12,897	484,832,000	687	11,566	363,456,000	**3.9**
Nyamira	1,597	30,270	489,480,000	2,660	31,269	551,640,000	**5.8**
Meru	1,208	24,054	462,350,000	2,575	17,499	387,438,292	**4.1**
Kirinyaga	718	12,965	320,930,000	709	12,940	348,380,000	**3.7**
Nakuru	483	10,982	234,946,000	1,553	24,501	700,980,163	**7.4**
Nyeri	657	7,404	173,066,717	1,352	34,199	310,593,376	**3.3**
Bungoma	464	7,450	172,800,000	273	7,300	105,200,000	**1.1**
Embu	553	8,297	165,940,000	538	18,727	354,673,440	**3.8**
Uasin Gishu	253	4,167	152,995,000	511	2,117	105,810,000	**1.1**
Busia	730	6,751	121,677,904	733	6,380	120,447,500	**1.3**
Nandi	238	2,719	117,282,000	368	7,661	257,755,000	**2.7**
Trans Nzoia	455	3,862	113,000,000	296	1,047	20,940,000	**0.2**

Source AFA-Horticulture Crop Directorate (2020)

Accordingly, Kenya currently exports three types of avocado: Fuerte, Hass, and the local Jumbo variety (Yanyan, 2018). Avocado production in the country is around 115 000 metric tons per year, with small-scale production accounting for about 70% of the fruits (Avocado, 2020). According to Basil (2020), Kenya's avocado exports increased by 15% to 68,000 tons in the year to October 2019, bringing in Sh14 billion (US$12, 820, 5140) for the country. The adoption of higher market led international quality standards has been credited for this. Avocados are grown commercially in seven different Kenyan counties, with about 70% of the fruit coming from smallholder farmers, 20% from medium-scale farmers, and 10% from commercial plantations (Africa Research, 2018). According to Pleguezuelo *et al.,* (2018), the Fuertes variety has over 15 sub species that are grown and sold for their high fat content. Moreover, the local avocado varieties are superior in taste and consistency, and thus sells well locally (Juma *et al.,* 2019). However, Kenya has intensified the cultivation of the most common avocado fruit, Hass (Figure 2), which is the most popular variety worldwide (Hategekimana, 2019). The county governments, national government agencies such as the Kenya Forestry Research Institute (KEFRI), AFA and World Bank have spearheaded small holder engagement in the avocado sector through provision of certified seedlings, availing capital and provision of technical skills the National Agriculture Value Chain Development project (NAVCDP) (World bank, 2021).

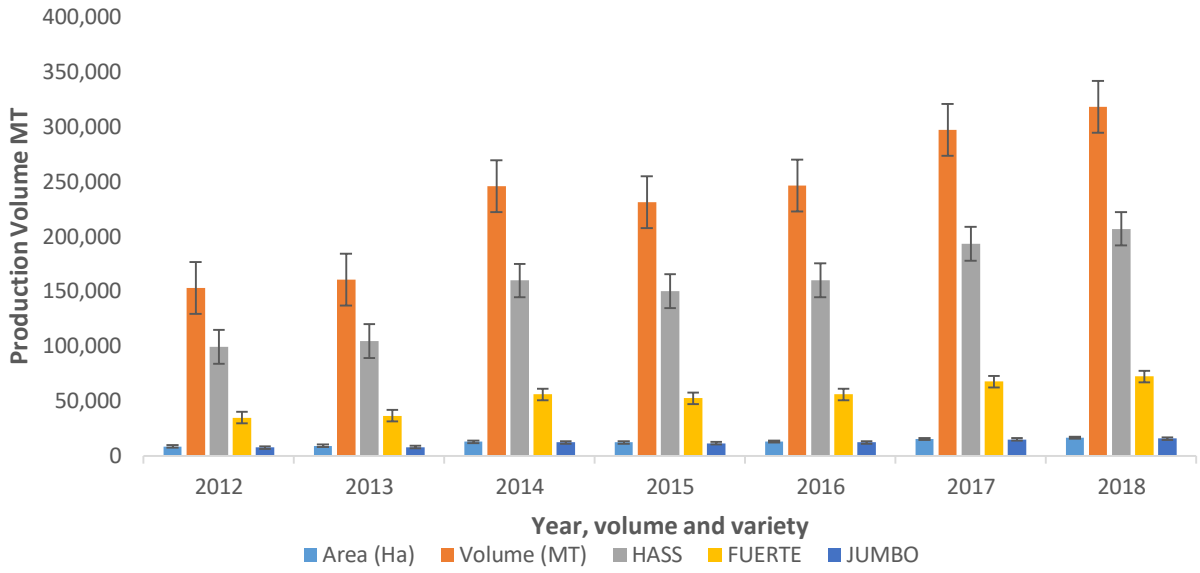

Figure 2. Avocado production volumes trends in Kenya (HCD 2020)

Nutritional properties of avocado

Avocado have been shown to contain a variety of nutrients that are beneficial to a wide range of people. Avocados contain approximately 73% water, 15% fat, 8% carbohydrates (primarily fibers), and 2% protein (USDA 2022). According to USDA (2019), half of an avocado fruit contains about 160 calories (at around 100g). Avocado have a low sugar content compared to other fruits, with half a fruit (100g) containing about 0.66g of sugar (fructose, glucose, galactose, and sucrose) (USDA, FoodData Central, 2019). The fruits according to Dreher and Davenport (2013), have a low glycemic index because of the low sugar content and do not significantly raise blood sugar levels. According to Carvajal-Zarrabal *et al.,* (2014), avocados are high in monounsaturated fatty acids, the most common of which are oleic acids, which are beneficial to consumer's health. Moreover, they are a good source of vitamins C, E, K, and B-6 (Benbrook and Davis, 2011). Avocado fruits are also important sources of carotene, omega-3 fatty acids, and lutein making them highly nutritious (Table 4).

The fruits are high in fat, with nearly three-quarters of it being monounsaturated fats, which may help protect against cardiovascular disease and lower blood pressure, according to recent studies (Salazar-lópez *et al.,* 2020). Oleic acids, the most common monounsaturated fat, are important for preventing cancer (Carvajal-Zarrabal *et al.,* 2014). In addition, Herman, 2021 indicated that fruits in Kenya are rich in 18 of the 22 amino acids including the 8 essential amino acids and in addition provide consumers with vitamins A, B complex C and E. However, the fats are also high in antioxidants, vitamin E and carotenoids such as lutein and zeaxanthin, which are beneficial health wise. Moreover, the avocado also has high levels of potassium, fiber, and folate, all of which are beneficial to the heart and circulatory system (Salazar-lópez *et al.,* 2020).

Table 4. Nutritional composition of avocado

Nutritional composition	Units	Quantity Per 100 g (Fresh weight)
1. Proximate composition		
Water	Aw (mL)	72.3
Energy	Kcal	167
Protein	g	1.96
Total lipid (fat)	g	15.41
Ash	g	1.66
Carbohydrate	g	8.64
Fiber	g	6.8
Sugars	g	0.3
Starch	g	0.11
2. Minerals		
Calcium	mg	13
Iron	mg	0.61
Magnesium	mg	29
Phosphorus	mg	54
Potassium	mg	507
Sodium	mg	8
Zinc	mg	0.68
Copper	mg	0.17
Manganese	mg	0.15
Selenium	µg	0.4
3. Vitamins and Phytochemicals		
Vitamin C	mg	8.8
Thiamine	mg	0.08
Riboflavin	mg	0.14
Niacin	mg	1.91
Pantothenic acid	Mg	1.46
Vitamin B-6	mg	0.29
Folate	µg	89
Choline total	mg	14.2
Betaine	mg	0.7
Vitamin B-12	µg	0
Vitamin A	µg	7
β-Carotene	µg	63
α-Carotene	µg	24
β-Cryptoxanthin	µg	27
Lutein + zeaxanthin	µg	271
Vitamin E (α-tocopherol)	mg	1.97
Tocopherol β	mg	0.04
Tocopherol γ	mg	0.32
Tocopherol δ	mg	0.02
Vitamin K1 (phylloquinone)	µg	21

Source USDA (2019)

Postharvest losses of avocado fruit in Kenya

Although there has been a significant increase in avocado demand at the international market, local avocado cultivars, which have a short shelf life when ripe, are only sold in domestic markets (Juma *et al.,* 2019). Despite high production in the East African region, there have been few studies on the postharvest handling of local cultivars, limiting the exploitation of avocado value chains. According to Kiaya (2014), the "postharvest system" includes "a range of interconnected activities, from harvest to processing, marketing, preparation, and finally consumer consumption decisions." Avocados, according to Anjichi *et al.,* (2006), are highly perishable fruits that ripen within a few days of harvest. This means that appropriate post-harvesting technologies and operations are required to ensure that postharvest losses are kept to a minimum (Kiaya, 2014).

Avocados are grown by a lot of small-scale farmers in Kenya although most of them don't have access to preservation technologies or even know how to handle them properly. As a result, they report high postharvest losses (Mutui *et al.,* 2011). According to Anjichi *et al.,* (2006) and Herman 2021, the majority of postharvest losses occur between the time of harvest and the time of shipment due to poor postharvest handling practices and a lack of preservation technologies and tools. Herman, 2021 estimated that small holders experience huge economic losses with a price range loss of between Ksh.2.5 to Ksh.6 per kg sold which is estimated to be about 20% loss.

According to Mutui et al. (2011), the majority of Kenyan records show a large number of small-scale farmers producing avocados. The majority of them have inadequate postharvest handling and lack modern technologies and tools to preserve the fruits. As a result, according to the authors, Kenya experiences high postharvest losses. Avocados are a highly perishable fruit, and Kenya reports approximately 40% postharvest losses (HCD, 2018). According to this report, nearly half of all avocado fruits produced are never consumed (Kader and Rolle, 2004). More recently Kimaru *et al.,* 2020 attributed athracnose disease to 60% of all losses attributed to disease infestation of avocados. Losses are costly in avocado growing because it is a labor-intensive and an expensive form of horticulture with likelihood of waste of resources as well as loss of high-nutritional food during glut (Kader and Rolle, 2004).

Kenyan farmers incur losses of fruits supplied to the market as a result of mechanically damaged fruits with poor quality fetching low prices at the market. Damages on fruits is due to poor infrastructure coupled with the use of unacceptable holding equipment. The damages on avocados are manifested in changes in skin color and decreased nutritional value marked by reduced chlorophyll with increased anthocyanin levels, cyanidin 3-O-glucoside which reduces exports and health benefits, while producers suffer losses (Juma *et al.,* 2019).

For the majority of rural households, home-grown fruits and avocados are an important source of micronutrients required for a healthy balanced diet (Booth and Mutebi, 2014).

However, despite increased avocado production in Kenya, most of the varieties produced in the region are unfit for export, implying that the majority of them are consumed locally, resulting in reduced consumption, which in turn promotes increased wastage. Similarly, according to Hailu and Derbew (2015), almost half of the avocados produced in Kenya are lost, reporting that more than 40% of fruits are lost before reaching the end-user due to poor postharvest activities such as harvesting, handling, transporting, sorting, packaging, and storage. A few farmers have access to the necessary technologies for preserving the fruits after harvest, but the vast majority do not (Kiaya, 2014)). Kiambu and Murang'a counties are among the leading producer of avocados in Kenya for export (HCD 2020) there is a similarity between Murang'a and Kiambu counties in that most farmers have common postharvest handling knowledge, which justifies the high losses in both counties (Anjichi *et al.,* 2006).

Avocado consumption and utilization in Kenya

According to HCD, 2020 avocado is ranked among the most traded fruit after bananas, mangoes, and pineapples, the fruit ranks fourth among the most economically important fruits in the country.

The avocado fruits is an important forex source for the country, there are various exporters in Kenya who engage in large scale production and exportation of the Hass and Fuertes varieties though the country only exports 10% of its production (HCD, 2020). The leading exporters include Vegpro, Kakuzi, Kenya Horticulture exporters (KHE), East African Growers (EAG), Biofarms Ltd, Frutplanet, Sunripe, and most recently Keitt exporters Limited. According to HCD, 2020 Kenya traded avocado worth 14.7B Ksh in 2020 to various global markets such as EU, UAE and Middle East making avocado export as the leading fruit export earner.

The avocado fruit is frequently consumed fresh in Kenya, and given the limited industrial processing, it is estimated that the majority of the annual production is lost due to avocado farmers' limited postharvest handling and preservation practices (Cervantes-Paz and Yahia, 2021).

Apart from avocado being consumed fresh after ripening, globally avocado pulp, seed and peeling are used for oil extraction with the oil being rich in oleic acid. The amount of oil produced in Kenya from avocado remain low, according to (Mwaura, 2021) only 10% of avocado are exported with information on the use of the 90% remaining scanty. According to (USAID, 2016) over 90% of oil produced from avocado in Kenya is exported to Europe, United States and East Asia to be used in culinary and cosmetic industry. The by-products from oil extraction are used to produce manure, transformed to animal feeds while in large quantities they may be used as a source of biogas (USAID, 2016).

Avocado value addition in Kenya

The avocado fruit is suitable for a variety of industrial applications and uses which include making condiments and guacamole (Cortés-Rojo *et al.,* 2019). While considerable research has been conducted on processed avocados, a dearth of documentation on East African processed fruits continues to be a bottleneck in the fruit's value chain (Salazar-lópez *et al.,* 2020). This review is critical because it contributes to the increases fruit consumption and shelf life while also increasing the profitability of the fruit. According to Dhillon et al. (2011), value addition in horticulture entails achieving a premium price for a given volume of a primary product through processing, packing, quality improvement, or other associated methods.

As previously stated, avocado are highly perishable products that lose their freshness quickly, according to Marulanda *et al.,* (2018). As a result, value addition enhances the fruits' nutritional value and properties while also extending their shelf life (Marulanda *et al.,* 2018). Numerous farmers are constantly looking for ways to increase the value of their products in order to increase profits while also extending the shelf life of their products (Munene, 2020). Pasteurization, drying, cooking, and blending are just a few of the processes that add value to avocados. While many framers are already aware of value-added methods, marketing continues to be a significant issue in East Africa (Olielo, 2013). Nonetheless, avocados are used to enhance the value of a variety of products.

Avocado products

Although avocado is used to make a variety of products on a global scale there are limited processing practices for the fruit in Kenya, and only a small number are available in these regions. Avocado products include avocado pulp, oils, dehydrated products, guacamoles, and ice creams, which are discussed further in this section (Jimenez *et al.,* 2020). This section will discuss various avocado products designed to extend the shelf life and profitability of avocados.

Avocado pulp

The cold process method for extracting edible oil from the pulp of Persea americana (Mill) involves pulping avocados after they have been cleaned. De-stoning and squeezing the pulp with commercial pulpers or electric blender machines is the next step (Morais *et al.,* 2017). Avocado pulp can be used in a

variety of ways. Avocado oil, for example, is made from avocado pulp due to its high lipid profile, making it the main interest, according to Duarte et al. (2016). Because of the higher pulp yield, avocado varieties with lower core and shell percentages are the most sought for oil extraction, and the Hass, Quintal and Fuerte varieties have stood out for their high oil yield (Dreher and Davenport, 2013). Apart from the oil, the avocado pulp is also used to make juices (Duarte *et al.,* 2016), with various flavors created by combining the pulp with other products such as soy milk, almond, or full-fat cow's milk to make it creamy, or fruits to boost the nutritional value (Duarte *et al.,* 2016).

Avocado oils

Due to the avocado fruit's high oil content, it is used in large quantities to produce oil via a variety of methods. Avocado oil contains a high concentration of lipid-soluble bioactive compounds, but the concentration varies according to a number of factors. Numerous phytochemicals found in the oil have been associated with cancer prevention (Cervantes-Paz and Yahia, 2021). Avocado oil is popular in the food, pharmaceutical, and cosmetic industries, and it is gaining popularity in other fields such as structured lipids, nanotechnology, and environmental stewardship (Cortés-Rojo *et al.,* 2019).

Avocado oil is primarily extracted mechanically (via cold pressing) and chemically (via the use of organic solvents) from the flesh of the avocado fruit, though it is occasionally extracted from the skin and seed. Avocado oil yield and quality are determined by factors such as fruit cultivar, maturity stage, extraction method, fruit tissue type, and the different extraction conditions such as pH, temperature, or added enzymes. Although the oil produced on a large scale meets the quality standards for culinary use, it is typically refined further for use in the cosmetic industry (Cervantes-Paz and Yahia, 2021). There is, however, limited industrial oil extraction process in Kenya therefore limiting the exploitation of this key avocado product.

Dehydrated avocado products

Avocados can be dried whole, cut into two pieces, or cut into smaller pieces and dried using freeze or vacuum drying. Avocado powder is also made from dried avocado halves and shreds. This powder has several advantages over fresh fruit, including being less bulky and retaining its freshness for an extended period of time (Mujaffar and Dipnarine, 2020). Drying techniques such as hot air (oven) drying, heat pump assisted drying, and superheated steam drying have all been thoroughly investigated. Significant issues are associated with hot air drying which include shriveling of slices, tough and rubbery slices, oil leakage and unappealing color (Munene, 2020). Insufficient drying has an impact on safe storage, and rancidity during storage. Also, studies on hot air drying of avocado pulp slices and cubes examined at drying (5-8h) and temperatures ranging from 50 to 80°C have shown acceptable product quality (Munene, 2020).

The development of a bitter aftertaste in avocado pulp during thermal processing is attributed to a class of compounds known as oxylipins. Off-taste may develop as a result of tissue collapse in the fresh avocado fruit and defrosting of the frozen pulp (Husen *et al.,* 2014). The resulting powder is an intense shade of green with excellent water mixing properties. Avocado powder is versatile and can be used in a variety of applications, including ice creams, smoothies, desserts, soups, spreads, sauces, dips, salads, ready-to-use products, flavoring ingredients, and healthy snack coatings. When avocado powder is combined with water, it instantly transforms into a paste. The powder does not require refrigeration, which makes it more convenient for consumers (Mujaffar and Dipnarine, 2020).

Avocado guacamoles

Despite the fact that avocado guacamoles are rarely prepared in Kenya because the fruit is often consumed in its natural state, they are popular among sports fans and people who want to improve their health (Munene, 2020). Avocado is the main component of guacamole, which is combined with lime juice and salt. Fresh avocado, vegetables, spices, antioxidants, preservatives, condiments, and other ingredients, as well as lemon, are used to

make guacamole dressing, which is kept refrigerated. It's an oil-in-water (O/W) emulsion that behaves like a thermodynamically unstable colloidal system, necessitating additives for proper emulsification and stability, resulting in flavor, aroma, color, and improved appearance (Cortés-rodríguez *et al.,* 2019).

Guacamole is made with ripe avocados and various chemical and natural additives to extend its shelf life. The most commonly used additives are antioxidants with lipid and/or enzymatic effects (sodium erythorbate, butylhydroxytoluene (BHT), sulfur dioxide, ascorbic acid, citric acid, and tocopherol) preservatives (sodium benzoate and potassium sorbate), and spices such as garlic and onion, which have been linked to anti-browning properties. When the mixture is ready, it is packaged in disinfected glass jars or plastic cans to keep fresh (Cortés-rodríguez *et al.,* 2019).

Avocado- blended ice creams

Avocados are also used in ice cream and smoothies (Wijana *et al.,* 2012). The process begins with blending the fruit pulp with condensed milk or cream milk, then blending until the mixture is completely smooth and free of avocado chunks. The mixture is then transferred to a much larger mixing bowl, where more heavy cream is added and beaten with a low-speed hand mixer until it thickens. When the cream is frozen, it tastes the best (Munene, 2020).

Effects of different processing methods on avocado fruit nutrients

As previously stated, various methods are used to add value to avocado fruits, extending their shelf life and increasing producer profitability (Jimenez *et al.,* 2020). Cooking, pasteurization, drying, freezing and blending were all mentioned (Cortés-rodriguez *et al.,* 2019). While all of these methods are beneficial for extending the shelf life of avocados, some of them are detrimental to the nutritional properties of the fruits and sometimes have a negative effect on their nutritional value (Nnaji and Okereke, 2016). For example, according to some studies (WIP, 2004), cooking avocados destroys some heat-sensitive vitamins, including vitamin C and folate.

While cooking fruits makes them easier to combine with other foods and extends their shelf life, cooking may result in decreased nutritional value, meaning that an individual who consumes cooked fruits may obtain fewer nutrients than an individual who consumes them fresh (Nnaji and Okereke, 2016). As a result, controlled processing is recommended in order to preserve the nutritional value of avocado fruits. Additionally, Castaeda-Saucedo et al., (2014) reported that their study indicated that freeze-drying avocado fruits had a minor effect on their nutritional value. The results indicated a reduction in linoleic acid of approximately 1.43 g/100g, with the authors concluding that, while freezing avocado fruits is significantly beneficial, it can occasionally result in nutritional changes. In general, sound processing approaches are based on established standards to ensure the preservation and maintenance of essential nutrients; otherwise, substandard processing methods result in low nutritional value. Nonetheless, processing methods not only extend the shelf life and profitability of avocados, but also preserve the product's nutritional value (Jimenez *et al.,* 2020). Avocado processing, according to Jimenez et al. (2020), produces waste, including seeds, which, if discarded, could harm the environment, but can be processed into other valuable products. Although avocado seeds have been evaluated for plastic processing due to the pressing need to find ways to recycle waste, avocado processing has been hampered by research gaps in Kenya, where avocado processing is still very low.

Conclusion

This review revealed the current levels of avocado production, utilization, post-harvest handling practices and their effect on fruit quality in Kenya. From this review the findings show a significant gap in value addition, there is a high potential in reducing economic losses experienced by small holders, exporters and value chain actors. Only 10% of the current fruit production is exported as fresh fruit, the 90% that remains can be transformed to various other products

through value addition, creating much needed employment to the youth and women in the society.

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