Review

The Avocado (*Persea americana* Mill.): A Review and Sustainability Perspectives

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Abstract: Avocado (*Persea americana* Mill.) plant fruits are well-known for their high nutritional value, unique test, and healthy oil. It has a history of about 10,000 years. Avocado fruit offers many health benefits, and its production is rapidly increasing. The Food and Agriculture Organization (FAO)'s recent data suggest that the Avocados produced in the world in 2019 was twice that of 2010 (3778010 tons). Avocado's global Gross Production Value was about 5.812 billion USD in 2018, and it is likely to increase rapidly because of the increasing demand for Avocado fruits. Avocado oil is also used in the cosmetic industry because of its therapeutic properties, and it boosts the economic value of the Avocado industry. Avocado fruits have a rough green-gold skin; however, fruits are called 'the green gold' because of their massive global demand in the worldwide market and a lucrative business. The cultivation of Avocado has tremendous potential in increasing the rural economy, rural agriculture-based employment and reducing the poverty rate of growers. On the other hand, the Avocado industry is highly criticised because of deforestation, massive water utilisation, polluting water bodies with insecticides and fertilisers, posing a threat to other plant species, and environmental pollution. However, it doesn't preclude the importance of Avocado. Cameroon's average temperature is about 23 °C, which is considered optimal for Avocado propagation and commercial cultivation. Cameroon Association of Active Youths (CAMAAY) want to explore the possibilities of engaging Cameroon youths in Avocado cultivation. This review is aimed to provide an overview of Avocado. The review also highlights Avocado cultivation related issues from one health and sustainability perspective in line with the global goals.

Keywords: Agriculture; antioxidants; Avocado; Cameroon; CAMAAY, deforestation; environment; food security; green gold; health; one health; sustainable development goals (SDGs); sustainability.

1. Introduction

The Cameroon Association of Active Youths (CAMAAY) is a non-political, non-religious, non-profit association based in Cameroon. The vision of the CAMAAY is that "the future belongs to youth, and they have a clear vision of the world we need to build together peace, the preservation of our beautiful planet, and the opportunity to make a

better life." The CAMAAY endeavour to achieve goals through activities that promote sustainable community development in Cameroon. These activities involve the active participation of local community members, CAMAAY members, and volunteers from across the globe. The organization provides educational, advocacy, charity, and development activities to at-risk and vulnerable individuals, especially youths within the community. The CAMAAY is managed by democratically elected officials and youth, with the support of elders and other stakeholders. Its organizational structure consists of one general assembly, several executive board members, a board of advisors, and several individual members.

The CAMAAY pledge to work closely with other associations, foreign representatives, institutions, the United Nations, Non-Government Organizations (NGOs), local and international volunteers, and the Cameroon Government to promote the principles and practices of quality agriculture, education, healthcare, sports, social well-being, and environmental protection. Over the years, the CAMAAY has received grants and funding from Global Giving, Almabre Food Service, Rhodes Scholars Fund, OCDA, and ELAK Council. The CAMAAY's recently completed projects include: 1) The Rural Women Empowerment Project, 2) Orphans and Vulnerable Children Project, 3) Water for All Partnership Project, 4) Sports for Development Partnership Project, 5) Children and Youth Sustainable Forest Management Project, and 6) the School Organic Vegetable Garden Project.

This project was aimed to acquire an overview of Avocado to explore the possibilities of engaging the CAMAAY members and associated youths in Avocado cultivation. The United Nations Online Volunteers (UNOVs) were tasked to collect the essential information from the published literature on various aspects of Avocado, which is available in the public domain. The broad topics such as the history and origin of the Avocado plant, the biology of the Avocado plant, nutritional attributes, oil extraction methods, properties and applications, propagation methods, organic Avocado farming, organic certification and Avocado agriculture in Cameroon, methods for whole and cut Avocado fruits preservation, Avocado-based entrepreneurship for boosting the rural economy, and Avocado farming, deforestation, and sustainability issues were covered under this project. Based on the UNOVs input, the essential information deemed necessary is provided in the following sections.

2. History and Origin of the Avocado Plant

Avocado is a fruit with a history of about 10,000 years, produced from tropical trees characterized by a pear shape and blackish-green colour with high nutritional value, creamy texture, and unique taste [1, 2]. Avocado is considered as 'Green Gold' and has a great value because of its commercial importance [3]. From a broader perspective, a brief history of Avocado is explained below:

2.1. Etymology of the Word "Avocado"

"Ahuacatl," "Avocado," and "aguacates" are three words with the same meaning but in different languages. The word's etymology comes from the phrase *ahuacatl,* the Nahuatl way (native American language) that means testicle and denotes the shape of the fruit [4]. "Aguacate," a term developed by the Spanish historian Pedro de Cieza de Leon, and the first use of that word was in 1550 AD. "Avocado," an English word, was coined by Sir Henry Sloan in 1669 AD, and it spread in America in 1679 AD [5].

2.2. Discovery of the Avocado

The oldest traces of Avocado were found about 10,000 years ago in Mexico in Coaxcatlan, Puebla [4, 6]. The ancient civilizations of North, Central, and South America considered the fruits of Avocado as a gift from God to these peoples "Aztecs, Olmec and Maya" [4]. The seed remains found in Mexico's Tehuacan Valley may indicate ancient human settlements there as early as 8000-7000 BC and may have been domesticated at least 5000 BC by the Mesoamerican group [6].

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2.3. Arrival of Avocado to the Rest of the World

In 1492, European colonizers arrived in North America and began moving to the south until the Spanish and Portuguese invaders reached South and Central America in 1514. It did not take long for the Spaniards to discover the fruits of Avocado in northern-south America, Central America, and Mexico [7]. It is worth noting that the King of Spain was very eager to find out the new lands and learn a lot about those fruits that are the fruit of the pear. Martin Fernandez de Inciso wrote a detailed account of what he saw there in 1526 at the king's request. The article was called "Sumario de la Natural Historia de las Indias" [7].

2.4. Avocado Distribution

Avocado (*Persea americana* Mill) is one of the oldest flowering plants in history, and the genus *Persea* belongs to the family Lauraceae [8]. All varieties of *Persea* originated in the countries of the Old World, whose numbers reach 81 species, except for the *Persea indica* species, which originated in the Canary Islands - Madeira - Azores. Some species originated in Southeast Asia [8].

Persea is divided into the First subgenus *Eriodaphne* is a group of species that are immune to Avocado root rot but unfortunately have no economic value as the percentage of palatable meat is very low [6, 7]. Second subgenus *Persea*, which includes Avocado (*Persea americana* Mill) [5]. The centre was northern Mexico and spread north and south, northward in the direction of the southeastern United States, and south towards Brazil and Colombia, to Bolivia and Chile [4]. *Avocado* distribution is depicted in Figure 1.

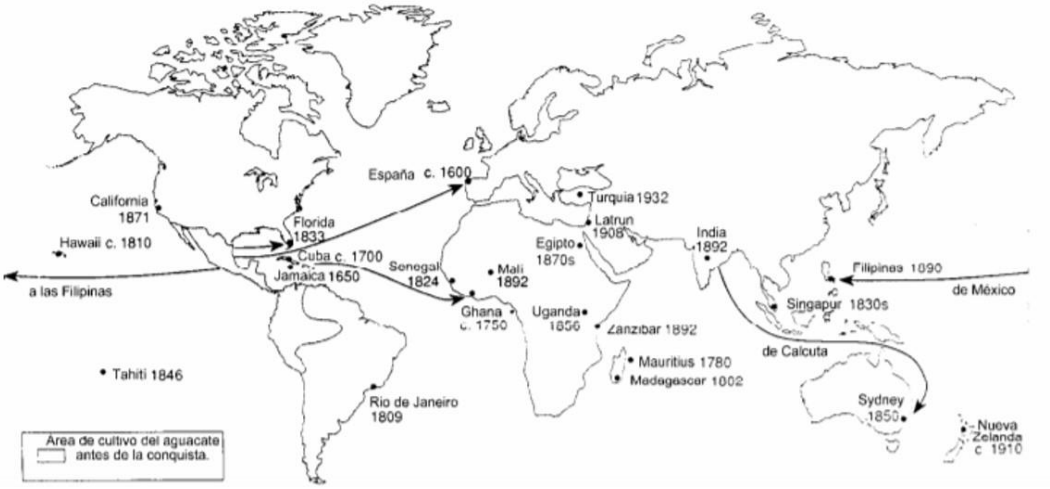

Figure 1. Avocado distribution after the colonization (until 1915) [9].

3. Biology of the Avocado Plant

The Avocado (Figure 2) is a subtropical fruit tree plant, which has become popular because of its nutritious fruits. Mexico, Dominican Republic, Peru, Colombia, Indonesia, Kenya, Brazil, Haiti, Chile, and Israel are well known for the commercial cultivation of Avocado [10]. However, it is also cultivated in the United States, South Africa, Australia, and some other countries [11].

The cultivars of cultivated Avocados can be grouped into three distinct races, namely, West Indian, Guatemalan, and Mexican, based on their characteristics and ecological adaptations [13]. However, they share similar growth and flowering behaviour. The commercial development of Avocados in different climates and the conflicting research information on Avocado reproductive biology led to a general confusion on pollination, fertilization, and fruit set [14]. Certainly, environmental conditions are an essential element to consider in Avocado reproduction [15].

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Figure 2. Avocado plant picture captured in 2011, one year after the tree was stumped [12].

3.1. Flowering

An Avocado tree generally produces more than a million flowers during the flowering period, but most of them fall without producing fruit. The Avocado flowers are bisexual, which means each flower has both female and male organs. It is characterized by protogynous dichogamy, which means that each bisexual flower opens twice, with an intermediate closing [16]. While the first time, the flower opens functionally as female (stigmas are receptive), the second time, it closes and reopens the next day functionally as male (dehiscence of anthers). The stigma is white in colour and becomes receptive to pollen before dehiscence of the anthers (release of the pollen grains from the pollen sacs). Less than 1% of the flowers produced at anthesis are able to set fruits. Environmental conditions play a vital role in this phenomenon. An experiment in southern Spain led by Alvarez and Hormuz analyzed the pragmatic phase from pollution to fertilization to show why most flowers prematurely abscise and others remain intact on the tree [17, 18].

Avocado is an evergreen tree native to México and Central America. Avocados can be divided into three horticultural races: Mexican (called subtropical), Guatemalan (called semitropical), and West-Indian (called tropical) [13]. The distinction of the races is made based on the different morphological, physiological, and horticultural traits.

The female stage flower (Figure 3A) opens first and closes after two or three hours remaining closed for the rest of the day and night. The flower opens the following day again, but the stigma does not remain receptive to pollen grains. In this male-stage flower (Figure 3B), the flower sheds pollen and closes again [19, 20].

According to their flowering sequence, the Avocado cultivars are grouped into two complementary flowering categories: A type cultivars and B type cultivars [21]. As stated by Stout [22], in the type A cultivars, the flower opens in the morning functionally as female. It closes at midday and reopens in the afternoon of the following day functionally as male. On the other hand, the flowers of type B cultivars open as females during the afternoon, close overnights, and reopen the following morning in the male stage. The behaviour of flowers of Avocado is highly influenced by environmental conditions.

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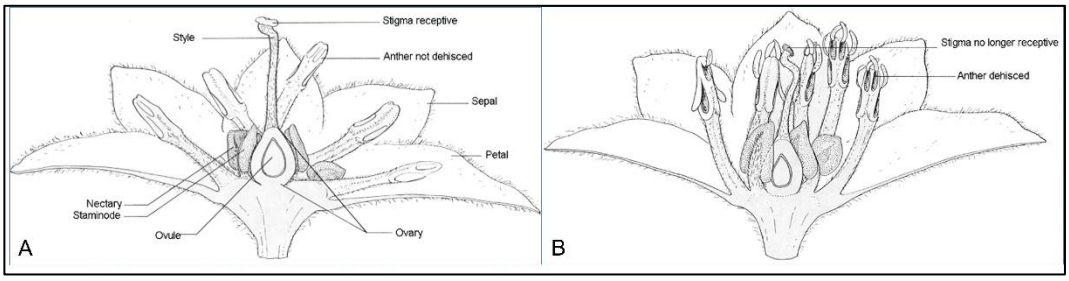

Figure 3. Bisexual flowers of the Avocado; A) Female stage; B) Male stage [19, 20].

Although pollination is a crucial stage guaranteeing fertilization and seed production, it is also a critical step in sexual plant reproduction. Most of the flowers do not receive pollens when they close in the female stage. According to Burd, Larson and Barrett, and Ashman *et al*., the amount required to fertilize the ovules is less than the number of pollen grains that arrive on the stigma, but insufficient pollination can be responsible for the low yield [23, 24, 25].

The studies on Avocado production conducted by Alvarez and Hermaza showed that the main limiting element on fruit set is the deficient pollen deportation on the stigma of female flowers [26].

3.2. Pollination

There are three modes of pollination in Avocado. The first one is cross-pollination which occurs under warm weather conditions. Pollen moves from male flowers of A-type to female flowers of B-type, and vice versa [21]. Its efficiency is characterized by the distance between the pollen donor and the pollinated trees or by the male and female-stage flowers' overlap duration. The second type is close pollination between neighbouring flowers on the same plant during the overlap period of male and female stage flowers when pollen from male flowers land on stigmas of female flowers. When pollen grains reach the stigma within the same flower, pollination is called self-pollination [22, 25]. It occurs only in a male-stage flower when stamen releases pollen that falls onto the receptive stigma.

The Avocado flowering behaviour is a sophisticated mechanism that restricts and even prevents effective self-pollination, close-pollination, and cross-pollination. For this reason, a better understanding of the pollination process may contribute to improving fruit sets and increasing the yield of Avocados, bearing in mind that only 1% of Avocado flowers produce fruits [27]. Proper pollination constitutes an essential step in the production of fruits. In A type, flowers function as a female in the forenoon and as male in the afternoon, while B type flowers function as male in the forenoon and as a female in the afternoon. Thus, self-pollinations and close-pollinations are restricted, and there is an alteration of the reciprocal cross-pollination between members of the two groups [25]. Negative results were given by numerous trials with artificial cross-pollination between types A and B [21, 22].

On the contrary, other studies demonstrated that cross-pollination has the best opportunity for fertilizing the ovum. If this type of pollination does not occur, the Avocado adopts self-pollination depending on environmental conditions. However, it is problematic that grains are windburn because they are connected through a sticky substance that covers the pollen of Avocado, which led flying insects to be very important for moving pollen, completing the pollination process for Avocado flowers. Clark, in the 1920s, observed that bees prefer other bee pastures to the Avocado orchards [28]. In California and Israel, bees are the main pollinators of Avocado, while in Jamaica, Trinidad and Florida, the primary pollinators are *Politest wasp* and *Metabolybia sigulata* [29]. The literature concerning potential pollinating agents is not clear with conflicting information. On the one side, bees in some areas at certain times play a crucial role in Avocado pollination.

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However, other insects are also essential in the fruitfulness of Avocado. To improve pollination, some studies suggest taking different steps. Firstly, increase honeybee hives in the orchard since one hive is rarely sufficient; secondly, locate the hives in a sunny location; thirdly, place pollen-donor trees enough close; and fourthly, open canopy [30].

3.3. Optimal Growth Conditions

To be fruitful, the Avocado plant needs warm temperatures and sunny windless locations. Three types of Avocados (West Indian, Mexican, and Guatemalan) differ in their oil yield and growth. West Indian Avocados grow to the largest size, although they have the least amount of oil. Mexican Avocados have the highest oil content [2, 31]. Guatemalan types fall in the middle. Mexican variety is the most cold-hardy; they can resist to 16 degrees Fahrenheit (-8°C), while West Indian varieties will die in temperatures below freezing, and Guatemalan trees will survive in temperatures down to 24F (-4°C). Generally, Avocado trees should be protected from high winds and freezing temperatures [32].

Some studies showed that Avocados grow best at between 20-25°C, and temperatures above 10°C at night and between 20°C and 30 during the day are required at the flowering stage for a good fruit set [33]. However, Avocado trees can resist well above this temperature as long as they are watered sufficiently. Avocado flowers are extremely sensitive to environmental conditions. Observations in California, Florida, Australia, Israel, and France demonstrated that with the best climatic conditions, daily flower openings are uniform and predictable, while cloudy days lead the flowers to open irregularly. Under low-temperature conditions, both male and female flower openings in A-type cultivars may be retarded to the point that they become reversed, assuming a behaviour that is typical of B-type cultivars [21].

4. Nutritional Attributes

Avocados are typically regarded as vegetables because they are frequently used in salads and have a savoury rather than sweet flavour. Fruits are with a tough outer layer, a fleshy centre, and a shell around a seed. Fruits can be with pale yellow-green flesh, which is smooth and buttery, with a faintly nutty flavour and texture like a firm, mature banana. Globally, about 7.18 million metric tons of Avocado fruits were produced in 2019 [34].

4.1. The Nutritional Worth of Avocado

The Avocado is a one-of-a-kind fruit. It is full of healthy fats, unlike other fruits, which are primarily carbs. It has been shown in numerous studies that Avocados have significant health benefits. The nutritional worth of Avocado is highlighted below:

4.1.1. Avocados are Nutrient-Rich Fruits

Avocado fruits contain Vitamin K, which is 26% of the daily value (DV), Folate is 20% of the DV, Vitamin C is 17% of the DV, Potassium is 14% of the DV, Vitamin B5 is 14% of the DV, Vitamin B6 is 13% of the DV, and Vitamin E is 10% of the DV in a single 3.5 ounce (100 gram) serving. It also contains small amounts of magnesium (Mg), manganese (Mn), copper (Cu), iron (Fe), zinc (Zn), phosphorus (P), and niacin (vitamin B_3) [35, 36, 37].

4.1.2. Avocados Have a Higher Potassium Content Than Bananas

Avocados have a lot of potassium in them. Compared to bananas, which are a typical high-potassium food, a 3.5-ounce (100-gram) portion contains 14% of the recommended daily intake (RDA) [37].

4.1.3. Avocado Is High in Monounsaturated Fatty Acids

Monounsaturated fatty acids are proven good for heart health. Avocados are heavy in fat. It contains 77% fat calories, making it one of the fattiest plant foods on the planet. They don't, however, contain just any fat. Avocados are high in oleic acid, a monounsaturated fatty acid, which is known for some of its health advantages [37, 38].

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4.1.4. Avocados Are a Great Source of Fibre

Avocados are high in fibre, with roughly 7% by weight, which is a lot compared to other foods. Fibre may provide significant weight-loss and metabolic-health effects [37, 39].

4.1.5. Avocado Eaters Are Often Healthier

Avocado eaters were found to be significantly healthy compared to those who did not consume this fruit. Avocado eaters consumed far more nutrients and were half as likely to suffer from metabolic syndrome, a group of symptoms that is a key risk factor for heart disease and diabetes [40]. Avocado eaters were also lighter, had a lower BMI, and had much less abdominal fat. They also had greater levels of HDL cholesterol (the 'good' kind) [37].

4.1.6. Avocados May Assist with Weight Loss

Avocados have some indication of being a weight-loss-friendly food [41]. In one study, those who ate Avocado with their meal felt 23% more full and had a 28% reduced desire to eat over the next 5 hours than people who did not eat Avocado. If this holds true over time, incorporating Avocados in your diet may automatically help you eat less calories and make it simpler to maintain good eating habits [37].

4.2. Avocado Varieties

Avocados come in a variety of shapes and sizes. Even though the fruit is mostly pear-shaped, some types are virtually round. They also come in a variety of sizes, depending on the kind. Bacon, Fuerte, Gwen, Hass, Pinkerton, Reed, and Zutano Avocados are the most prevalent varieties, with many chefs favouring the Hass kind [35]. Due to the pebbly, rough skin of one of the most popular kinds, the Hass Avocado is also known as the Avocado pear or alligator pear in some locations. You can learn to differentiate them by their appearance and feel even if they don't have a label. Avocados are available year-round in the market, even though their optimum season is late winter or early spring. Avocados, which were formerly a rare treat, are now widely available, even on fast food sandwiches [42].

4.2.1. Commercial Varieties of Avocado

Table 1, shown below, depicts commercially cultivated 15 Avocado varieties.

Table 1. Varieties of Avocados and uniqueness of the respective types [2, 4, 13, 42, 43-54].

Varieties		The uniqueness of the variety
i.	Hass	Hass Avocados are the most well-known of all Avocado varieties, and many believe that this variety is the best. The flavour is strong, and the flesh is rich and creamy.
ii.	Pinkerton	The Pinkerton Avocado is highly recommended because of its regular production, quality, and manageable tree size. This cultivar produces a lot of green pebbly-skinned meaty fruit. The little seeded fruits have a great flavour and are reasonably easy to peel.
iii.	Miguel	Miguel Avocado is a huge, fruitful, and high-quality Avocado. Commercial growers employ it as a compliment because they

Table 1. *Continued…*

Varieties		The uniqueness of the variety
		have the same blooming period and opposite flowers as Simmonds.
iv.	Bacon	With a regular oval shape and green skin, the Bacon Avocado hails from California. They are medium-large in size and have a more delicate flavour than certain other varieties. They are available from autumn through spring.
v.	Brogdon	Brogdon Avocados are pear-shaped and weigh little about a pound on average. The flavour is nutty and deep, similar to Hass.

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		At maturity, the skin is thin and dark purple in colour (often described as black).
vi.	Bernecker	Bernecker Avocados have medium green skin that is smooth and silky. Many Floridian gardeners prefer them since they grow well in the state. This tree's fruit is massive, weighing up between 24 and 40 ounces. The size of the tree varies from medium to huge.
vii.	Lula	Lula Avocados have a pear shape and glossy green skin. Oil content ranges from 12 to 16% in the flesh. In Florida, the fruit ripens from October to February.
viii.	Reed	Reed Avocado, according to the Guinness Book of World Records, is the heaviest Avocado ever. It was cultivated in Hawaii and is thought to be a Reed. It weighed more than five and a half pounds and was about the size of a full-grown adult's skull. It takes approximately a year for a reed Avocado to mature on the tree.
ix.	OroNegro	Oro Negro, which translates to "BLACK GOLD," is a collector's Avocado variety. One of the most delicious Avocado kinds ever created. It's an indoor plant with a creamy butter feel and a lot of vitamins.
x.	Gwen	Gwen Avocados are similar in appearance to Hass Avocados, although they are slightly larger. They're round and plump, with thick green skins and pebbled texture that turn dull green when fully mature. The seeds of this variety are tiny to medium with creamy gold-green flesh.
xi.	Russell	Avocados with long necks are known as Russell Avocados. Avocados with a gourd shape and a glossy exterior are commonly grown in southern Florida.
xii.	Fuerte	The Fuerte Avocado has a distinctive elongated shape and is widely grown throughout Mexico and Central America, despite its hybrid origins (half between Mexico and Guatemala). It's one of the most popular Avocado varieties out there.
xiii.	Zutano	The Zutano Avocado is a cold-tolerant. In appearance, it resembles Fuerte, but it has a milder flavour.
xiv.	Simmonds	Simmonds Avocado trees are pear-shaped, huge, light green fruit that is commercially propagated in Florida. The skin is leathery, malleable, non-granular, and readily removed from the meat when fully ripe. Trees can readily be pruned to a reduced size for fruit harvesting.
xv.	Choquette	The Choquette Avocado is a commercial Avocado cultivar named after a South Florida resident. The fruit is enormous, weighing between 30 and 40 ounces and having an oval form with a glossy smooth green skin. The fruit contains around 13% oil.

4.3. Medicinal Properties

Although the Avocado fruit is mainly used as a meal, it also has many therapeutic properties. The medicinal properties of Avocado are as follows:

4.3.1. A Cure for High Cholesterol

In a small-scale scientific trial, 16 men ranging in age from 27 to 72 were given varying amounts of Avocado (12 to 112 fruits per day). Half of them had a significant drop in cholesterol, whereas none of the others had an increase. Avocados may not be a bad option for folks with excessive cholesterol or triglyceride levels [37, 55].

4.3.2. Atherosclerosis, Angina Pectoris, And Alzheimer's Disease

The fruit contains alpha-carotenes, which have antioxidant characteristics and may protect against the oxidation of the 'bad' LDL-cholesterol, lowering the risk of

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atherosclerosis [55]. Avocado consumption may also help those with atherosclerosis-related angina pectoris. Antioxidant levels in the blood may have a role in Alzheimer's disease progression [56]. According to studies, folks who have this disease have much lower alpha-carotene levels in their blood than healthy people [37, 55, 57].

4.3.3. Aid In Digestion and Blood Sugar Balance

Because of its alkaline qualities and the softening and protecting actions of the fat on the mucous membranes, the Avocado fruit is regarded to be beneficial for patients with ulcers or gastritis. Studies have demonstrated that avocado-eating assists diabetics in maintaining their optimal blood sugar levels, suggesting that the fruit may be helpful to diabetics [58].

4.3.4. Skincare Using the Pulp of Avocado

The mashed pulp of Avocado fruits can be used directly as a soothing cure for the skin and protection for sunburns [58]. It is also used to protect skin from irritations and suppurating wounds. It can also be applied (massaged) onto the scalp to relieve itching and promote hair growth. Using mashed Avocados, egg white, egg yolk, or honey, you may make a soothing and cooling face mask for dry or aged skin [35].

4.3.5. Avocado Oil in Aromatherapy, Cosmetics and Skincare

Avocado oil has gained popularity as a natural carrier oil, and it is used as a base oil in cosmetics and aromatherapy in a variety of combinations. Natural skincare lotions, liniments, hair treatments, massage creams, muscle oils, soaps, and shampoos all include it. Avocado oil is a mild, vitamin-rich oil that moisturizes and protects the skin [56]. Avocado oil disperses well on the skin and is well absorbed. The oil is particularly beneficial to dry, ageing skin, dermatitis, and sun-damaged skin. Avocado oil has been discovered to be helpful as a treatment for psoriasis when combined with vitamin B_{12}. Some dermatologists believe it can help with eczema [59].

4.4. Use Of Avocado in Traditional Medicine

The fruits and other parts of the Avocado tree have been used as herbal medicine for a long time in locations where it grows wild [59, 60].

Diarrhoea, bloating, and gas-related ailments are treated using Avocado tea brewed from its leaves. By eliminating uric acid from the body, it is also thought to help with coughs and gout. Tea can also be used to cleanse the liver and lower blood pressure. Avocado leaf herbal teas are believed to speed up menstruation, which can lead to abortion, which is why it's been used in Mexico for centuries to treat menstrual disorders and as a contraceptive. Avocado leaf extracts efficiently inhibit herpes simplex virus types I and II, which cause cold sores (I) and genital herpes (II), according to laboratory tests (II) [61]. Avocado seeds are antibacterial and antifungal and have traditionally been used to treat diarrhoea and dysentery. The fruit's peel is sometimes used to cure intestinal worms, while the pulp is thought to have sex-stimulating effects (aphrodisiac) [62].

The blood pressure-lowering, antiviral, and anti-inflammatory benefits of leaf extracts have been established using animal models, but few medicinal applications of the leaves, bark, and seed have been systematically examined using human subjects [63].

4.5. Antioxidant Property

Avocados not only aid in the absorption of antioxidants from other foods, but they are also high in antioxidants. The carotenoids lutein and zeaxanthin are beneficial for eye health. According to studies, they've been associated with a significantly lower incidence of cataracts and macular degeneration, both of which are common in older persons. Therefore, eating Avocados should benefit your eye health over the long term [37, 60].

4.6. A Source of Water-Insoluble Fibres

In diet, fibres are vital. Avocado fruits are a relatively rich source of fibre. It's an indigestible plant matter that can help you lose weight, lower your blood sugar, and reduce

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your risk of a variety of health ailments [39]. A distinction is often made between soluble and insoluble fibre. Soluble fibres feed the friendly gut bacteria in the intestine, which are very important for optimal body function. Avocado has 7 grams of fibre every 3.5-ounce (100-gram) serving, which is 27% of the RDA [37, 39].

4.7. The Anti-Inflammatory and Anti-Microbial Property

According to Penn State researchers, an extract from Avocado seeds displayed anti-inflammatory capabilities in a laboratory trial. Hence, it could be a source for novel anti-inflammatory chemicals as a functional food ingredient or medicine. The researchers used cell culture models and enzymes involved in immune response and inflammatory illnesses to investigate the anti-inflammatory effects of Avocado seed extract. It demonstrates that Avocado seeds contain bioactive substances with anti-inflammatory properties [64, 65,66].

Antimicrobial therapy is an effective way to combat infectious diseases in general and antibiotic-resistant bacteria. Avocados have a variety of antibacterial metabolites. Antibacterial action was demonstrated by the 1,2,4-trihydroxy-n-heptadeca-16-en isolated from Avocado fruit and seeds [64, 65, 66].

4.8. Anti-Ulcer Property

The most common cause of stomach ulcer disease, one of the most common gastrointestinal problems afflicting individuals all over the world, is the long-term usage of anti-inflammatory medications. Avocado seeds are commonly discarded as waste. However, seeds can be utilized to treat gastrointestinal disorders.

Avocado seeds contain important phenolic compounds like caffeoylquinic acid, flavonoids, phenylpropanoids, and tannins, which inhibit pathways involved in gastric ulcer formation. Therefore, Avocado seed extract could be an excellent natural source for preventing and treating stomach ulcers [67].

4.9. Toxicological Effects

Persin has been proven in laboratory research to trigger apoptosis (programmed cell death) in breast cancer cells, and it is being studied as a therapy for the disease. However, animal toxicosis has been linked to the consumption of Avocado fruit, leaves, stems, and seeds, the leaves being the most toxic. Horses that ate Avocado fruit and/or leaves suffered from myocardial infarction, mastitis, and colic. Avocado toxicosis is caused by eating the Avocado plant's fruit, stems, leaves, or seeds. In breastfeeding mammals, it causes sterile mastitis, and in vulnerable mammals and birds, it causes cardiac necrosis. There are currently no tests available to aid in the diagnosis of Avocado toxicosis, and treatment is confined to treating the symptoms [68].

Avocados may appear beneficial in many situations, but pregnant and breastfeeding women should avoid them. Avocado lowers milk production and has even been linked to mammary gland damage [68].

4.10. Molecular Markers and Gene Studies

Avocado is a highly profitable crop. It is also grown in China's tropical and subtropical regions. However, there is a scarcity of information about local Avocado germplasm's ethnic origins and genetic diversification. The 56 Avocado accessions were classed as complex hybrids, specifically Guatemalan Mexican West Indian hybrids, based on a race-specific competitive allele-specific PCR genotyping analysis [69]. A quality trait evaluation and molecular characterization were used to determine the genetic links among Avocado accessions. The total flavonoid content proved to be a way to distinguish various native Avocado accessions. The Avocado accessions were distinguished by cluster analysis, principal component and coordinate analyses of qualitative parameters and molecular features, but not by geographical origins. Thus, the artificial movement of Avocado germplasm or seed exchanges among farmers within certain regions may have

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contributed to Avocado germplasm from different collections having similar genetic histories [69].

To determine races and genetic diversity, 56 native Avocado accessions were studied, including 46 from Baodao New Village and ten from the Jianfeng private farm. At first, 20 Avocados were tested [see Figure 4].

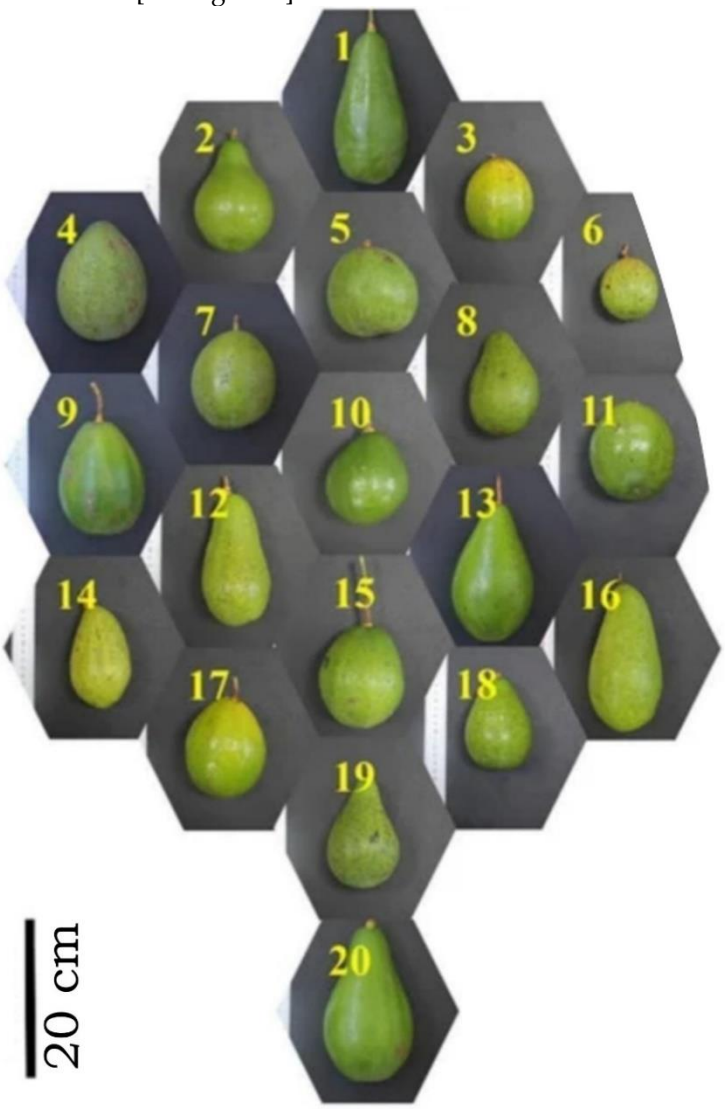

Figure 4. Appearance of 20 Avocado samples, which were selected for their quality traits evaluation. Code names of 20 avocado samples—1: JFPF-1; 2: JFPF-2; 3: JFPF-3; 4: JFPF-4; 5: JFPF-5; 6: JFPF-7; 7: JFPF-8; 8: BDNV-2; 9: BDNV-3; 10: BDNV-4; 11: BDNV-6; 12: BDNV-8; 13: BDNV-11; 14: BDNV-12; 15: BDNV-14; 16: BDNV-15; 17: BDNV-21; 18: BDNV-29; 19: BDNV-35; 20: BDNV-37; BDNV, avocado accessions that originated from Baodao New Village; JFPF, avocado accessions that originated from the Jianfeng private farm (Picture Credit Liu *el al*., [69]).

The information offered by Liu *et al*. [69] about the diversity of Avocado germplasm could be helpful in the breeding program.

4.11. Avocado Genome Attributes

Avocado (*Persea americana*) is a commercially important fruit crop around the world as its fruits have a high nutritional value. Avocado breeding is hampered by directed crossings and because of its long vegetative stage (about 6–8 years). Genome sequence information could be extremely useful in breeding programs, allowing for faster selection of attractive cultivars and rootstocks [70].

The Avocado Genome Consortium was founded in 2016 as a global collaboration of genomics experts with the goal of sequencing and annotating the genome of the Avocado

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plant. To improve on the quality of the draft genome that is already available, the group plans to sequence a homozygous Avocado and re-sequence two Avocado rootstocks (one from the UCR breeding program and one from WTS). The Avocado genome is now being sequenced and annotated by analyzing 20 Avocados accession based on seven quality traits [Figure 5], and it is expected that this will lead to significant breakthroughs in research tools and chances to explore the genetics behind complex features like disease tolerance and abiotic stress tolerance [69, 70].

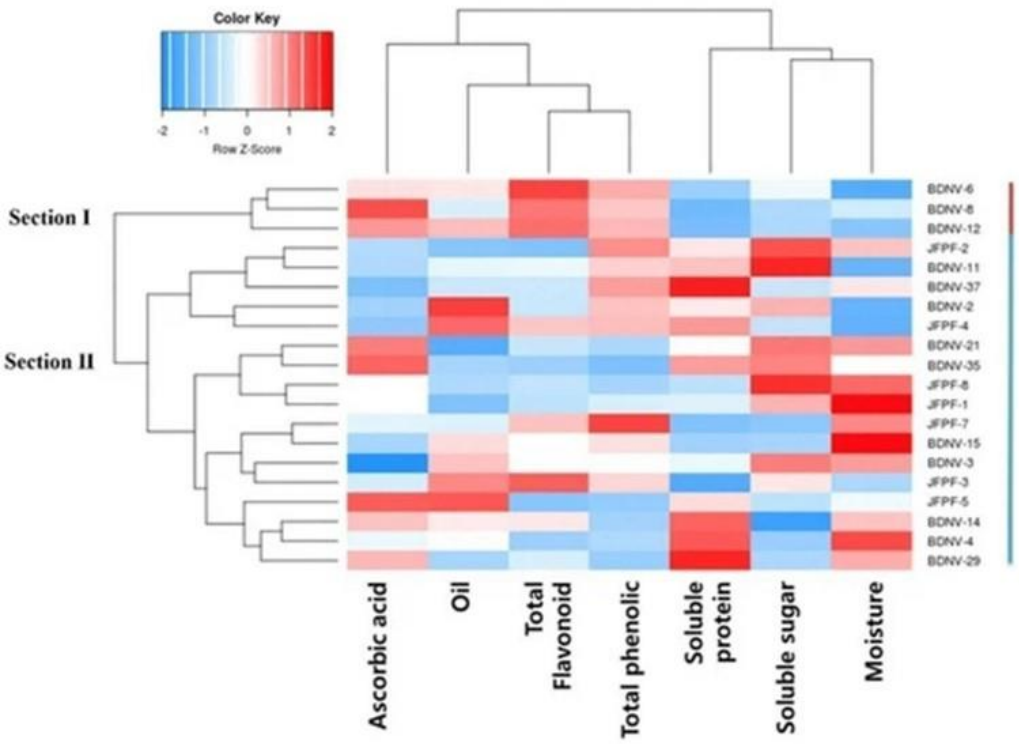

Figure 5. Cluster analysis of 20 avocado accessions based on seven quality traits. The red and blue highlights correspond to high and low contents. The z score indicates quality traits values. BDNV, avocado accessions that originated from Baodao New Village; JFPF, avocado accessions that originated from the Jianfeng private farm (Adopted from Liu *et al*. [69]).

Transcriptomic data has been generated as part of the Avocado Genome Consortium's broader goals. The data analysis-based findings will be used to address fundamental questions about Avocado evolutionary biology, gene expression, physiological processes, and molecular pathways. The identification of Avocado defence targets and finding pathogen effectors involved in host-pathogen interactions will be aided by transcriptomic data from an RNA-sequencing experiment involving Avocado challenged with *Phytophthora cinnamomi*. The Avocado genome and related genetic diversity will provide crucial information and a molecular toolkit to help breeders create more effective breeding programs and further study all aspects of Avocado [70].

5. Oil Extraction Methods, Properties and Applications

Traditionally, the extraction of oil is done by a series of mechanical means, including crushing, pressing, and decantation (the separation of the oil and vegetable water phases). Constant progress has been made in oil extraction methods to ensure quality and low operation costs [71, 72]. The advancement in the oil extraction process allows its scaling the extraction of oil is well optimized by the industry [73, 74]. The methods of extraction and processing of Avocado oil are briefly explained below:

5.1. Extraction and Processing of Avocado Oil

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The importance of studying different extraction methods of Avocado oil is related to the preparation of fruit pulp, extraction rate, physicochemical properties of the oil and the fatty acids profile and volatile compounds. Several methods have been proposed for the recovery of Avocado oil, including solvent extraction, pressing, centrifugation, ultrasonic, supercritical fluid extraction, and the use of technical agents such as salt, microwaves, micro talc, and enzymes to improve the oil extraction rate [2].

5.1.1. Conventional Solvent Extraction of Avocado Oil

Organic solvent extraction is the most widely used method in oil separation. Oils are highly soluble in various organic solvents, such as chloroform, benzene, hexane, acetone, and cyclohexane. In the processes, the organic solvents destroy the plant cell walls or disrupt the interactive forces between lipids and the tissue matrix to extract the oil. In this method, Avocado fruit is sliced, dried and grounded, and the oil is extracted with organic solvents [2].

- *Hexane Extraction*: This method can be scaled up [75]. On a small scale, Avocado pulp is dehydrated at 70°C in a vacuum oven under a working pressure equivalent to 100 mmHg, till the sample reaches 27% moisture. Then the oil is extracted using the Soxhlet method (AOAC 963.15). A few defatted anti-bumping aids are added to a 250 mL Erlenmeyer flask and dried for one h at the temperature of 100 °C; then, it needs cooling in desiccators. The thimble containing the dried sample is placed in the Soxhlet device, supporting it with glass beads. The dehydrating beaker is rinsed with 150 mL of petroleum ether, and the washing is added to the thimble. The sample is refluxed for 4 h, with the heat adjusted, so the extractor siphoned ≥30 times. The flask needs to be removed, and the solvent is evaporated on a steam bath. The flask is dried at 70 °C to constant weight (1.5-2 h).
  Based on research [76], the process efficiency of Avocado oil extraction can be improved in both extraction yield and quality of oil produced. The response surface methodology study found the optimum process extraction parameters that will result in a high yield of oil at a temperature of 60°C with 1.53 ml of hexane per gram of Avocado for an extraction time of 128 minutes. These parameters are predicted by the program to yield an oil concentration of 344.35 g/L. The study found that a high extraction temperature to favour a high yield and lower solid-liquid ratio also favoured a high yield of oil. The high solid-liquid ratio was found to lead the reaction to equilibrium, whereas the lower ratio favours the forward reaction. The quality of oil with respect to stability was found to have increased with increased temperature during extraction; this resulted in oil with higher stability than the one extracted at lower temperatures. From the fatty acid profile study, it was also found that the oil extracted at higher temperatures had lower trans fatty acids than the oil extracted at lower temperatures.
- *Acetone Extraction*: A patent reports a method [77] that Avocado oil can be extracted by using a solvent, acetone. After peeling and seed removal, Avocado is ground into small particles (3–5mm). Firstly, the acetone is mixed with fruit particles at 25°C. In this period, most of the water in the Avocado fruit was extracted into the acetone phase. Then, another extraction operation of a substantially water-free Avocado with acetone solution is carried out at 55°C. After that, all liquid solutions obtained from both extractions are admixed and cooled to ambient temperature, as well as obtaining two main fractions, which were separated: the upper layer of oil-acetone-water, which contains mainly the unsaponifiable matter; the lower layer of oil-acetone-water contains Avocado oil mainly. Through distillation, the acetone is removed. And it is recycled in the extraction operation. The oil is separated in the upper phase above the aqueous phase.
  Light microscopy results showed that extraction using hexane caused the idioblastic oil cells to become irregularly shaped and rough-surfaced; on the other

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hand, extraction using acetone produced more changes in the cellular structure [72].

Although oil can be extracted effectively by an appropriate solvent, there are some flaws in this technique, like environmental pollution and solvent residue in the final products, which limits the use of Avocado oil in food and pharmaceutical applications.

5.1.2. Supercritical CO_2

Supercritical fluid extraction (SFE) has been used in separating desired compounds from solid matrices in the pharmaceutical and food industries. CO_2 is a nonpolar molecule. Thus, the Supercritical CO_2 ($scCO_2$) can extract nonpolar and low polarity substances, such as lipids. The $scCO_2$ is mainly used as it is a green solvent, ensuring biological safety. It leaves no solvent residue in the final product, compared with organic solvents used in traditional oil extractions [78].

The $scCO_2$ extraction has proven to be technically feasible for Avocado oil extraction, especially at higher pressure conditions (400 bar) with 97-98% oil recovery [79]. Except at 80°C and 200 bar, ethanol as a co-solvent in the second extraction step favours extraction of the remaining oil, obtaining a differentiated fraction enriched in tocopherols.

5.1.3. Technological Aids in Cold-Pressed Avocado Oil Extraction

- *Inorganic Salt*: The solid additives could be used to reduce moisture and viscosity in Avocado pulp to increase the oil extraction yield. Non-toxic, insoluble solid additives with a certain hardness and granularity are needed for the extraction. For instance, adding grains of sand, rice, and sorghum rice have better impacts on squeezing than sugar, salt and rice husk [80].

  The results reported by Shen *et al*. [81] suggest the following recommended procedure for industrial use. Dilute Avocado paste with water (5:1, w/w) and add 5% (w/w) $CaCO_3$ or $CaSO_4$. Mix in blender at high speed, acidify with 1 NHC1 to pH 5.5 and heat at boiling for 5 min with constant stirring. Let it stand for four days at 37°C and then centrifuge at 12,300 × g for 10 min. Let it stand 30 min at ambient temperature and discard the aqueous phase. Wash with two parts water per part original paste (w/w) in three steps; discard aqueous phase. Dry it overnight at 60°C in a vacuum oven. When this procedure was followed in triplicate with $CaCO_3$, oil recovery is increased substantially to 80.1 vs 69.8% in the no-prior-settling procedure. For extraction at the household level for home use, centrifugation may be supplanted by gravity settling, but oil recovery will be lower. The addition of salts favours the extraction from complex pastes [82].
- *Enzymes*: In the enzyme-assisted centrifugation technique, before centrifugation, endogenously cellulitic and the added exogenous enzymes together hydrolyze and degrade the cellular walls, favouring the release of oil from the cells. Pectolytic, α-amylase, proteases, pectinases, and celluloses enzymes can be used as the added exogenous enzymes. The oil extraction yield is greatly affected by many factors, including enzyme type and concentration, enzymatic reaction temperature, reaction time and dilution ratio of paste to water. It has been reported that compared with non-enzyme assisted centrifugation, the extraction yield from Avocado paste was significantly improved by more than 25 folds by enzyme-assisted centrifugation [83]. Some research evaluated the profitability of enzymatically assisted aqueous extraction technology by using the payback period and internal rate of return as the evaluation criteria [84]. Oil content in Avocado pulp and extraction yield is required greater than 10% and 60% to reach higher productivity, respectively, when considering the price of raw material, plant capacity, enzyme price and selling price. They concluded that this process is economically attractive.

5.1.4. Pressing Extraction

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The pressing method is used for a long time to obtain olive oil. The method that oils are extracted by pressing or squeezing with a screw press or hydraulic press is called pressing extraction, which is widely applied to squeeze oil from oilseed materials with reasonably high oil content. The water content of pulp influences the oil yield greatly. Pretreatment methods of Avocado pulp occupy a prominent position. The pretreatment approaches include slicing and drying of Avocado flesh, microwave-oven drying, the addition of solid additives. Traditional drying methods are quite time consuming, such as oven-drying and sun-drying to dry the slices to 4% –5% water content, but it may result in insufficient oil quality. In contrast, the microwave-oven drying process is not only shortening the drying time but also destroy the structure of the cell [78]. Then the method starts by grinding the olives (with stone); this usually occurs in stone mills. This type of mill consists of large round or conical granite stones that roll over the olives, crushing them and releasing the olive oil from the interior of the vacuoles. In the mill itself, the malaxation stage occurs, consisting of joining the tiny drops of oil dispersed in the olive paste, forming larger droplets, and improving the extraction yields. The separation of the solid and liquid fractions from the pulp takes place by pressing the olive paste in a discontinuous system of hydraulic presses. The mass is disposed of in the middle of cast discs, through which the olive oil flows when the pressing force is exerted. The liquid fraction is then collected in a settling tank to separate the oil and water (naturally present in the olives). However, this method is not used because of the deposition of olive mass in the guts of the pressing discs, resulting in fermentative processes and reducing the quality of the oil produced [85]. The oil extraction yield can be affected by many factors, including the number of samples, the intensity of microwave energy, time of microwave exposure, etc.

5.1.5. Ultrasound-Assisted Aqueous Extraction

The application of the ultrasound approach in extracting plant oils has received increasing attention in recent years. It utilizes the cavitation forces produced by acoustic waves to decompose the cell walls of the oil cells and the structure of the oil emulsion, thereby releasing these intracellular components into the solvent [86].

In this method, the Avocado powder is placed into a beaker (250 mL, for small scale extraction), made up to the required volume with distilled water, and sonicated in an ultrasonic bath (Thermo-10D; 40 kHz frequency; 240 W ultrasonic output power; with an internal dimension of 500 × 300 × 150 mm). When the required sonication temperature and time were reached, to press the mixture to obtain an aqueous–oil mixture, a screw press at a small scale is used. To separate the oil from the water layer, the aqueous–oil mixture is centrifuged at 8,000 rpm for 20 min at room temperature. A Pasteur pipet is used to remove the top oil layer and weighed [87].

5.2. Comparison of Different Methods

After the pulp of Avocado fruits is processed through different drying and oil extraction methods, oil is obtained. It can be used to evaluate the quality of the oil and the physicochemical characteristics of the Avocado cultivar. After drying the pulp in an oven under ventilation (40 °C and 60 °C) and vacuum oven (60 °C). It is followed with the oil extraction by mechanical pressing or the Soxhlet method [88]. Among the approximately 72% pulp in the fruit of the Avocado, the 16% fraction is lipids. The quality indices evaluated in Avocado oil show better results when the pulp is dried at 60 °C under vacuum and oil extraction is done by the Soxhlet method with petroleum ether. In contrast, the bioactive compounds are better preserved when the Avocado pulp is dried at the temperature of 60 °C through ventilation.

Mechanical pressing is then used for the oil extraction. Among the fatty acids found, oleic acid takes the most significant proportion. The researchers reported that Avocado pulp stands out for its high content of moisture, proteins, and high antioxidant activity. The best quality indices of Avocado oil are obtained by drying the pulp at 60 °C under vacuum with subsequent extraction of the oil by the solvent. Bioactive compounds of

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Avocado oil are better preserved when the pulp is dried at 60 °C and using mechanical pressing. The higher percentage of oleic acid in the oil is obtained by applying the vacuum drying process at 60 °C and then subsequent cold pressing extraction. The best process to obtain Avocado oil with excellent bioactive properties and within the quality parameters recommended by the legislation is oil extraction by mechanical pressing, where the pulp is dried at 60 °C in a vacuum oven.

The literature also suggests that the highest yield is obtained when using the combined microwave-hexane extraction method. The slightest modification to the characteristic of the oil is obtained with the microwave-squeezing method. The trans-fatty acid amount generated in the microwave-squeezing method is under the limit proposed by the FDA. The compound hexanal was found only when the sample was exposed to microwaves. In general, it appears that a greater deterioration of the oils is caused by solvents rather than microwaves [89].

In a study by Tan *et al.* [87], Avocado oils extracted using $scCO_2$ and UAAE are compared with the conventional solvent extraction. Although the oil yield obtained by $scCO_2$ and UAAE (16.97% and 15.13%, respectively) are lower than solvent extraction (20.79%), but $scCO_2$- and UAAE-extracted oils are found to be lighter in colour and contained higher levels of unsaturated fatty acids than solvent-extracted oil. Hence, it appears that $scCO_2$ and UAAE are effective methods for Avocado oil extractions, and there is a commercialization potential using these methods.

The ethanol extracted, n-hexane extracted, hot-pressed, cold-pressed and aqueous extracted were used to obtain the Avocado oil. Physic-chemical properties, antioxidant properties, etc., are tested to evaluate the difference between the five methods. As a whole, it appears that the quality of Avocado oil obtained from the aqueous method is best among the five extraction methods [90].

5.3. Other Factors Affecting the Extraction

According to an investigation [91], in which different drying conditions extracted the Avocado oil, their results suggest that the drying process at more than 80°C interferes with the quality of the oil.

Furthermore, we need to consider that the Avocado flesh cellular structure ruptures more easily in late-season fruits, enabling more oil release and improved extraction yields [92].

5.4. Applications of Avocado Oil

There is a constant demand to produce healthy foods that can maintain their nutritional properties over time and environmentally friendly technological solutions at the industrial level. Avocado oil is mainly sold for direct consumption due to some critical compounds, including fatty acids, vitamins, antioxidants. Avocado oil has several applications, and it is used in the cosmetic formula due to its beneficial properties [93].

Some researchers studied the impact of Avocado oil on insulin resistance [94]. Their research findings suggest that glucose tolerance and insulin resistance induced by high sucrose diet in Wistar rats can be reduced by the dietary addition of 5-20% Avocado oil [94].

Some studies found that an Avocado oil-rich diet administered for two weeks to Wistar rats induced a higher AngII-induced blood pressure response and modified the fatty acid composition of cardiac and renal microsomes. Apart from the Avocado fruits with a larger, better-valorised size, many smaller fruits are usually discarded. A study has shown that compared to the large-sized type, small-sized “Hass” Avocados have greater TFC, TPC, and inhibition of DPPH radicals, higher content of individual flavonoids and phenolic acids, in addition to the higher activities of CHS, PAL, and PPO in the APEs. Peels from small Avocado fruits are an excellent source of phenolic compounds and enzymes, with multiple industrial applications in food, pharmaceuticals, biochemistry, and analytics. Moreover, it is recommended that eco-friendly extraction technologies to

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enhance the economy of the Avocado industry and promote sustainability in a biorefinery framework be implemented [95].

The clinical trial results provide evidence that the recently developed vitamin B_{12} cream containing Avocado oil has considerable potential as a well-tolerated, long-term topical therapy of psoriasis [96].

Some researchers evaluate the effects of 90-day Avocado oil intake on brain mitochondrial function and oxidative status in streptozotocin-induced diabetic rats (STZ rats). Their results showed that Avocado oil improves the brain's mitochondrial function in diabetic rats preventing impairment of mitochondrial respiration and mitochondrial membrane potential, besides increasing complex III activity. Avocado oil also decreased ROS levels and lipid peroxidation and improved the GSH/GSSG ratio as well. These results demonstrate that Avocado oil supplementation prevents brain mitochondrial dysfunction induced by diabetes in association with decreased oxidative stress [97]. Avocado oil improves mitochondrial ETC function by attenuating the deleterious effects of oxidative stress in the liver of diabetic rats independently of a hypoglycemic effect or by modifying the fatty acid composition of mitochondrial membranes. These findings might also have significant implications in the progression of NAFLD in experimental models of steatosis [98].

Some research investigates the hypercholesterolaemic and hepatoprotective effects of virgin Avocado oil (VAO) using diet-induced hypercholesterolaemia rats. The liver damage index was markedly reduced in all treated rats. The findings demonstrated the potential hypercholesterolaemic and hepatoprotective benefits of VAO in the preclinical study [99].

In a study, the effects of Avocado oil administration on biochemical markers of cardiovascular risk profile in rats with metabolic changes induced by sucrose ingestion are evaluated. Their findings suggest that Avocado oil supplementation has a positive health outcome because it reduces inflammatory events and produces positive changes in the biochemical indicators studied related to the development of the metabolic syndrome [100].

An experiment was performed in a four-stroke VCR engine, and their research findings suggest that the performance parameters for Avocado biodiesel were higher, and the parameters for emissions were lower than those for conventional diesel. Brake thermal performance and actual fuel consumption were also tested in full load conditions and verified to be higher for the fuel blends compared to diesel fuel. It can also be interpreted that the amount of HC, CO, NOx for biodiesel blends at all load conditions was significantly reduced compared to diesel. The CO and HC emissions have been found to increase with the added load for all the biodiesel blends. The Nerium based catalytic converter is played an important role which can increase or decrease the emission parameters of the engine [101].

Non-agglomerated AuNPs have been successfully fabricated by using Avocado oil under the influence of natural sunlight via reduction of Au3+ by unsaturated fatty acids, vitamin E, vitamin C, vitamin B6 and β-carotene of Avocado oil. The synthesized AuNPs were further confirmed by UV− visible, TEM, DLS, XRD, and FTIR analysis. The AuNPs were various shapes with 48.8 ± 24.8 nm of average size, crystalline, well dispersed and stable for more than two months. It showed enhanced antioxidant (30%, 40μL) and photocatalytic (84%, 500 μL) activity against DPPH and MB. Therefore, the proposed approach provides a clean, cost-effective, and convenient method for the synthesis of AuNPs and might be applicable in various biotech sectors. Avocado oil can be utilized as a natural bioreduction in materials science and health-beneficial products by conjugation with nanoparticles [102].

A non-ionic Gemini surfactant, namely N,N-diethylaminedialkyldiamide, was synthesized from the fatty acids contained in wasted Avocado oil and used as a green inhibitor for the CO_2 corrosion of API X-52 steel under static and dynamic conditions at 50 °C by using electrochemical techniques. Results have shown that N,N-

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diethylaminedialkyldiamide is a suitable corrosion inhibitor that is physically adsorbed onto the steel by following a Langmuir adsorption isotherm to protect it [103].

5.5. Comparison with Other Oils

In a research, 80 varieties of vegetable oils, including Avocado oil, were compared to investigate the chemical compounds within them. Their results showed that Avocado oil is composed of over 60% of monounsaturated fatty acids, like olive oil, hazelnut, and macadamia nut profiles. Compared with olive oil, Avocado oil has a higher proportion of saturated fatty acids (16.4%), with a predominance of palmitic acid (15.7%), a lower proportion of monounsaturated fatty acids (67.8%), with a predominance of oleic acid 60.3% and a higher proportion of polyunsaturated fatty acids (15.2%), the most important of which was linoleic acid at 13.7% [104].

In addition, a similar profile of fatty acids has been published [105], showing that Avocado oil has a higher polyunsaturated/unsaturated fatty acid content than olive oil and a higher omega-6 / omega-3 ratio. The results show that the content of phytosterol in Avocado oil (3.3 ~ 4.5 mg/g oil) is higher than that in olive oil, and the content of B-glutamate sterol is the highest, followed by sitostanol, cycloartenol, cycloeucalenol and D7-avenasterol. Avocado oil sterol content is high, 4-demethylsterol content is the highest, accounting for 80% of the total sterol content. In addition, Avocado oil has less vitamin E than olive oil. Studies have shown that Avocado oil has similar thermal stability to olive oil.

6. Propagation Methods

6.1. The Best Climate for Avocado Propagation

Like other plant species, the Avocado does have its requirement for its optimal growth and development. For its normal growth and development, the temperature should range from 17°C to 24 °C [106]. Avocado plants are known to tolerate low temperatures (10 °C to 17 °C). However, for the fruits to set, the temperature in the range of 28 °C to 33 °C is desirable. Although the Avocado crop is highly resistant to cold, it is better to establish orchards in frost-free areas.

The average temperature in Cameroon (Figure 6) is about 23 °C, the highest average temperature is in the city of Maroua, being 27.0 °C, and the lowest in the city of Bamenda, with an average annual temperature of 19.3 °C [107].

With its temperature optimal for the agriculture of the Avocado, Cameroon's central-south weather seems to be perfect for the propagation and commercial cultivation of the Avocado.

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Figure 6. Map of Cameroon; (Source of the map, InterCarto, https://www.globaltrade.net).

6.2. Soil Disinfection Before Propagation

Good disinfection of the soil guarantees the rapid and healthy growth of the seedlings and tree graft. Without soil disinfection, organisms and fungi that are in the soil will interfere with the root growth, causing damage, poor growth, and fruit in disrepair [108]. Some chemical disinfectants that can be used are highlighted below:

6.2.1. Pentachloronitrobenzene

Pentachloronitrobenzene is also known as PCNB. It helps in preventing fungal growth in the soil [109]. Its recommended application is 40 g/m^2; the soil must be damp before application of PCNB, eight days in advance. Eight days after the application, the graft can be planted on the land [110].

6.2.2. Chloroneb

It is an organochlorine fungicide that helps eliminate certain fungi and prevents their growth [111]. The dose is 150 - 200 g /18 L of water and should be placed two days before sowing [6, 112]

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6.2.3. Dazomet

It acts against insects, fungi, and weed seeds. For its application, the soil must be moist ten days before, and it must be dug up to 20cm to place Dazomet in the ground [113]. The recommended dose is 40 g/m^2. Once the disinfectant has been placed, new soil must be placed over the 20cm and compressed with a shovel. After seven days of application, the soil must be mixed so that the disinfectant gases escape; after eight days of the soil treatment, Avocado can be sown [6].

In addition to these methods, some farmers use other products to treat the soil. It includes but is not limited to hydrogen peroxide, carbendazim, and fosetyl-Al.

6.3. Propagation by Grafting Method

The advantages of using the grafting method are as follows:

i. Shortens the juvenile period to enter production at an early age.
ii. Reduces the size of the plant to better control pruning (low pruning).
iii. Transfer resistance to pests and diseases by creating patterns.

The pattern that will be used for the grafting must meet the requirements to enable the grafting [110]. This pattern should be from a completely healthy tree, approximately 60cm tall and 1cm wide, as shown in Figure 7. The leaves closest to the ground (between 35 cm and ground level) are removed, leaving the stem of the pattern without leaves. Next, a bevelled cut is made, and the graft of a healthy tree, which has already fruited, is inserted in the bevel cut. This graft should be approximately 10cm. Later, the graft should be covered with plastic to prevent it from falling, and then it is entirely covered with a plastic bag to prevent it from getting wet when watering [114, 115].

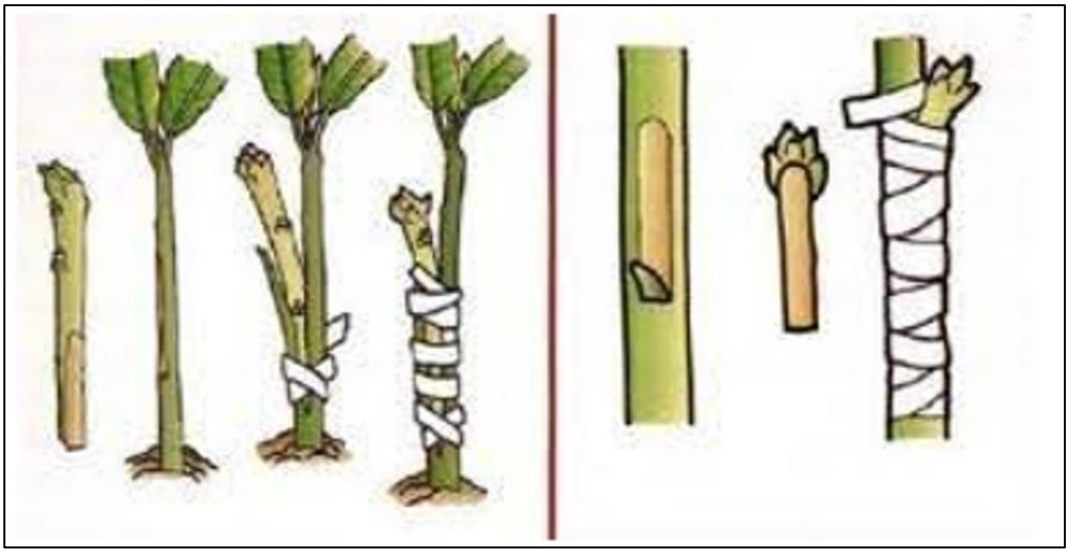

Figure 7. Propagation by grafting method [115].

6.4. Propagation Through Sowing Seeds

The seeds should be from ripe Avocados and not the seeds collected from the immature harvested or fallen fruits. Once the seeds are selected, they must be disinfected at 50 °C and immediately transferred to cold water. This is done to avoid contamination by fungi or organisms [116]. Later, the individual seed is sown at 1 to 5 cm intervals between lines and between seeds, the basal part (wider and flatter) is placed downwards. The germination process occurs between 41 and 62 days after sowing (see Figure 8) [116]. It should not be exposed to direct sunlight for a long time to avoid dehydration of the seed. At night, seeds can be uncovered. When seedlings have two extended leaves, they are ready for soil transplantation [5].

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Figure 8. Propagation of Avocado by sowing its seed [117].

When the seedling is ready to transplant, a 20 cm hole must be made in the ground, and the new seedling can be introduced [118]. It is essential that at this stage, the soil is not fertilized since the seed carries enough nutrients for the growth of the seedling. It must be watered as soon as it is transplanted and the next day as well to preserve the moisture of the seed and prevent it from drying out. This method is not recommended for long commercial plantations as the fruiting time takes longer.

6.5. Propagation by Transplantation

The saplings become ready for transplantation four to six months after it's grafting. The planting frames will be determined depending on the soil type, topography, variety, or cultivar (due to growth habit) and by the prevailing environmental conditions (see Figure 9).

The holes in the soil, made for transplanting the trees, should generally have 60 centimetres of depth [119]. In soils with low fertility, it is recommended to add 2 kilos of organic matter or substrate to the holes a week before; free of pathogens to avoid contamination to the plant. The bag should be removed from the plant and placed centrally in the 60-centimetre hole, and fill it with soil. It must be tamped, and the plant must be in level with the soil surface [119].

In general, distances range from 7m x 9m to 10m x 12m; the spacing of 10 m between plants and 10 m between rows is commonly used. There are several planting systems used: For instance, the square that can be 8 x 8 with 156 plants in one hectare, 9 x 9 m with 123 plants per hectare, or 10 m x 10 m with 100 plants per hectare. The staggered one can be 8 x 8 with 180 plants. The 9 x 9 with 142 plants and the 10 x 10 with 115 plants [120].

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Figure 9. Propagation of Avocado by transplantation it in its early stage [119].

6.5.1. Substrates to Improve the Crop

Inorganic materials such as sands and gravels, volcanic products (pumice, perlite, vermiculite, expanded clays), and coconut fibres are used as substrates. Organic materials of various origins have also been developed, such as peat (blond peat and black peat), Sphagnum peat, forest, and agricultural residues (bark, pine needles, rice husk, coconut fibre), animal by-products (manure, wool, and feathers) are also used [8] [121].

6.5.2. Watering Process

This is an essential aspect since great care must be taken not to subject the plants to water stress, meaning not too much or not too little water [122]. It is advisable to have a permanent and efficient irrigation system. Watering should be focused on the foot of the plant to prevent water from entering the graft incision. Irrigation should be done preferably in the morning, every 2 or 3 days in the rainy season if necessary, and daily in the dry season, considering factors such as the climate, the phenological state of the plants, and the physical properties of the substrate used etc. A realistic estimate to decide the frequency or start of irrigation can be detected through the change in colour of the substrate surface, from dark (wet) to lighter (dry), complemented by the touch of the substrate humidity.

6.6. Rapid Propagation Using Tissue Culture Techniques

The multiplication of plants by the proliferation of axillary shoots is the most reliable micropropagation method in terms of the genetic stability of the plant [123, 124). Plant tissue culture is very cost-effective and can be used for the rapid multiplication of genetically superior plants of Avocado. Different techniques of micropropagation can be used for Avocado plant multiplication through its young shoots (axillary and apical buds) are preferred explants (see Figure 10).

The members of the CAMAAY, who are in Avocado cultivation business or intend to start supplying elite planting material business, should consider a plant tissue approach to meet the demand for reliable planting material. Interested CAMAAY members can consider establishing small scale tissue culture facilities or having mobile tissue culture labs. The rapid propagation of Avocado can be done by following the standard

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micropropagation protocols. However, CAMAAY members who are interested in taking up Avocado micropropagation as a business will need training and nurturing.

Figure 10. Avocado plant material for micropropagation; A) Young shoots of Avocado plant; B) A twig showing axillary bud.

7. Organic Avocado Farming

Despite evolving in subtropical climates, the Avocado tree has been successfully grown across other environments. Even though the plant may be established in different conditions, many places have achieved good production levels. When establishing an Avocado orchard, there are a few factors that need to be considered. In the following sections, aspects regarding the climate, soil and plant management are described.

7.1. Soil Requirements and Management

Avocado trees can grow on a wide variety of soils. An ideal site should have well-drained soil with an excellent physical structure that facilitates root growth and provides adequate water [125], avoiding water stagnation [126]. In well-drained soils, despite having a shallow root system [125], the Avocado tree can reach a depth of 1.5 m with most of the main root system (70-80%) developing in the first 60 cm [127]. Poor root growth can be present in poorly drained soils with inadequate structure, lack of aeration and high salinity [125].

One way to improve the physical and chemical properties of the soil while maintaining beneficial microorganisms for the plant is with the management of organic matter [125]. It is possible given that organic matter manages to absorb and retain water (enhancing water field capacity) [125, 128], has a positive effect on soil structure, raises biological activity, decreases erosion and makes nutrients more available [128]. The ways to improve organic matter content in the soil are explained below, considering organic amendments that are both environmentally benign and enhance soil quality [129].

Given that the Avocado is a subtropical tree that usually grows in a forest environment containing a layer of decomposing plant leaves, mulching is essential for production success. It promotes the development of a layer of organic matter in the soil surface [125]. By definition, mulching is applying any layer of plant material (or other suitable material) to the soil without its incorporation into the soil [130]. Some organic mulch materials can be pruning waste (when finely chopped [129], plant foliage, cover crops, hay, and crop residues.

When using mulch, not only there are benefits such as improved water conservation, better root growth and suppression of root disease [129, 130], there are also adverse effects; one is the danger of nitrogen 'draw-down'. Mulches with high carbon to nitrogen ratio (C:N) have insufficient nitrogen for the populations of soil microorganisms resulting in a 'draw-down' or 'negative period' where the roots are unable to obtain enough nitrogen

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[130]. Ideal Avocado orchard mulches must have: a C:N ratio between 25:1 to 100:1 and fibrous and/or strawy materials with a moderate rate breakdown [130].

Another way to contribute organic matter to the soil is through compost. Compost is the result of the decomposition of organic matter through a controlled microbiological process [128]. It occurs through the activity of microorganisms naturally found in soils, where earthworms, nematodes, mites, ants and beetles do most of the starting mechanical breakdown of organic materials into smaller particles [131]. In order to have a good environment where the organisms can thrive, they must be provided with nutrients, water and oxygen while maintaining thermophilic temperatures (over 40ºC) [132].

Compost plays a vital role and has a positive impact on soil and plants. It can improve water retention in sandy soils and promote soil structure in soils with high clay content [131]. Compost can also reduce risks of contamination with nitrates and pathogens and turns the nitrogen contained in manure into a stable organic form [133]. The quality of the resulting compost depends on the composition and the preparation of the materials; these can be classified according to its chemical nature (organic or mineral), state (solid or semisolid) and origin (domestic, industrial or agricultural) [133]. Some materials need treatment before the process of composting. For example, when it comes to manure, its high amount of humidity demands a treatment to lose moisture or mix the material with solid agents (from agriculture or forestry) [133].

There are a few conditions to take into consideration when making compost. For the C:N ratio to start composting, the ideal lies between 25:1 – 35:1, to avoid losses of nitrogen and the unnecessary extension of the process [9]. The humidity content should be 50 – 60%, with the optimum at 55%, and excessive aeration should be avoided [133].

These practices are proven to have a positive impact on the tree's growth and development. During the first years of growth, the use of mulch, compost or cover cropping [134] is relevant in order to have: a good source of organic matter and a way to support plant health [129, 134]. And once the trees are in full production, there are still benefits to the reinforcement of the natural litter since it has been proven that practices can help to increase the fruit numbers and total yield [135].

7.2. Tree Establishment

Avocado orchards have been traditionally planted in a square configuration allowing the natural development of the trees [136]. However, it is essential to consider the growth habit of the respective variety [126] and the conditions of climate and soil. If there are favourable conditions, the tree will have high vigour, and a wide spacing within and between rows will be needed, i.e. from 10 x 8 m to 12 x 9 m [127]. Despite having general planting distances between 6 to 12 m [126], some studies show that cultivars such as Hass and Edranol can be planted in high densities ranging from 5,5m x 3m to 4m x 1,5m [125].

7.3. Plant Nutrition

Most of the problems farmers encounter when they grow Avocados organically are related to nutrition, pest control and weed management [134]. When it comes to nutrition, the questions are regarding the demand of the tree, its availability through the soil and the efficiency of the nutrient input. The answers to these questions lie in understanding the tree's phenological stage, the environment, the soil condition, and anecdotal evidence [127].

Avocado trees have a relatively low nutrient demand [134]; usually, the need for inputs of nutrients is high in places with shallow, light or rocky soils [138]. Despite the trees' conditions, the main nutrient losses will occur with the same events: at harvest with the fruit removal and with the senescence and abscission of leaves, twigs and flowers [127]. Therefore, the main goal of organic farmers is to recover the nutrients lost during those events, relying on renewable resources [128] and sustainable practices.

Both plant and animal materials can be used for nutrition purposes. Materials like crop residues, food waste and manure [128] can be applied. However, efforts should be

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taken to avoid introducing contaminated waste (i.e., weeds' seeds and/or plant pathogens) into the orchard [125]. Out of the options mentioned, manure is a significant source of nutrients. However, it may contain high levels of pathogens and soluble or volatile nutrients that may affect the air and water quality, causing pollution. It is also likely that it is carrying weed seeds, needing to be composted before use [128]. Another source of nutrients used in organic farming is the application of mined minerals [128] such as rock phosphate, limestone, potassium and sulfate.

The macronutrients are the elements that are required in the most significant amounts by the plant; these are nitrogen, potassium, and phosphorus. The Avocado trees will need the input of macronutrients to replenish what is removed in the harvest and those nutrients that are not recycled efficiently within the soil [125]. The amounts of each nutrient removed by the crop are shown below in Table 2. These values are an estimate, and alternate bearing must be considered, given that during 'on' years, the loss will be more significant than during 'off' years.

Table 2. Nutrients removed from an Avocado orchard[$].

Nutrient	% of dry weight	kg/ha
N	0.54	11.3
P	0.08	1.7
K	0.93	19.5
Ca	0.10	2.1
Mg	0.24	5.0
Cl	0.07	1.5
S	0.30	8.0

[$]Adapted from Lahav and Kadman [14].

7.3.1. Nitrogen (N)

This element has a significant influence on the growth and production of the Avocado tree [127, 138]. Some deficiency symptoms include restricted growth, pale and small-size leaves, early leaf shedding, and in extreme cases, the leaf veins turn yellow [127, 138]. For the proper development of plants, 30 – 40 g N/tree should be applied during the first year, 80g in the second year, 160g in the third and 200g in the fourth year [138].

Alternate bearing and cultivar also influence the demand of the tree. A cultivar that tends to have high fertility requires more N before an 'on' year and lower before an 'off-year' [138]. Despite these differences between years, some considerations are relevant for each season; for example, nitrogen fertilisation is not recommended during the phenological stages of blossom and the fruit setting period [125].

7.3.2. Phosphorus (P)

Symptoms of phosphorus deficiency are rare in Avocado orchards [127]; some detail the presence of small round leaves, a decrease in vegetative growth, early leaf shedding, branch dieback and leaves of brownish-green colour and burnt [138]. The practice of applying P to the soil is mainly done in orchards growing on poor soil (high sand content), otherwise raising the phosphorus level when it is low has no effect on the resulting yield [138].

It is essential to consider that the use of manure to fertilize trees not only carries nitrogen. Manure contains high amounts of phosphorus, leading to the accumulation and storage of this element [125]. Since all materials that provide phosphorus (phosphorous acid, fertilizer phosphorus, phosphorus from organic matter) undergoes a very rapid transformation to minerals, any major input can create large reserves able to maintain the supply of this element for many years before depletion occurs [125].

7.3.3. Potassium (K)

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Potassium is an essential nutrient for the normal growth and development of Avocado plants [127]. Despite having big K losses with each harvest, it's challenging to reach deficiency. For example, for trees grown in sandy soils, the symptoms appear only after eight years of no K input [138]. Some symptoms of deficiency are small and narrow leaves with brownish-red necrotic spots that develop on older leaves [127, 138].

When it comes to organic fertilization, as was the case with phosphorus, manures and other organic materials contain high amounts of potassium in relation to nitrogen, resulting in an abundant supply of the macronutrient [125], enough to contribute and fulfil the demand of the plant.

7.4. Climate

Young plants are more susceptible to damage from climate circumstances; due to this, they need to be protected from exposure to extreme cold, sunburn and wind [126]. As the trees develop, there are vital stages during each season in which damage can significantly affect the resulting yield.

Heat damage occurs when high temperature and low humidity conditions are maintained over several days (and nights), generating damage, especially during flowering [127]. A way to handle this problem is increasing the frequency of irrigation or adding half of the budgeted amount of water before an expected heatwave [127].

Opposite to heat damage, there's frost damage. Since Avocado is a subtropical tree, temperatures at (or below) freezing point harm the fruit, buds and foliage [138]; but the susceptibility to damage depends on the dormancy status of the tree [127]. One option to manage this situation depends on the plant's nutrition, more specifically maintaining good nitrogen levels since N helps the tree overcome low-temperature conditions [139]. Irrigation control can also contribute to these situations, considering that trees in dry topsoil get more damaged than those where topsoil is wet [127].

7.5. Pruning

The pruning requirements will change throughout the growth and development of the trees. The first 3 – 4 years of growth are essential to determine the shape of the tree. During these first years of managing the Avocado trees, it's important to develop the central leader [140], the main axis of the tree. Although the leader must be protected, it's essential to consider that the tree must have sufficient complexity of side shoots with lateral branching [140].

Once the tree is formed, the importance of pruning comes from avoiding dense canopies with unproductive areas inside the trees [137]. Given the growing tendency of Avocado, trees pruning tends to be a practice required multiple times during the season [140]. The timing of pruning is crucial, especially considering that if it is done at a point where the vegetative growth is stimulated (over the development of the fruit), it will affect the resulting yield [141].

Some key moments for pruning are during spring (with the first flush of vegetative growth), summer and post-harvest. In general, principles to take into account are: (i) remove shoots with acute angles to the vertical, (ii) tip side shoots when they reach 20 cm (forcing lateral growth), (iii) remove side shoots that are more than 1/3 the thickness of the central leader and (iv) ensure that horizontal shoots are evenly dispersed (avoiding one shoot to be over another shoot) [136, 140]. Water shoots must be removed during the second growing season and during the summer pruning period to maintain branch hierarchy [136]. Lastly, during post-harvest, it is essential to shape the trees and control their height, preventing treetops from becoming too wide and tall [137]. Post-harvest is also relevant to remove upright growing shoots and branches to improve light penetration and avoid overshadowing [136, 137, 140].

7.6. Irrigation

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Like many other crops, Avocado is often grown in environments that differ from those in which it evolved [127]. Avocado is originally from the subtropical and tropical regions of central and South America [127], and irrigation is the most crucial aspect of production for achieving its successful fruit production [142].

Avocado trees have the potential to grow vigorously and tend to develop into very large trees [136, 140]. These trees then become harder to manage, making practices such as the harvest more difficult, affecting the yield. A way to control plants with excessive growth is with nutrient and water management [136, 140].

During each season, there are critical moments where it is vital to have good water management to not have a loss in yield. Some of these moments are flowering (to not affect fruit-set), early fruit development (to avoid fruit browning) [141, 143], the final period of rapid fruit growth and maturity (to reduce fruit drop and increase fruit size) [142].

Avoiding water deficit during the early development of the fruit (3 to 4 months after fruit-set) is key to preventing fruit browning during post-harvest [141, 143]. The tree can display Signs of water deficit. Some of these symptoms regarding a shortage in the water supply are a reduction in tree height and trunk circumference [127]. On the other hand, if irrigation is too frequent, it will stimulate vegetative growth [143], making agricultural practices more complicated and creating spots within the tree with no fruit production.

The irrigation cycle length changes through the season, being short during the summer and long in winter [142]. This variation means that water use can range from 40 L/day in winter to a maximum in summer of 115 – 135 L/day, depending on the conditions [142]. Farmers should avoid a fixed cycle length of irrigation; instead, they should allow the tree to determine when irrigation should take place [142] or create intervals according to the rate of soil water depletion [127]. Some frequencies for hot climates are 7 – 12 days for under-tree sprinkling, 2 – 7 days for mini – sprinklers and 1 – 3 days for drip irrigation [127].

7.7. Plant Protection

When it comes to organic farming, Avocados are a crop that most easily lends itself to organic practices because of the relative low pest pressure, low nutrient demand, and, when mature, low weed pressure [134]. Out of all the issues that can happen in the production, the biggest problem in the orchard will be dealing with root rot caused by *Phytophthora cinnamomi* [134, 138]. Conditions such as soils with high water content or high clay content make it faster for the disease to develop [127]. In contrast, other sources of stress like poor water management, low temperatures (freeze), and even heavy fruit load increase the tree's susceptibility [134].

Weed management is very important during the first years of the growth of Avocado plants. Weeds should be removed until the leaf layer develops, controlled by weed whips and cover cropping [134]. These leaves also have the effect of recycling nutrients back to the tree and possibly help in pest suppression by harbouring a number of natural predators and parasites [134].

7.8. Advantages of Organic Avocado Farming

Choosing organic over conventional farming is very important when it comes to the production of any crop. Among the advantages that come with organic farming is that it's a more sustainable system of production in comparison to a traditional farming approach. When it comes to Avocado trees, the crop lets itself be a good option for organic management due to the few difficulties that may arise compared to other fruit trees and their possible diseases and pests. Other general benefits related to organic systems are maintaining good soil fertility, mitigating climate change effects and reserve desertification, and maintaining and improving biodiversity [144]. Some disadvantages are that it may be less concentrated when fertilizing with an organic product, so the quantities for the needed product become larger.

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8. Organic Certification and Avocado Agriculture in Cameroon

8.1. Organic Certification

Organic farming practices are known for prioritizing natural biological cycles and sustainable production. The FAO/WHO Codex Alimentarius guidelines [145] define organic agriculture as "a holistic production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity". The International Federation of Organic Agriculture Movements – IFOAM [146] defines organic agriculture as a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions [combining] tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved [147].

The organic products certification is the procedure by which a certifier ensures in writing that a given product, process or service complies with organic production norms and practices. Certified organic food is produced according to documented standards that ensure that the production process avoids the use of synthetic fertilizers, pesticides, hormones, genetically modified organisms, and irradiation [148].

Certification involves applying organic standards, documenting farm history and current setup, inspecting the farmlands and processing facilities, keeping detailed records, and paying certification fees [149]. The certification is usually done by third parties: accredited organic certification agencies that will ensure that the production and processing of the agricultural products are in accordance with national or international organic standards. Certification bodies can be either state or private organizations, which will provide farmers with a logo or symbol to identify their products as organic and differentiate them from others.

Third-party certifications are necessary as they assure international consumers that international standards are followed in the process. They are defined by the importing markets (e.g., the EU and the USA) standard. This certification system is often expensive and demanding for the producers who have to pay high fees to certifiers for their monitoring services and have administrative demands that make it nonviable at the individual level for small African producers [150].

As a viable alternative, organic certification can also be obtained via Participatory Guarantee Systems (PGS). It is defined by IFOAM [147] as locally focused quality assurance systems that certify producers based on the active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange. The PGS are alternative and complementary to third-party certification and enable the direct participation of producers, consumers, and other stakeholders in the process of certification by allowing them to make joint decisions on the definition of standards and certification process. Organic certification from the perspective of organic Avocado's production in Cameroon is highlighted below.

8.2. Organic Certification in Cameroon

In Cameroon, it is not yet possible to find a national organic agriculture regulation [151]. Organic certification of products rely heavily on third-party certification, and the standards for certifications are usually based on the European Union regulations [152].

According to Bayiha *et al.* [153] there are three identified types of organic farming in Cameroon: certified organic farming according to international specifications; hybrid organic agriculture; and natural organic farming that refers to traditional practices with low use of inputs.

8.2.1. Certified Organic Farming

Certified organic farming targets the international market and follows the standards set out by the importing countries. In Cameroon, a network of agro-entrepreneurs composed of small private companies and certification bodies are concentrated in Douala (see Figure 6) and organised themselves into an inter-professional organization. These agro-

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entrepreneurs follow European certification standards and do business with a European certification body called ECOCERT.

This type of organic farming focuses on tropical agricultural products for export. Entrepreneurs select small producers with environmentally-friendly farming techniques through formal and informal contracts, and training and support are offered through programs such as PIP-COLEACP (Europe-Africa-Caribbean-Pacific Liaison Committee) financed by the European Union [154].

The lack of logistical support for export sometimes leads these agro-entrepreneurs to sell their products locally in supermarkets which are then consumed mainly by high-income consumers. Bayiha *et al.* [153] refer to it as the "innovation niche".

Some literary sources [155-157] mention that there are two organizations gathering operators of the organic sector. One organization is the Association for the Promotion of Organic Agriculture in Cameroon (ASPABIC) in the French-speaking part. The second is the Association of Vegetable Growers (AVEGRO) in the English-speaking area.

8.2.2. Hybrid Organic Farming

With a more intensive and technological agricultural practice, this type of farming targets national and regional markets. While referring to their products as organic and seeking to preserve a natural feature, they are not accompanied by any label of certification. The agro-food companies that work with this type of organic farming invest primarily in marketing plans to increase their market shares, highlighting the products' organic features in packaging and promotional campaigns, without a third-party label certifying the products.

This type of organic farming brings together a very large number of individual agro-entrepreneurs, but according to Bayiha *et al.* [153] they do not form a network or association but rather a dispersed group with very diversified agricultural and commercial practices.

8.2.3. Natural Organic Farming

Natural organic farming is considered the type of farming based on local knowledge and deemed as "traditional". In this type farmers associate with ancestry, with empirical knowledge transferred over generations, a type of farming without the recourse of synthetic inputs.

This type of agriculture is family-based and practised in small farms in which the producers mobilize old technical routines that are sometimes qualified as traditional. The products are diverse, ranging from roots (cassava, yams), fruits, condiments, and processed products such as bobolo and tapioca.

This type of farming targets local markets and does not necessarily use or claim the term "organic". No third-party certification is applied: trust between the consumer and the producer about the agricultural production method is ensured by identifying the localized character of the production [153].

An alternative certification via Participatory Guarantee Systems (PGS) can be developed focusing on natural organic farming. This type of certification is supported by civil society such as Groupement d'Appui pour le Développement Durable (GADD) [158] that offers support and guidance to local actors to promote best practices and improve socio-economic conditions of the population [153].

8.3. Recommendations to Promote Organic Avocado Agriculture in Cameroon

Environmental concerns are pressuring agriculture to be sustainable, i.e., economically viable, but socially equitable and ecologically sustainable at the same time [159], while also maintaining a good yield. To promote organic agriculture, it's important to strengthen group formation [160] among farmers and raise awareness of the positive impacts of organic agriculture and the benefits that it entails for farmers.

8.3.1. Some Considerations

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The lack of national uniform legislation for organic farming certification poses a challenge for small producers in Cameroon. As is the case for many West African countries, the organic industry in Cameroon is still underdeveloped [156], and there is ample space for initiatives, improvements, and promoting organic farming.

Within the context of Cameroon, it is clear that, as per the recommendation of Bayiha *et al.* [153], the development of organic farming must be put in place through institutional mechanisms for the recognition, enhancement and stabilization of the plural forms of existing organic agriculture. While there are no sufficient institutional measures to support producers in their organic certification, farmers can seek assistance through PGS and organizations such as IFOAM that can offer guidance and services for the organic certification and associated activities.

9. Methods for Whole and Cut Avocado Fruits Preservation

9.1. Avocado Polyphenol Oxidase

The Avocado tree produces tasty fruits that are well known all over the world. Avocados are becoming expensive and popular because of their rich nutrients that are good for the human body. It is challenging to preserve Avocado fruits because of the speed of turning brown when they are cut [Figure 11].

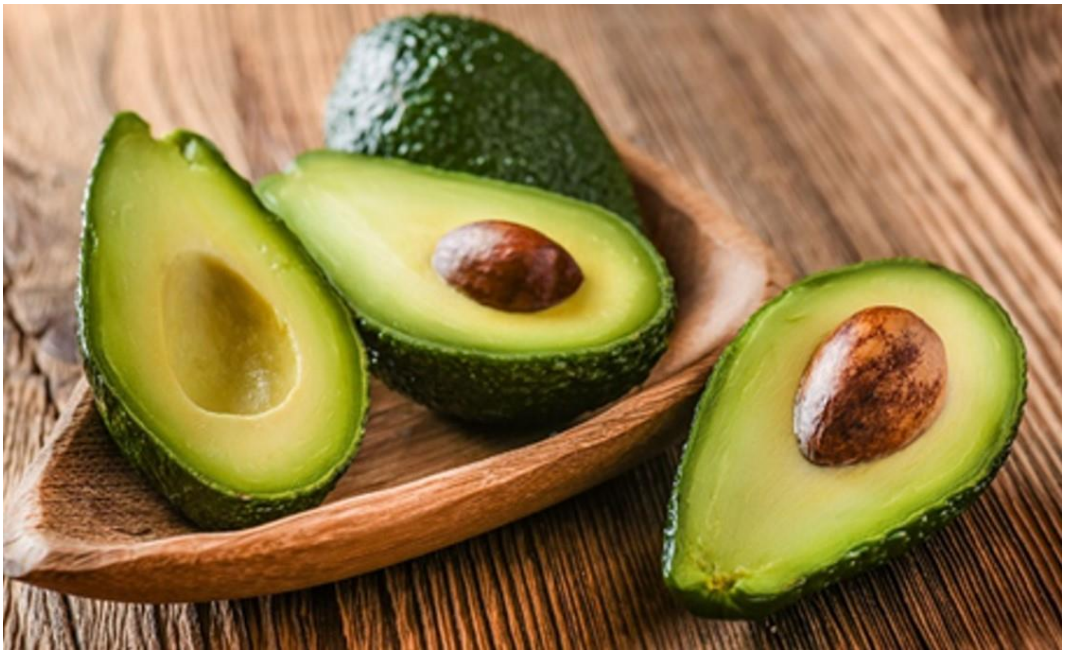

Figure 11. Cut Avocado fruits showing its internal features [161].

The enzyme Avocado polyphenol oxidase (aPPO) shows its impact once the Avocado is cut. The PPO is a common name for oxidoreductases that involve a dinuclear copper centre to stimulate two types of reactions: the insertion of oxygen in a position ortho- to an existing hydroxyl group in aromatic ring oxidation of *o*-diphenols [see Figure 12]. Because of the appearance of oxygen, aPPO has a double activity in catalyzing the mono phenols and polyphenols. Finally, o-quinone products are covered by brown polymeric melanins in subsequence. PPOs commonly appear in our daily lives. For instance, many fruits, such as apples, vegetables, etc., get brown because of PPOs [162].

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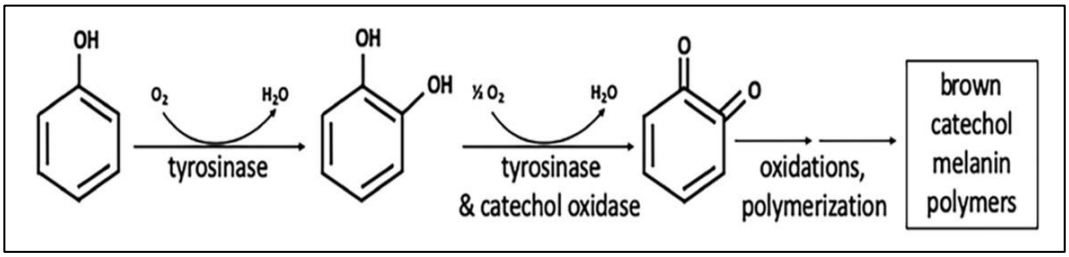

Figure 12. Process of chemical change when Avocado polyphenol oxidase (aPPO) takes place. Mono oxygenation and oxidation are the first two steps in the chain. They are catalyzed by dual enzyme activities of aPPO with the oxygen. For non-enzymatic polymerization, it has multiple subsequent steps to react. As a result, the brown polymers appear and becomes visible [162].

To keep Avocado fruits in a good state, certain precautions should be taken. Some recommendations (*Things to not do with Avocados*) are listed below:

i. Don't refrigerate an Avocado initially [163]. If Avocado fruits are kept in a fridge initially, they will not be completely ripe.
ii. Do not skip the lemon or lime juice [163]. If you are not planning to eat the complete Avocado and do want it to get brown, you can brush the exposed surface with lemon or lime juice.
iii. Do not store it inappropriately [163]

If Avocados are unripe, you can put them on the counter to let them ripe. Cool and dark condition is the best for the storage of Avocado, with a consummate temperature of 68 F (20 °C) [164]. To shorten the ripening period, you can place the Avocado in a brown paper or plastic bag with a fresh, unpeeled apple or banana for a few days [165].

The flesh of the Avocado gets brown and dark quickly once it is exposed to the air. Therefore, it is necessary to work with the meat when an Avocado is cut. We can slow down the process of Avocado fruit browning by adding acidic agents. The lemon juice/lime juice is recommended as an acidic agent to slow down the browning. The enzymes that allow the enzymatic browning reactions to happen are oppressive in an acidic environment. Hence, their activity slows down in the presence of acidic agents such as lemon/lime juice.

Refrigeration technique can be used to prolong the life of Avocado fruits. When can you refrigerate Avocado fruits? Some recommendations are as follows:

1. You can put a ripe, uncut Avocado in the refrigerator for one or two weeks. You can just simply store it in your crisper drawer [166]. For business purposes, tailor-made refrigerators can be made.
2. To save a cut Avocado, put some lemon or lime juice on the exposed flesh, cover with cling wrap and refrigerate them. Fruits can be stored in the fridge for a few days [166].
3. Avocado keeper (Figure 13) can be used to store fruits in the fridge. The Avocado keeper's shape helps reduce air exposure and slows down the oxidation process [166]. Hence, the browning of fruits can be avoided.

9.2. Pickling Avocados

Pickling is one of the methods to store Avocados. Fruits of Avocados that are just barely ripe and still firm are used to make pickles [164]. Avocado fruits can be stored in the fridges for up to a week. The broad outline on – how to make Avocado pickles is summarised briefly below:

The steps involved in making Avocado pickles.

i. Heat a mixture of one part water to one part vinegar with salt, sugar, and whole spices, such as peppercorns or coriander.
ii. Boil it to dissolve the salt and sugar, and let it cool down.

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iii. Cut Avocado fruits in half and then slice them into small pieces.
iv. Throw away the peel and pit.
v. Put in a jar and top with vinegar mixture.
vi. Leave it for a couple of hours or a day or more.
vii. Avocado pickles can be made at a small or large scale using this traditional method.

Making Avocado pickles on a commercial scale can make an additional stream of income for small-scale entrepreneurs.

Figure 13. The Avocado keeper is an alternative to save a cut Avocado. The perfect shape of the Avocado keeper makes the cut Avocados last longer [166].

10. Avocado-Based Entrepreneurship for Boosting Rural Economy

In the past decade, the global market of Avocados has continued to expand. FAO (2019) data suggest that the Avocados produced in the world in 2019 (7,179,689 tons) is twice that of 2010 (3778010 tons). The world Gross Production Value of Avocado reached US$ 5,811,886,000 in 2018, and it is likely to increase [167]. Hakizimana and May (2011) believe that the reason for this trend is that demand for the nutrition and natural ingredients of Avocados continues to rise. The development of the processing industry has increased the economic value of Avocado [168]—for example, Avocado cosmetics and fruit oil. Avocados have a variety of value chain models. Not only can fresh fruits be sold directly to consumers by producers, fruit collectors, and retailers, but they can also be produced and processed into a variety of commodities with higher economic value. It can boost the rural economy, reduce the poverty rate of growers, and promote rural young people's employment.

The population survey data of Cameroon (The world factbook, 2018) shows that although this country has more than 60% of young people under the age of 25, the jobs are far from enough to provide young people. The shortage of employment opportunities has promoted the trend of international immigration, and a large number of young people from Cameroon have sought more employment opportunities in neighbouring countries. Unfortunately, the uneasy situation has displaced these young people. At the same time, the poverty situation in rural areas continues to increase due to the decline in income caused by reduced employment opportunities and poor public financial management [169]. It is inferred from this that reducing poverty and increasing employment opportunities are critical to improving the status quo in Cameroon. Therefore, if young people undertake opportunities in the Avocados industry, the main conflict in the Cameroon area will be alleviated. The reason is that Avocado-based companies can substantially impact the rural economy to promote employment and reduce poverty.

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10.1. Economic Value of Avocado Companies to Cameroon

10.1.1. Reducing Rural Poverty

The scale of small farmers based on Avocado production reduces rural poverty and promotes the development of the rural economy by increasing the wealth of growers and improving the quality of life of growers. The evidence is shown in the case analysis of the local Avocado industry in Giheta Burundi. Hakizimana and May (2018) believe that compared with family businesses that do not grow Avocados in Giheta Burundi, households that grow Avocados are more likely to expand their rate (57.4%) and employee employment rate (36.8%) [170]. At the same time, through Giheta's further research on the Avocado economy, researchers found that the Avocado-based industry has a positive relationship with the quality of life of local residents [171].

A quantitative study on the local area of Giheta Burundi found that households that sell Avocados have more assets, including bicycles, radios, new clothes, emergency deposits, and sufficient money to pay for medicines, than households that do not produce Avocados. The association between child hunger rate and Avocado cultivation has also been confirmed. The study results also indicate that the probability of children not being hungry in Avocado-growing families is 2.5 times that of non-Avocado-growing families in the past year. In addition, researchers have studied the relationship between poverty alleviation rate and Avocado cultivation. Further research shows that the increase in the wealth of Avocado producers and the improvement of the quality of life have a positive impact on promoting rural economic development and poverty alleviation [170].

10.1.2. Promoting Local Employment

Innovations based on Avocado enterprises have a positive impact on the employment issues of the rural economy. Different supply chain links require a large amount of labour to ensure efficient operation. For example, the research and development of packaging materials require specialized enterprises and institutions, the construction of factories in the production and processing links, the procurement of processing materials and the workers in the production lines, the sellers in the export trade links, logistics companies, and Internet workers. Therefore, the Avocado value chain of Dar es Salaam in Ethiopia has created lots of employment opportunities for local residents, especially young people. Other commercial crops can have a similar impact. For instance, a Cassava value chain study on Nigeria confirmed that the development of the value chain had created new employment opportunities for farmers [172].

In the research on the contribution of Southern California agriculture to employment and economy, Daniel and colleagues (2012) pointed out that Avocados play a vital role in the local economy and creating jobs. This is mainly reflected in the sales share of Avocados, accounting for 15% of the total local fruit. The Avocado industry provided 40 thousand jobs for local residents and produced US$ 2.3 billion in labour value and US$ 320 million in fruit economic value added from 1990 to 2010 [173].

10.2. Market Analysis of Cameroon Avocado

The Cameroon Republic is located in Africa's central and western parts, bordering Nigeria and Equatorial Guinea (refer to Figure 6). The land area is 472,710 squares, but the water area is only 2,730 squares. According to FAO (2020) data, the production volume of Avocados in the Cameroon area was 74.7 thousand tons in 2019. The export volume was 10.93 thousand tons, and the export value was 27.44 thousand US dollars [174]. The main Avocado exporting countries are Switzerland and Belgium. Tagne (2019) proposed that Avocado production is mainly concentrated in the western region [175].

10.3. Analysis of the Value Chain of Avocado Enterprises

The industrial value chain means that the products follow the activity chain of a specific industry in a particular order, and each link will produce a certain amount of economic added value. Typically, the financial added value is greater than the sum of a single

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activity [176]. Intermediaries of other groups collect Avocados from farmers and resell them to other groups, wholesalers (buy Avocados in bulk from farmers or collectors and then ship them to the end consumer market), retailers (deliver goods to consumers directly from Producers or collectors), processors and final consumers (individuals or households who buy products from other groups) constitute Nega *et al*. (2015) [177]. Therefore, the Avocado industry in the Cameroon region can refer to this value chain model. The value chain model provides procedural support for the development of local Avocado enterprises.

10.3.1. Economic Value-Addition by Avocado Industry

There are two ways to increase the value of Avocados. The first is to improve the quality of the product through packaging and selection of fresh Avocados. This link mainly focuses on the manufacturing cost of the product. The second method involves the extraction of Avocado oil and the production of cosmetics [178].

10.3.2. Economic Value Analysis for Fresh Avocado Supply Chain

The economic value added without fruits processing is mainly manifested in the value chain linked to the selection, grading, packaging, and branding. First, the selection is to find the more popular high-quality varieties of Avocados. In the domestic market, the selected value chain is mainly manifested in the direct selection of farm producers. In the export market, the participation of farm growers and professional pickers are required to identify the quality of the products. This value chain link can reduce the transportation cost of poor-quality fruits and improve the overall quality level of the product. Second, grading refers to the classification of Avocados based on consumer preferences such as size and price. In the domestic market, retailers classify Avocados fruits based on their different sizes, tastes, and maturity. However, in the export market, Avocados are mainly graded by packaging warehouses. Third, good packaging can maintain the quality of the Avocado and simplify the handling of the product by consumers.

In the domestic value chain, fruit producers use polyethylene bags to weigh and pack fruits. The export value chain requires factories to package the fruits in special high-density cartons. Fourth, the economic value-added of branding refers to giving products a trustworthy logo to make supermarkets or suppliers more choices, allowing consumers to link products and value together to generate brand loyalty. The value chain mainly involves producers, cluster-scale production, the marketing role of advertisers, and the accumulation of consumer reputation.

10.3.3. Economic Value of Avocado By-products Supply Chain

The economic value-added by the byproducts of Avocado is mainly manifested in the extraction of its oil, use of its ingredients in various cosmetic products and other by-products. Several scholars point out the economic value-added through Avocado byproducts. Barbosa-Martin *et al*. (2016) pointed out that the fruits of Avocado can be processed into Avocado jam, or Avocado can be frozen quickly [179].

López-Cobo (2016) believes that Avocado oil contains lots of health-boosting nutrients [180]. For instance, monounsaturated fatty acids (Oleic acid), tocopherols, lutein and vitamins. A large amount of waste is generated in the production of Avocados. For example, whole cellulose from skins and seeds (which contain many nutrients such as fatty acids, polyphenols, steroids, etc.) can be used to produce various raw materials and sugars. Then this raw material can be transformed into many valuable products such as biofuels and bioenergy [180]. It can also be used to process and extract Avocado oil and produce products [179, 181]. These results were also confirmed by Saavedra *et al*. (2017) [182].

Furthermore, Javier *et al*. (2017) analyzed the Colombian biorefinery plant's processing cost and selling price and found that the recycling process can promote waste management; as a result, recycling enables reducing production costs [183]. At the same time, the processing of Avocados can increase the actual economic added value, thereby improving the local agricultural industry chain, which has a certain impetus for the local and export markets.

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10.3.4. Case Studies of the Avocado Value Chain Model

By reviewing the Avocado value chain model in Ethiopia, it appears that in the Avocado market of Ethiopia, Avocado fruits are mainly sold directly from producers to local fruit collectors and wholesalers at lower prices and finally sold to the Addis Ababa market by these intermediaries at higher prices [184]. For instance, Ethiopia's Avocado value chain is mainly composed of three parts: The first part: sorting and packaging according to the transportation needs of collectors and retailers. Wiersinga and Jager (2009) pointed out that most Avocado packaging materials did not meet industry standards, and most of the packaging materials were imported from the Netherlands [185].

Local entrepreneurs who have discovered this hot spot are working on launching local products suitable for fruit packaging. The second part: production and processing. Some local companies in Ethiopia have started to produce cosmetics made from Avocado [186]. The third part: consumption. Although Ethiopian Avocados are mainly used for local consumption, some Avocados are exported to other countries. At the same time, by reviewing the Dar es Salaam Avocado industry chain, the local Avocados mainly flow to the domestic market. There are mainly three value chains: The first part: separate transportation of Avocados through 10-ton FUSO trucks. A truck can load an average of 90 bags of Avocado, 120 kg per bag. In the second part, the packaging is made of plastic bags. One bag can hold fruits ranging from 120kg to 350kg. These case studies could provide insights for the potential Avocado-based entrepreneurs in Cameroon.

10.4. Entrepreneurship and Innovation Opportunities in Cameroon

Analyzing the economic added value of Avocado companies is crucial for young people in the Cameroon area to start an Avocado business, as it can provide insights and inspiration for local young people to start Avocado ventures. For example, in the selection and grading process, local young people in Cameroon can set up small companies to sort Avocados according to size and quality, saving time for producers and improving the overall quality of local Avocados. In the packaging process, local young people can start small enterprises for developing packaging materials to provide them to growers and manufacturers. The advantage of this is that it will help in reducing the local or national dependence on foreign packaging materials and can help to reduce the production cost of Avocados. In the branding process, local young people can set up advertising companies and online sales companies to rely on the development of the Internet, dedicated to selling local Avocados to other cities to open up the local market. In the process of processing, local young people can start the business of extracting Avocado oil. By building factories, purchasing machinery and equipment, and hiring more workers and mechanics, the creation of Avocado cosmetics companies is also creative business ideas by hiring professional chemistry Extract the research institute and more local workers. At the same time, companies in the food industry, including the production of Avocado and canned, frozen food, can also be established locally by young people. The processing industry needs to use a large amount of Avocado raw materials. It can reduce the cost of the company by reaching a large-scale acquisition agreement with local farmers. Form a synergistic effect with stimulating the development of the local economy.

10.5. How Can SME Be Registered in Cameroon?

Forms of setting up a company: Natural persons and legal persons of any nationality can set up companies locally, including partnerships, limited companies, stock companies, or economic interest groups. There are eight steps in the process of registering a company.

i. Provide information about the company (to be registered), including company name, registered capital, legal representative, shareholders (shareholder ratio), company business scope and company headquarters location to the staff of the notary office.

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ii. Prepare the company's articles of association.
iii. The applicant submits a letter of commitment to the organization.
iv. The applicant submits a business plan to the notary office.
v. Apply for a business license by submitting the company's articles of association, letter of commitment and Business plan.
vi. Submit the business license to the Ministry of Commerce to obtain the business registration.
vii. Apply for a tax card on the CFCE website after obtaining the business registration.
viii. Apply for CNPS from the social security company [187].

10.5.1. Potential Support for SME

The Cameroon government promulgated the Cameroon Investment Law in 1994, which aims to support local productive investment and create job opportunities through the active use of local resources. The bill has certain tax incentives for entrepreneurs, which are mainly reflected in the exemption of capital increase registration tax within three years of the establishment of the enterprise, the real estate transfer tax in the investment plan, and the 50% reduction or exemption of corporate tax in the first year of tax payment, in order to achieve investment planned house, land and building contract tax. During the business period, the company can reduce or exempt the minimum corporate tax, special corporate tax, and 50% of the current assets' income proportional tax during the operating phase [188].

In 2013, the Cameroon government promulgated the Encourage Private Investment Law to promote the development of private assets and expand employment. The bill updates and supplements the connotation of the investment law and introduces new preferential tax policies and exceptional encouragement support. Preferential taxation policies mainly include exemption of registration tax for houses, transaction tax for building purchases, business tax, tariffs on equipment purchases for investment projects, etc., and processing business tax for enterprises with an investment and business period of less than ten years after the investment is established (within five years), and registration tax and stamp duty related to processed products. At the same time, special support will be given to the agriculture and local product packaging industry to avoid value-added tax through investment project loans and processing enterprise factory property tax [189].

In 2009, the Cameroon government issued the Vision Plan for 2035. The plan aims to achieve national industrialization in African countries by 2035, focusing on agriculture, expanding energy production, and strengthening infrastructure construction. On November 16, 2020, Cameroon announced the 2020-2030 National Development Strategy (NDS30), representing that the country has implemented the second phase of the long-term plan. The ten-year development strategy is focused on the structural reform of the social economy, the promotion of basic social services, and sustainable economic development [190].

FAO has issued two agricultural enhancement projects to actively promote the dissemination of crop seeds in the Cameroon area and the local seed recycling fund. The project mainly selected 66 farmers to provide training on the management and management of revolving funds. Subsequently, several groups were linked together, including service agencies, agricultural research and development agencies to provide seed supply, national seed certification agencies, and financial institutions. Through skill training for farmers and the cooperation of various research institutions, the revolving fund of seed business in the Cameroon area has been promoted. The inner meaning is the loans obtained by the farmers from the project are deposited in the bank as a revolving fund. The local bank encourages farmers to add 15% of seed sales to increase the number of revolving funds through the management of the national committee. This fund is used to support the production and sales activities of seed companies. This activity solves the problem of seed supply shortage and poor quality, and at the same time, provides support for the development of the local seed economy [191]. Several agricultural research non-

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governmental organizations (NGOs) have taken a series of measures because they have recognized the restrictions on cultivating crops in Africa by seeds. For example, International Center for Maize and Wheat Improvement (CIMMYT) provides farmers seeds far below the market price to support local agricultural production [192].

11. Avocado Farming, Deforestation and Sustainability Issues

11.1. Water Pollution from Avocado Orchards

Taking Michoacán, Mexico as a case study, this city has experienced losses of about 23% (51,747 ha) of the forest that existed in 1976 in less than 30 years [193] due to the continuously increasing demand for Avocado since 2005. The deforestation that happens for cultivating more Avocado crops benefits the producers in the short term. The long-term consequences, including environmental degradation in the vicinity of the cultivation area, don't get due consideration. There are reports which highlight that about 80% of the groundwater is used for the irrigation of Avocado crops. This hydrological basin is characterized by the high permeability of substrates, being this crucial for the recharge of aquifers and dynamics of the springs [193]. The decrease in this aquifer puts civil society at risk and Avocado producers due to the use of this water for irrigation. Not only does it lose water recharges through the forest, but it also decreases the availability of water. Because water evaporation and transpiration from Avocado orchards far exceed that from coniferous forests, being the last ones, where the most important forest reserves in the country are.

Every year between 600 and 1,000 hectares of forest are lost for this reason, according to data from the government's National Institute of Forestry, Agricultural and Livestock Research (INIFAP) [194]. In certain local rivers and lakes, phosphates are observed in very high quantities, being higher (0.2 to 5mg / L), where international and national standards establish a limit for surface currents of 0.1mg/L [195].

11.2. Increase in Temperature Due to Avocado Crops

As a part of Avocado cultivation or orchards management, farmers cut old bushes and trees to ensure that Avocado plants receive more sunlight. This practice also contributes to deforestation and, consequently, climate change and global warming [196]. Currently, Michoacán has experienced an increase in temperature and unpredictable rains. Studies detected a trend in the relationship between drought and increased temperatures, with a lower intensity of cold seasons, necessary to maintain environmental balance, in turn, also a dilation of extreme hot seasons with more intense cyclones.

The accelerated increase in Avocado plantations has represented a change in the forest floor to the production of Avocado itself, causing deterioration of the forest ecosystems of Michoacán, generating losses due to deforestation of 500 hectares per year [195]. It is among the causes or factors that increase temperature, environmental pollution, and deterioration of ecological health.

11.3. Insecticides in Avocado Orchards and Consequences

The indiscriminate and excessive use of insecticides and pesticides in the orchards of Michoacán, 450 thousand litres of insecticides, 900 thousand and 30 thousand tons of fungicides and fertilizers are applied annually, respectively [195]. Apart from air pollution, insecticides, fungicides, and fertilizers have also caused water pollution. In this sense, up to a thousand ppm of nitrates and 150 ppm of potassium have been recorded in leached [193]. In large quantities, such as in Avocado orchards, they can cause skin, liver, and nervous system-related diseases in exposed humans [195].

The use of paraquat, a pesticide, in addition to eliminating vital microorganisms for plant growth, also generates irreversible lung lesions. In turn, the use of Malathion, apart from being toxic to animals and man, resists for several years polluting the waters. A study carried out by the National Institute of Forestry, Agricultural and Livestock

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Research (NIFALR) sustains those chemical fertilizers that contaminate groundwater systems [195]. The frequent use of pesticides throughout the different cultivation cycles in Avocado orchards, and some of them have high rates of degradation, or even perennial, end up accumulating in the soil. Irrigation and precipitation drive residual pesticides into wastewater and water bodies, thus leading to pesticide contamination, water consumption by humans or orchards irrigation with these contaminated waters. These challenges associated with Avocado cultivation must be considered to mitigate the risks of environmental pollution.

11.4. Sustainable Management of Avocado Cultivation

In the first year of Avocados cultivation, it is recommended not to use herbicides. If necessary, the use of graminicide is recommended as it generates less contamination [197]. The growing weeds or grasses in the orchard helps in keeping the soil from washing away nutrients and provide organic matter to crops.

Avocado cultivation demands a percentage of organic matter ranging from 2% to 5%. Therefore, the usage of these materials is critical [197]. When employing organic materials, care must be taken to ensure that they are composted (to eradicate undesired pathogens), as this will prevent contaminating agents from entering the crop. The nutritional contribution of organic matter will be determined by the type of materials used. A shortage of organic matter hampers Avocado production; thus, its application will increase output and the physical and chemical properties of the soil.

A fertilizer plan should be developed based on the results of the soil and foliar chemical analyses. Because a low pH in the soil might reduce fertilizer efficiency, the application of amendments is recommended based on the soil analysis results [197]. Fertilization must be done following the plant's physiological status and the anticipated crop. It is critical to note that nitrogen-rich formulations should not be abused because they promote vigorous foliage development but are weak in structure, allowing pests to thrive. Another point to consider is the little fruit set that can develop if this element is present in excess in the plant. As a result, it is always best to seek the advice of a specialist.

12. Final Thoughts and Perspectives

In Cameroon, about 16,292 hectares of agricultural land is under avocado cultivation. In 2018, the reported Avocado production in the country was 74,101 tonnes, which is expected to increase due to increasing demand [198]. Globally, Avocado production is growing (see Figure 14) [34]. In 2019, Cameroon sold over 31 tonnes of avocados (Figure 15) [198]. Belgium, France and Switzerland were the primary importers of their Avocados (Figure 16) [198].

In Cameroon, the local authorities, the federal government, non-governmental organizations like CAMAAY, and other stakeholders can promote the cultivation of Avocados to boost the local economy and to create new jobs to minimise unemployment. In fact, it is essential. However, all Avocado associated projects and activities should be aligned with respective sustainable development goals (SDGs) in line with the global agenda-2030

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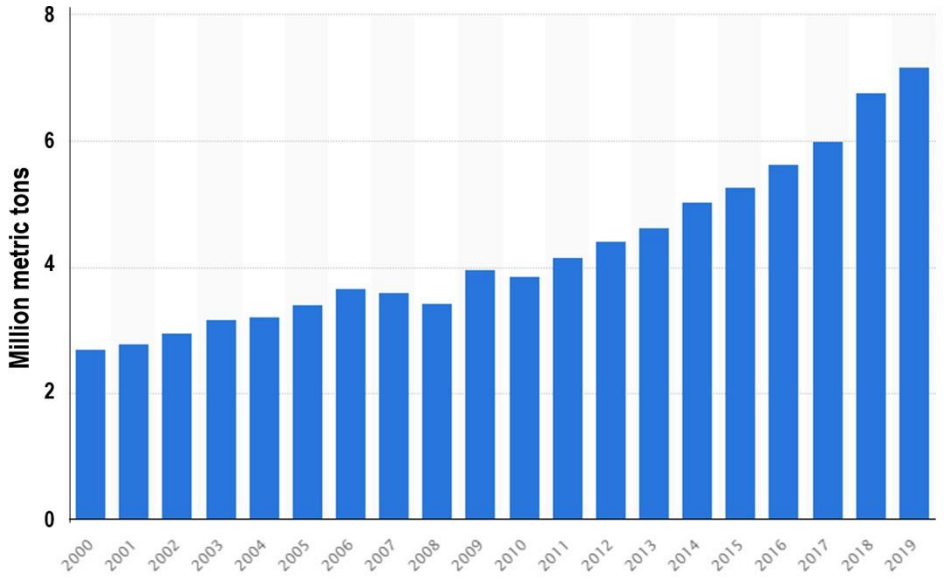

Figure 14. Global Avocado production [34].

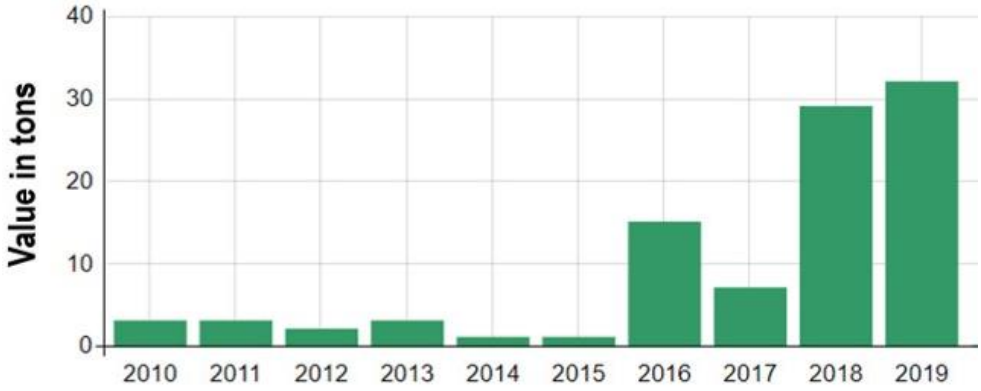

Figure 15. Avocado production in Cameroon [198].

COUNTRY	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Belgium									21	21
France	2	1	2		1	1	15	7	1	5
Switzerland		1							5	4
Italy	1									0

Figure 16. Cameroon Avocados export market (in '000 US$) [198].
for better output from one health perspective [199, 200, 201].

Jobs created through promoting Avocado cultivation will not only minimise unemployment but also can contribute to reducing poverty. Therefore, promoting avocado cultivation can be attributed under the SDG number 1, ''no poverty' [200, 202].

From a local or national perspective, the Avocado industry can contribute to achieving sustainable development goal 3 (good health and well-being), goal 8 (decent work and economic growth), goal 4 (quality education), goal 12 (responsible consumption and production), goal 15 (life on land), and Goal 11 (sustainable cities and communities) in addition to goal 1 (no poverty) [203, 204, 205].

Stakeholders interested in undertaking Avocado cultivation or promotion need to consider the challenges even though Avocado-based business appears lucrative. For instance, a grower should employ the best farming practices to ensure that Avocado trees will not get infected by pests such as thrips and moth insects [206]. Avocados are also susceptible to various fungal diseases including, anthracnose, Cercospora, root rot, and scab [206].

Shortage of safe drinking water and agricultural water is a challenge in Cameroon and beyond [207, 208, 209]. Avocado plants require a regular water supply. Some estimates suggest that a kilogram of Avocado consumes 389 litres of water on average [210]. Hence, innovative approaches must be used while cultivating Avocados to minimise water and energy use [211].

Furthermore, Avocado plants can bear fruits within a year or two. However, to reach an actual commercial production state needs 3-5 years. Hence, Avocado growers or entrepreneurs need to have some innovative strategies for financial sustainability [212]. To nurture the Avocado growers and entrepreneurs, effective communication within growers association and efficient coordination at the national, regional, district and village level is essential for dealing with the challenges of the Avocado industry [213].

The challenges of the Avocado industry comes with various opportunities. Avocados are widely used in the food, medicine, and cosmetics industry across the globe. Hence, a ready export market is available to the growers [214]. Potential Avocado entrepreneurs among CAMAAY or in Cameroon, if appropriately groomed, should tap the growing demand for Avocado fruits and contribute to alleviating the country's unemployment and poverty.

Large-scale Avocado farming is known to create environmental issues, including soil degradation, contamination of surrounding water bodies and pollution. However, small landholders and their Avocado cultivation business is at the centre of a workable, sustainable farming approach in line with SDGs [3, 199-201]. Avocado is also considered an alternative crop to coffee farming, and its cultivation is on the rise among small landholders in various African countries [2, 3, 34, 198].

Climatic conditions are suitable for Avocado cultivation in Cameroon. Hence, the federal government, state governments, and local administrations should encourage the local youths to take on Avocado cultivation. The CAMAAY, other similar non-governmental organizations, educational institutions, and other stakeholders can play their constructive role in nurturing the youths to make them more skilful and competent. It will create a pool of well-equipped youth to take on the challenges and realise the opportunities, including entrepreneurship prospects. If Cameroon develops and nurtures more entrepreneurs, it will help create a sustainable financial ecosystem, which will support the sustainable development of agriculture, associated sectors, and the country.

13. Conclusions

The benefits of Avocados were realised a long time ago, even before the arrival of the Spanish and Portuguese to American lands. Due to health benefits, Avocados has become popular and cultivated in various subtropical and tropical countries. The Avocado plants have a unique mechanism that enables outcrossing. It is grown predominantly in warm environments, and the information on necessary agricultural practices to cultivate it is in the public domain.

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One of the limitations in commercial Avocado production is its flowers abscission, which leads to the low total number of fruits yielded per plant despite intense flowering. Unfavourable climatical conditions during the specific period of flowering or fruit set lead to loss of flowers and or young fruits. Therefore, the presence of pollinators is vital at the time of flowering to facilitate pollination. Insects and honeybees play an essential role as effective pollinators of Avocados.

Avocado fruits are considered very healthy. Fruits can be consumed directly or in a variety of healthy eating plans. Avocado consumption provides nutrients and dense phytochemical food. It contains dietary fibre, magnesium, potassium, vitamin A, vitamin C, vitamin E, vitamin K_1, folate, vitamin B_6, niacin pantothenic acid, riboflavin, and choline. The high content of potassium and lutein in Avocado fruits is considered beneficial in maintaining its eater's normal blood pressure and regulating oxidative/inflammatory stress. If fruits are eaten in salads or salsa, it improves the bioavailability of carotenoids. In addition to fruits, the byproducts of it (Avocado) are also popular among people. For instance, its oil is popular because of the high content of monounsaturated fatty acids in it. Awareness among people about Avocados health benefits is one of the reasons for the high demand for it.

Propagation of Avocado using seed is not recommended for commercial plantations as it results in significant genetic variability that affects the fruit size and quality. On the other hand, grafting is the most appropriate method to reproduce the varieties selected for commercial cultivation since the grafted trees are uniform in terms of the fruits' quality, shape, and size. However, tissue culture techniques are the best option for the mass production of genetically superior planting material. Furthermore, tissue culture techniques allow achieving more homogeneous plantations. Therefore, vegetative propagation of genetically superior Avocado plants is highly recommended to produce the planting material.

Avocados can be cultivated in a wide variety of soil conditions, types of climate and production systems, as the plants have very few phytosanitary problems. It is very suitable for organic production. Factors such as soil and climatic condition-based irrigation to avoid root rot, managing the vigour of the plant, and nutrition needs to be considered, especially if the trees are established in sandy soils.

The cultivation of Avocados is essential and recommended. However, deforestation should not be done for its cultivation as it will affect biodiversity, water production, erosion reduction, carbon sequestration, and climate regulation. It is necessary to incorporate a long-term plan for local and regional sustainability in Avocado production. Effective management of soil, water, flora and fauna resources to avoid environmental degradation should not be ignored while cultivating Avocados.

Cameroon's climatic conditions are suitable for Avocado cultivation. Currently, a limited number of farmers and or private companies are cultivating Avocados in Cameroon. The promotion of Avocado cultivation in Cameroon has the potential of alleviating poverty and unemployment. Therefore, Avocado cultivation should be promoted as it will contribute to minimising poverty and unemployment. Local authorities, the federal government, non-governmental organizations like CAMAAY, and other stakeholders need to systematically promote Avocado cultivation in Cameroon. The effectiveness of coordinated efforts of all stakeholders will determine the overall progress and success of the Avocado industry in Cameroon.

Limitation of the study

There were no volunteers or stakeholders from Cameroon to provide the information on the ground realities of the Avocado industry in the country. The views expressed and the information provided in this overview are from the UNOV's perspective. Hence, CAMAAY, its members, stakeholders and other readers of this review need to consider the latest ground realities on Avocado cultivation either in Cameroon or elsewhere.

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