agronomy

Review

Multifunctional Role of *Acca sellowiana* from Farm Management to Postharvest Life: A Review

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Abstract: Feijoa (*Acca sellowiana* (O. Berg) Burret syn *Feijoa sellowiana* Berg) is a monotypic species belonging to the Myrtaceae family. Feijoa is cultivated in different countries, and it is mainly consumed as fresh fruit, due to its attractive nutritional quality, nevertheless, several feijoa-based products have been produced and are available in some niche and local markets. The fruits are not the only edible part of the tree since petals of hermaphrodite showy flowers can also be eaten. Fruits are rich in vitamin C, fiber, potassium, iodine, phosphorus, sugars, and calcium. In addition, a large number of bioactive compounds, with many health-promoting benefits, have been identified. This review is carried out with the aim to provide comprehensive and updated over-view of the state of the art related to the knowledge on feijoa, evaluating the main agronomic, qualitative, and nutraceutical traits of its edible parts. Moreover, the variability in feijoa genetic resources to identify and select promising genotypes useful for breeding programs and the postharvest management of fruit and edible flowers will be discussed. Overall, feijoa has great potential to be considered as a sustainable fruit crop from farm to table.

Keywords: feijoa; edible flowers; agronomy; nutraceutical; genetic; postharvest

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1. Introduction

Feijoa tree (*Acca sellowiana* (O. Berg) Burret syn *Feijoa sellowiana* Berg.) native of extreme southern Brazil, northern Argentina, western Paraguay, and Uruguay, is now widely cultivated in different countries of the world such as USA, France, Italy, Turkey, Iran, Australia, and New Zealand for the production of its fruit or as ornamental tree [1,2]. Feijoa remains a relatively underutilized species compared to other fruit crops, but, thanks to its easy adaptability in subtropical regions, it could be cultivated in other countries and commercialized as a new high-value fruit crop for its fruit and edible flowers [3]. This crop also has good development prospects in organic farming based on its high adaptability to different agronomic conditions and low susceptibility to pests and diseases [4].

Feijoa is an exotic species with a high economical potential for its functional fruits with sweet and aromatic flavor and a high level of bioactive compounds which promote numerous benefits to human health and/or reduce the risk of developing chronic diseases [3,5,6]. Furthermore, the sweet taste of the feijoa petals makes them interesting for the supply chain of edible flowers [7].

Feijoa peel represents about 60% (*w*/*w*) of total fruit weight and it is a rich source of functional bioactive compounds that is discarded during the industrial processing or consumption of whole fresh fruits [8,9]. This by-product still has relevant chemical and nutritional value and could be upcycled for human consumption, being a potential source of functional ingredients for industrial applications in the food and pharmaceutical industries [10].

This review was created with the aim to provide a comprehensive and updated overview of the recent advances on feijoa from agronomic features to nutraceutical traits of feijoa flowers and fruits. The postharvest management and the reuse of processing waste are also reviewed.

2. Biological and Agronomic Features

Feijoa is a slow-growing evergreen tree that naturally grows to a height of 4–6 m [4] (Figure 1A). The branches have opposite persistent, elliptical, and leathery leaves, bright green on the upper side and whitish on the underside [11]. The showy and hermaphrodite flowers, inserted on the current season's shoot, are single or in a cluster [12,13].

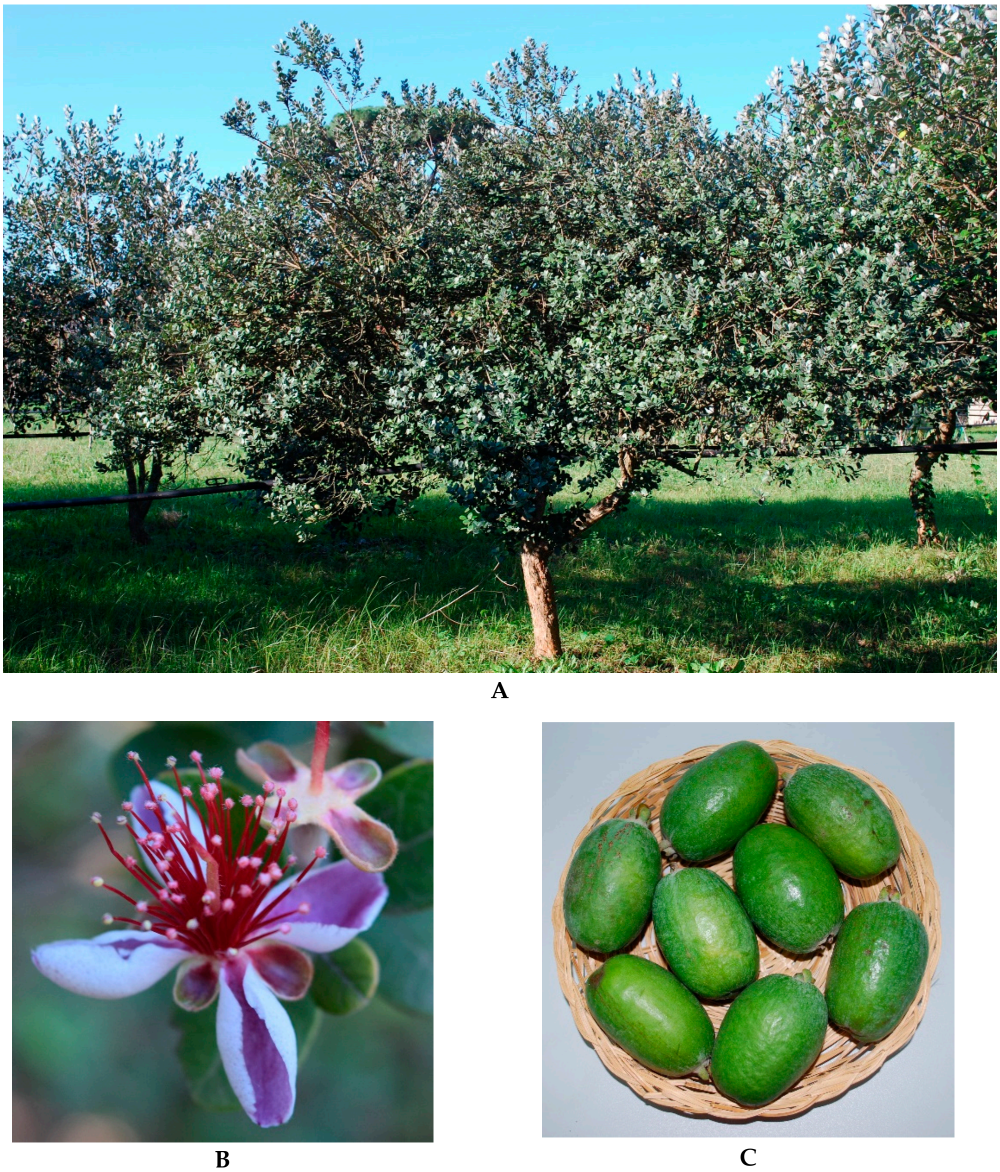

Figure 1. Feijoa experimental orchard located in Caserta, Southern Italy (41°90′ N, 14°80′ E) and owned by the CREA-OFA (Italy) (**A**), flower (**B**), and fruits cv Mammouth (**C**).

Flowering period occurs in spring, but it is variable depending on the cultivars and environmental conditions [13] (Figure 1B). In the Mediterranean area, floral development and emergence last for two months (Mid-April to June) and this was also confirmed in Chinese feijoa orchards by Zou et al. [14]. Feijoa cultivars bear different barriers to selffertilization, some of them are strictly self-incompatible, while others are compatible or partially compatible [13]. Cross-pollination increases a fruit set up to 80–90%, while self-pollination halves it; this is due to a higher percentage of abscission in self-pollinated than in cross-pollinated flowers [15].

Fruit shows persistent calyx with four sepals with variable shape and weight (40–150 g) [4] (Figure 1C). Skin berry may be smooth or rough and wraps a white granular flesh made up of sclereids in the outer parenchymatous region that becomes brown in color at ripeness [16]. Small and flattened seeds are immersed in a jelly substance placed in a central cavity constituted of about four locules [4]. Fruit ripening occurs from March to June in the southern hemisphere and from October to December in the northern hemisphere [4,6]. The fruits have an intense and aromatic flavor reminiscent of strawberry and pineapple and are mainly consumed as a fresh product.

Nowadays, feijoa is cultivated in different countries and the optimization of crop management conditions has allowed to improve its bio-agronomic performances obtaining productions that reach 20 t ha^{-1} or more in commercial orchards [17]. For optimal crop management conditions, it is recommended to always use different feijoa cultivars to overcome self-sterility barriers. The planting densities are influenced by cultivar vigor ranging from 400 trees ha^{-1} (more vigorous) to almost 880 trees ha^{-1} (less vigorous) with 5 m and 4.5 m between rows and 5 and 2.5 m between trees, respectively. Feijoa needs a well-drained and slightly acidic (pH 6.0–6.5) soil with a high organic matter content [18,19]. This species grows well in free exposure to direct solar radiation of $\geq$1500 h (direct sunlight per year) up to 700–1000 m.a.s.l., but in Colombia, it is well-adapted until 1800–2700 m.a.s.l. [17]. Quintero-Castillo [20] demonstrated that good production can be obtained in areas where there are 1000 h/year of direct sunlight with favorable pedoclimatic conditions. Furthermore, the production of saplings in nurseries and orchards of this species should be under full sun or up to 30% shade, because it makes saplings more vigorous and can anticipate and improve fruit production [21].

Feijoa tolerates winter frosts, and temperatures down to −4 °C do not cause significant damage in adult plants [11]; it requires a certain number of chilling hours below 7 °C to produce a major number of flowers, about 100–200 h, as suggested by Sharpe et al. [22].

Pollination and fruit set are negatively influenced by high temperatures (>32 °C), combined with low relative humidity [23]. During fruit ripening, a variation of the temperature from day to night of about 10 degrees is important to increase fruit flavor and taste [24].

Feijoa has high water requirements, especially during bloom and fruit development. The production of feijoa is favored by precipitation between 700 and 1200 mm/year, but this species tolerates up to about 2000 mm if there is good light and low relative humidity of around 70% [23,25]. Drought tolerance is different in feijoa genotypes and water-loss of 20–25% in leaves can cause the destruction of photosystem II [26].

Stress factors such as drought and high air temperatures during active vegetation in feijoa leaves altered some antioxidant enzyme such as catalase involved in hydrogen peroxide detoxification [27].

Feijoa has a low requirement of nitrogen compared to potassium and phosphorus, but an adequate amount of nutrients in every stage of tree growth allows to obtain high-yield and high-quality fruit. In young plants (one-year-old), Thorp and Bieleski [18] recommended to apply 12–18 kg ha^{-1} of N, splitting in 3 times, while Morley-Bunker [28] suggested to use 25–30 kg ha^{-1} of N, probably due to different soil features. Nitrogen fertilization increases gradually until reaching 120 kg ha^{-1} after ten years of age [28]. Concerning phosphorus and potassium fertilization, in young plants, the recommended amount is 40 kg ha^{-1} and 20 kg ha^{-1}, respectively, that increases gradually up to 80 kg ha^{-1} and 80 kg ha^{-1} respectively in adult trees [28]. In a feijoa mature orchard, excessive amounts of nitrogen can cause high fruit development and negatively affects postharvest shelf-life [29].

Arioli et al. [29], by analyzing fruit composition, determined the amount of nutrients that plants take up for an annual yield of 20 t ha^{-1}, which is: 26 kg (N); 1.5 kg (P); 41 kg (K); 2.4 kg (Ca); 1.9 kg (Mg).

In Italy, feijoa commercial orchards are subject to few pests and diseases compared to Brazil where this species shows a high susceptibility to pathogens [30]. Anthracnose (*Colletotrichum gloeosporioides*) is the main disease that affects this crop and causes important fruit losses both in the field, while fruit are still on the tree, and during postharvest life [19,30]. Recently, *C. siamense* has also been identified in feijoa fruit with well-defined dark spots of irregular shape [31]. *Botrytis cinerea* can cause enormous losses in crops generating rot in unripe fruits during the rain periods [32]. Other adversities are the basal stem rot and the root rot due to fungi of genus *Phytophthora*, *Pythium,* and *Rosellinia*.

Feijoa is considered a pest-free crop, but occasionally attacks of black scale and fruit flies (*Ceratitis capitata*) have been observed in California [33]. Presence of leafroller, mealybug, hard wax scale has been reported in New Zealand. These pests do not produce big loss, but can reduce yields by damaging leaves and small shoots [34].

3. Genetic Resources and Molecular Tools

Feijoa cultivars widespread in the world are all based on the Uruguayan fruit type with soft juicy flesh and small seeds and classified into three groups based on ripening-time (early, mid, and late) [4]. The development of new cultivars with superior fruit quality traits and adapted for new environments is needed to accelerate the commercial exploitation of this species. Genetic variability of this species is maintained in germplasm collections around the world such as the Feijoa Active Germplasm Bank (BAG) in Sao Joaquim-SC (Brazil), the National Feijoa Center (CENAF) in La Vega (Cundinamarca, Colombia), and the Nikitsky Botanical Garden (Crimean Peninsula) that preserve 313, 1500, and 400 accessions, respectively, and develop novel resources for genetics and breeding research [11,35]. For fruit tree species, such as feijoa, the breeding process is slow and costly because of the long juvenile period, extensive phenotyping cost, and limited field space [36]. In fact, fruit production starts in year 2–3 after planting, gaining full production in years 5–8 and the length of the juvenile phase seems to be determined by pruning strategies rather than from genotype differences [37]. For this reason, breeding for new genetic resources is currently based on the use of molecular markers that are also useful for characterization and marketing of existing cultivars. Nonetheless, genomic resources in NCBI for A. sellowiana consist altogether of a total of 197,247 referring to 54 DNA fragments, which also include the complete sequence of the chloroplast (159,370 bp) [38]. Among these fragments, 24 microsatellites (13,882 bases) are included, predominantly transferred from Eucalyptus to feijoa [39,40]. The species has been the subject of several sequence studies aimed mainly at establishing taxonomic relationships in the Myrtaceae family [41–43]. These studies have mainly analyzed the intergenic spaces of the chloroplast, ribosomal genes, maturase K, and NADH dehydrogenase. Sequences obtained in the context of barcoding projects with applications also in the epidemiological field are also worth mentioning [44]. From a more strictly genetic point of view, it is worth mentioning the in-depth characterization of the leafy gene and its regulation, which is crucial for the induction of flower buds [45]. Altogether, markers available are limited to few simple sequence repeat (SSR) [38,39,46], and to several random amplified polymorphic DNA (RAPD) [47] and sequence-related amplified polymorphism (SRAP) [6], with a low need for genomic resources. The molecular diversity of the species is documented in few studies in which low-throughput molecular markers are used [6,48,49]. Amplified fragment length polymorphisms (AFLP), intersimple sequence repeat (ISSR), and a small number of simple sequence repeats (SSR) markers were used in the construction on the first genetic map of the species [50]. This map represents the first one developed for fruit species within the Myrtaceae family. Recently, a new high-density map has been developed for feijoa based on SNP markers. This was based on new genomic resources that were released in form of SRA databases [51]. The availability of SRA databases opens the possibility for the construction of new user-friendly markers based on single nucleotide polymorphism (SNP), useful for breeding and cultivar identification. Markers on SNP based on FRET chemistry, as an example, are emerging as useful and reliable for fruit tree genetic resource management [52–54].

4. The Edible Flowers of *A. sellowiana*

The flowers of the feijoa are axillary, erect, actinomorphic, hermaphrodite, showy, very abundant on the plant, and often collected in groups. Four pubescent green glaucous sepals are arranged alternately with respect to the petals form the calyx. The corolla is composed of four to six fleshy petals, pinkish-white inside and white outside, with the edges folded upwards with respect to the major petal axis. The androecium is composed of very showy crimson red stamens with yellow anthers, their number and length varying according to the different varieties. The stigma, also coral-colored, protrudes beyond the stamens and is connected to the inferior ovary with three or four niches. In each niche, there are 36–60 ovules [55,56]. Feijoa varieties and genotypes differ not only in the shape and size of their fruits, but also in the intensity and hue of the flower color [57]. Feijoa flowers do not produce nectar and they attract pollinators, mostly birds and insects, with petals rich in sugars [58]. The sweet taste of the feijoa petals makes them interesting also to enrich the sweet or savory preparations of chefs. The feijoa petals tend to melt on the tongue and become creamy; they are sweet, their taste is reminiscent of papaya and melon with floral notes and a blueberry aftertaste without any hint of acidity. This feature opens a new type of market that requires cultivation measures for the development of a new niche product. Like other ornamental and aromatic plants [59–61] whose flowers are edible, the production of flowers must use the organic system without pesticides. In addition to an aesthetic interest, feijoa petals contain secondary compounds of interest to human health. Recent studies [62,63] have examined compounds present in feijoa flowers. Among the most present secondary compounds are pedunculagin, gallic acid, cyanidin glucoside (an anthocyanin responsible for the color of the petals), ellagic acid (a phenolic compound), a flavone, and a flavonoid (gossypetin arabinofuranoside). Some of these compounds have pharmacological importance. For example, ellagic acid is known for its anti-inflammatory, antimutagenic, antioxidant, antimicrobial, and anticarcinogenic activity [64]. The latter activity is also displayed by the flavone, gallic acid, and the pedunculagin. Magri and collaborators [7] investigated the bioactive compounds change during flower development and senescence: the petals contain the greatest amount of bioactive compounds when the flowers are not fully open and the filaments and anthers are dark reddish in color (F2 stage). At stage F2, the feijoa petals show peaks in both polyphenols and flavonoids, anthocyanins, and ascorbic acid content, and then at this stage, the antioxidant activity is also higher. Generally, the secondary compounds present in the petals influence their antioxidant activity, and the latter is highly correlated to total polyphenolic compounds in edible flowers [60]. The decline in bioactive compound content during feijoa flower development is probably due to active degradation or dilution of compounds resulting from the expansion of the petals. The inner color of feijoa petals changes during flower development becoming a good indicator: with senescence, feijoa petals lose their color and the intense pink fades to purple and finally in white. The color loss is accompanied by wilting, making the petals inappropriate for marketing and consumption. Considering the massive flower generation during the bloom, storage methods can be used to avoid the loss of the product part. De Souza et al. [65] tested cold postharvest conservation of feijoa flowers, applying different concentration of salicylic acid, ascorbic acid, sucrose, and 1-methylcyclopropene. The authors recorded that the cold storage (10 °C) with 1-methylcyclopropene at 500 $\mu L\ L^{-1}$ is the best treatment to conserve the petal color, delaying the wilting and the darkening of feijoa petals for at least four days. To date, no trials have been conducted on the drying of the flowers or processed in different preparations (sauces, preserves etc.) In fact, feijoa flowers can be used in formulations for food and pharmaceutical supplements or confectionery industries.

Processes and technologies can be applied to improve the feijoa flower preservation but so far, no sufficient trials have been carried out to extend the flower shelf life of feijoa.

5. Fruit: Nutraceutical Compounds and Health Benefits

Feijoa fruits are a source of essential nutrients for human health, such as vitamins, minerals, dietary fibers, and various bioactive compounds, which have been reported to have positive effects on the reduction of incidents of degenerative diseases [3,66]. Physicochemical characteristics are shown in Table 1. Several studies have demonstrated that variations in the fruit weight, size and shape were mostly influenced by the genotype, soil, climatic conditions, and the fruit maturity stage [6,67–69]. The total acid (TA) content and total soluble solids (TSS) are important factors for fruit quality, while the ratio TSS:TA is usually used for determination of the taste and palatability of the fruit and, therefore, the consumer acceptability [69].

Table 1. Physicochemical and nutritional characteristics of fresh feijoa fruit.

Parameter	Range
Moisture (%)	84–89
Water (%)	85
Proteins (%)	0.50–1.2
Fat (%)	0.05–0.4
Iodine (mg $100g^{-1}$ FW%)	3
Sodium (mg $100g^{-1}$ FW%)	0–9
Potassium (mg $100g^{-1}$ FW%)	90–170
Calcium (mg $100g^{-1}$ FW%)	4–15
Magnesium (mg $100g^{-1}$ FW%)	5.8–9.0
Iron (mg $100g^{-1}$ FW%)	0.0–0.4
Phosphates (mg $100g^{-1}$ FW%)	10–17
pH	3.2–4.4
Acidity (g malic acid $100g^{-1}$ FW%)	0.80–1.60
Soluble solids content (%Brix)	10–16
Glucose + Fructose (%)	0.60–3.0
Sucrose (%)	2.5–7.5
Fiber (%)	3.8–5.0
Ash (%)	0.20–0.40

The main compounds contributing to soluble solids (TSS) content are fructose, glucose, and sucrose [70]. At fruit maturity, total sugar content ranged between 10–16 °Brix. Most fruits are sweet, have a pleasant texture and flavor, and are eaten as a dessert or snack-food. Titratable acid is mainly dominated by malic and citric acid in a similar concentration [70].

Table 1 shows the nutritional composition of feijoa. Water is the most abundant component and makes up about 85% of the fruit [3]. The fruit is characterized by a good amount of carbohydrates, low protein content, as well as fat. For these reasons, feijoa fruit is considered a valid diet adjuvant. Feijoa appears to be a good source of dietary fiber (3.8–5.0% of fruit fresh weight) [71]. It is well documented that an adequate intake of dietary fiber, mainly derived from the peel, is essential for a healthy gut and has also been related to a reduced risk for developing common ‘life-style diseases’ such as heart disease, certain cancers, and type 2 diabetes [69,72].

The fruit is also characterized, like apples, by a very high amount of pectin. It is commonly consumed fresh or as a juice, but it is also used by the food industry to produce some confectionery products, such as sorbet, ice cream, or incorporated into bakery products, sauces, pies, or drinks.

Feijoas are an excellent source of iodine (3 mg/100g FW) [73] and, therefore, perform an important preventive action in the treatment of the thyroid gland and in the endocrine system in general [71,74]. The major mineral is potassium, followed by calcium, magnesium, sodium, iron, and zinc (Table 1). It should be emphasized that the low sodium level, balanced by the high potassium content, allows to maintain the body's salt balance.

These fruits, therefore, could be considered as good sources of vitamin C for the purpose of human nutrition (Table 2) [6,69]. It is well known that ascorbic acid levels are dependent of a wide variety of environmental factors including light, temperature, salt and drought stress, the presence of atmospheric pollutants, metals, and herbicides, which impact the composition of plant products [66].

Table 2. Vitamin C content, total phenolic content, and total antioxidant activity of peel and pulp tissues of the feijoa fruit.

Parameter	Peel	Pulp
Vitamin C (mg ascorbic acid 100 g^{-1} FW)	77.64	57.21
Total phenolic content (mg GAE 100 g^{-1} FW)	114.04	85.02
Total antioxidant activity (EC_{50}; mg FW/g^{-1} DPPH)	9.04	42.49

In addition to vitamin C, feijoa also contained vitamin E (α-tocopherol). Many studies have shown that a high intake of vitamin E is correlated with a reduced risk of developing non-communicable diseases [75]. Alpha-tocopherol, the most biologically active form of vitamin E, was found as the main tocopherol constituent in the feijoa fruit samples.

Feijoa contains high amounts of polyphenols (80–120 mg gallic acid/100 g FW) [62,76], such as hydroxycinnamic acids (caffeic, chlorogenic, p-coumaric, ferulic and syringic) [1], flavonoids (catechin, rutin, quercetin, eriocitrin, eriodictyol, and pyrocatechol) [9,62,76] and carotenoids (β-carotene) [77,78].

Environmental conditions (temperature, relative humidity, light) and the collection period play a significant role in plant development and influence the biosynthesis of secondary metabolites [66].

Numerous studies conducted both in vitro and in vivo have demonstrated the antimicrobial [79,80], anticarcinogenic [81], anti-ulcer [82], antifungal [83] and anti-inflammatory [84,85] properties of the feijoa plants. The high content of bioactive compounds of these fruits could be a valuable tool to promote their consumption and represent good perspectives for nutraceutical and cosmetic purposes [2].

The functional compounds are not only present in the pulp, but also found at a high level in the other tissues such as the leaf and peel. In fact, the edible fruit peel showed higher content of vitamin C and phenolic compounds [66] than the pulp (Table 2) with high antioxidant properties [1,8]. Therefore, there is ample interest in the development technologies to introduce this tissue in nutraceutical products.

Furthermore, feijoa is rich in volatile compounds such as methyl benzoate, ethyl butanoate, and ethyl benzoate [3,77], which account for about 90% of the volatile fraction, giving this fruit an 'unique' flavor profile [2,86]. Limonene (36.2%), β-cariofillene (12%), ledene (9.6%), α-umulene (6.3%), β-elemene (4.9%) and δ-cadinene (4.8%) were the major components in the oil [86]. Many studies have demonstrated the antitumor and antimicrobial properties of this oil [2,69].

The essential oil of *A. sellowiana* may be valuable for the flavoring of foods, such as chewing gums and sweets. Feijoa can be used in other cosmetic products, such as shampoos, soaps, shower gels, as well as in perfumes and deodorants. Furthermore, it could be used in the food preservation due to high antimicrobial compounds [80].

6. Postharvest Management

Feijoa is usually consumed as fresh fruit or as juice, but it is also used by the food industry to produce a range of products such as jam, sorbet, ice cream, and fermented beverage [78,87]. Commercial production of fruits is advanced in New Zealand, Colombia, California, Georgia, and Azerbaijan [3,11]. In Italy, feijoas are mainly produced for fresh consumption, on a small and local scale, although a slightly increased interest in exporting fruits to reach new market opportunity has been recently observed [88]. However, the general low consumer demand seems to be the consequence of a lack of clear information regarding fruits and their nutritional quality [89].

Feijoas have a very short harvest season with a limited shelf-life after harvest. Unlike other fruits, feijoas do not change color markedly during ripening, thus it is very difficult to harvest ripe fruit. The technique of 'touch picking', which relies on using low force to detach the fruit from its stalk, is consider a practical and reliable method to harvest ready-to-eat feijoas just prior to the time of fruits' natural drop [90]. This method is widely accepted as commercial standard in New Zealand, but it is not always suitable for fruit which must withstand long periods in storage, in which early picking is required to reduce chilling injury incidence and retain quality attributes [91]. The use of near-infrared spectroscopy (NIRS) has high potential as an innovative non-destructive approach to assess the feijoa maturity at harvest [92,93]. Chlorophyll fluorescence, which indirectly indicates the physiological status of a green tissue, has been studied as a promising non-destructive technique in predicting ripening in the feijoas, but not reliable in detecting chilling injury [94].

During the postharvest phase, a variety of changes occur determining the quality of feijoas and leading to fruit senescence [95]. Although highly variable among cultivars, they generally include weight loss, taste deterioration, a rapid darkening of the flesh, and a higher susceptibility to fungal pathogens [96]. Anthracnose rot (*Colletotrichum gloeosporioides*) is the main cause of product loss both in the field and after harvest [97,98], followed by rots caused by *Botrytis cinerea*, *Penicillium* spp., and *Pestalotiopsis* spp., which particularly occur during the period of storage [99,100].

Regarding postharvest handling of fruits, no standard procedure from harvest to final consumption has been documented, and fruit handling specifications are provided differently by markets [91]. For this reason, in some cases, fruits are brushed to enhance glosses, whereas others are sold with the natural wax, both without washing [18].

Various studies have indicated the typical climacteric behavior of fruits with high respiration rates and ethylene production [18,101,102]; thus, the immediate refrigeration of fruit after harvest is required to reduce respiration rate, transpiration, ethylene activity, and microbial growth [96]. To eliminate ethylene from storage environments, an adequate ventilation with clean air from outside is necessary. The use of materials able to oxidize or absorb ethylene (zeolite, ozone, potassium permanganate) are recommended when ventilation is not possible, i.e., in controlled atmosphere [103]. A laser-based photoacoustic detector, with a sensitivity of 0.3 nL L^{-1}, was studied by Gwanpua et al. [104] to assess, in real time, fruit physiological status by endogenous ethylene measurement produced.

Feijoa, being a sub-tropical fruit, suffers from chilling injury at the recommended storage temperature of 4 °C. This physiological disorder affects fruits, reducing their marketability. Externally, the peel develops sunken spots that turn from green to brown and finally to black; internally, the vascular elements become brown, and the flesh develops a pink to brown color [105]. Often, these symptoms will not be visible until after fruits are transferred to 20 °C, making them unsaleable, with the consequence of substantial economic losses [18]. Although the chilling injury mechanism of development is not still well understood, Sevillano et al. [106] noted that ethylene biosynthesis, polyamines (PAs), and cellular abscisic acid (ABA) increased in chilled injury fruit.

Different strategies have been suggested to control chilling injury development in cold stored feijoa. Postharvest application of carnauba-based wax coating resulted in the reduction of weight loss and internal browning [107]. Treatments with 15% calcium chloride ($CaCl_2$) solution resulted in rots and weight loss reduction, with beneficial effects on fruits' storage life [52]. Moreover, the efficacy of intermittent warming was also studies, by alternating shorter warm periods with longer cold period to increase fruit resistance to low temperatures; differently from other fresh products, results showed an accelerated fruit ripening that led to faster deterioration [108].

The effect of cold storage on feijoas quality parameters was studied by several researchers with the aim to extend fruit shelf-life [90,109–111]. Application of 5 ± 1 °C and

90–95% relative humidity enabled to achieve four weeks of storage before the organoleptic qualities become altered and the flesh begins to darken. Klein and Thorp [100] obtained a varying response about internal browning and fruit quality, on feijoas stored at 4 °C for up to four weeks, with a subsequent shelf life of 5–7 days at 20 °C, depending on the cultivar, agricultural practices, and maturity. Some cultivars did not show internal browning during the whole storage, whereas others showed browning after only seven days of storage; in most cases, even if the fruit retained an external appearance, the flesh already showed signs of darkening and losses in taste and aroma.

Kwamboka [91] found that cold storage by polyliner packaging appeared beneficial to extending feijoa's shelf-life for up to 8 weeks at 1 °C, by water loss reduction and firmness and skin color retention. Nonetheless, many fruits developed chilling injury, thereby requiring integrated treatments able to reduce this physiological alteration. Moreover, an increased rots incidence, due to condensation inside packaging, was reported.

In addition to cold storage, controlled atmospheres (CA) and modified atmospheres (MA) have been studied as strategies useful to manipulate the activity of ethylene on fresh produce and extend its storage life. As reported by Zhuang et al. [112], inside CA or MAP bags, the high CO_2 levels produced inhibited activity of 1-aminocyclopropane-1-carboxylate (ACC) synthase, a key enzyme in ethylene biosynthesis. Al-Harthy et al. [113] applied CA to refrigerated 'Opal Star' feijoa fruit at 4 °C, obtaining slightly results in extending shelf-life, by 2.1 oxygen (O_2) and 0% carbon dioxide (CO_2), while reducing ethylene production, weight loss, and maintaining fruit firmness up to 10 weeks of storage. Despite the good visual fruit appearance, the same authors found that CA affected volatile production by suppression of the main volatile constituent.

Rupavatharam et al. [90] noted that the application of the ethylene activity inhibitor 1-methylcyclopropene (1-MCP) to 'Unique' feijoa during storage, resulted in no relevant quality effects on touch picked fruit. On the contrary, fruit harvested 2 weeks prior to touch picked maturity appeared visually acceptable after 6 weeks of storage; however, low soluble solid content (SSC) and high titratable acidity (TA) were reported. Amarante et al. [114] reported that the application of 1-MCP at 1500 nL L^{-1} for 8 h retain firmness and skin color during storage of the cultivar 'Brazilian' for 30 days.

Recent research interest has been focused on different use of feijoas by the development of innovative nanocomposite films for food packaging, made by biodegradable polymeric matrix and natural antioxidant. Through the studies carried out in the last few years, polyethylene oxide (PEO) nanocomposite films were produced, integrating feijoas aqueous extract from waste by-product, bringing an additional use of this multipurpose product as an alternative material to produce active food packaging [115]. Nanocapsules produced with feijoa and fortified with vitamin D3 were instead studied for the controlled release of active compounds (food fortification), to improve their bioavailability during food processing and storage, thus reducing nutritional deficiencies [116].

7. Conclusions and Future Perspectives

Feijoa trees are currently extensively cultivated in California and mainly in New Zealand, but it has a good adaptability to different environments. Climate changes are shifting the established pattern of fruit crops in Mediterranean area, favoring in some areas the cultivations of new tropical fruits. This species, firstly introduced as a home-garden plant, nowadays has begun to be cultivated in commercial orchards for its aromatic and nutraceutical fruits. Furthermore, feijoa edible flowers could be a profitable enterprise niche, especially for farms marketing to consumers and chefs interested in a novel use of edible flowers with high health and nutritional values. Optimization of appropriate strategies and agronomic management are needed to guarantee the sustainability of this fruit crop from farm to table. Furthermore, other studies are needed to advance the development and application of postharvest technologies that facilitate appropriate feijoa management, storage, and a possible re-use of processing waste, in view of a successful transition to a circular economy.

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