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Effect of preharvest conditions on the quality of important Myrtaceae fruits in Colombia. A review

Efecto de las condiciones precosecha sobre la calidad de frutas mirtáceas importantes en Colombia. Una revisión

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Fructification of feijoa tree. The fruiting behavior on the trunk is curious.
Photo: H.B. Balaguera-López

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ABSTRACT

The aim of this review is to provide information on the conditions that facilitate the production of high-quality Myrtaceae fruits that are important in Colombia. Many fruits of the Myrtaceae family have very important nutritional, functional, and economic characteristics. In Colombia, commercial fruit trees of the Myrtaceae family include guava (*Psidium guajava* L.), feijoa (*Acca sellowiana* [Berg] Burret), arazá (*Eugenia stipitata* McVaugh), and champa (*Campomanesia lineatifolia* R. & P.). Each of these species, and their varieties, must be planted in a suitable climate, soil and altitudinal range, and these factors influence their quality (nutraceutical, organoleptic, and physicochemical). Furthermore, the crop must be managed with the best cultural practices that guarantee the achievement of its genetic potential. These practices include pruning, which guarantees a physiological balance between vegetative and reproductive branches; nutrition, depending on the content of elements assimilable in soil; and tools such as foliar analysis. Regarding water, sites with a bimodal rainfall regime can guarantee two harvests per year, except in the case of champa, for which only one is reported, although irrigation can bring this forward. Facilitating effective pollination is a requirement for fruit formation and quality. Regarding the development of quality, guava and feijoa stand out for their high content of phytochemical substances (phenols, ascorbic acid, carotenoids, and antioxidant activity), which support their own defense in stressful conditions, and could help human consumers to counteract chronic diseases. Unfortunately, there is a lack of studies on these crops regarding, for example, the cultural practices that can increase these bioactive compounds in the fruit. More research is needed in the country to improve the quality of these fruits, with champa, which is grown only in department of Boyaca, being the least studied.

Additional keywords: *Psidium guajava*; *Acca sellowiana*; *Eugenia stipitata*; *Campomanesia lineatifolia*; fruit quality; tropical fruits; crop management.

RESUMEN

El objetivo de esta revisión es proporcionar información sobre las condiciones que facilitan la producción de frutas de alta calidad de la familia Myrtaceae, que son importantes en Colombia. Muchos frutos de la familia Myrtaceae poseen características nutricionales, funcionales y económicas muy importantes. En Colombia, dentro de los frutales comerciales de la familia Myrtaceae se encuentran entre otros, la guayaba (*Psidium guajava* L.), la feijoa (*Acca sellowiana* [Berg] Burret), el arazá (*Eugenia stipitata* McVaugh) y la champa (*Campomanesia lineatifolia* R. & P.). Cada una de estas especies, con sus variedades, debe ser sembrada en suelo, clima y rango altitudinal aptos que influencian su calidad (nutraceútica, organoléptica, físico-química); además el cultivo debe manejarse con las mejores prácticas culturales que garanticen el aprovechamiento de su potencial genético. Estas especies necesitan poda que garantice un equilibrio fisiológico entre ramas vegetativas y reproductivas, una nutrición dependiendo de los contenidos de elementos asimilables en el suelo; y herramientas como los análisis foliares. Los sitios con régimen pluvial bimodal pueden garantizar dos cosechas por año, excepto en la champa que solo tiene una, pero el riego si la puede adelantar. Facilitar una polinización eficaz es requisito para la formación del fruto y su calidad. En el desarrollo de la calidad, los frutos de las guayabas y feijoas se destacan por sus altos contenidos en sustancias fitoquímicas (fenoles, ácido ascórbico, carotenoides, actividad antioxidante), no solamente para su propia defensa en condiciones del estrés, sino también para los consumidores humanos para probablemente contrarrestar enfermedades crónicas. Lastimosamente estos cultivos carecen de estudios como para conocer las prácticas culturales que pueden aumentar estos compuestos bioactivos en el fruto. Se necesita más investigación en el país para mejorar la calidad de estos frutos, siendo la champa que se cultiva solamente en el departamento de Boyacá, la menos estudiada.

Palabras clave adicionales: *Psidium guajava*; *Acca sellowiana*; *Eugenia stipitata*; *Campomanesia lineatifolia*; calidad de la fruta; frutas tropicales; manejo del cultivo.

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INTRODUCTION

In Colombia, "exotic" fruits with sensory characteristics offer high nutritional and economic value (Combariza and Aranda, 2012). Due to increased awareness of their nutritional and health benefits, the consumption of tropical fruits has risen nationally and internationally in recent years (FAO, 2024). This has benefited Andean countries, which have significantly increased their export volumes in this new century (Moreno-Miranda *et al*., 2019).

Many fruits in the Myrtaceae family possess highly promising nutritional, functional, and economic characteristics (Lima *et al*., 2016; Araújo *et al*., 2019). In Colombia, the most prominent of the commercially grown Myrtaceae family fruits are guava (*Psidium guajava* L.) (Fig. 1A), feijoa (*Acca sellowiana* (Berg) Burret) (Fig. 1B), arazá (*Eugenia stipitata* McVaugh) (Fig. 1C), and champa or chamba (*Campomanesia lineatifolia* Ruiz and Pavon) (Fig. 1D), the last of which is currently grown to a lesser extent but has great potential. These fruits are well-received by consumers (Balaguera-López *et al*., 2022), their seeds have bioherbicidal potential (Martínez *et al*., 2022; Maestre *et al*., 2023), and their leaves possess medicinal properties (Neves *et al*., 2023). Guava is native to Central America and southern Mexico (Blancke, 2016), feijoa to southern Brazil, Uruguay, the highlands of western Paraguay, and northeastern Argentina (Parra-Coronado and Fischer, 2013), arazá to the western Amazon region between the Marañon and Ucayali rivers and near Requena city (Peru) and the headwaters of the Amazon River (Hernández *et al*., 2006); and champa to the Amazon regions of Brazil, Peru, Colombia, and Bolivia (Villachica *et al*., 1996). The fruits of these Myrtaceae species can be consumed fresh due to their rich flavor. Still, it is also common for them to undergo agro-industrial processes to produce juice, yogurt, jam, ice cream, and various other derivatives of great market interest (Farias *et al*., 2020).

The latest statistics on the area and production of these crops, according to MinAgricultura (2024), indicate that guava has the largest area and highest yield, while champa has the second-highest yield, but a small planted area. The production of these Myrtaceae crops is mainly concentrated in six departments. MinAgricultura (2024) also reports data for guava pear ('Palmira ICA-1'), with a planted area of 6,504 ha in 2018, predominantly in the department of Meta (52.2% of national production); and the hybrid 'Manzana', with 220 ha in 2017, especially in department of Huila (61.6%).

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Figure 1. Some Myrtaceae fruits, grown in Colombia. A, guava (photo: G. Fischer); B, feijoa (photo: G. Fischer); C, arazá (photo: J. Barrera), and D, champa (photo: A.L. Balaguera).

Table 1. Area and production of guava, feijoa, arazá, and champa in Colombia, including the two departments with the highest production (MinAgricultura, 2024).

Species	Year	Area (ha)	Production (t)	Yield (t ha^{-1})	Departments (% national production)
Common guava	2022	12,292.5	163,115.67	13.27	Santander (38.89%) Meta (19.46%)
Feijoa	2022	339.3	3,133.3	9.23	Boyacá (71.98%) Cundinamarca (23.38%)
Arazá	2022	227.8	771.24	3.39	Amazonas (48.75%) Putumayo (25.48%)

Champa	2022	8.1	89.7	11.07	Boyaca (100%)

The Myrtaceae family stands out for its botanical abundance and agro-industrial importance, including 5,800 species across 121 genera that develop aromatic fruits. According to Farias *et al*. (2020), it is one of the most notable commercial families globally. The species of this family are distributed throughout the tropics, with concentrations in South America, Australia, and Southeast Asia (Asif, 2015).

Parra-O. (2014) mentions that in Colombia there are 24 genera and 165 species of Myrtaceae, with 52% of the native species of this family distributed between 0 and 1,000 m above sea level (m a.s.l.) and only 10% between 2,000 and 3,500 m a.s.l. From a commercial perspective, there are some species and varieties whose fruits are useful for human consumption, others with antioxidant and fungicidal properties derived from extracts of their leaves and branches, and others that can be used as rootstocks for commercial varieties (Trujillo *et al*., 2018).

As well as the four species mentioned in table 1, there are other known Myrtaceae fruits in the country. These are not commercialized crops and are often used for traditional medicine purposes, for example camu-camu (*Myrciaria dubia*), pitanga (*Eugenia uniflora*), jaboticaba (*Myrciaria jaboticaba*), and pomarrosa (*Syzygium jambos*).

Asrey *et al.* (2018) note that the physiological behavior, as well as the quality and perishability of the fruits, depend on the individual characteristics of each fruit, in addition to environmental conditions, crop management, and post-harvest treatments. Wills and Golding (2016) defines quality as the desired attributes of products being marketed, including the attributes of appearance, texture, flavor (aroma), and nutritional value of the fruits. The attributes that define the quality of the fruit depend on who is classifying it; thus, for the marketer, appearance, firmness, and post-harvest shelf life are the most important, while for the consumer, good taste and nutritional value are key, among other factors.

The quality characteristics of fruits at harvest and post-harvest are determined largely by factors relevant to the cultivation stage, since post-harvest technologies can only maintain quality, not improve it (Yahia, 2019). In many cases, post-harvest studies have not sufficiently considered the influence of factors during cultivation, such as climate conditions and management practices, on fruit quality (Barman *et al*., 2015). Due to this

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situation, the production of high-quality Myrtaceae fruits requires the right variety, suitable environmental conditions, and appropriate crop management practices (Fischer *et al*., 2018). Therefore, the aim of this review is to provide information on the conditions that facilitate the production of high-quality Myrtaceae fruits that are important in Colombia, namely: guava, feijoa, arazá, and champa.

DEVELOPMENT OF FRUIT QUALITY DURING CULTIVATION

As previously indicated, decisive factors for the development of fruit quality during cultivation are the environmental conditions, plantation management, the genetics of the variety, and the interactions between these factors (Fischer *et al*., 2018).

Environmental factors and fruit quality

In many cases, as Raza *et al*. (2020) state, fruit trees are grown in unsuitable conditions that do not allow them to reach their maximum potential. These suboptimal environmental conditions result in yields far lower than the reported maximum. Environmental factors greatly affect the quality and nutritional value of the fruit (Yahia *et al*., 2019a), but these conditions are difficult to control in open fields. Additionally, fruit trees are among the species most affected by climate change, as global warming leads to reduced yields and fruit quality, especially in tropical and subtropical regions (Shukla *et al*., 2019). The environmental conditions of the planting site are crucial for fruit quality formation and form the basis for the production of commercial crops in a given region or country (Fischer and Orduz-Rodríguez, 2012; Fischer *et al*., 2018).

Ladaniya (2008) specifies that the cultivation environment influences processes such as photosynthesis, respiration, transpiration, translocation of photoassimilates, and overall plant metabolism. Consequently, these processes are essential for the development of both external and internal fruit quality and their post-harvest behavior. Therefore, ecophysiology studies are of the outmost importance in ensuring that the full potential of a variety in a given location is reached. According to Lambers and Oliveira (2019), plant ecophysiology studies the physiological mechanisms resulting from ecological observations, with a focus on the growth, physiology, reproduction, and survival of plants, as these processes depend on the interactions between plants and their physical, chemical, and biotic environments.

In Colombia, a tropical country with significant mountainous areas, Myrtaceae are cultivated at different altitudes, ranging from 0 to 2,700 m a.s.l. (Tab. 2). It is important to note that, with every 100 m of elevation gain, the temperature decreases by 0.6 to 0.7°C (Benavides *et al*., 2017; Fischer *et al*., 2022a). Similarly, atmospheric pressure and the partial pressures of O_2, CO_2, and N_2 decrease by 11% (at 20°C) for every 1,000 m increase in altitude (Körner, 2007). In contrast, with a 1,000 m increase in altitude, UV-B radiation increases by 10-12% (Benavides *et al*., 2017).

Table 2. Recommended climatic and altitude conditions for the production of four Myrtaceae fruits in Colombia.

Climatic factor	Common guava	Feijoa	Arazá	Champa
Altitude (m a.s.l.)	0-2,000	1,800-2,700	0-650	800-1,600
Temperature (°C)	15-30	13-21	18-30	22-30
Light/solar radiation	≤ 2,000 µmol photons m^{-2} s^{-1}	≥1,500 h sunlight brightness/year	1,200-2,000 h sunlight brightness /year	~1,500 h sunlight brightness /year*
Precipitation (mm $year^{1}$)	1,000-2,000	700-1,200	2,500-4,000	>1,500
References	Solarte *et al*. (2014), Fischer and Melgarejo (2021)	Fischer and Parra-Coronado (2020)	Escobar *et al*. (1999), Barrera *et al*. (2012)	Balaguera-López *et al*. (2022)

* The requirement for the species is not known, it was estimated using the values from the production zone.

This information on the changes in climatic effects with altitude is key to their optimal cultivation due to the temperature requirements of the crops. Only feijoa can withstand cold conditions above 2,000 m a.s.l. (Tab. 2). The fruits can be affected by sunburn due to the increase in UV-B radiation (Fischer *et al*., 2022b), especially during dry seasons and when there is insufficient canopy shading over the fruits. Due to the high sun exposure susceptibility of arazá, it is recommended that this crop will be integrated into an agroforestry system that provides moderate shade, such as with *Cordia alliodora* or *Hevea*

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brasiliensis (Van Kanten and Beer, 2005; Fernández-Trujillo *et al*., 2011). Sunburn has not been reported as a limiting factor in champa, possibly due to the tree's abundant foliage.

However, within certain ranges, exposure of fruits to direct sunlight favors the fruit's protection system by increasing the production of antioxidants (especially phenols) in their epidermis, which also enhances the nutritional and medicinal values of this edible organ (Fischer *et al*., 2016). In cases of excessive and prolonged solar radiation, the temperature of the epidermal tissues increases, which can cause necrosis, fruit cracking, and other problems (Fischer *et al*., 2021).

On the other hand, if crops are planted at higher altitudes, it may be possible to offset the detrimental effects of heat, with these tropical elevations being considered "escape zones from global warming" given the temperature increase due to climate change (Fischer *et al*., 2022a). Thus, Duarte and Paull (2015) recommend planting arazá at even higher elevations than those indicated in table 2, specifically below 700-800 m a.s.l. and preferably in warm, humid tropics.

Due to the colder environments at higher altitudes, production cycles start later and fruit development is prolonged (Fischer *et al*., 2024). Parra-Coronado *et al*. (2015a, 2015b) observed the growth of feijoa at two altitudes in Cundinamarca. They found that fruits grown at 2,580 m a.s.l. (in Tenjo township, average temperature 12.3°C) developed over 180 d and had higher concentrations of sucrose (Parra-Coronado *et al*., 2022) and total soluble solids (Parra-Coronado *et al*., 2015a) than fruit grown in San Francisco de Sales township (1,800 m a.s.l., 18.5°C), which took only 149 d to develop. According to Parra-Coronado *et al.* (2015a), this improved quality is due to higher accumulated solar radiation at the higher elevation site. Furthermore, prediction models and regression analyses confirmed that altitude, accumulated precipitation, and growing degree days (GDD) had the greatest impact on physicochemical characteristics during fruit development (Parra-Coronado *et al*., 2016), especially the weight and size of mature feijoa fruits.

Champa has one harvest per year, with peak production in September (López and Rodriguez, 1995). However, harvesting in lower-altitude zones in the same region can begin much earlier, even as early as May, indicating the role of temperature in shortening the phenology of this species. At 1,432 m a.s.l. with an average temperature of 22.3°C, Balaguera-López *et al*. (2012) estimated that the duration from flowering to fruit harvest of champa was 145 d, accumulating 1,422.8 GDD. The duration of fruit development can vary due to several factors, and another previous report estimated the duration at 160 d (Balaguera *et al*., 2009).

Regarding the effect of CO_2, which increases due to climate change but decreases with increasing altitude, these fruit trees are not likely to be affected because higher levels promote photosynthesis, biomass production (Lambers and Oliveira, 2019; Fischer *et al*., 2022c), and in some cases, fruit quality (Moretti *et al*., 2010). Also, elevated CO_2 concentrations will lead to more efficient water use (Fischer *et al*., 2022c). However, there is much uncertainty due to increasing temperatures and extreme changes in humidity. There is still a lack of research on this topic in fruit trees, with no studies at all for most commercial Myrtaceae species (Fischer *et al*., 2024).

Furthermore, in fruit trees, it is possible that the number of leaf stomata increases with increasing altitude, as found by Fischer and Melgarejo (2020) in cape gooseberry at 2,690 m a.s.l., to counteract the lower partial pressure of CO_2 at high altitudes. This effect has not yet been investigated in most fruit species.

However, guava, arazá, and champa thrive in temperatures of up to 30°C (Tab. 2). Increases in temperature due to global warming can affect the growth and development of plant organs, causing morphological, anatomical, physiological, and biochemical changes that drastically affect the commercial yield of crops (Moretti *et al*., 2010). In guava fruits, very high temperatures, such as in the summers of subtropical regions, decrease sugar and organic acid levels, which are used in respiration (Solarte *et al*., 2014). Similarly, in feijoa, global warming will not only reduce the time for fruit development but also increase sugar levels at the expense of acids (Ubeda *et al*., 2020), resulting in fruits with an undesirably high sugar/acid ratio.

Knowledge of the base temperature (minimum for growth) or for a specific phenological phase of the fruit tree is very useful when choosing a site for planting. Parra-Coronado *et al*. (2015b) calculated the base temperature for feijoa fruit development as 1.76°C and for flowering as 3.04°C, while Ferreira *et al.* (2019) calculated the minimum temperature for guava plant growth as 10.9°C, and Insuasty *et al*. (2007) observed that guava fruits do not ripen at temperatures as low as 3°C. For champa, the base temperature has not yet been identified, although GDD have been determined (Balaguera-López *et al*., 2012).

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Due to feijoa's adaptation to lower temperatures, it can also be grown in temperate zones, producing large fruits with higher yields in locations with not-so-low winter temperatures (Morley-Bunker, 2010). In this context, Duarte and Paull (2015) note that, in warmer temperatures, the phenological stages of flowering and fruit ripening of feijoa are brought forward by up to 8 weeks compared to colder climate zones.

In feijoa, as mentioned earlier, higher accumulated solar radiation increases the sugar content (total soluble solids [TSS] and sucrose) in the fruit. For arazá, Hernández *et al.* (2006) reported that plants that develop in shaded habitats do not achieve very high photosynthetic rates but are still efficient at these low light intensities.

Due to the relative uniformity of temperature and photoperiod in the tropics throughout the year, rainfall has a greater impact on the growth, production, and quality of fruit trees (Ramírez *et al*., 2021). Prolonged periods of drought, which have increased significantly due to global warming, are the most prevalent abiotic stressors globally, greatly limiting the growth and productivity of fruit trees (Taiwo *et al*., 2020). Low ambient humidity and drought during the flowering stage severely affect fruit set, leading to fruit drop as reported by Paull and Duarte (2012) for guavas. In more advanced stages of guava development, Mercado-Silva *et al*. (1998) found that water scarcity promotes an increase in sugar concentration due to a concentration effect, with fruits only reaching a medium or small size under severe drought conditions (Lozano *et al*., 2002). Balerdi *et al.* (2003) classified guava as moderately tolerant to drought conditions. In feijoa, a rather dry climate promotes flowering (Quintero, 2012); however, a long dry season can cause the dropping of flowers, fruits, and leaves and prolong fruit ripening (Fischer and Parra-Coronado, 2020).

Interestingly, guava also tolerates waterlogging (Balerdi *et al*., 2003). Indeed, crops in areas with abundant rains making them more susceptible to cracking (Fischer and Melgarejo, 2021). Additionally, prolonged rainy seasons result in watery fruits with low contents of ascorbic acid, titratable acidity, and sugars (Souza *et al*., 2010). Furthermore, many of these fruits fall due to the increased incidence of diseases in very humid conditions (Solarte *et al*., 2010). In addition, in feijoa, very humid conditions during flowering decrease the number of set fruits due to the incidence of *Botrytis cinerea* in flowers and the difficulty of pollination because pollinating birds do not fly in the rain, resulting in fruits formed under these conditions being of low caliber and asymmetric (Quintero, 2012). For

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arazá, Fernández-Trujillo *et al*. (2011) report large fruits with good color (h* 83 to 88º, C* 49 to 54 units) with rainfall between 200 and 300 mm per month, while Duarte and Paull (2015) mention that arazá adapts to such different rainfall conditions between 1,500 and 4,000 mm per year. Moreover, for champa, planting is generally recommended in areas with rainfall exceeding 1,500 mm per year (Tab. 2). In this fruit, cracking also occurs because of irregular water supply (Fig. 2).

Figure 2. Champa fruit with cracking symptom. Photo: A.L. Balaguera.

Cultural practices and fruit quality

Proper crop management increases the productive potential of the species and variety, as well as their quality at harvest and post-harvest (Fischer *et al*., 2018; Fallik and Ilic, 2018). This proper management involves understanding the implications of factors such as pruning, irrigation, fertilization, and pollination, among others. Below are some considerations regarding these factors in the management of the Myrtaceae of interest.

Pruning. Many tropical fruit species have a natural tendency to develop in a suitable form; however, they often need assistance to form the desired canopy (Paull and Duarte, 2012). As a general rule, to avoid sunburn, Myrtaceae fruit trees need leaves above their fruits to reduce the intensity of direct sunlight, especially UV in high-altitude areas; this can be achieved by pruning and proper training (Lal and Sahu, 2017; Fischer *et al.*, 2022b). It is important that trees maintain a physiological balance between vegetative and reproductive branches, which is achieved by pruning after harvest and/or by removing some unwanted branches during fruit development, such as suckers and non-fruiting parallel branches, and by tipping very long branches to remove overly vegetative branches that compete for assimilation with developing fruits (Casierra-Posada and Fischer, 2012).

Excellent results have been achieved with the formation of more open canopies for guava, for which the single-trunk tree should branch out at a height of about 50 cm, or the central axis should be tipped to encourage the insertion of branches in a more horizontal position (Fischer *et al*., 2012).

Technified feijoa crops require pruning because of the effects this has on floral induction, improvement of productivity, and quality of production, as well as to support phytosanitary controls (Quintero, 2012). For feijoa, highly productive trees with a central leader and more horizontal lateral branches (up to a maximum of 90°) are preferred, which reduces vegetative growth in favor of fruiting and ensures good fruit size (Quintero, 2003). In feijoa pruning, very thin and short branches (about 15 to 30 cm, mostly hanging inside the canopy) should not be removed, as these are very fruitful (Duarte and Paull, 2015). A more intense pruning in feijoa, thinning out branches with low production or overly vigorous branches within the canopy, reduces the leaf area and the number of fruits but favors the size of the remaining fruits (Sánchez-Mora *et al*., 2017). In feijoa trees, Quintero (2003) observed that pruning in the reproductive state (with floral buds, flowers, or newly set fruits) ensures the induction of new branches with more floral buds, unlike when the plant is pruned in a state of "infertility."

For arazá, Reyes (2012) recommends forming plants with three or four thick primary branches, and then, during production, applying only maintenance and sanitary pruning.

For champa, there are no established pruning systems, a result of low cultivation technification. The plant grows while maintaining its natural architecture and can reach up to 10 m in height, with a strong main stem and a densely branched canopy (Balaguera, 2011; Nates-Parra *et al*., 2016). This creates difficulties in management, mainly in harvesting, which is why it is common for fruits to be collected from the ground after they detach from the tree (Villachica *et al*., 1996; Balaguera-López *et al*., 2012), causing mechanical damage that further limits their short post-harvest life. The high density of the canopy can also generate fruit quality problems by limiting the entry of light for photosynthesis and fruit ripening, creating a microclimate with higher humidity that can increase disease problems. The champa tree is similar to the guava tree, so initially, the pruning recommendations for this species can be followed (Fischer *et al*., 2012), while establishing a specific pruning for champa.

Nutrient application and plant hormones. The nutrition of fruit trees greatly influences the production and quality of their fruits, with proper nutrient management being vital for tree growth and development (Buitrago *et al*., 2021). Proper nutrient management in fruit trees also helps better control diseases that can affect fruit quality and reduces the use of pesticides, ensuring higher sustainability in production systems (Bautista-Montealegre *et al*., 2022). Fertilization decisions for commercial crops depend on soil and foliar sampling results (Fischer *et al*., 2012).

In guava, Lozano *et al*. (2002) reported that excessive nitrogen fertilization during flowering induces floral abortion, while near to harvest, it restricts post-harvest life. To increase average yields of guava fruit by 45%, as well as the content of TSS, sugars, and ascorbic acid in the fruit, Paull and Duarte (2012) recommend applying urea and phosphate in the leaves at the pre-flowering stage and point out that Ca deficiency can cause blossom-end rot in fruits, leading to their abscission.

Due to the effect of potassium on the yield and quality of fleshy fruits (Rengel *et al*., 2023), trials with foliar application of K_2SO_4 (2%) or KNO_3 (2%) in guava ('Sardar') resulted in high-quality physical and chemical fruit parameters (Ritthe *et al*., 2023). The best results were found when applying 2% KNO_3 in the 'Allahabad Safeda' variety (Shukla and Bisen, 2021).

On the other hand, Sau *et al*. (2018) suggest foliar fertilization, combining boric acid with zinc sulfate (0.2% H_3BO_3 + 0.5% $ZnSO_4$), which increased the weight, volume, total soluble solids, and ascorbic acid of 'Allahabad Safeda' guava fruit compared to the control. Meanwhile, Kumar *et al*. (2017) found higher TSS, ascorbic acid, and fruit firmness, as well as lower acidity, in 'Taiwan Pink' guava when applying 3% potassium phosphate foliar pathway, compared to treatment with zinc sulfate (0.2-0.4%) or urea (2-4%). These results on fruit quality, which are sometimes contradictory, indicate the significant influence of soil and leaf nutritional status, variety, plant age, and climatic zone of cultivation.

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Regarding the application of plant hormones in guava, Tiwari *et al*. (2024) applied 200 mg L^{-1} of naphthalene acetic acid (NAA) in the "marble" stage of 'L-49' guava fruit, with a second application 15 d later. They found this had a very beneficial effect, increasing physical characteristics, yield, and fruit quality (TSS and ascorbic acid) compared to benzyl adenine (BA) and different combinations of the two hormones.

Fischer *et al*. (2020) reported for feijoa that soils with a Ca/Mg ratio ≥10 develop fruits that are brown, chlorotic, cracked, and have a short shelf life (<3 d post-harvest), which can be controlled with dolomitic lime (3 kg/plant-year) (Quintero, 2003). Also, feijoa plants in soils with pH <5.0 can develop chlorotic fruits, especially in combination with nitrogen deficiencies, and for this reason Quintero (2014) recommends amending with dolomitic lime (3 kg/plant-year) and applying nitrogen fertilizers (urea, 17-6-18-6, or 18-18-18), 500 g every 4 months.

Rupavatharam *et al*. (2016) applied aminoethoxyvinylglycine (AVG), an ethylene synthesis inhibitor, 4 weeks before commercial harvest in 'Unique' feijoa and observed a delay in maturity and a lower ethylene production during storage. However, these fruits increased their titratable acidity content while decreasing soluble solids, compared to fruits not treated with AVG, affecting their maturity ratio.

Arazá performs well with N applications in conditions of poor soil, as well as with P and N in acidic tropical soils, and overall, K seems to be an effective fertilizer for this crop, according to Duarte and Paull (2015). Good results in fruit production have been achieved by applying organic matter in a fractionated form, around 8 kg/plant-year, or by applying 1 kg of chicken manure per plant every three months, which is increased every year by 1 kg (Reyes, 2012).

Regarding champa, no fertilization studies have been conducted, and it is considered that there is an urgent need to know at least the nutritional requirements and main deficiency symptoms. This will provide basic information to generate appropriate fertilization plans for the species. Villachica *et al*. (1996) mention that, for plantings of 6 × 6 m, it is recommended to apply 10 kg of organic fertilizer and 100 g of triple superphosphate at each site. Champa fruit is highly perishable, and one of the causes of this is its low firmness (Balaguera-López *et al*., 2022). In this regard, special attention is recommended through fertilization with calcium and boron.

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Irrigation. It is well known that, in fruit plantations, regular water supply is key to meeting the trees' need for optimal vegetative and reproductive growth. For feijoa, Duarte and Paull (2015) note that two harvests per year are possible where a bimodal rainfall regime exists.

In these tropical and subtropical fruits, different phenological stages have their own water requirements. Moderate humidity periods promote floral induction, while for full flowering, fruit setting, and fruit filling, sufficient soil moisture is required to produce a good number of fruits with adequate size for national and international markets (Fischer and Melgarejo, 2021). These authors also point out that excessive rainfall or over-irrigation during fruit development can make them watery, with low firmness and low content of sugars, titratable acidity, and ascorbic acid.

In guava, Salazar *et al*. (2006) reported that the trees require a water apply of approximately 1,000 to 2,000 m^3 ha^{-1} per year. However, Aguilera-Arango *et al*. (2020) observed good crop development and production in areas with a bimodal rainfall pattern, where annual precipitation ranges from 800 to 1,300 mm and is well-distributed. For arazá crop, approximately 2,500-4,000 mm of precipitation per year (Tab. 1) should be supplied. If rainfall is insufficient, an irrigation system should be used, as a water deficit affects flowering and fructification (Hernández *et al*., 2006). It has been found that the formation of flower buds is possibly stimulated by rainfall (Hernández *et al*., 2006). The champa production area has a monomodal rainfall distribution. The tree naturally blooms once a year when the rainy season begins between March and April (Rodríguez *et al*., 2015), after a prolonged dry period. This is a general indication that a water deficit, followed by a good water supply, is necessary to induce flowering. Some farmers who are able to do so provide irrigation to the trees in the dry season after the rest period because it is an interestingly deciduous tropical species. In this way, they have managed to advance flowering and harvest.

Pollination. Guava develops bisexual flowers with a 60 to 75% self-pollination rate and a 35% cross-pollination rate, with few problems in fruit set in most clones. If one wants to cultivate triploid cultivars, Paull and Duarte (2012) advise establishing them together with diploid clones as pollen donors.

In the case of feijoa, the pollination process is a key reproductive event for the fruit set (Ramírez and Kallarackal, 2017). In feijoa, it is important to note that, besides some self-fertile cultivars (autogamy), others require cross-pollination (allogamy), mainly by birds (e.g., blackbirds) and some insects like bees or hoverflies in commercial plantations (Santos *et al*., 2022). The first flowers are allogamous and the later ones autogamous, with cross-pollination resulting in the highest percentage of fruit set, between 80 and 90%, and larger harvested fruits (Quintero, 2012). In Colombia, for establishing a feijoa plantation, Quintero (2014) recommends using cultivars from the CENAF selection: 41, 8-4, 15-1, UN, and K3, planting more than one cultivar in the plantation.

In arazá, after self-pollination (2%), the best pollination is done by bees such as *Apis mellifera* (L.), *Eulaema mocsaryi* (Friese), *Eulaema bombiformis* (Packard), *Melipona lateralis* (Erichson), *Megalopta* sp., and *Melipona pseudocentris* (Cockerell), ensuring a 25% fruit set (Reyes, 2012).

Champa has white flowers with numerous stamens. The floral characteristics facilitate self-pollination, but cross-pollination is required for successful seed and fruit formation (Nates-Parra *et al*., 2016). Interestingly, pollen from the same plant can initiate fruit formation, but then abortion occurs, indicating that it is an obligate xenogamous species and requires pollinators (Rodríguez, 2014; Rodríguez *et al*., 2015). Nates-Parra *et al*. (2016) report that anthesis is diurnal, occurring between 5:30 and 8:00 am and lasting around 10 h, with peak pollination in the morning. The flower is highly aromatic but does not produce nectar, so the only reward for pollinators is pollen. The species has several insect visitors, but the main ones are bees of the *A. mellifera* species and various species of the *Melipona* genus (Calderón-Acero and Nates-Parra, 2013; Rodríguez, 2014). Interestingly, multiple visits from the same species or combined visits from two or more species are required for successful fruit formation (Nates-Parra *et al*., 2016).

Phytosanitary status. Due to climate change and climate variability, there are uncertainties regarding the impacts of some pests and diseases (Tito *et al*., 2018), which can influence quality and affect food security. Additionally, outside their optimal altitudinal range, crops may suffer from a higher incidence of pests and diseases (Fischer *et al*., 2024).

The pests that affect the quality of guava fruit are mainly the fruit fly (*Anastrepha striata* [Schiner] or *A. fraterculus* [Wiedemann]). To protect improved varieties from these pests or from sunburn, fruits in Colombia are bagged, using bags made of PE with a thickness between 0.5 and 3 mm, measuring 20 cm long by 15 cm wide. These bags are placed on healthy and clean fruits with one month of development (Fischer *et al*., 2012). This practice of bagging guava fruit is very common in its largest producing country, India, where non-woven polypropylene bags are used, thus controlling pests and diseases and improving quality, especially during the rainy season (Sharma *et al*., 2020). The most limiting diseases of guava fruit are fruit rot (*Pestalotia versicolor* [Spegazzini] Steyaert) and anthracnose (*Colletotrichum gloeosporioides* or *C. psidii*) (Fischer *et al*., 2012).

For feijoa, the pests that most affect the fruit are, as in guava, the fruit fly (*A. fraterculus*) and lepidopterans that oviposit on the fruits, known as the "pink worm" (Quintero, 2012). Regarding diseases, *Botrytis* affects the petals and, in the case of intense rainfall, can cause the total loss of flowers and fruits (Quintero, 2012). The blackbird (*Turdus fuscater* Orbigny and Lafresnaye), one of the main pollinating agents, eats the sweet petals of the feijoa, including those affected by *Botrytis*, thus controlling the disease, especially during drier weather conditions (Perea *et al*., 2010).

Also, in arazá, the fruit fly (*Anastrepha obliquoa* [Macquart] and *A. striata*) affects the fruit, as do the weevil *Conotrachelus* sp. and the black bee *Trigona branneri* (Cockerell), while the diseases of this organ are mainly anthracnose (*C. gloeosporioides*), brown spot (*Cylindrocladium scoparium* [(Ellis and Everhart) Rossman *et al*.]), and rust *Puccinia psidii* ([G. Winter] Beenken) (Fernández-Trujillo *et al*., 2011; Reyes, 2012).

In champa, the main pests are *A. striata*, whose parasitism in fruits can be around 39% (Carrejo and González, 1999), and the coleopteran *Costalimaita ferruginea* (Fabricius) (Villachica *et al*., 1996).

GENETIC MATERIAL AND QUALITY

The development of new varieties is essential for fruit trees to maintain fruit production and quality in the face of extreme climatic events (Balfagón *et al*., 2022). In this regard, due to the potential of Myrtaceae crops for producers and national and international markets, as well as their high phytogenetic value, a country-wide program to find genotypes superior to current ones in terms of resistance to combined abiotic and biotic stress along with high fruit quality, would greatly contribute to the resistance of these crops against climate change (Valdés-Infante *et al*., 2012; Fischer and Melgarejo, 2021).

In Colombia, for guava, consumers prefer large fruits with red pulp and oval and oblong shapes that show suitable postharvest behavior (Fischer *et al*., 2012). The varieties selected as outstanding by the Colombian Corporation for Agricultural Research (Agrosavia) include 'Palmira ICA-1' (sweet, known as 'Pera'), 'Roja ICA-2', and recently, 'Corpoica Carmín 0328' and 'Corpoica Rosa-C', among others. The last two, originating from the Guava Germplasm Bank of the Palmira Research Center, are notable for their high yield (>20 t ha^{-1}), high vitamin C content (≥75 mg/100 g pulp), and agro-industrial value (>10.4 °Brix, acidity <0.7% citric acid, and maturity ratio >11.7) (Carabalí *et al*., 2019). Apart from these selected varieties, the Thai hybrid 'Manzana' meets the preferences of consumers in the country (Fischer *et al*., 2012). Unfortunately, there is no information on how these varieties behave under conditions of climate change. Additionally, Lozano *et al*. (2002) warn of possible genetic problems in plants propagated from seed due to early maturity and poor fruit quality.

The CENAF farm (National Feijoa Center) near La Vega township (Cundinamarca) has more than 1,500 accessions of feijoa, from which the five cultivars for technified crops were selected: 'Clone 41' (Quimba), '8-4', '15-1', 'UN', and 'K3'. These cultivars produce fruits >60 g and yield >20 kg/plant per year, have smooth skin, especially 'Quimba', and have a maximum of only 20% inferior quality (industrial) (Quintero, 2012). In order to preserve the quality of feijoa fruit in regions with higher temperatures, such as the aforementioned undesirable increase in the sugar/acidity ratio, Parra-Coronado and Fischer (2013) recommend selecting genotypes that do not exhibit this behavior. Likewise, there is a need to develop new feijoa varieties with a reduced content of the unpleasant soluble oxalate (Zhu, 2018).

In arazá, there are no varieties, but two subspecies have been reported: *Eugenia stipitata* subsp. *stipitata* and *E. stipitata* subsp. *sororia*, the last of these being considered the cultivated type (Reyes, 2012) and closer in habits of a shrub (Duarte and Paull, 2015).

For champa, there are no reports of varieties; it is only known that the cultivated species is *Campomanesia lineatifolia* Ruiz & Pavon. However, the heterogeneity in the size and organoleptic quality of the fruit suggests that, in addition to environmental and management conditions, there could be genetic variability.

FRUIT GROWTH, YIELD, HARVEST AND QUALITY

The four Myrtaceae species in this review are climacteric fruits, meaning that their growth and development can occur when they are attached to the plant or after harvest, depending on their stage of development (Fischer *et al*., 2018). The degree of maturity chosen as optimal at harvest depends on the destination of the fruit and greatly affects its post-harvest life and commercialization (Parra-Coronado, 2014).

As mentioned earlier, guava shows high variation among its varieties in terms of growth, physicochemical composition, and fruit yield (Fischer *et al*., 2012). Depending on the cultivar, TSS can increase from 3% in green fruits to over 10% in mature ones, and total titratable acidity from 0.2 to 1.5% (Paull and Duarte, 2012), with large differences between varieties. Due to the decrease in temperature with altitude, the content of organic acids increases in several guava varieties (Solarte *et al*., 2014), while TSS increases with the average temperature of the site (Chiveu *et al*., 2019).

Paull and Duarte (2012) report average guava yields in Hawaii of 26.9 t ha^{-1}, while in Colombia yields only reach half that, 13.3 t ha^{-1} (Tab. 1) (MinAgricultura, 2024), indicating an urgent need for improvements in the country's cultivation. Guava fruit development follows a simple sigmoid curve that can last between 120 and over 220 d depending on the temperature of the plantation site, with differences between varieties of up to 60 d to reach the maturity period (Paull and Duarte, 2012). Harvesting later than indicated in table 3, when the fruit is more mature, carries the risk of fruit fly stings and subsequent larval development in the pulp (Paull and Duarte, 2012). Additionally, bioactive compounds and antioxidant capacity vary according to the developmental stage and variety of guava. While Shukla *et al*. (2018) observed a decline in bioactive constituents and antioxidant capacity during fruit development, except for vitamin C, which increases with ripening, Araújo *et al*. (2015) detected the opposite, i.e., a decrease in ascorbic acid content and an increase in flavonoids with fruit maturity.

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Table 3. Recommended harvest index for the four Myrtaceae fruits.

Specie	Maturity index of harvest[1]	Author
Guava	Color change from green to yellow with initial softening of the pulp.	Paull and Duarte (2012)
Feijoa	Fruit detaches from the peduncle; lower consistency in the equatorial zone of the fruit.	Schotsmans *et al*. (2011)
Arazá	Skin color "hue" value (h*) of about 110° (dull green), pulp firmness of 30 N, with a titratable acidity (TTA) of 300 mmol L^{-1} of H^+.	Fernández-Trujillo *et al*. (2011)
Champa	Color change from green to yellow. Fruits that are 100% yellow (L*: 76.2, a*: -3.4, b*: 51.3) exhibit optimal organoleptic characteristics but have a short postharvest life.	Balaguera-López and Herrera (2012)

[1]The index can vary depending on the destination of the fruits and particular export requirements.

Commercial production of feijoa begins in the sixth year (Quintero, 2014). At full production (from the 6th year onwards), a feijoa orchard can yield between 20 and 25 t ha^{-1} (30-40 kg/tree) (Thorp, 2008). However, the national average yield is 9.2 t ha^{-1} (Tab. 1) (MinAgricultura, 2024), which Quintero (2014) attributes to the planting of unimproved genetic material. Fruit development, as observed by its weight and diameter, follows a simple sigmoidal curve, similar to guava (Galvis, 2003). According to Quintero (2012), it takes between 120 and 150 d for feijoa fruit to reach harvest maturity, depending on the variety and cultivation conditions. However, as described earlier, Parra-Coronado *et al*. (2015a) waited up to 180 d for the Quimba variety in Tenjo (Cundinamarca) before harvesting it. Parra-Coronado *et al*. (2016) obtained a logistic sigmoidal growth model for feijoa fruit weight as a function of thermal time and elevation of the production area. As it is a green fruit, determining harvest maturity requires a lot of experience, and indicators include peduncle detachment, fruit firmness (Tab. 3), fruit shape and size, and shade of green (Parra-Coronado and Fischer, 2013). In optimal conditions with very abundant feijoa production, Duarte and Paull (2015) suggest thinning out unsuitable fruits (very small or deformed) at their early stage of development, which promotes the size and quality of the remaining fruits.

Significant yields in arazá begin in the third year, and by the fifth year, it reaches high yields, with an adult tree producing between 10 and 35 kg of fruit per year and producing fruit throughout the year if soil moisture and temperatures are optimal (Duarte and Paull, 2015). The arazá fruit growth behavior pattern is sigmoidal fitted a logistic model, the period between fruit set and full ripening of fruit grown in the Colombian Amazonia was 55±5 d (Hernández *et al*., 2007). Fruits destined for the fresh market should be harvested when they are green but beginning to turn yellow (breaker), following the indications given by Fernández-Trujillo *et al*. (2011; Tab. 3). Fruits harvested when fully green do not ripen later (Galvis and Hernández, 1993), and fruits harvested later than the breaker stage are only suitable for processing. Fruits harvested at the breaker stage ripen in 2-3 d to a fully yellow and very soft texture, requiring daily harvesting (Duarte and Paull, 2015).

Currently, champa is propagated sexually through seeds (Porras *et al*., 2020), mainly due to a lack of knowledge about more appropriate methods. This results in a delay to the onset of production of around 5 years and generates variability in quality. Harvesting of this species is annual, with a harvest period of 80 to 90 d per year and a peak production in September (López and Rodríguez, 1995), resulting in low market availability, which has limited its popularity to production areas (Villachica *et al*., 1996). Champa tree production can range from 5 kg for young trees to 500 kg for adult trees, and a tree can remain productive for over 20 years (López and Rodríguez, 1995; Álvarez-Herrera *et al*., 2009). Yield estimates for champa are very general; statistical figures from MinAgricultura (2024) indicate a yield of 11.07 t ha^{-1} (Tab. 1). Harvesting is done every third day, and up to 75 kg per tree can be collected in each harvesting session (Álvarez-Herrera *et al*., 2009). The maturity index used by producers for harvesting is from green to yellow (Tab. 3), although fruits are most commonly collected directly from the ground (Nates-Parra *et al*., 2016).

As mentioned earlier, harvesting can be done between 145 and 160 d after full bloom (Balaguera *et al*., 2009; Balaguera-López *et al*., 2012). Champa is known to show a sigmoidal pattern of development (Balaguera *et al*., 2009; Balaguera-López *et al*., 2012), and to be a climacteric fruit, which means it undergoes rapid softening during ripening, caused in part by polygalacturonase activity, a high sugar content, and a high acid content, which, along with volatile compounds, give it an exquisite flavor and aroma. The predominant sugar is sucrose, and the most concentrated acid is citric acid (Balaguera-López *et al*., 2022). All these production and quality characteristics should be studied in more detail, as the pre-harvest factors affecting them are not yet fully understood.

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Preharvest conditions and phytochemical fruit quality

Tropical and subtropical fruits, including those of the Myrtaceae family, contain a wide range of bioactive compounds, antioxidants, and free radical scavenging properties that may have potential health benefits for humans (Fernández-Trujillo *et al*., 2011). Antioxidants in the fruit, particularly phenolic compounds, act as reducing agents against reactive oxygen species (ROS) (Amarante *et al*., 2017).

The qualitative and quantitative content of phytochemicals can be affected by different conditions that could negatively alter the nutraceutical value of these fruits (Yahia, 2017). Climate conditions and changes in climate, in particular, affect fruit quality components and their physiological behavior, influencing the production of secondary metabolites and their functional properties (Ali *et al*., 2021). Pre-harvest conditions, such as climate, soil, or crop management, influence the development of important phytochemicals in the fruit (Yahia *et al*., 2019a), and when these conditions are closest to the crop's needs, its genetic potential can be maximized (Pérez and Melgarejo, 2015).

To increase the content of phytochemical compounds in horticultural products, Schreiner (2005) suggests various cultural practices, such as species and variety selection, nutrition, water management, and selection of production season harvest time, with prerequisite research into the interactions between genotype, eco-physiological effects, and phytochemical formation in the fruit. Yahia (2017) note that there is a general lack of information from the tropics and subtropics on the influence of crop management (fertilization, soil, irrigation, pruning, plant hormones, protected cultivation, among others) on these bioactive compounds. Furthermore, environmental conditions and physiological factors can modify the expression of phytochemical compounds, but in general, the genetic aspect of the variety is the most determining factor (Schreiner, 2005).

As phytochemicals are substances that protect the plant against different types of stress, their concentration can increase when, for example, drier soil conditions or high solar radiation occur (Schreiner, 2005; Yahia *et al*., 2019a). As UV radiation increases in plantations with higher elevation, the concentration of antioxidants in the fruit increases (Fischer *et al*., 2022a). In particular, carotenoids are pigments considered important in adaptation to high solar radiation (Yahia *et al*., 2019b). Thus, light is a determining factor in the accumulation of carotenoid and anthocyanin pigments in fruits because it affects the expression of genes related to pigment synthesis in the fruit (Benkeblia *et al*., 2011). Carotenoids protect chlorophylls from light damage (Yahia *et al*., 2019b). Similarly, Zoratti *et al*. (2014) indicate that the intensity of radiation influences flavonoid metabolism, increasing their concentration in plant tissues in full sun. Muñoz-Ordoñez *et al*. (2023) found a detrimental effect of lower radiation due to increased rainfall in passion fruit, which decreased antioxidant capacity and ascorbic acid in the fruit compared to the previous harvest cycle with drier weather and good solar radiation.

As shown in table 4, guava has a higher content of ascorbic acid, total phenols, and antioxidant activity than the other three Myrtaceae studied, as well as a high content of carotenoids (lycopene) (Prado *et al*., 2017). Some researchers found that varieties with red pulp have lower phytochemical content than white ones (Singh, 2011); however, the 'Regional Roja' variety tended to have higher concentrations of bioactive compounds than the 'Regional Blanca' in Santander (Colombia) (Rojas-Barquera and Narváez-Cuenca, 2009). Espinal *et al*. (2012) found that the Regional Roja and Palmira ICA varieties showed lipophilic antioxidant activity that is very high compared to the Regional Blanca variety, also that the lipophilic antioxidant activity of the Regional Roja variety is strongly influenced by β-carotene. On another note, Olaya and Restrepo (2012) report that higher concentrations of vitamin C and phenols have been found in the guava fruit epidermis than in the pulp, possibly to better protect against diseases and pests and, especially, against UV radiation, thus avoiding damage to the fruit's internal tissues.

Table 4. Important bioactive substances and antioxidant activity determined in the pulp of mature Myrtaceae fruits.

Species, variety	Antioxidants[1]	Reference
Guava, var. Regional Roja	Ascorbic acid: 206,6 mg 100 g^{-1} Total phenols: 508 mg AG 100 g^{-1} Antioxidant activity ABTS: 107.3 Antioxidant activity FRAP: 77.0 Antioxidant activity DPPH: 26.1	Rojas-Barquera and Narváez-Cuenca (2009)
Feijoa, var. Triumph	Ascorbic acid: 38.5 mg 100 g^{-1} Total phenols: 178.5 mg AG 100 g^{-1} Total Flavonoids: 28.8 mg CE 100 g^{-1} Antioxidant activity DPPH: 2.1	Pasquariello *et al*. (2015)

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Arazá	Ascorbic acid: 8.9 mg 100 g^{-1} Total phenols: 111 mg AG 100 g^{-1} Antioxidant activity ABTS: 20.2 Antioxidant activity FRAP: 11.4	Contreras-Calderón *et al*. (2011)
Champa (fruit) Champa (dry pulp)	Ascorbic acid: 74.44 mg 100 g^{-1} Total phenols: 229.37 mg AG 100 g^{-1} Antioxidant activity ABTS: 14.54 Antioxidant activity FRAP: 31.44 mg of trolox g^{-1} dry pulp Antioxidant activity DPPH: 11.36 mg of trolox g^{-1} dry pulp	Lima *et al*. (2016) Otalvaro-Álvarez *et al*. (2017)

[1]All measurements related to fresh weight. GA: gallic acid; ABTS: 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid); FRAP: ferric reducing antioxidant power; DPPH: 1,1-diphenyl-2-picrylhydrazyl; CE: catechin equivalent. Antioxidant activity is expressed in μmol Trolox equivalents/g fresh weight.

Paull and Duarte (2012) indicated that the concentration of ascorbic acid increases with increasing solar radiation in guava; however, there may be limits to the levels tolerated by this species, given that Solarte *et al*. (2014) observed that with radiation exceeding 2,000 μmol photons m^{-2} s^{-1}, vitamin C began to decrease in the fruit.

Regarding feijoa, Zhu *et al*. (2018) highlight the high content of phenolic compounds that provide this fruit with excellent antioxidant properties (Tab. 4). Four-teen genotypes from Uruguay showed phenol content in the pulp, containing catechin, quercetin, ellagic acid, gallic acid, rutin, syringic acid, pyrocatechol, eriodictyol, and eriocitrin (Monforte *et al*., 2014), in addition to a level of vitamin C and bioflavonoids (Pasquariello *et al*., 2015). Several feijoa varieties have a higher concentration of antioxidants in the fruit skin than in the pulp, as found by Amarante *et al*. (2017) in the Mattos, Nonante, and Helena varieties, for total phenols and total antioxidant activity (ABTS method), making the fruit skin an important source of nutrients and bioactive compounds in this species.

Also, the content of these bioactive substances can be much higher in the seeds than in the pulp (Tab. 4), as found by Contreras-Calderón *et al*. (2011) in arazá, where the antioxidant activity in the seeds, according to the FRAP and ABTS methods, was 258 and 440, respectively, and total phenols were 1,624 mg GAE 100 g^{-1}. Acosta-Vega *et al*. (2024) reported that arazá fruit is rich in bioactive compounds in its three fractions (seed, pulp, and peel), such as ascorbic acid, phenolic compounds (and their derivatives), and carotenoids.

Fischer, G., A. Parra-Coronado, M.S. Hernández, and H.E. Balaguera-López. 2024. Effect of preharvest conditions on the quality of important Myrtaceae fruits in Colombia. A review. Revista Colombiana de Ciencias Hortícolas 18(3), e18019. Doi: https://doi.org/10.17584/rcch.2024v18i3.18019

As mentioned above, the genetic aspect of the variety is the most determining factor in the quality and quantity of phytochemical compounds; all studies have shown marked differences between varieties, as found by Pasquariello *et al*. (2015) with 12 feijoa varieties in Brazil, determining total phenols, ascorbic acid, total flavonoids, and antioxidant activity.

The champa fruit has a significant content of ascorbic acid, which is even higher than that of feijoa and arazá, with moderate antioxidant activity (Tab. 4), making it suitable for regular consumption. Otalvaro-Álvarez *et al.* (2017) indicate that this fruit is an important source of phenolic compounds with antioxidant activity that are useful for the agrifood industry, for example, as natural additives to extend the shelf life of different products.

To improve the study of the functional properties of fruits, it is highly recommended to expand the monitoring of pre and post-harvest influences on the content of these phytochemicals (Schreiner, 2005).

CONCLUSIONS

The fruits of the Myrtaceae family stand out for their good nutritional, bioactive, and other promising characteristics. Among these myrtaceous plants, the most cultivated in Colombia on a commercial scale are guava, feijoa, arazá, and champa.

Each of these species and varieties thrives in its own soil, climate, and suitable altitude range, which define its quality. Likewise, specific cultural practices are needed to ensure the best use of their genetic potential. The fruits of guavas and feijoas stand out for their high content of phytochemicals (phenols, ascorbic acid, carotenoids, and antioxidant activity), not only for their own defense under stress conditions but also for their benefits to human consumers in countering chronic diseases.

Unfortunately, there is a lack of studies on these crops, for example, regarding the most suitable cultural practices to increase these bioactive compounds in the fruit. More research is needed in the country to improve the quality and production of these fruits, with champa, mainly cultivated in Boyacá, being the least studied.

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BIBLIOGRAPHIC REFERENCES

Acosta-Vega, L., D.A. Moreno, and L.N. Cuéllar. 2024. Arazá: *Eugenia stipitata* Mc Vaught as a potential functional food. Food 13(15), 2310. Doi: https://doi.org/10.3390/foods13152310

Aguilera-Arango, G.A., E. Rodríguez-Henao, H.N. Chaparro-Zambrano, and J.O. Orduz-Rodríguez. 2020. Estado actual de la investigación para el cultivo de guayaba en Colombia. Agron. Mesoamer. 31(3), 845-860. Doi: https://doi.org/10.15517/am.v31i3.40207

Ali, M.M., A.F. Yousef, B. Li, and F. Chen. 2021. Effect of environmental factors on growth and development of fruits. Trop. Plant Biol. 14(3), 226-238. Doi: https://doi.org/10.1007/S12042-021-09291-6

Álvarez-Herrera, J.G., J.A. Galvis, and H.E. Balaguera-López. 2009. Determinación de cambios físicos y químicos durante la maduración de frutos de champa (*Campomanesia lineatifolia* R. & P.). Agron. Colomb. 27(2), 253-259.

Amarante, C.V.T., A.G. Souza, T.D.T. Benincá, and C.A. Steffens. 2017. Phenolic content and antioxidant activity of fruit of Brazilian genotypes of feijoa. Pesq. Agropec. Bras. 52(12), 1223-1230. Doi: https://doi.org/10.1590/S0100-204X2017001200011

Araújo, F.F., I.A. Neri-Numa, D.P. Farias, G.R.M.C. Cunha, and G.M. Pastore. 2019. Wild Brazilian species of *Eugenia* genera (Myrtaceae) as an innovation hotspot for food and pharmacological purposes. Food Res. Int. 121, 57-72. Doi: https://doi.org/10.1016/j.foodres.2019.03.018

Araújo, H.M., F.F.G. Rodrigues, W.D. Costa, C.F.A. Nonato, F.F.G. Rodrigues, A.A. Boligon, M.L. Athayde, and J.G.M. Costa. 2015. Chemical profile and antioxidant capacity verification of *Psidium guajava* (Myrtaceae) fruits at different stages of maturation. EXCLI J. 14, 1020-1030. Doi: https://doi.org/10.17179/excli2015-522

Asif, M. 2015. Bioactive phytochemical constituents of some edible fruits of Myrtaceae family. Am. J. Nutr. Res.1, 20150619.

Asrey, R., S. Kumar, and N.K. Meena. 2018. Influence of water quality on postharvest fruit and vegetable quality. pp. 169-187. In: Siddiqui, M.W. (ed.). Preharvest modulation of postharvest fruit and vegetable quality. Academic Press, London.

Balaguera, H.E. 2011. Estudio del crecimiento y desarrollo del fruto de champa (*Campomanesia lineatifolia* R. & P.) y determinación del punto óptimo de cosecha. MSc thesis. Facultad de Agronomía, Universidad Nacional de Colombia, Bogota.

Balaguera, H.E., J.G. Álvarez, and D.C. Bonilla. 2009. Crecimiento y desarrollo del fruto de champa (*Campomanesia lineatifolia* Ruiz & Pavón). Rev. UDCA Act. Div. Cient. 12(2), 113-123. Doi: https://doi.org/10.31910/rudca.v12.n2.2009.697

Balaguera-López, H.E., G. Fischer, and A. Herrera-Arévalo. 2022. Postharvest physicochemical aspects of *Campomanesia lineatifolia* R. & P. fruit, a Myrtaceae with commercial potential. Rev. Colomb. Cienc. Hortic. 16(2), e14185. Doi: https://doi.org/10.17584/rcch.2022v16i2.14185

Balaguera-López, H.E. and A. Herrera. 2012. Determining optimal harvest point for champa (*Campomanesia lineatifolia* R. & P.) fruit based on skin color. Ing. Inv. 32(1), 88-93. Doi: https://doi.org/10.15446/ing.investig.v32n1.28523

Balaguera-López, H.E., A. Herrera, and D. Cortés-Moreno. 2012. Growth of champa fruit under agroecological conditions of Miraflores, Boyacá, Colombia. Pesq. Agropec. Bras. 47(12), 1722-1730. Doi: https://doi.org/10.1590/S0100-204X2012001200007

Balerdi, C.F. J.H. Crane, and B. Schaffer. 2003. Managing your tropical fruit grove under changing water table levels. Doc. HS957. IFAS Extension, University of Florida, Gainesville, FL.

Balfagón, D., V. Arbona, and A. Gómez-Cadenas. 2022. The future of citrus fruit: the impact of climate change on citriculture. Metode Sci. Stud. J. 12, 123-129. Doi: https://doi.org/10.7203/metode.12.20319

Barman, K., M.S. Ahmad, and M.W. Siddiqui. 2015. Factors affecting the quality of fruits and vegetables: recent understandings. pp. 1-50. In: Siddiqui, M.W. (ed.). Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance. CRC Press Taylor and Francis Group, Boca Raton, FL. Doi: https://doi.org/10.1201/b18438

Barrera, J.A., M.S. Hernández, A. García, G. Vargas, D. Caicedo, O. Martínez, L.M. Melgarejo, and J.P. Fernández-Trujillo. 2012. Maximum leaf photosynthetic light response for araza (*Eugenia stipitata* McVaugh) plants growing in four environments of the Southern Colombian Amazonian region. Acta Hortic. 928, 187-192. Doi: https://doi.org/10.17660/ActaHortic.2012.928.22

Bautista-Montealegre, L.G., L.Y. DEantonio-Florido, W.A. Cardona, M.M. Bolaños-Benavides, and G. Fischer. 2022. Mineral nutrition and tolerance to *Colletotrichum* spp. of Andean blackberry (*Rubus glaucus* Benth.) in nursery. Agron. Mesoamer. 33(3), 48655. Doi: https://doi.org/10.15517/am.v33i3.48655

Benavides, H.O., O. Simbaqueva, and H.J. Zapata. 2017. Atlas de radiación solar, ultravioleta y ozono de Colombia. Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Bogota.

Benkeblia, N., D.P.F. Tennant, S.K. Jawandha, and P.S. Gill. 2011. Preharvest and harvest factors influencing the postharvest quality of tropical and subtropical fruits. pp. 112-141. In: Yahia, E.M. (ed.). Postharvest biology and technology of tropical and subtropical fruits fundamental issues. Woodhead Publishing, Oxford, UK. Doi: https://doi.org/10.1533/9780857093622.112

Blancke, R. 2016. Tropical fruits and other edible plants of the world: an illustrated guide. Cornell University Press, Ithaca and London. Doi: https://doi.org/10.7591/9781501704284

Buitrago, S., M. Leandro, and G. Fischer. 2021. Symptoms and growth components of feijoa (*Acca sellowiana* [O. Berg] Burret) plants in response to the missing elements N, P, and K. Rev. Colomb. Cienc. Hortic. 15(3), e13159. Doi: https://doi.org/10.17584/rcch.2021v15i3.13159

Calderón-Acero, L.V. and G. Nates-Parra. 2013. Visitantes florales y posibles polinizadores de chamba *Campomanesia lineatifolia* (Myrtaceae) en la provincia de Lengupá, Boyacá, Colombia. pp. 72-79. In: Memorias VIII Congreso Mesoamericano de Abejas Nativas. Heredia, Costa Rica.

Carabalí, A., D.L. Correa, A. Jaramillo, E. Rodriguez, R. Tarazona, L.C. Grajales, D.E. Canacuan, and M. Montes. 2019. Prácticas de manejo sostenible para el cultivo de guayaba. Corporación Colombiana de Investigación Agropecuaria (Agrosavia), Palmira, Colombia.

Carrejo, N.S. and R. González. 1999. Parasitoids reared from species of Anastrepha (Diptera: Tephritidae) in Valle del Cauca, Colombia. Flo. Entomol. 82(1), 113-118. Doi: https://doi.org/10.2307/3495842

Casierra-Posada, F. and G. Fischer. 2012. Poda de árboles frutales. pp. 169-185. In: Fischer, G. (ed.). Manual para el cultivo de frutales en el trópico. Produmedios, Bogota.

Chiveu, J.C., M. Naumann, K. Kehlenbeck, and E. Pawelzik. 2019. Variation in fruit chemical and mineral composition of Kenyan guava (*Psidium guajava* L.): inferences from climatic conditions, and fruit morphological traits. J. Appl. Bot. Food Qual. 92, 151-159. Doi: https://doi.org/10.5073/JABFQ.2019.092.021

Combariza, J.A. and Y. Aranda. 2012. Producción y comercialización. pp. 16-34. In: Fischer, G. (ed.). Manual para el cultivo de frutales en el trópico. Produmedios, Bogota.

Contreras-Calderón, J., L. Calderón-Jaimes, E. Guerra-Hernández, and B. García-Villanova. 2011. Antioxidant capacity, phenolic content and vitamin C in pulp, peel and seed from 24 exotic fruits from Colombia. Food Res. Int. 44(7), 2047-2053. Doi: https://doi.org/10.1016/j.foodres.2010.11.003

Duarte, O. and R.E. Paull. 2015. Myrtaceae. pp. 51-59. In: Exotic fruits and nuts of the new world. CABI Publishing, Wallingford, UK. Doi: https://doi.org/10.1079/9781780645056.0000

Escobar, C.J., J.J. Zuluaga, C.A. Cárdenas, and E.H. Rivas. 1999. El cultivo del arazá (*Eugenia stipitata* McVaugh). 2nd ed. Cartilla Divulgativa Regional 10. Corpoica; SENA. Florencia, Colombia.

Espinal, M., J.I. Daza, and L.P. Restrepo. 2012. Lipophilic antioxidant activity of guava fruit varieties Palmira ICA I, Regional Roja and Regional Blanca in four ripening stages. Agron. Colomb. 30(2), 251-259.

Fallik, E., and Z. Ilic. 2018. Pre- and postharvest treatments affecting flavor quality of fruits and vegetables. pp. 139-168. In: Siddiqui, M.W. (ed.). Preharvest modulation of postharvest fruit and vegetable quality. Academic Press, London.

FAO. 2024. Major tropical fruits: market review. Preliminary results 2023. Rome.

Farias, D.P., I.A. Neri-Numa, F.F. Araújo, and G.M. Pastore. 2020. A critical review of some fruit trees from the Myrtaceae family as promising sources for food applications with functional claims. Food Chem. 306, 125630. Doi: https://doi.org/10.1016/j.foodchem.2019.125630

Fernández-Trujillo, J.P., M.S. Hernández, M. Carrillo, and J. Barrera. 2011. Arazá (*Eugenia stipitata* McVaugh). pp. 98-115. In: Yahia, E.M. (ed.). Postharvest biology and technology of tropical and subtropical fruits. Vol. 2: Açai to citrus. Woodhead Publishing Ltd., Oxford, UK. Doi: https://doi.org/10.1533/9780857092762.98

Ferreira, M.C., F.B. Martins, G.W.L. Florêncio, and L.A.A.P. Pasin. 2019. Cardinal temperatures and modeling of vegetative development in guava. Rev. Bras. Eng. Agric. Ambient. 23(11), 819-825. Doi: https://doi.org/10.1590/1807-1929/agriambi.v23n11p819-825

Fischer, G., P.J., Almanza-Merchán, and F. Ramírez. 2012. Source-sink relationships in fruit species. A review. Rev. Colomb. Cienc. Hortic. 6(2), 238-253. Doi: https://doi.org/10.17584/rcch.2012v6i2.1980

Fischer, G., H.E. Balaguera-López, and J. Álvarez-Herrera. 2021. Causes of fruit cracking in the era of climate change. A review. Agron. Colomb. 39(2), 196-207. Doi: https://doi.org/10.15446/agron.colomb.v39n2.97071

Fischer, G., H.E. Balaguera-López, A. Parra-Coronado, and S. Magnitskiy, 2024. Adaptation of fruit trees to different elevations in the tropical Andes. pp. 193-208. In: Tripathi, S., R. Bhadouria, P. Srivastava, R. Singh, and R.S. Devi (eds.). Ecophysiology of tropical plants - Recent trends and future perspectives. CRC Press, Boca Raton, FL. Doi: https://doi.org/10.1201/9781003335054-22

Fischer, G. and L.M. Melgarejo. 2020. The ecophysiology of cape gooseberry (*Physalis peruviana* L.) - an Andean fruit crop. A review. Rev. Colomb. Cienc. Hortic. 14(1), 76-89. Doi: https://doi.org/10.17584/rcch.2020v14i1.10893

Fischer, G. and L.M. Melgarejo. 2021. Ecophysiological aspects of guava (*Psidium guajava* L.). A review. Rev. Colomb. Cienc. Hortic. 15(2), e12355. Doi: https://doi.org/10.17584/rcch.2021v15i2.12355

Fischer, G., L.M. Melgarejo, and H.E. Balaguera-López. 2022c. Review on the impact of elevated CO_2 concentrations on fruit species in the face of climate change. Cienc. Tecnol. Agropecu. 23(2), e2475. Doi: https://doi.org/10.21930/rcta.vol23_num2_art:2475

Fischer, G., L.M. Melgarejo, and J. Cutler. 2018. Pre-harvest factors that influence the quality of passion fruit: A review. Agron. Colomb. 36(3), 217-226. Doi: https://doi.org/10.15446/agron.colomb.v36n3.71751

Fischer, G. and A. Parra-Coronado. 2020. Influence of some environmental factors on the feijoa (*Acca sellowiana* [Berg] Burret): A review. Agron. Colomb. 38(3), 388-397. Doi: https://doi.org/10.15446/agron.colomb.v38n3.88982

Fischer, G., A. Parra-Coronado, and H.E Balaguera-López. 2020. Aspectos del cultivo y de la fisiología de feijoa (*Acca sellowiana* [Berg] Burret). Una revisión. Cien. Agri. 17(3), 11-24. Doi: https://doi.org/10.19053/01228420.v17.n3.2020.11386

Fischer, G., A. Parra-Coronado, and H.E. Balaguera-López. 2022a. Altitude as a determinant of fruit quality with emphasis on the Andean tropics of Colombia. A review. Agron. Colomb. 40(2), 212-227. Doi: https://doi.org/10.15446/agron.colomb.v40n2.101854

Fischer, G. and J.O. Orduz-Rodríguez. 2012. Ecofisiología en frutales. pp. 54-72. In: Fischer, G. (ed.). Manual para el cultivo de frutales en el trópico. Produmedios, Bogota.

Fischer, G., J.O. Orduz-Rodríguez, and C.V.T. Amarante. 2022b. Sunburn disorder in tropical and subtropical fruits. A review. Rev. Colomb. Cienc. Hortic. 16(3), e15703. Doi: https://doi.org/10.17584/rcch.2022v16i3.15703

Fischer, G., F. Ramírez, and F. Casierra-Posada. 2016. Ecophysiological aspects of fruit crops in the era of climate change. A review. Agron. Colomb. 34(2), 190-199. Doi: https://doi.org/10.15446/agron.colomb.v34n2.56799

Galvis, J.A. 2003. Manejo de cosecha y poscosecha de feijoa. pp. 111-123. In: Fischer, G., D. Miranda, G. Cayón, and M. Mazorra (eds.). Cultivo, poscosecha y exportación de la feijoa (*Acca sellowiana* Berg). Universidad Nacional de Colombia, Bogota.

Galvis, J.A. and M.S. Hernández. 1993. Análisis del crecimiento y determinación del momento oportuno de cosecha del fruto de arazá (*Eugenia stipitata* Mc Vaugh). Colomb. Amazón. 6(2), 107-121.

Hernández, M.S., O. Martínez, and J.P. Fernández-Trujillo. 2007. Behavior of arazá (*Eugenia stipitata* Mc Vaugh) fruit quality traits during growth, development and ripening. Sci. Hortic. 111(3), 220-227. Doi: http://doi.org/10.1016/j.scienta.2006.10.029

Hernández, M.S., J.A. Barrera, and M. Carrillo. 2006. Arazá. Instituto Amazónico de Investigaciones Científicas (SINCHI), Bogota. https://sinchi.org.co/files/publicaciones/publicaciones/pdf/araza_2web.pdf

Insuasty, O., R. Monroy, A. Díaz-Fonseca, and J. Bautista. 2007. Manejo integrado del picudo de guayaba (*Conotrachelus psidii* Marshall) en Santander. Produmedios, Bogota.

Körner, C. 2007. The use of 'altitude' in ecological research. Trends Ecol. Evol. 22(11), 569-574. Doi: https://doi.org/10.1016/j.tree.2007.09.006

Kumar, G.N.K., V.S. Vani, A.V.D.D. Rao, P. Subbaramamma, and R.V. Sujatha. 2017. Effect of foliar sprays of urea, potassium sulphate and zinc sulphate on quality of guava cv. Taiwan pink. Int. J. Chem. Stud. 5(5), 680-682.

Ladaniya, M.S. 2008. Preharvest factors affecting fruit quality and postharvest life. pp. 79-102. In: Citrus fruit, biology, technology and evaluation. Elsevier, Oxford, UK. Doi: https://doi.org/10.1016/B978-012374130-1.50006-1

Lal, N. and N. Sahu. 2017. Management strategies of sun burn in fruit crops - A review. Int. J. Curr. Microbiol. Appl. Sci. 6(6), 1126-1138. Doi: https://doi.org/10.20546/ijcmas.2017.606.131

Lambers, H. and F.S. Oliveira, 2019. Plant physiological ecology. 3rd ed. Springer Nature Switzerland, Cham, Switzerland. Doi: https://doi.org/10.1007/978-3-030-29639-1

Lima, J.S.S., J.M.C. Castro, L.B.S. Sabino, A.C.S. Lima, and L.B.V. Torres. 2016. Physicochemical properties of gabiroba (*Campomanesia lineatifolia*) and myrtle (*Blepharocalyx salicifolius*) native to the mountainous region of Ibiapaba–CE, Brazil. Rev. Caatinga 29(3), 753-757. Doi: https://doi.org/10.1590/1983-21252016v29n327rc

López, M. and J. Rodríguez. 1995. Diagnóstico del mercadeo de la champa en el municipio de Miraflores Boyacá. Undergraduate thesis. Instituto de Educación Abierta y a Distancia; Universidad Pedagógica y Tecnológica de Colombia, Tunja, Colombia.

Lozano, J.C., J.C. Toro, R. García, and R. Tafur. 2002. Manual sobre el cultivo del guayabo en Colombia. Fruticultura Colombiana, Santiado de Cali, Colombia.

Maestre, L., E. Palacios, B.L. Moreno, H.E. Balaguera-López, and J.P. Hernández. 2023. Hydroalcoholic extracts of *Campomanesia lineatifolia* R. & P. seeds inhibit the germination of *Rumex crispus* and *Amaranthus hybridus*. Horticulturae 9, 177. Doi: https://doi.org/10.3390/horticulturae9020177

Martínez, C.A., H.E. Balaguera-López, and J.A. Fonseca. 2022. Bioherbicidal activity of seed extract of *Campomanesia lineatifolia* on the weed *Sonchus oleraceus* L. Agron. Colomb. 40, 49-57. Doi: https://doi.org/10.15446/agron.colomb.v40n1.98502

Mercado-Silva, E., P. Benito-Bautista, and M.A. Garcia-Velasco. 1998. Fruit development, harvest index and ripening changes of guavas produced in central Mexico. Postharvest Biol. Technol. 13(2), 143-150. Doi: https://doi.org/10.1016/S0925-5214(98)00003-9

MinAgricultura, Ministerio de Agricultura y Desarrollo Rural Colombia. 2024. Agronet: Área, producción y rendimiento nacional por cultivo: guayaba común, feijoa, arazá y champa. In: https://www.agronet.gov.co/estadistica/Paginas/home.aspx?cod=1

Monforte, M.T., V. Fimiani, F. Lanuzza, C. Naccari, S. Restuccia, and E.M. Galati. 2014. *Feijoa sellowiana* Berg fruit juice: anti-inflammatory effect and activity on superoxide anion generation. J. Med. Food 17, 455-461. Doi: https://doi.org/10.1089/jmf.2012.0262

Moreno-Miranda, C., R. Moreno-Miranda, A.A. Pilamala-Rosales, J.I. Molina-Sánchez, and L. Cerda-Mejía. 2019. El sector hortofrutícola de Ecuador: principales características socio-productivas de la red agroalimentaria de la uvilla (*Physalis peruviana*). Cien. Agri. 16(1), 31-55. Doi: https://doi.org/10.19053/01228420.v16.n1.2019.8809

Moretti, C.L., L.M Mattos, A.G. Calbo, and S.A. Sargent. 2010. Climate changes and potential impacts on postharvest quality of fruit and vegetable crops: a review. Food Res. Int. 43(7), 1824-1832. Doi: https://doi.org/10.1016/j.foodres.2009.10.013

Morley-Bunker, M. 2010. Miscellaneous fruits. pp. 280-293. In: Jackson, D.I. N. Looney, and M. Morley-Looney (eds.). Temperate and subtropical fruit production. 3rd ed. CABI Publishing, Wallingford, UK.

Muñoz-Ordoñez, F.J., N. Gutiérrez-Guzmán, M.S. Hernández-Gómez, and J.P. Fernández-Trujillo. 2023. The climactic conditions limit fruit production and quality in gulupa (*Passiflora edulis* Sims f. *edulis*) under integrated fertilization. S. Afr. J. Bot. 153, 147-156. Doi: https://doi.org/10.1016/j.sajb.2022.11.043

Nates-Parra, G., R. Ospina, A.T. Rodríguez-Calderón, F.J. Chamorro, M.M. Henao-Cárdenas, L.V. Calderón, and M.S. Pinilla-Gallego. 2016. Polinización en cultivos promisorios. pp. 239-252. In: Nates-Parra, G. (ed.). Iniciativa colombiana de polinizadores - abejas - ICPA. Universidad Nacional de Colombia, Bogota.

Neves, N.C.V., M.P. Mello, I. Zaidan, L.P. Sousa, A.V. Braga, R.R. Machado, W. Kukula-Koch, F. Boylan, M.V. Caliari, and R.O. Castilho. 2023. *Campomanesia lineatifolia* Ruiz & Pavón (Myrtaceae): isolation of major and minor compounds of phenolic-rich extract by high-speed countercurrent chromatography and anti-inflammatory evaluation. J. Ethnopharmacol. 310, 116417. Doi: https://doi.org/10.1016/j.jep.2023.116417

Olaya, J.A. and L.P. Restrepo. 2012. Estudio del contenido de fenoles y actividad antioxidante de guayaba en diferentes estados de madurez. Acta Biol. Colomb. 17(3), 611-624.

Otalvaro-Álvarez, A.M., L.C. Pabón-Baquero, M.R. Redón-Fernández, and M.P. Chaparro-González. 2017. Microwave extraction of champa (*Campomanesia lineatifolia* Ruiz & Pav.) fruit: alternative to obtain natural antioxidants. Acta Agron. 67(1), 53-58. Doi: https://doi.org/10.15446/acag.v67n1.61367

Parra-Coronado, A. 2014. Maduración y comportamiento poscosecha de la guayaba (*Psidium guajava* L.). Una revisión. Rev. Colomb. Cienc. Hortic. 8(2), 314-327. Doi: https://doi.org/10.17584/rcch.2014v8i2.3223

Parra-Coronado, A. and G. Fischer. 2013. Maduración y comportamiento poscosecha de la feijoa (*Acca sellowiana* (O. Berg) Burret). Rev. Colomb. Cienc. Hortic. 7(1), 98-110. Doi: https://doi.org/10.17584/rcch.2013v7i1.2039

Parra-Coronado, A., G. Fischer, H.E. Balaguera-López, and L.M. Melgarejo. 2022. Sugar and organic acids content in feijoa (*Acca sellowiana*) fruits, grown in two altitudes. Rev. Cienc. Agr. 39(1), 55-69. Doi: https://doi.org/10.22267/rcia.223901.173

Parra-Coronado, A., G. Fischer, and J.H. Camacho-Tamayo. 2015a. Development and quality of pineapple guava fruit in two locations with different altitudes in Cundinamarca, Colombia. Bragantia 74(3), 359-366. Doi: http://doi.org/10.1590/1678-4499.0459

Parra-Coronado, A., G. Fischer, and J.H. Camacho-Tamayo. 2016. Growth model of the pineapple guava fruit as a function of thermal time and tropical altitude. Ing. Inv. 36(3), 6-14. Doi: https://doi.org/10.15446/ing.investig.v36n3.52336

Parra-Coronado, A., G. Fischer, and B. Chaves-Cordoba. 2015b. Tiempo térmico para estados fenológicos reproductivos de la feijoa (*Acca sellowiana* (O. Berg) Burret). Acta Biol. Colomb. 20(1), 163-173. Doi: http://doi.org/10.15446/abc.v20n1.43390

Parra-O., C. 2014. Sinopsis de la familia Myrtaceae y clave para la identificación de los géneros nativos e introducidos en Colombia. Rev. Acad. Colomb. Cienc. Ex. Fis. Nat. 38 (148), 261-277. Doi: https://doi.org/10.18257/raccefyn.128

Pasquariello, M.S., F. Mastrobuoni, D. DiPatre, L. Zampella, L.R. Capuano, M. Scortichini, and M. Petriccione. 2015. Agronomic, nutraceutical and molecular variability of feijoa (*Acca sellowiana* (O. Berg) Burret) germplasm. Sci. Hortic. 191, 1-9. Doi: https://doi.org/10.1016/j.scienta.2015.04.036

Paull, R.E. and O. Duarte. 2012. Guava. pp. 91-122. In: Tropical fruits. Vol. 2. 2nd ed. CABI International, Wallingford, UK. Doi: http://doi.org/10.1079/9781845937898.0000

Perea, M., G. Fischer, and D. Miranda. 2010. Feijoa *Acca sellowiana* Berg. pp. 330-349. In: Perea, M., L.P. Matallana, and A. Tirado (eds.). Biotecnología aplicada al mejoramiento de los cultivos de frutas tropicales. Universidad Nacional de Colombia, Bogota.

Pérez, L.V. and L.M. Melgarejo. 2015. Photosynthetic performance and leaf water potential of gulupa (*Passiflora edulis* Sims, Passifloraceae) in the reproductive phase in three locations in the colombian andes. Acta Biol. Colomb. 20(1), 183-194. Doi: https://doi.org/10.15446/abc.v20n1.42196

Porras, Y.C., M.C. Pedreros, W.L. Reyes, and H.E. Balaguera. 2020. Light effect on germination of champa (*Campomanesia lineatifolia* R. & P.) seeds. Cien. Agri. 17(2), 23-31. Doi: https://doi.org/10.19053/01228420.v17.n2.2020.10979

Prado, R.M., J.P. Souza Junior, G.B. Silva Junior, and I.H.L. Cavalcante. 2017. Guava: the relationship between the productive aspects, the quality of the fruits and its health benefits. pp. 1-16. In: Murphy, A. (ed.). Guava: cultivation, antioxidant properties and health benefits. Nova Science Publishers, Hauppauge, USA.

Quintero, O. 2003. Selección de cultivares, manejo del cultivo y regulación de cosechas de feijoa. pp. 49-71. In: Fischer, G., D. Miranda, G. Cayón, and M. Mazorra (eds.). Cultivo, poscosecha y exportación de la feijoa (*Acca sellowiana* Berg). Universidad Nacional de Colombia, Bogota.

Quintero, O.C. 2012. Feijoa (*Acca sellowiana* Berg). pp. 443-473. In: Fischer, G. (ed.). Manual para el cultivo de frutales en el trópico. Produmedios, Bogota.

Quintero, O.C. 2014. La feijoa en Colombia. pp. 167-178. In: Mem. VI Encontro sobre Pequenas Frutas e Frutas Nativas do Mercosul. Empraba Clima Temperado. Pelotas, Brazil.

Ramírez, L.N., G.P. González, and J.-A. Cleves-Leguizamo. 2021. Mathematical modeling of climatological data to estimate passion fruit crop yield (*Passiflora edulis* L. f. *flavicarpa* y *purpurea*). Rev. Bras. Frutic. 43(3), e-182. Doi: https://doi.org/10.1590/0100-29452021182

Ramírez, R. and J. Kallarackal. 2017. Feijoa [*Acca sellowiana* (O. Berg) Burret] pollination: a review. Sci. Hortic. 226, 333-341. Doi: https://doi.org/10.1016/j.scienta.2017.08.054

Raza, A., F. Ashraf, X. Zou, X. Zjang, and H. Tosif. 2020. Plant adaptation and tolerance to environmental stresses: mechanisms and perspectives. pp. 117-146. In: Hasanuzzaman, M. (ed.). Plant ecophysiology and adaptation under climate change: mechanisms and perspectives I: general consequences and plant responses. Springer Nature Singapore, Singapore. Doi: https://doi.org/10.1007/978-981-15-2156-0_5

Rengel, Z., I. Cakmak, and P.J. White. 2023. Marschner's mineral nutrition of plants. 4th ed. Elsevier, London.

Reyes, C. 2012. Arazá (*Eugenia stipitata* Mc Vaugh). pp. 928-935. In: Fischer, G. (ed.). Manual para el cultivo de frutales en el trópico. Produmedios, Bogota.

Ritthe, R.D., R.A. Patil, V.N. Shinde, S.N. Band, and N.S. Ingle. 2023. Effect of pre-harvest chemical spray and bagging on physico-chemical quality of guava (*Psidium guajava* L.) fruits cv. Sardar. Pharm. Innov. 12(12), 1286-1290.

Rodríguez, A.T. 2014. Requerimientos y valor económico del servicio de polinización prestado por abejas en dos frutales promisorios colombianos, (champa *Campomanesia lineatifolia* Ruiz & Pav. y cholupa *Passiflora maliformis* L.). M.Sc. thesis. Universidad Nacional de Colombia, Bogota.

Rodríguez, A., F.J. Chamorro, L.V. Calderón, M.S. Pinilla, M. Henao, R. Ospina, and G. Nates-Parra. 2015. Polinización por abejas en cultivos promisorios de Colombia: agraz (*Vaccinium meridionale*), chamba (*Campomanesia lineatifolia*) y cholupa (*Passiflora maliformis*). Universidad Nacional de Colombia, Bogota.

Rojas-Barquera, D. and C.-E. Narváez-Cuenca. 2009. Determinación de vitamina C, compuestos fenólicos totales y actividad antioxidante de frutas de guayaba (*Psidium guajava* L.) cultivadas en Colombia. Quim. Nova 32(9), 2336-2340. Doi: https://doi.org/10.1590/S0100-40422009000900019

Rupavatharam, S., A.R. East, and J.A. Heyes. 2016. Effects of preharvest application of aminoethoxyvinylglycine (AVG) on harvest maturity and storage life of 'Unique' feijoa. New Zeal. J. Crop Hort. Sci. 44(2), 121-135. Doi: https://doi.org/10.1080/01140671.2016.1152980

Salazar, D.M., P. Melgarejo, R. Martínez, J.J. Martínez, F. Hernández, and M. Burguera. 2006. Phenological stages of the guava tree (*Psidium guajava* L.). Sci. Hortic. 108(2), 157-161. Doi: https://doi.org/10.1016/j.scienta.2006.01.022

Sánchez-Mora, F.D., L. Saifert, M.S. Pasa, M.N. Ciotta, H.N. Ribeiro, A. Rojas-Molina, G. Lombardi, and R.O. Nodari. 2017. Poda de frutificação em variedades comerciais de goiabeira-serrana. p. 73. In: XV Encuentro Nacional de Fruticultura de Clima Temperado. Fraiburgo, Brazil.

Santos, E., Y. Mendoza, B. Vignale, M. Vera, S. Diaz-Cetti, D. Cabrera, E. Morelli, and C. Invernizzi. 2022. Animal pollination dependence in feijoa [*Acca sellowiana* (Berg) Burret] (Myrtaceae) and variation of pollinators between regions of Uruguay. Braz. J. Anim. Environ. Res. 5(4), 3728-3745. Doi: https://doi.org/10.34188/bjaerv5n4-023

Sau, S., S. Sarkar, B. Ghosh, K. Ray, P. Deb, and D. Ghosh. 2018. Effect of foliar application of B, Zn and Cu on yield, quality and economics of rainy season guava cultivation. Curr. J. Appl. Sci. Technol. 28(1), 1-10. Doi: https://doi.org/10.9734/CJAST/2018/42131

Schotsmans, W.C., A. East, G. Thorp, and A.B. Woolf. 2011. Feijoa (*Acca sellowiana* [Berg] Burret). pp. 115-135. In: Yahia, E.M. (ed.). Postharvest biology and technology of tropical and subtropical fruits. Vol. 3: cocona to mango. Woodhead Publishing, Oxford, UK. Doi: https://doi.org/10.1533/9780857092885.115

Schreiner, M. 2005. Vegetable crop management strategies to increase the quantity of phytochemicals. Eur. J. Nutr. 44, 85-94. Doi: https://doi.org/10.1007/s00394-004-0498-7

Sharma, R.R., A. Nagaraja, A.K. Goswami, M. Thakre, and E. Varghese. 2020. Influence of on-the-tree fruit bagging on biotic stresses and postharvest quality of rainy-season crop of 'Allahabad Safeda' guava (*Psidium guajava* L.). Crop Prot. 135, 105216. Doi: https://doi.org/10.1016/j.cropro.2020.105216

Shukla, M. and B. Bisen. 2021. Effect on pruning intensity and foliar application of KNO_3 on plant growth, flowering and fruiting of guava cv. Allahabad Safeda. Pharm. Innov. 10(9), 225-228.

Shukla, S., D. Kaur, S. Kaur, and R. Prasad. 2018. Effect of seasonality and fruit ripening stages on bioactive constituents and antioxidant potential of guava fruit cultivars. Plant Arch. 18(2), 2363-2371.

Shukla, P.R., J. Skea, R. Slade, R. Van Diemen, E. Haughey, J. Malley, M. Pathak, and J.P. Pereira (eds.). 2019. Climate change and land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems: technical summary. In: https://www.ipcc.ch/site/assets/uploads/sites/4/2019/11/03_Technical-Summary-TS.pdf ; consulted:

Singh, S.P. 2011. Guava (*Psidium guajava* L.). pp. 213-245. In: Yahia, E.M. (ed.). Postharvest biology and technology of tropical and subtropical fruits. Vol. 3: cocona to mango. Woodhead Publishing, Oxford, UK. Doi: https://doi.org/10.1533/9780857092885.213

Solarte, M.E., L.M. Melgarejo, O., Martínez, M.S. Hernández, and J.P. Fernández-Trujillo. 2014. Fruit quality during ripening of Colombian guava (*Psidium guaja*va L.) grown at different altitudes. J. Food Agric. Environ. 12(2), 669-675.

Solarte, M.E., H.M. Romero, and L.M. Melgarejo. 2010. Caracterización ecofisiológica de la guayaba de la hoya del río Suárez. pp. 25-56. In: Morales, A.L. and L.M. Melgarejo (eds.). Desarrollo de productos funcionales promisorios a partir de la guayaba (*Psidium guajava* L.) para el fortalecimiento de la cadena productiva. Universidad Nacional de Colombia, Bogota.

Souza, M.E., A.C. Silva, A.P. Souza, A.A. Tanaka, and S. Leonel. 2010. Influência das precipitações pluviométricas em atributos físico-químicos de frutos da goiabeira 'Paluma' em diferentes estádios de maturação. Rev. Bras. Frutic. 32(2), 637-646. Doi: https://doi.org/10.1590/S0100-29452010005000060

Taiwo, A.F., O. Daramola, M. Sow, and V.K. Semwal. 2020. Ecophysiology and responses of plants under drought. pp. 231-268. In: Hasanuzzaman, M. (ed.). Plant ecophysiology and adaptation under climate change: mechanisms and perspectives I. Springer Nature Singapore, Singapore. Doi: https://doi.org/10.1007/978-981-15-2156-0_8

Thorp, G. 2008. Feijoa *Acca sellowiana* (Berg) Burret, Myrtaceae. pp. 526-533. In: Janick, J. and R.E. Paull (eds.). Encyclopedia of fruit and nuts. CAB International, Wallingford, UK.

Tito, R., H.L. Vasconcelos, and K.J. Feeley. 2018. Global climate change increases risk of crop yield losses and food insecurity in the tropical Andes. Global Change Biol. 24(2), 592-602. Doi: https://doi.org/10.1111/gcb.13959

Tiwari, S., D. Ram, D. Mishra, and N. Gurudev. 2024. Effect of plant growth regulators on yield and quality of winter season guava (*Psidium guajava* L.) cv. L-49. Plant Arch. 24(1), 1355-1362. Doi: https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.1.190

Trujillo, R., M. Hernández de la Torre, I.Y. Hernández, and I.E. Méndez. 2018. *Psidium acidum* (DC.) Landrum (Myrtaceae): frutal de reciente cultivo en Cuba. Agrisost. 24(3), 207-214.

Ubeda, C., R. Hornedo-Ortega, A.B. Cerezo, M.C. García-Parrilla, and A.M. Troncoso. 2020. Chemical hazards in grapes and wine, climate change and challenges to face. Food Chem. 314, 126222. Doi: https://doi.org/10.1016/j.foodchem.2020.126222

Valdés-Infante, J., N.N. Rodríguez, J.B. Velásquez, D.G. Sourd, G. González, J.A. Rodríguez, and W. Rohde. 2012. Herramientas para un programa de mejoramiento genético del guayabo (*Psidium guajava* L.) en Cuba. Agron. Costar. 36(2), 111-129.

Van Kanten, R. and J. Beer. 2005. Production and phenology of the fruit shrub *Eugenia stipitata* in agroforestry systems in Costa Rica. Agroforest. Syst. 64, 203-209. Doi: https://doi.org/10.1007/s10457-004-2105-6

Villachica, H., J.E.U. Carvalho, C.H. Muller, C. Diaz, and M. Almanza. 1996. Frutales y hortalizas promisorios de la Amazonía. Tratado de Cooperación Amazónica, Secretaria Pro-Tempore, Lima.

Wills, R.B.H. and J.B. Golding. 2016. Postharvest: an introduction to the physiology and handling of fruit and vegetables. 6th ed. CABI, Sydney. Doi: https://doi.org/10.1079/9781786391483.0000

Yahia, E.M. (ed.). 2017. Fruit and vegetable phytochemicals: chemistry and human health (2nd ed., Vol. 1 and 2). John Wiley and Sons, Oxford, UK. Doi: https://doi.org/10.1002/9781119158042.ch1

Yahia, E.M. 2019. Introduction. pp. 1-17. In: Yahia, E.M. (ed.). Postharvest physiology and biochemistry of fruits and vegetables. Elsevier, Cambridge, MA. Doi: https://doi.org/10.1016/B978-0-12-813278-4.00001-4

Yahia, E.M., A. Gardea-Béjar, J.J. Ornelas-Paz, I.O. Maya-Meraz, M.J. Rodríguez-Roque, C. Ríos-Velasco, J. Ornelas-Paz, and M.A. Salas-Marina. 2019a. Preharvest factors affecting postharvest quality. pp. 99-128. In: Yahia, E.M. (ed.), Postharvest technology of perishable horticultural commodities. Elsevier, Amsterdam. Doi: https://doi.org/10.1016/B978-0-12-813276-0.00004-3

Yahia, E.M., A. Carrillo-López, G.M. Barrera, H. Suzán-Azpiri, and M. Queijeiro Bolaños. 2019b. Photosynthesis. pp. 47-72. In: Yahia, E.M. (ed.). Postharvest physiology and biochemistry of fruits and vegetables. Elsevier, Cambridge, MA. Doi: https://doi.org/10.1016/B978-0-12-813278-4.00003-8

Zhu, F. 2018. Chemical and biological properties of feijoa (*Acca sellowiana*). Trends Food Sci. Technol. 81, 121-131. Doi: https://doi.org/10.1016/j.tifs.2018.09.008

Zoratti, L., K. Karppinen, A.L. Escobar, H. Häggman, and L. Jaakola. 2014. Light-controlled flavonoid biosynthesis in fruits. Front. Plant Sci. 5, 534. Doi: https://doi.org/10.3389/fpls.2014.00534