Bioactive Compounds Found in Brazilian Cerrado Fruits

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Abstract: Functional foods include any natural product that presents health-promoting effects, thereby reducing the risk of chronic diseases. Cerrado fruits are considered a source of bioactive substances, mainly phenolic compounds, making them important functional foods. Despite this, the losses of natural vegetation in the Cerrado are progressive. Hence, the knowledge propagation about the importance of the species found in Cerrado could contribute to the preservation of this biome. This review provides information about Cerrado fruits and highlights the structures and pharmacologic potential of functional compounds found in these fruits. Compounds detected in Caryocar brasiliense Camb. (pequi), Dipteryx alata Vog. (baru), Eugenia dysenterica DC. (cagaita), Eugenia uniflora L. (pitanga), Genipa americana L. (jenipapo), Hancornia speciosa Gomes (mangaba), Mauritia flexuosa L.f. (buriti), Myrciaria cauliflora (DC) Berg (jabuticaba), Psidium guajava L. (goiaba), Psidium spp. (araçá), Solanum lycocarpum St. Hill (lobeira), Spondias mombin L. (cajá), Annona crassiflora Mart. (araticum), among others are reported here.

Keywords: Brazilian savanna; functional foods; phenolic compounds; secondary metabolites
1. Introduction

Functional foods include whole grains, phytochemical-rich fruits and vegetables, legumes, nuts, dairy products, and tea [1] that present health-promoting effects by maintaining bio-homeostasis (in mental and physical spheres) and reducing the risk of chronic diseases [2]. These foods could act by regulating central and peripheral actions, appetite, absorption, and biodefense (including immunostimulation and suppression of allergies). They can also prevent lifestyle-related diseases by reducing reactive oxygen species (ROS) production and risk of chronic diseases such as hypertension, diabetes, cancer, hypercholesterolemia, anemia, and platelet aggregation. Functional foods are expected to prevent these diseases and are used in alternative medicine [2].

The use of herbal medicinal products and supplements has increased over the past three decades; 80% of people worldwide use these products as part of primary health care [3,4]. In developed countries, herbal therapy is used with the expectation that it will promote healthier living. In developing countries, herbal medicine is an integral part of the culture of communities [4]; synthetic drugs are imported, have high costs, and thus are inaccessible to majority of the population [5].

The Cerrado, encompassing more than 204 million hectares in the central part of Brazil, is the richest tropical savanna in the world in terms of biodiversity and the second most extensive biome in South America [6]. It has been identified as one of the world's biodiversity hotspots, with around 4400 endemic plants species [7]. An estimated 30% of this biodiversity is reasonably known [8]. The Cerrado flora encompasses grasses, herbs, and 30%–40% of woody plants; usually recovered with dense indumentum, trees and bushes display contorted trunk and branches with thick and fire-resistant bark, and shiny coriaceous leaves [8]. This singular phytophysiognomy is due to natural and anthropogenic fires, long periods of drought, and characteristics of the Cerrado soil such as poverty of nutrients, aluminum abundance, and aluminum acidity [8].

Although the Cerrado flora is rich in species containing several chemical compounds with biological activities, in general, it is overlooked and its area has decreased over time. It is estimated that natural vegetation covers just 49.1% of the biome in 2000 and the losses of natural vegetation in the Cerrado is around 11,812 km²/year from 2005 to 2010 [9]. High land use pressure, mainly after the introduction of extensive, mechanized production of grains for exportation, is causing heavy losses of natural vegetation [10–12].

Plants endemic to Cerrado have been receiving increased attention as a source of bioactive compounds [13]. While the shikimate pathway is enhanced in humid forests resulting in greater production of lignified biomass, in dry forests such as the Cerrado biome, lignin precursor molecules can be replaced by polyphenols [14,15]. Therefore, phenolic compounds are very common in Cerrado plants, probably because of the exposure to water stress, high ultraviolet radiation, herbivore attacks and fungi infections [8]. Phenolic compounds, especially tannins, are directly responsible for the therapeutic activity of plants in Cerrado biome. Phenolic compounds and their potential therapeutic activity, such as anti-inflammatory and antimicrobial actions, makes Cerrado plants good candidates for bioprospecting efforts [14]. Since these compounds are found in high concentrations in many fruits and vegetables, resulting in a continuous and long-term intake of such plant phenols, phenolic compounds play a particularly important role in human health. These compounds also present antioxidant, chemoprevention, cytoprotection, anti-mutagenic, anti-estrogenic and anti-angiogenic activities [16].
The Cerrado native fruits have been used by indigenous people and played a key role in feeding the explorers and settlers of the central Brazil region [17]. Some Cerrado fruits are gaining acceptance, being used as juices, sweets, ice cream, and candies in Brazil. Studies have shown that the bioactive substances present in these fruits can act alone or together on various pathophysiologic targets to alleviate the symptoms of chronic diseases [18]. Phenolic compounds—including flavonoids, tannins, anthocyanins, and simple phenolic compounds—represent the main bioactive class of compounds that can be found in Cerrado fruits [8]. Fruits and vegetables are the main dietary sources of flavonoids, and their potential health benefits are associated with the contribution to redox regulation in cells [19]. Beside these, furanocoumarins, terpenes, stilbene derivatives, phytosterols, and fatty acids, among other kind of molecules, can be identified in this biome. Perhaps because alkaloids are commonly extracted from roots, stem bark, leaves, and wood [20], few reports about alkaloid presence in Cerrado fruits are available. The importance of Cerrado fruits was highlighted in the work of Siqueira and colleagues [21]. A comparison of 12 Cerrado fruits with *Malus domestica* (the Red Delicious apple) revealed that nine of them—araticum (*Annona crassiflora* Mart), cagaita (*Eugenia dysenterica* DC.), cajuzinho (*Anacardium humile* St. Hil.), ingá (*Inga laurina* Willd.), jenipapo (*Genipa americana* L.), jurubeba (*Solanum paniculatum* L.), lobeira (*Solanum grandiflorum* Ruiz & Pav.), mangaba (*Hancornia speciosa* Gomes), and tucum (*Bactris setosa* Mart)—showed high levels of phenolic contents [21]. Araticum and tucum are rich in flavonoids. The fruits cajuzinho, jatobá, jurubeba, and tucum showed high content of anthocyanins. Cagaita, cajuzinho, lobeira, mangaba, and tucum showed high levels of vitamin C. The high content of bioactive compounds found in araticum, cagaita, cajuzinho, jurubeba, lobeira, mangaba, and tucum corroborate the high antioxidant activity of these fruits [21]. These results indicate that a daily consumption of Cerrado fruits could protect human tissues against oxidative stress, and thus potentially prevent chronic diseases and premature aging [21].

In this way, Cerrado fruits can provide a source of bioactive compounds with nutritional and functional properties beneficial to health, which should stimulate the pharmaceutical and food industries to develop new products. This would value Cerrado constituents, promoting the sustainable development of Cerrado regions and contributing to the conservation of the biodiversity of this biome [21,22]. The possibility of introducing Cerrado fruits in the form of wines, juices, pulp, or residue powdered (capsulated or bulk), could increase their use in dietary or cosmetic products and lead to trade in international markets [23]. However, more detailed agronomic, phytochemical, and pharmacologic information is needed before these advances will be feasible [18]. To compile information about Cerrado fruits and highlight the nutraceutical and pharmacologic potential of this biome, we reviewed the available literature as shown in Table 1. The functional compounds, their chemical structures (Figure 1), and their biological activities beneficial in human health are emphasized.
Table 1. Cerrado fruits with main metabolites and functional properties described.

| Name (Scientific/Popular) | Main Metabolites * | Functional Properties |
|---------------------------|--------------------|-----------------------|
| **Anacardiaceae**         |                    |                       |
| *Spondias mombin/*cajá or taperebá | β-Cryptoxanthin (26) | Antioxidant         |
| **Annonaceae**            |                    |                       |
| *Annona crassiflora/*araticum | Ascorbic acid (17), caffeic acid (54), quinic acid (5), ferulic acid (55), xanthoxylin (56), and rutin (57) | Antioxidant |
| **Arecaceae (Palmae)**    |                    |                       |
| *Mauritia flexuosa/*buriti | β-Carotene (25), α-carotene (24), lutein (41), and gallic acid (2) | Reverse clinical xerophthalmia and restore liver reserves of vitamin A |
| **Caryocaraceae**         |                    |                       |
| *Caryocar* spp.*pequi     | Ethyl galate (1), gallic acid (2), methyl shikimate (3), lupeol (4), quinic acid (5), quercetin (6), and quercetin 3-O-arabinose (7), ethyl hexanoate (8), ethyl octanoate (9), β-ocimene (10), and hexanoic acid (11) | Antioxidant, antiaging, antiapoptotic, and immunomodulatory |
| **Leguminosae**           |                    |                       |
| *Dipteryx alata*/*baru    | Oleic, linoleic (12), linolenic (13), gadoleic (14), and erucic (15), phytic acid (16) | Antioxidant and cardiovascular diseases protection |
| **Myrtaceae**             |                    |                       |
| *Eugenia dysenterica*/*cagaita | Ascorbic acid (17), acetic acid (18), lactic acid (19), malic acid (20), succinic acid (21), tartaric acid (22), citric acid (23), α-carotene (24), β-carotene (25), β-cryptoxanthin (26) and lycopen, α- (27), β- (28), γ- (29) and δ-tocopherol (30), tocotrienol (31), tetrahydrofolate (32), 5-methyltetrahydrofolate (33), 5-formyltetrahydrofolate (34), and ellagic acid (35) | Laxative and anti-obesity |
| *Eugenia uniflora*/*pitanga | Delphinidin-3-O-β-glucopyranoside (36), myricetin (37), cyanidin (38), quercetin (6), ellagic acid (35), and proanthocyanidins | Promising natural ingredient for food and nutraceutical manufacturers |
| *Myrciaria cauliflora*/*jabuticaba | Cyanidin-3-O-glucoside (42), delphinidin-3-O-glucoside (36), gallic acid (2), ellagic acid (35), isoquercitrin (43), quercimeritrin (44), quercitrin (45), myricitrin (46), and quercetin (6) | Antioxidant, anti-inflammatory, anti-diabetic, anti-obesity, could be used in chronic obstructive pulmonary disease (COPD) treatment |
Table 1. Cont.

| Name (Scientific/Popular) | Main Metabolites a | Functional Properties |
|--------------------------|--------------------|-----------------------|
| **Myrtaceae**            |                    |                       |
| *Psidium guajava/goiaba* | Ascorbic acid (17), myricetin (37), abscisic acid (47), and madecassic acid (48) | Antioxidant, antidiarrheal, antimicrobial, could reduce blood pressure and sugar, triglycerides and cholesterol blood levels, analgesic, and anti-inflammatory |
| *Psidium spp./araçá*    | (−)-Epicatechin (49), gallic acid (2), taxifolin (50), quercetin (6), ellagic acid (35), all-trans-β-cryptoxanthin (51), β-carotene (25), and lutein (41) | Antimicrobial, antiproliferative, and could be involved in vasodilation |
| **Rubiaceae**            |                    |                       |
| *Genipa americana/jenipapo* | Campesterol (38), stigmasterol (39), and β-sitosterol (40) | Anti-obesity, antioxidant, and antiproliferative |
| **Sapotaceae**           |                    |                       |
| *Hancornia speciosa/mangaba* | β-Carotene (25), ascorbic acid (17), tocotrienol (31) and (6S)-5-formyl-5,6,7,8-tetrahydrofolate (5-FTHF) (34) | Antioxidant, antidiabetic, and anti-obesity |
| **Solanaceae**           |                    |                       |
| *Solanum lycocarpum/lobeira* | Solamargine (52) and solasonine (53) | Antidiabetic, anti-inflammatory, and anticancer |

a The numbers in parentheses indicate the correspondence of the molecules in Figure 1.
Figure 1. Cont.
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Figure 1. Molecular structures (1 to 64) of the compounds found in Cerrado fruits.

2. *Caryocar brasiliense* Camb.

*Caryocar brasiliense* Camb., known in Brazil as pequi, presents commercial importance because of its edible fruit, called pequi. This fruit is characterized by the presence of several nutrients mainly in mesocarp (light-yellow, pulpy, rich in oil, vitamins and proteins) [24]. Phenolic compounds and phytosterols were detected in epicarp and external mesocarp of the pequi fruits. According to Ascari and coworkers, ethyl galate (1), gallic acid (2), methyl shikimate (3), and lupeol (4) were detected in pequi pulp, using nuclear magnetic resonance (NMR) [22]. On the other hand, using electrospray ionization mass spectrometry (ESI-MS), Roesler and coworkers detected potent antioxidants in pequi pulp, such as gallic acid (2), quinic acid (5), quercetin (6), and quercetin 3-O-arabinose (7) [25].
The pequi fruit has a characteristic flavor, making it a valued spice in the regional cuisine [26]. The flavor of some Cerrado fruits is due to the combination of the volatile molecules present in the essential oils of these fruits. Hydrocarbons, fatty acids, and terpenoids have been identified in the pequi fruit essential oil; esters are the predominant molecule class in this fraction [26]. The esters ethyl hexanoate (8) and ethyl octanoate (9) and the acyclic monoterpene \( \beta \)-ocimene (10) are the major components of the pequi fruit essential oil [26–28]. Ethyl hexanoate (8) is a colorless liquid with the intense fruity odor characteristic of many fruits [29], including pineapples [30], green apples, and strawberries [31] and of beverages such as wine [31], beer [32], Chinese liqueurs, and Japanese sakes [33]. Ethyl octanoate (9) is a liquid with a sweet, fruity-floral odor that is present in the essential oils of many fruits and in the alcoholic beverages fermented from them [31]. \( \beta \)-Ocimene (10) can be found in the essential oil of many fruits, but its use is generally restricted to perfumery [34]. The combination of these three substances may produce the sweet and floral taste characteristic of the pequi fruit [26]. Hexanoic acid (11) has also been identified in the essential oil of pequi fruit [26]. Although linear saturated fatty acids, when isolated, appear to contribute little to the food flavor, they are commonly used to artificially enhance flavor and aroma of foods. For instance, hexanoic acid (11) possesses the ability to enhance both fruity and cheesy flavors and aromas [34]. Therefore, the presence of this substance could give a slightly cheesy flavor in addition to the characteristic fruity flavor of pequi pulp [26].

Pequi carotenoid-rich oil is efficient in reducing tissue injuries in runners, particularly in women, and in reducing DNA damage in both genders, making this oil a good candidate for use as an antioxidant and an antiaging supplement [35–38]. Because of its antioxidant potential, the pequi oil has potential against tumor growth, to increase lymphocyte-dependent immunity, and reduce the adverse effects associated with doxorubicin-induced oxidative damage to normal cells [39]. Besides the oil, the pulp also has highly efficient antioxidant activity, perhaps because of the potent natural antioxidants detected in the fruit [25], as described above.

3. *Dipteryx alata* Vog.

The baru nut is a seed of the Baruzeiro plant (*Dipteryx alata* Vog.), a species of shrub belonging to the Fabaceae family, which is native to the Cerrado. This species produces fruit from July to October [40]. Despite the extreme climatic conditions of the Cerrado biome, baru nuts contain high-quality proteins and lipids, mainly unsaturated fatty acids such as oleic (12), linolenic (13), gadoleic (14) and erucic (15) acids [41,42]. The baru fruit also contains calcium, iron, and zinc, as well as phytate and tannins. Tannins and others polyphenols are important to human health because of their antioxidant properties [43,44].

The consumption of aqueous and ethyl acetate extracts of the baru nut by rats supplemented orally with iron provided tissue protection against iron-induced oxidative stress. This activity might be attributed to the phytic acid (16), but it is possible that phenolic compounds may also be involved [45]. Dietary supplementation of mildly hypercholesterolemic subjects with baru nuts improves serum lipid parameters; this fruit might therefore be included in diets aiming at reducing cardiovascular diseases. Baru almonds reduced total cholesterol, low-density lipoprotein cholesterol, and non–high-density lipoprotein cholesterol in subjects consuming a diet that included this part of fruit (20 g/day for 12 weeks) [44].
4. Eugenia spp.

The species of Eugenia genus belongs to the Myrtaceae family. Among the species of native edible fruit from the Brazilian Cerrado, “cagaita” (Eugenia dysenterica DC.) is popular with the local population. Its fruits are tasty and rich in nutritional substances, such as ascorbic acid (vitamin C), proteins, lipids and dietary fiber [46]. According to Schwan and coworkers [47] the pulp of E. dysenterica fruits contains organic acids (acetic acid (18), lactic acid (19), malic acid (20), succinic acid (21), tartaric acid (22), and citric acid (23)) and carbohydrates (mainly glucose, sucrose, and fructose). Tannins also represent a phenolic class present in cagaita fruits [48]. The work of Cardoso and colleagues [49], using high performance liquid chromatography (HPLC) with a diode array detector and HPLC with fluorescence detection, showed that cagaita fruits contain other substances, such as carotenoids (α-carotene (24), β-carotene (25), β-cryptoxanthin (26), and lycopene), vitamin E (α- (27), β- (28), γ- (29), and δ-tocopherol (30) and tocotrienol (31)) and folates (tetrahydrofolate (32), 5-methyltetrahydrofolate (33), and 5-formyltetrahydrofolate (34)). Ellagic acid (35) was also found in cagaita commercial pulp [50].

The consumption of this fruit provides a portion of the recommended daily amounts of vitamin A and folates needed by children, adults, and pregnant women, contributing to the importance of this food [49]. This fruit also has laxative properties, according to popular use [51]. Lima and colleagues detected a 7 kDa peptide using a semipreparative HPLC column, MALDI-TOF, and Tris/Tricine SDS-PAGE of HPLC fractions [52]. This molecule showed laxative properties in experiments carried out in rats after charcoal meal administrations, increasing intestinal motility by 15% [52]. A recent study demonstrated that phenolic-rich extracts from cagaita fruits affect obesity and metabolism problems caused by intake of a high-fat and high-sucrose diet in male mice. The increase in body weight was attenuated by the administration of the cagaita extracts to the animals [53].

Pitanga fruits (Eugenia uniflora L.) can be found in various biomes, such as the Brazilian Cerrado, and are rich in phenolic substances (hydroxybenzoic acids, hydroxycinnamic acids, and flavonoids) and anthocyanin. Delphinidin-3-O-β-glucopyranoside (36) was detected in pitanga fruits using HPLC, NMR, and liquid chromatography-mass spectrometry (LC-MS) analyses [53]. Myricetin (37), cyanidin (38), quercetin (6), ellagic acid (35), and proanthocyanidins were found in pitanga residue powder, consisting of residual fruit pulps, seeds, and peels after juice extraction. It makes pitanga-dried residue a promising natural ingredient for food and nutraceutical manufacturers, due to their rich bioactive compound content [54]. In this same genus, the species Eugenia calycina Cambess is commonly referred to as “red pitanga or pitanga cherry of Cerrado”, a fruit widely consumed in this area of Brazil [55]. However, there are few reports regarding E. calycina phytochemical profile and functional properties.

5. Genipa americana L.

Genipa americana L., belonging to the Rubiaceae family, is a species widely distributed in tropical Central and South America, including the Cerrado biome. It yields an edible fruit popularly known as genipap or jenipapo [56]. Costa and colleagues have reported that the pulp of this fruit and seeds possess phytosterols such as campesterol (38), stigmasterol (39), and β-sitosterol (40) [57]. Phytosterols are present in high levels in genipap nuts and pulps, and this concentration can be compared with those in kidney bean, soybean, pecan, cashew nut, peanut, peanut oil, olive oil, and soybean [58]. Phytosterols...
have the potential to decrease the levels of serum low-density lipoprotein (LDL) cholesterol, which make them useful to the development of some foods enriched with these plant sterols [59,60].

Omena and colleagues evaluated the antioxidant activities of genipap pulp using the TBARS inhibition assay, which indicates protection against lipid peroxidation [61]. Ethanolic extracts of the pulp provide an acetylcholinesterase inhibition zone similar to that of the positive control, carbachol, suggesting that this extract is a potential antioxidant supplement for use in the human diet and in the pharmaceutical and cosmetic industries [61]. Conceição and coauthors [62] verified the effect of *G. americana* fruit ethanolic extract on the proliferation and differentiation of trophoblast-like cells; results showed that the extract did not cause cytotoxicity or any interference in cell differentiation. However, a significant antiproliferative state related to inhibition and reactivation of the tested cells was observed. These results suggest that the ethanolic extract of *G. americana* may affect placental cell regulation [62].

6. *Hancornia speciosa* Gomes

*Hancornia speciosa* Gomes, known as mangabeira, yields a round-shaped fruit, known as mangaba, which has a fragile peel that is yellow-green in color with red spots. The pulp that is rich in vitamin C, vitamin E, and folate is green and viscous with numerous beige seeds [63]. Mangaba has dietary fiber content similar to fruits considered good sources of dietary fiber, including tangerine and pear [64]. Moreover, carotenoids, vitamin C, vitamin E, and folate compounds have been identified in mangaba pulp. Among the carotenoids, \(\beta\)-carotene (25) was the major component (52.6% of total carotenoids). Among vitamins, ascorbic acid (17) and tocotrienol (31) were the major vitamin C and vitamin E compounds, respectively. \((6S)-5\text{-formyl-5,6,7,8-tetrahydrofolate (5-FTHF)} (34) was the prevalent folate in mangaba pulp [63].

Because of the presence of these natural antioxidants, mangaba pulp is considered to have great radical-scavenging capacity [65]. The high fiber content of mangaba could be important for human health since it may help improve the glycemic index of the diet, glycemic control, and weight control [63,66]. Moreover, the high antioxidant and folate contents of mangaba pulp could reduce the risk of development of several chronic-degenerative diseases, such as cancer and cardiovascular diseases [63,67,68].

7. *Mauritia flexuosa* L.f.

Buriti (*Mauritia flexuosa* L.f.) is a palm found in the Cerrado biome. It produces a fruit with a characteristic color that ranges from yellow to dark reddish brown [69]. These fruits contain high levels of provitamin A carotenoids, mainly \(\beta\)-carotene (25) [70]. In recent work, total phenolics from buriti fruits were quantified using Folin-Ciocalteau reagent. Gallic acid (2) was detected in amounts higher than that in other species of the same family (Arecaceae), such as *Oenocarpus bacaba* Mart. (bacaba), *Euterpe edulis* (jussara), *Euterpe oleracea* (açaí), and *Copernicia prunifera* (carnaúba) [71]. These authors also determined the chromatographic profile of carotenoids, identifying \(\alpha\)-carotene (24), \(\beta\)-carotene (25), and lutein (41) (a xanthophyll with two hydroxyl groups). These results confirmed the predominance of \(\beta\)-carotene (25), an important vitamin A precursor. Tocopherol (27–30) is also found in buriti fruits. However, the content of vitamin E in fruits and vegetables can be affected by species,
maturity, growing conditions (weather, growing season, intensity of sunlight, and soil), and time and manner of harvesting. After harvesting, the concentration of vitamin E can also decline based on factors such as processing procedures, storage time and conditions, sample preparation, and analytical method variation [72].

Because of its high β-carotene (25) content, buriti pulp can reverse clinical xerophthalmia and restore liver reserves of vitamin A, suggesting potential use in intervention programs to combat vitamin A deficiency in countries where the fruit is available or has the potential for cultivation [73].

8. Myrciaria cauliflora (DC) Berg

*Myrciaria cauliflora* (DC) Berg, popularly known as jabuticabeira or “Brazilian grape tree,” is native to Brazil and provides a typical fruit known as jabuticaba that is widely consumed mainly in the southeastern part of this country [74,75]. This fruit has been called a “super fruit,” mainly in the food industry. Its protective effects can be attributed, in part, to phenolic secondary metabolites [76]. The jabuticaba peel is a good source of nutrients such as minerals, soluble and insoluble fibers, and a group of phenolic compounds known as anthocyanins [77,78]. The major anthocyanins found in jabuticaba peels are cyanidin-3-O-glucoside (42) and delphinidin-3-O-glucoside (36). The presence of these substances accounts for the fruit’s antioxidant activity [79]. Other phenolic compounds were detected in jabuticaba, including gallic acid (2), ellagic acid (35), isoquercitrin (43), quercimeritrin (44), quercitrin (45), myricitrin (46), and quercetin (6) [75].

Several epidemiologic works show that diets rich in dark-colored fruits reduce the incidence of cardiovascular diseases, diabetes, cancer, and stroke [80]. The presence of depsides and anthocyanins, which have strong antioxidant, anti-inflammatory, anti-diabetic, and anti-obesity properties, may explain this effect. Moreover, these compounds are potential treatments for chronic obstructive pulmonary disease [75,81–84].

9. *Psidium* spp.

The *Psidium* genus, native to tropical and subtropical America, includes around 100 species of trees and shrubs. *Psidium guajava* L., known as goiabeira, is the most economically important species [17,85]. Its fruits contain many vitamins and minerals and have large amounts of phenolic substances. Guava fruits contain four times more ascorbic acid (17) than orange and also contain flavonoids, triterpenoids, and other biologically active secondary compounds [86]. The guava pulp contains total phenols and total flavonoids in amounts higher than in fruits such as cajá, mango, pineapple, and tamarind [87]. In a study of seven cultivars of guava fruits, the flavonoid myricetin (37), sesquiterpenoid abscisic acid (47), and triterpene madecassic acid (48) were detected in all varieties by mass spectrometry [88].

The extracts of the *P. guajava* cultivars are potent free-radical scavengers and may be used as a good source of natural antioxidants for food, pharmaceutical, medical, and commercial uses [88]. Although the ripe fruit could be a laxative, the unripe fruit is used as astringent and antidiarrheal agent in popular medicine [89]. On the other hand, a galactose-specific lectin, isolated from ripe fruit, was shown to bind to *Escherichia coli* (a common diarrhea-causing bacterium), preventing its adhesion to the intestinal wall and thus preventing diarrhea [90]. Previous reviews pointed that the fruit or its juice have
antimicrobial activity and could reduce blood pressure and serum glucose, triglyceride, and cholesterol levels, and also ameliorate rheumatism (analgesic and anti-inflammatory effects) [91].

Psidium cattleianum Sabine, P. firmum O. Berg, and P. guineensis Sw., known as aracazeiro, present yellow or red berries with potential commercial interest [17,92]. The fruit, aracá, presents a high content of dietary fiber, folate, and vitamin C, around three or four times higher than other citrus fruits, and a low lipid content, indicating that this fruit is nutritionally valuable [93,94]. Aracá has a total phenolic content higher than strawberry (Fragaria ananassa Duch.) and grape (Vitis vinifera L.) [92]. HPLC-UV has shown that (−)-epicatechin (49) and gallic acid (2) are the major phenolic compounds present in aracá [92]. Mass spectrometry (MS) has identified gallic acid (2) and taxifolin (50) as the major phenolic compounds present in aracá [95]. Quercetin (6) and ellagic acid (35) were also detected in aracá [50]. Even though aracá is not a good source of carotenoids, these compounds were identified in aracá pulp using MS. The all-trans-β-cryptoxanthin (51) was the major carotenoid, representing 34% of the total carotenoid content in this fruit, followed by β-carotene (25) and lutein (41), corresponding to 26% and 20% of the total content, respectively [95].

Through vasodilation and reduction in blood pressure, (−)-epicatechin (49) could contribute to reducing risks of cardiovascular diseases [96]. Moreover, polyphenols could play an important role in cancer prevention through epigenetic mechanisms, mainly by DNA methylation, histone modification, or regulation of mRNA expression [97]. Aracá extracts present antimicrobial effects against Salmonella enteritidis, possibly owing to the presence of phenolic compounds, which could destabilize the bacterial cell membrane responsible for prokaryotic respiration [92]. Moreover, aracá extracts reduced survival rates of breast and colon cancer cells (MCF-7 and Caco-2, respectively) in vitro, by mechanisms not yet described, indicating an antiproliferative effect of aracá extracts [92].

10. Solanum lycocarpum St. Hill

Solanum lycocarpum St. Hill (Solanaceae) is a native shrub that produces a fruit popularly known as lobeira. Glycoalkaloids and polyphenols are the most common elements obtained from S. lycocarpum, which has a great importance for use in food and as medicine in Cerrado [98]. This fruit contains two major glycoalkaloids, solamargine (52) and solasonine (53) [99]. These compounds are structurally similar, with the same steroidal moiety, solasodine, differing only in their sugar chain moieties, solatriose for solasonine and chacotriose for solamargine [100].

Several alkaloids isolated from natural herbs exhibit antiproliferative, antibacterial, antiviral, insecticidal, and antimetastatic effects on various types of cancers both in vitro and in vivo [101]. The glycoalkaloids solamargine (52) and solasonine (53) were identified in various species of the Solanaceae family [102], but S. lycocarpum stands out for the production of these compounds [103]. Solamargine (52) and solasonine (53) could function as antidiabetic compounds, since they inhibit the increase of rat serum glucose levels, probably by suppressing the transfer of sucrose from the stomach to the small intestine [100]. Because of the presence of these glycoalkaloids, high-fiber S. lycocarpum flour reduced plasma glucose in diabetic rats. In S. lycocarpum flour-treated diabetic rats (TDRs), serum glucose, water and food intake, urine excretion, and urine sodium concentration reduced compared with diabetic control rats (DCRs). In addition, TDRs did not show signs of kidney hypertrophy, unlike those in the DCR group. These results suggest that the use of S. lycocarpum flour can be an effective support in
diabetes mellitus treatment [104]. Moreover, an alkaloid fraction of *S. lycocarpum* fruits induced a dose-dependent reduction in edema formation and leukocyte migration [105], suggesting that *S. lycocarpum* solamargine (52) and solasonine (53) may act as anti-inflammatory compounds.

Solamargine (52) and solasonine (53) have antitrypanosomal [98,106], schistosomicidal [107], antiherpetic [108], antifungal [109,110], immunomodulatory [99], and anticancer [111–114] activities. Formulations based on *Solanum*-derived glycoalkaloids may be useful for topical therapy of several skin disorders, mainly skin cancer, but also leishmaniasis, herpes, and dermatophytosis [103,115]. Recently, investigators reported a promising topical formulation containing solamargine (52) and solasonine (53) extracted from *S. lycocarpum* that allows the penetration of the glycoalkaloids into deeper skin layers, where cancerous lesions commonly take place [103].

11. *Spondias mombin* L.

*Spondias mombin* L. is a member of the Anacardiaceae family and is found in the tropical areas of America, Asia, and Africa. The fruit of this tree, known as cajá or taperebá, is a small ovoid drupe with thin yellow skin and a sour-sweet taste [116]. The cajá pulp has high levels of micronutrients, such as potassium, magnesium, phosphorus, and copper. Moreover, high levels of phenolic and carotenoids compounds are present in this fruit, resulting in a high level of cajá antioxidant activity above the fruits average [117]. Five different carotenoids were identified in cajá pulp, with β-cryptoxanthin (26) the major compound (48% of the total carotenoid amount) [117]. Its presence gives cajá high nutritional and functional value that may help prevent various diseases, including cardiovascular disorders [117,118].

12. Other Cerrado Fruits

*Annona crassiflora* Mart. is a tree 4–8 m high; it produces an oval-round fruit known as araticum [17]. Its yellow pulp is sweet, with a strong, peculiar aroma [119]. Important bioactive molecules have been identified using ESI-MS in araticum fruit, including ascorbic acid (17), caffeic acid (54), quinic acid (5), ferulic acid (55), xanthoxylin (56) and rutin (57) [120]. These compounds could be involved with the antioxidant activity observed in this fruit [119,121].

The pulp and kernel of three palm fruits distributed in Brazilian Cerrado, *Syagrus oleracea* (guariroba), *Syagrus romanzoffiana* (jerivá), and *Acrocomia aculeata* (macaúba), have been studied [122]. Jerivá pulp had the highest percentage of fibers, followed by guariroba and macaúba. Pulp oils were richer in the bioactive compounds carotenoids and tocopherols than kernel oils. Jerivá pulp oil showed considerable carotenoid and tocopherol amounts, especially α-tocopherol (27), thus representing an important source of antioxidant vitamins A and E [122].

Some Cerrado fruits have potential use in production of wines, such as *Campomanesia pubescens* (DC.) O. Berg (gabiroba) and *Myrciaria jaboticaba* Berg (jabuticaba). Gabiroba is a Cerrado native fruit consumed fresh or used in the production of homemade ice cream, jam, and juices [17]. Jabuticaba and gabiroba wine chemical characterization was performed [123]. In both wines, the following monoterpenic alcohols were detected: linalool (58), α-terpineol (59), and geraniol (60). In contrast, 4-terpineol (61), borneol (62), citronellol (63), and myrtenol (64) were detected only in gabiroba wine. The monoterpenic compounds play an important role in the varietal flavor of wines [124].
13. Conclusions

Brazilian Cerrado is an important source of food or medicine to the local communities. The fruits found in this biome contain several nutrients, such as fibers, micronutrients, and vitamins A, C, and E. Moreover, secondary metabolites with biological activities were identified in Cerrado fruits, especially phenolic compounds such as tannins, flavonoids, anthocyanins, and single phenols. Because of their rich bioactive compound content, Cerrado fruits could be promising ingredients for nutraceutical and pharmaceutical manufacturers, expanding the market utility of these fruits. The information presented in this review should be useful for further exploitation of several species found in the Cerrado biome.

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Author Contributions

Elisa Flávia Luiz Cardoso Bailão and Leonardo Luiz Borges conceived the idea and wrote the paper. Ivano Alessandro Devilla and Edemilson Cardoso da Conceição contributed to critical discussions and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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