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Review

Brazilian savannah fruits: Characteristics, properties, and potential applications

Cinthia Aparecida de Andrade Silva and Gustavo Graciano Fonseca*

Laboratory of Bioengineering, Faculty of Biological and Environmental Sciences, Federal University of Grande Dourados, CEP 79.804-970, Dourados-MS, Brazil

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*Corresponding Author
Tel: +55-67-3410-2214
Fax: +55-67-3410-2190
E-mail: ggf@ufgd.edu.br

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Abstract The Brazilian savannah is the second largest biome of the country, and it displays great biodiversity. The fruits of the native trees have peculiar characteristics and are recognized for their nutritional and therapeutic aspects. However, little is known about their technological and biotechnological potential applications. The existing information concerning these aspects has never been compiled so far. It is known that many of these fruits contain many bioactive compounds of industrial interest, such as carotenoids and phenolic constituents. Another aspect of the fruit is the high fatty acid content of some species. Pequi, bocaiuva, jatoba, baru, amburama, and buriti, for instance, are among those fruits described as being rich in fatty acids, mostly unsaturated ones. Here, we reviewed 18 species from the Brazilian savannah identified to be of interest because of high potencial for sustained medium- and short-term explorations, under the technological and biotechnological aspects, seeking the development of new products from these scarcely studied raw materials.

Keywords: Bocaiuva, buriti, cagaita, guavira, pequi

Brazilian Savannah

The Brazilian savannah is one of the largest and most important biomes in South America, especially because of its high biodiversity (1). The number of vascular plants is greater than that found in most regions of the world: herbaceous, shrubs, and arboreal plants and vines represent more than 7,000 species (2).

Many native species from savannah have peculiar characteristics, varied shapes, attractive colors, and uncommon flavors, constituting potential sources of economic exploitation. The fruits are nutritious and commonly used in popular diet, being consumed in various forms (3,4).

The Brazilian savannah is the second largest biome of Brazil, after Amazonia, comprising 21% of the land area. It is mainly located in Central Brazil but extends over several states. It covers the Federal District and the states of Goiás and Tocantins, parts of the states of Bahia, Ceará, Maranhão, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Piauí, Rondônia, and São Paulo, beyond occur in areas in the north of the states Amapá, Amazonas, Pará, and Roraima (5).

The Brazilian savannah is formed by different vegetation physiognomies according to their structure: tree and scrub savannah with 20 to 30% tree cover, grassland with scattered trees with canopy coverage of up to 5%, and occasional patches of a dry, closed canopy forest, with trees with a height between 12 and 15 m (6,7). Gallery forests are found throughout the region, although they are technically not considered part of the biome.

The biome has a high variety of species and high endemism of plants and vertebrates. However, this biome is under a rapid conversion process to soybeans and corn crops and extensive livestock and imminent expansion to cane sugar plantations. Currently, about 39% of its land is without vegetation cover (8). Given its high degree of endemism and strong human pressure, the Brazilian savannah is considered to be one of the hotspots (priority areas for conservation) of biodiversity in the world (9). Nevertheless, efforts made for its preservation have been insufficient (10). Considering that only 2.2% of the Brazilian savannah is protected, at the current rate of loss, the ecosystem could be extinct by 2030 (11). Within the great diversity of flora, native fruit species have a prominent place in this biome (12).

Brazilian Savannah Fruits

Brazilian savannah fruits have a great potential for agricultural use and are traditionally used by the locals. They are an important option of food and income. The fruits are manually collected and generally

consumed raw or in the form of juice, liquor, ice cream, jam, and several types of sweets (13).

Studies about Brazilian savannah fruits were published (mostly in Portuguese) in a dispersed manner until 1994 (14). In that same year, botanical, agronomic, and nutritional data of about 35 species of the most important fruits for this region were compiled in a book (15), which was later expanded and republished with 57 species (16).

However, technological and biotechnological aspects of the fruits have been scarcely studied so far, and related information had never been compiled until now. Table 1 presents the main fruits from the Brazilian savannah with considerable potential for technology and biotechnology. The savannah pineapple and the savannah passion fruit, although reported as species with potential for exploration in the mid and short terms, respectively (14), are poorly described in the literature. The other species highlighted in Table 1 are briefly described here.

Amburana (*Amburana cearensis*) Amburana is also known as cumare and cumaru (3). It is frequently utilized as traditional medicine for the treatment of respiratory diseases, including asthma (18).

Araticum (*Annona crassiflora*) The fruits of araticum are also known as marolo. They are consumed as food and are highly appreciated for their yellowish sweet pulp with very strong aroma. The seeds act against parasitic diseases of the scalp (19).

Baru (*Dypterix alata*) The fruit has different denominations, such as baruju, cumarurana, cumbaru, cocoa-bean, emburena brave, or monkey fruit. It is found in the central plateau region and is an excellent source of protein and oil. Its kernel has high protein content, suggesting various applications, either as a single ingredient or in the form of oils or flour. Moreover, in the food industry, it is also considered as a functional ingredient (20).

Bocaiuva (*Acrocomia aculeata*) Bocaiuva is also known as macauba. This palm is found in almost all Brazilian territories (21). Its fruit can be consumed in both the fresh form and the processed flour form. Bocaiuva is highly important from the ecological point of view because it is used as a food source for various species of local fauna (22).

Buriti (*Mauritia flexuosa*) Buriti is a palm native to Brazil, but it is

Table 1. Common and scientific names of the main savannah fruits

Common name	Scientific name	Common name	Scientific name
Amburana[a,f]	*Amburana cearensis*	Jeriva[b]	*Syagrus romanzoffiana*
Ananas/Savannah pineaple[a,e]	*Ananas ananassoides*	Lobeira[a,f]	*Solanum lycocarpum*
Savannah arassa[a,e]	*Psidium firmum*	Macauba/Bocaiuva[a,f]	*Acrocomia aculeata*
Araticum[a,d]	*Annona crassiflora*	Mamacadela[a]	*Brosimum gaudichaudii*
Babassu[b]	*Orbygnia cf. phalerata*	Mangaba[a,c,d]	*Hancornia speciosa*
Bacupari[a]	*Salacia crassiflora*	Snake passion fruit[b]	*Passiflora coccinea*
Bacuri	*Scheelea phalerata* Mart.	Savannah passion fruit[b,d]	*Passiflora cincinnata*
Chicken lard[b,f]	*Swartzia langsdorfii*	Sweet passion fruit[b]	*Passiflora alata* Curtis
Baru[a,d]	*Dypterix alata*	Native passion fruit[b]	*Passiflora eichleriana*
Buriti[a,d]	*Mauritia flexuosa*	Purple passion fruit[b]	*Passiflora edulis*
Cagaita[a,d]	*Eugenia dysenterica*	Calf marmelade[a]	*Alibertia edulis*
Savannah tree cashew[b]	*Anacardium othonianum*	Dog marmelade[b]	*Alibertia sessillis*
Crawling cashew[b]	*Anacardium pumilum*	Chick marmelade[b]	*Alibertia elliptica*
Savannah little cashew/Monkey nut[a,e]	*Anacardium humile*	Savannah watermellon[b]	*Melancium campestre*
Chicha[a,f]	*Sterculia striata*	Murici[a,e]	*Byrsonima verbascifolia*
Savannah little coconut[a]	*Syagrus flexuosa*	Wood palmetto[b]	*Euterpe edulis*
Croadinha[b]	*Mouriri elliptica*	Pequi[a,d]	*Caryocar brasilliense*
Curriola[b]	*Pouteria ramiflora*	Dwarf pequi[b]	*Caryocar brasilliense* subsp. *Intermedium*
Armadillo fruit[b]	*Crhysophyllum soboliferum*	Savannah pear[a,e]	*Eugenia klostzchiana*
Guabiroba/Guavira[a,f]	*Campomanesia pubescens*	Little pear[b]	*Eugenia lutescens*
Gravata[b]	*Bromelia balansae*	Monkey pepper[a]	*Xylopia aromatica*
Guapeva[a]	*Pouteria cf. gardineriana*	Red Brazilian cherry/Red pitanga[b]	*Eugenia calycina*
Guariroba[b]	*Syagrus oleraceae*	Savannah pitomba[b,f]	*Talisia esculenta*
Savannah inga[a,f]	*Inga alba*	Puça[b]	*Mouriri pusa*
Jaracatia[b]	*Jacaratia hiptaphylla*	Saputa[b]	*Salacia elliptica*
Savannah jatoba[a,e]	*Hymenaea stigonocarpa*	Savannah tucum[b]	*Bactris* spp.
Wood jatoba[b]	*Hymenaea stilbocarpa*	Savannah native grape[b]	*Vitis* spp.

[a]Reference 3. [b]Reference 17. [c]Species also found in the Caatinga biome. [d]Fruits with high potential for sustained short-term exploration. [e]Fruits with high potential for sustained medium term exploration. [f]Also reported in the literature as species with potential for sustained exploration.

also found in Venezuela. These plants grow near rivers, rainforests, and savannahs and can adapt to occasional periods of drought. Buriti has been widely studied because of its pulp oil, which has the potential for biodiesel production. Buriti oil has a high concentration of fatty acids and high nutritional quality (23).

Cagaita (*Eugenia dysenterica*) Cagaita is mostly utilized fresh. A few precautions should be taken with the amount of Cagaita ingested since it can act as a laxative, especially when fermented in the sun (19,24). Besides the nutritional value of its fruits, the species renders itself as an ornamental and honey plant and for cork extraction. Its shell can be used in tanneries (25).

Chicken lard (*Swartzia langsdorfii*) This species is also known as parrot banana and monkey pacova. Its tree is small and notable for its very large fruits (similar to the common mango) with pulp arils and orange color. Its smell is not very pleasant (19,26).

Guavira (*Campomanesia pubescens*) Guavira is also popularly known as guabiroba. Its fruits are eaten by several species of birds and mammals (27) and have the potential to be used as fresh products in the food industry and as flavoring in the beverage industry because of its attributes such as acidity, ascorbic acid, minerals, fiber, and monoterpene hydrocarbons. The hydrocarbons are present in greater amounts in the volatile oil of the fruit, giving guavira a citrus aroma (28).

Lobeira (*Solanum lycocarpum*) It is popularly known as wolf apple, fruit for wolves, or lobeira. Its fruits are used as food and as reputed medicine. The pulp has a very active and pervasive smell and contains alkaloids of scarcely known nature (15).

Mangaba (*Hancornia speciosa*) The mangaba fruit has shown great potential as tropical fruits in both domestic and internationl markets. The fruits are popular and can be consumed fresh or processed into pulp, juice, or ice cream (29).

Murici (*Byrsonima verbascifolia*) It is mainly consumed fresh or in the form of juice, jam, ice cream, or liquor (30). The mature fruit exhibits a yellowish color and strong odor (30,31). The bark is used in dyeing to extract the black dye (32).

Pequi (*Caryocar brasilliense*) It is also popularly known as pequerim, pequia, piqui, and piquia brave. The fruit is not eaten fresh; it is cooked before consumption (33). The pulp is used in the preparation of several dishes, e.g., rice, bean, and chicken with pequi. The pulp contains a fair amount of edible oil and is rich in vitamin A and protein. The kernel is used as an ingredient in toasted cassava or maize flour mixtures and candies, and it is also consumed as a salted snack. The cultivation of pequi has still not been domesticated and its production is therefore the result of extraction (34). It is perhaps the most studied Brazilian savannah fruit.

Pitomba (*Talisia esculenta*) It is found throughout most of Brazil. The fruits are small drupes, in the form of globes, that are quite tasty when ripened. The seeds are large and oblong and when cooked are utilized to treat diarrhea and as an astringent. Tea prepared from the seeds is utilized to counter dehydration (35).

Savannah arassa (*Psidium firmum*) It is also known as little guava. Savannah arassa is not only present in the Brazilian savannah biome but also in the Amazon and Atlantic Forests. It is an acid fruit, and its pulp is used in the preparation of juice, ice cream, and jelly (36).

Savannah cashew (*Anacardium* sp.) Three species that differ by the type of leaves are related to this fruit: *Anacardium othonianum*, *A. pumilum*, and *A. humile.* The last one is also known as savannah little cashew or cajui, among other names. The use of *Anacardium* sp. for food applications is widespread among the locals. They are consumed fresh or used in the preparation of juice, jam, jelly, and ice cream. A sort of wine or brandy is obtained through the fermentation of the pulp. They are also recognized for their medicinal use (3).

Savannah chicha (*Sterculia striata*) It is also popularly known as wood peanut, monkey peanut, and arachacha (3). This plant provides white, soft, and lightweight wood. The bark contains tannin, and the seeds are edible raw, boiled, or roasted (37).

Savannah inga (*Inga alba*) It is also present in the Amazon region (3). The wood is used for carpentry. The fruit is edible and has a consistency similar to cotton. The bark is used in the form of medicinal tea (38).

Savannah jatoba (*Hymenaea stigonocarpa*) It is also known as jatai and jutai. The fruits have a mealy pulp and are popular among rural people, who consume them fresh and in the form of jelly, liquor, flour for cake, bread, or porridge (39).

Characteristics, Properties, and Potential Applications

Proximate composition The practical application of the enormous biodiversity of the Brazilian savannah can be an economical alternative to the sustainable development of the region. Many native species that are used by local present great potential for being used as raw material for the development of new products (4). Thus, it is essential to know these raw materials before determining appropriate applications of them. Table 2 shows the proximate composition of the main fruits in the Brazilian savannah.

Dry fruits such as baru, savannah cashews, and savannah jatoba, have, in general, excellent physical and chemical properties for consumption as they are rich in nutrients such as proteins and lipids

Table 2. Proximate composition of Brazilian savannah fruits (unit: g/100 g)

Fruit	Analyzed portion	Moisture	Crude protein	Total lipids	Ash	Carbohydrates	Fibers	Reference
Savannah arassa1	P	82.36±0.09	0.50±0.05	0.49±0.04	0.33±0.01	7.67±0.18	8.65±0.15	13
Araticum*	P	73.29±4.62	1.56±0.49	2.53±1.24	0.94±0.30	19.13±8.51	5.17±0.64	4,13,19,40,41
Araticum*	C	54.28±6.24	2.54±0.69	0.95±0.35	0.77±0.28	14.54±4.50	ND	19,41
Araticum*	S	34.40±5.94	10.12±0.89	15.35±0.97	1.15±0.01	13.48±6.02	ND	19,41
Chicken lard	P	76.22	3.77±0.23	0.46±0.15	0.54±0.10	34.04±2.77	ND	19
Chicken lard	C	82.95	7.72±0.23	0.29±0.02	0.62±0.29	17.91±3.31	ND	19
Chicken lard	S	45.58	2.67±0.47	0.45±0.05	0.93±0.03	18.41±2.09	ND	19
Baru	P	ND	5.59	3.40	1.70	58.46	29.50	42
Baru	S	ND	29.59	4.27	2.85	8.27	19.04	42
Bocaiuva/Macauba*	P	48.15±10.54	2.05±0.52	13.52±3.60	1.68±0.12	28.13±5.86	10.93±2.91	13,40,43,44
Buriti*	P	70.28±2.01	2.86±0.37	7.28±5.27	1.39±0.30	12.23±1.23	9.96±3.33	40,45
Cagaita	P+C	89.71	2.09±0.48	0.32±0.07	0.23±0.04	20.47±0.59	ND	19
Cagaita	S	51.15	4.42±1.36	0.49±0.11	0.75±0.12	17.84±1.84	ND	19
Cagaita*	P	93.17±2.58	0.91±0.12	0.32±0.17	0.26±0.03	4.25±1.65	1.04±0.08	4,13
Savannah tree cashew	P	87.57±0.11	1.18±0.02	0.63±0.05	0.33±0.01	6.97±0.16	4.26±0.16	13
Savannah little cashew	S	6.35±0.21	22.01±0.65	26.40	2.44±0.09	8.90±0.12	ND	4
Chicha	P	6.95±0.02	19.58±0.80	21.15±0.53	3.82±0.04	38.10±0.31	10.28±0.34	13
Guabiroba/Guavira*	P	85.06±3.19	1.05±0.78	0.56	0.37	12.24±2.35	1.17±0.52	13,45
Inga	P	83.00	1.00	0.10	0.40	1.50	1.20	45
Savannah jatoba*	S	9.84±0.48	7.44±2.28	3.55	2.43±0.90	35.40±1.40	85.31	4,46
Lobeira	P	74.70	1.79±0.44	0.40±0.05	0.58±0.23	24.17±1.41	ND	19
Lobeira	C	70.84	2.51±0.50	0.55±0.12	0.61±0.24	30.40±1.01	ND	19
Lobeira	S	36.19	13.41±0.50	3.73±0.26	1.80±1.01	ND	ND	19
Mangaba*	P	83.85±2.04	1.05±0.22	2.27±0.15	0.56±0.03	9.31±1.44	2.16	13,40
Murici*	P	79.70±3.46	0.83±0.09	2.17±0.86	0.67±0.10	13.3	5.96	13,45,47
Pequi*	P	48.61±0.19	1.79±0.81	33.28±1.03	0.61±0.03	10.49±3.07	5.89±0.45	40,48
Savannah pitomba*	P	86.83	0.78	0.15±0.06	0.11	10.66±2.62	2.20±0.28	13,45

K, kernel; P, pulp; S, seed; ND, not determined; *Data calculated by means of the results obtained by the authors.

(Table 2). Their low moisture and acidity are important characteristics from the microbiological point of view (4).

Baru and savannah cashews have high oil and energy contents, representing important sources for the formation and maintenance of the organism's cells (4,13). Baru's pulp has high fiber and carbohydrate contents, and the seed is distinguished by the protein content (42).

Savannah jatoba's seeds are good sources of fiber; in addition, seeds containing in their composition xyloglucans and galactomannans, which are the main hemicelluloses of the cell wall of dicotyledonous plants, are used to manufacture paper (46). The pulp is used in the production of sugar-free cookies, partially replacing the wheat flour for fibers (39).

Chicha and bocaiuva are rich in nutrients, presenting a high energy value. The lipid and carbohydrate contents are high in both fruits, with chicha being also rich in proteins (13).

Bioactive compounds Apart from the high nutritional value, the bioactive compounds present in Brazilian savannah fruits have applications in cosmetics and pharmaceutical industries (19). Table 3 shows certain bioactive compounds present in some Brazilian savannah fruits.

Carotenoids have important biological functions for humans, such as prevention of some cancers and photosensitization in certain skin diseases, as well as anti-aging properties (54–56). Buriti and bocaiuva are fruits rich in carotenoids (44,50). Pequi is also important because of its carotenoid content (51,57).

Roesler *et al.* (19) studied the performance of the ethanol extracts of chicken lard peel, pequi peel, araticum seed and peel, and cagaita seed. All extracts showed a high content of phenolic compounds, but the best results were obtained in the ethanolic extract of araticum seed and peel (49.18 and 30.97 $mg \cdot mL^{-1}$, respectively), whereas the ethanolic extract of the cagaita seed showed 14.15 $mg \cdot mL^{-1}$, demonstrating the antioxidant potential of all these fruits.

The identification of new food sources rich in ascorbic acid is of great concern to public health (36). Guavira stands out in relation to this compound (234 mg 100 g^{-1}) in comparison with other fruits recognized as traditional sources, like Brazilian cherry (42.9 mg 100 g^{-1}) (58) and guava (89.78 mg 100 g^{-1}) (59), apart from orange, lemon, and papaya, which present values between 50 and 100 mg 100 g^{-1} (60). This high concentration of ascorbic acid shows that guavira pulp is rich in vitamin C (61).

So, the potential use of each fruit depends on their specific properties. Further studies of these raw materials will imply the

Table 3. Bioactive compounds present in Brazilian savannah fruits

Fruit	Analyzed portion	Ascorbic acid (mg AA 100 g^{-1})	Total phenols (g GA kg^{-1})	Total carotenoids (μmol Trolox eq g^{-1}[a] or μg g^{-1}[b])	[c]DPPH/[d]TEAC (μmol/L Trolox /g[e] or mg GAE mL^{-1}[f])	Reference
Savannah arassa	P	4.70±0.50	1.29±0.09[g]	0.58±0.02[a]	4.10±0.20[c,e]	36
Araticum	C	ND	90.72±4.99	ND	198.28±8.24[c,f]	19
Araticum	S	ND	136.99±7.56	ND	417.54±11.06[c,f]	19
Araticum	P	ND	20.31±3.52	ND	1321.93±20.77[c,f]	19
Chicken lard	C	ND	99.18±3.93	ND	37.42±1.54[c,f]	19
Chicken lard	S	ND	7.38±0.42	ND	ND	19
Chicken lard	P	ND	4.68±0.57	ND	ND	19
Bocaiuva	P	ND	ND	49.00±2[b]	ND	44
Bocaiuva	C + P	185.1±14.8	ND	ND	ND	49
Buriti	P	0.70±0.00	1.081±0.06[g]	142±5.0[b,h]	5400.00±10.00[d,e]	50
Cagaita	P	9.80±0.20	1.5±0.11[g]	1.80±0.20[b]	13.30±0.40[c,e]	36
Cagaita	C + P	126.3±45.8	18.38±0.81	ND	879.33±11.70[c,f]	19,49
Cagaita	S	ND	136.96±6.21	ND	247.93±0.29[c,f]	19
Guabiroba/Guavira	P	234±2	ND	ND	ND	28
Jatoba	C+ P	330.4±61.5	ND	ND	ND	49
Lobeira	C	ND	35.15±19.26	ND	1328.98±9.42[c,f]	19
Lobeira	S + P	ND	35.58±19.72	ND	199.34±2.75[c,f]	19
Pequi	C	ND	209.37±3.57	ND	17.98±0.35[c,f]	19
Pequi	S + P	ND	27.19±1.24	ND	534.43±7.32[c,f]	19
Pequi[i]	P	ND	ND	6.78[b]	ND	51
Pequi[j]	P	ND	ND	8.37[b]	ND	51
Pequi[k]	P	ND	ND	11.34[b]	ND	51
Mangaba	P	102.77±12.82	ND	0.11±0.01[b]	ND	52
Murici	P	17.45±0.19	2.98±0.08[g]	ND	ND	53

AA, Ascorcorbic acid; GA, Gallic acid; DPPH, 2,2-diphenyl-1-picril hydrazil; ND, not determined.
[c,d]Methods to evaluate the ability to sequester free radicals; [g]Values converted to g GA/kg; [h]Values converted to μg/g; [i]harvest from tree; [j]harvest from ground after natural fall; [k]condition i+three days at environmental condition

Table 4. Compilation of studies of the Brazilian savannah fruits with potential benefits to health

Target of the study	Fruit	Reference
Antihypercholesterolemic	Baru	64
Antihypovitaminosis A	Bocaiuva	65
Antimicrobial Activities	Buriti	66
Antimutagenic	Mangaba, Gabiroba e Murici	62,67
Antioxidant	Buriti, Araticum	53,66,68
Hypotensive Effect	Óleo de Pequi	69
Laxativa	Cagaita	24

choice of viable fruit wastes for biotechnological applications.

In addition, some studies have been conducted to explore the properties of these fruits related to health benefits (Table 4). However, most of the studies evaluate bark, leaves, and roots, with a lack of studies on the fruit's potential (62). Another important issue is that despite these fruits being widely used as traditional medicine, there are scarce scientific studies on the relationship between biological activities and ethnobotanical applications (63).

Fatty acid composition Table 5 shows the fatty acid composition of some fruits from the Brazilian savannah. Among these, amburama, baru, bocaiuva, buriti, savannah jatoba, and pequi have in their composition a lipid content rich in oleic acid, which makes them useful in the food industry (70). Besides oleic acid, the palmitic acid content in pequi (40,71) and the fraction of linoleic acid in baru and savannah jatoba (46,70) must be underlined.

Unsaturated fatty acids were predominant in all the analyzed fruits (Table 6), with the highest incidence in savannah jatoba (85.60%). Bocaiuva kernel shows the highest content of saturated fatty acids (49.70%). Thus, fruits from the Brazilian savannah have great potential for oil exploration, especially the essential ones that may be used as dietary supplements.

Aiming at biodiesel production, the seed oils from four plants, including bacuri and amburana, were extracted and alkaline was transesterified to esters using methanol and ethanol. Oleic acid (30.5/32.3%, methyl and ethyl esters) was the main component of transesterification from bacuri oils and lauric acid (30.7/32.9%, methyl and ethyl esters) from amburana oils (81).

Enzymes and protein enrichment Recently, the enzyme production and protein enrichment were proposed for the utilization of Brazilian savannah fruits, i.e., mainly their wastes (82,83). Because of the interaction between microorganisms and fruit substrates, which act

Table 5. Fatty acid composition of Brazilian savannah fruits

Oil	C6	C8	C10	C12	C14	C16	C16:1 (n7)	C17	C17:1 (n8)	C18	C18:1 (n9)	C18:1 (n7)	C18:2 (n6)	C18:3 (n6)	C20	C20:1 (n11)	C20:1 (n7)	C20: 4	C22	C22:1 (n9)	C24	Reference
Amburana (K)	ND	ND	ND	ND	ND	15.60	0.30	0.10	ND	4.50	46.90	0.10	12.90	4.80	2.60	3.00	ND	ND	5.10	0.20	3.90	70
Bacuri (P)	ND	1.04	ND	6.17	3.23	17.13	0.35	0.05	ND	1.56	52.90	0.86	11.80	0.85	0.26	ND	0.21	tr	0.13	0.22	ND	72
Baru (K)*	ND	ND	ND	ND	ND	7.49	0.10	0.10	ND	5.01	47.98	0.10	28.68	1.16	1.22	2.9	ND	ND	3.10	0.40	3.61	42,70,73,74
Bocaiuva (P)*	0.47	0.43	0.25	1.71	0.47	16.69	2.05	ND	ND	4.01	67.02	ND	4.71	1.81	0.43	ND	ND	ND	ND	ND	ND	43,40,75
Bocaiuva (K)	ND	5.96	1.79	12.95	9.49	1.62	2.29	ND	ND	6.58	40.17	ND	5.91	1.92	0.30	ND	ND	ND	ND	ND	ND	75
Buriti (P)*	ND	ND	ND	0.03	0.08	18.18	0.32	0.08	0.07	1.86	74.59	ND	3.47	1.65	0.12	0.53	ND	ND	0.09	ND	0.09	76,77
Savannah jatoba (S)	ND	ND	ND	ND	ND	8.90	ND	ND	ND	4.70	31.60	ND	52.80	1.20	0.80	ND	ND	ND	ND	ND	ND	46
Pequi (P+S)	ND	ND	ND	ND	ND	44.28	ND	ND	ND	2.58	48.71	ND	4.43	ND	ND	ND	ND	ND	ND	ND	ND	71
Pequi (S)	ND	ND	ND	ND	0.30	26.00	ND	ND	ND	1.20	63.60	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	40
Pequi (P)*	ND	ND	ND	ND	0.15	39.96	0.79	ND	ND	1.75	55.08	0.30	1.48	0.62	0.17	0.70	0.20	ND	ND	ND	ND	40,48,70,77, 78,79,80

K: kernel; P: pulp; S: seed; nd: not detected; C6: caproic acid; C8: caprylic acid; C10: capric acid; C12: lauric acid; C14: myristic acid; C16: palmitic acid; C16:1(n7): palmitoleic acid; C17: margaric acid; C17:1(n8): margaroleic acid; C18: stearic acid; C18:1(n9): oleic acid; C18:1(n7): vaccenic acid; C18:2(n6): linoleic acid; C18:3(n-6): linolenic acid; C20: arachidic acid; C20:1(n11): gadoleic acid; C20:1(n7): gondoic acid; C22: behenic acid; C22:1(n9): erucic acid; C24: lignoceric acid. *Data calculated by means of the results obtained by the authors.

Table 6. Saturated and unsaturated fatty acid content in Brazilian savannah fruits

Oil	SFA (%)	UFA (%)
Amburana (A)	31.80	68.20
Bacuri (P)	29.79	66.97
Baru (A)	20.16	79.84
Bocaiuva (P)	24.45	75.55
Bocaiuva (A)	49.70	50.30
Buriti (P)	20.31	79.69
Savannah jatoba (S)	14.40	85.60
Pequi (P+S)	46.86	53.14
Pequi (S)	30.19	69.81
Pequi (P)	41.53	58.47

SFA, Saturated fatty acids; UFA, unsaturated fatty acids; K, kernel; P, Pulp; S, Seed; Data calculated from Table 5.

as the source of nutrients and support for microbial growth, ocorring biotransformation of these materials and the formation of products of biotechnological interest, via solid state bioprocess (BES) (84).

Table 7 shows the production of enzymes obtained via BES from microbial growth in the waste of some Brazilian savannah fruits. The production of amylase, β-glucosidase, carboxymethylcellulase (CMCase), lipase, and xylanase was observed for the fungi *Lichtheimia ramosa* and *Pleurotus sajor-caju* (82,83,85).

Table 8. Protein enrichment obtained from Brazilian savannah fruit waste

Fruit waste	Microorganism	Protein enrichment (%)	Reference
Araticum	*L. ramosa*	143.31	83
Bocaiuva	*L. ramosa*	67.88	83
Guavira	*L. ramosa*	102.42	83
	P. sajor-caju	37.20	82
Pequi	*L. ramosa*	160.04	83
	P. sajor-caju	30.31	82

Apart from enzyme production, another potential biotechnological application is the biotransformation of cellulolitic compounds from fruit waste in highly digestible proteins for animal feeding using microorganisms, which is also conducted via BES (Table 8). Protein enrichments up to 160.04% were observed with pequi fruit residue (85).

In summary, the compiled data from the literature reveals that Brazilian savannah fruits usually exhibit in their composition a high nutritional value, demonstrating their importance as food and food-product constituents. Furthermore, the significant presence of bioactive compounds in the fruits is of utmost importance for the pharmaceutical industry. Because unsaturated fatty acids are the

Table 7. Activity of enzymes produced from Brazilian savannah fruit waste

Fruit waste	Microorganism	Amylase (U/mL)	β-Glucosidase (U/mL)	CMCase (U/mL)	Lipase (U/mL)	Xylanase (U/mL)	Reference
Araticum	*L. ramosa*	ND	ND	ND	0.58*	ND	83
Bocaiuva	*L. ramosa*	1.80	0.01	0.58	0.02*	0.92	83,85
Guavira	*L. ramosa*	1.09	0.05	0.78	0.112*	0.63	83,85
	P. sajor-caju	0.75*	ND	0.40*	a.p.	0.50*	82
Pequi	*L. ramosa*	0.75	0.06	0.64	a.p.	0.68	83,85
	P. sajor-caju	0.94*	ND	0.45*	a.p.	a.p.	82

ND, not determined; a.p., absence of production. *Data converted from U/g to U/mL.

most commonly present in the fruits, they have great potential for oil exploration. Studies on biotechnological applications, e.g., biodiesel production, enzymes production, and protein enrichment, are still scarce. However, the knowledge of the characteristics and properties of the fruits, including the kernel, pulp, and seed, is important to conduct studies on more appropriate applications for each of the fruits. Despite all the potential applications, Brazilian savannah fruits have been quite neglected for many different industries. Nowadays, the fruits represent reasonable economic importance only for local low-income families and communities. Changes in the method of production and extraction to an organized supply chain are still far from being realized in Brazil.

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