Food Composition Data: Edible Plants in Cerrado

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1 Introduction

The use of plants is an ancient tradition in many places around world and in many cultures plays an important role in health, beauty, and nutrition. However, placing a new natural plant-derived product in the market is challenging (Box 1). Due to the difficulties, interest in natural products drug discovery declined in the 1990s. Yet despite this, a rapid increase in the number of scientific studies targeting plant-derived natural products has occurred in the twenty-first century. This reflects the fact that synthetic compound libraries are limited and represent only a small part of the great diversity of chemical compounds (Atanasov et al. 2015). Further, a

Box 1 Principal challenges for a new plant-derived natural product to reach the market

Botanical identification requires a specialist, which is increasingly rare nowadays.

The availability of natural products is low, and pharmacological testing consumes a lot of material.

Re-collecting wild species is difficult, since plant biomes can rapidly disappear under anthropic pressure.

A plant's chemical composition varies according to environmental factors, such as temperature, water availability, UV radiation, soil nutrients, altitude, and atmospheric composition, which limits the time window for recollection.

In plant-derived natural products, compound transformation and degradation can occur during extraction and isolation processes, making standardization of procedures difficult.

Due to the complexity of molecular mixtures, fewer chemical products or compounds are isolated.

The lack of knowledge concerning agricultural cultivation of certain wild species makes wildcrafting the only alternative, which makes the collection process very time-consuming and can result in ecological problems and the risk of species extinction.

Very stringent protective regulations in some countries make bio-prospecting of new plant-derived natural products difficult.

Development of methods for total synthesis or derivatization to obtain molecules similar to natural products is complex, since the chemical structures of natural products often contain numerous oxygen substituents and chiral centers.

Incompatibility of natural products with established high-throughput screening (HTS) platforms; test compounds should not decompose or precipitate and should not interfere with assay reagents nor show nonspecific effects; natural products often fail in fulfilling these requirements.

Determining the precise molecular mechanism of action of natural products is challenging.

Difficulties during clinical trials often occur since the therapeutic activity of plant extracts is usually based in the synergistic and simultaneous action of many chemicals.

The interest of pharmaceutical companies in natural products (that are not synthetically modified) is limited due to controversies concerning their patentability.

Sources: Corson and Crews (2007), Gobbo-Neto and Lopes (2007), Jones and Kinghorn (2012), Bucar et al. (2013), Atanasov et al. (2015), Li and Weng (2017), and Thomford et al. (2018)

negative correlation between the *in vitro* potential of many molecules and their ADME/T (absorption, distribution, metabolism, excretion/toxicity) profile is generally noted (Gleeson et al. 2011). Synthetic compounds present a significantly lower number of chiral centers and are both smaller and present greater flexibility, which results in weaker, less specific activity (Feher and Schmidt 2003). In contrast, plant-derived natural products present a diversity of bioactive compounds with differing chemical scaffolds (Atanasov et al. 2015). Plant-derived products possess properties, such as binding affinities for specific proteins, that are evolutionary optimized (Appendino et al. 2010; Hunter 2008). Such characteristics make plant-derived products more advantageous for conducting ADME/T tests (Atanasov et al. 2015). Another advantage in drug discovery using medicinal plants is the known good correlation between ethnopharmacological information (well documented) and the medical use of the plant. Around 80% of identified compounds present some ethnomedicinal use, whether identical or related to current usage of the active plant elements (Fabricant and Farnsworth 2001). Further, technological advances in systems biology, bioinformatics, plant specialized metabolism, and synthetic biology present opportunities through which the medicinal properties of plants are discovered, utilized, and expanded toward developing new herb-inspired medicines (Li and Weng 2017). Accordingly, plant-derived natural products still represent a valuable source for drug discovery, this, motivated by global public health challenges, such as COVID-19, HIV/AIDS, malaria, hypertension, diabetes, and cancer (Thomford et al. 2018). About a quarter of all Food and Drug Administration (FDA)- and/or European Medical Agency (EMA)-approved drugs are plant-derived (Patridge et al. 2016; Thomford et al. 2018).

In this context, Brazil possesses various biomes with a great portion of the world's biodiversity and approximately 20% of the plants and microorganisms on the planet (Calixto 2000). Among these biomes, the Cerrado is a neotropical savanna with rich flora (Klink and Machado 2005). Over 13,127 highly endemic plant species have been recorded within this biome (Myers et al. 2000; Overbeck et al. 2015; Silva and Bates 2002; Silveira et al. 2016). Yet, in regard to environmental conservation, only 41% of the original Cerrado still remains as native vegetation (Soares-Filho et al. 2014). This reduction is due to anthropogenic activities, such as monoculture, pasture expansions, mineral extraction, and the growth of urban areas (Faleiro et al. 2013). Considering only agricultural activity between 2002 and 2009, an estimated loss of 92,712 km² of natural Cerrado area has occurred (Overbeck et al. 2015). Preservation policies in Brazil need improvement, yet only 7% of the Cerrado is under legal protection (Soares-Filho et al. 2014).

Both the bio-prospecting potential of the Cerrado for medicinal species and knowledge concerning traditional medicines are disappearing faster than plant biodiversity (Appendino et al. 2010). Studies concerning plant-derived natural products found in the Cerrado could help valorization of the biome and call attention to the urgent need for conservation. Recent studies have highlighted the pharmacological importance of little explored Cerrado plants (Bailão et al. 2015; Dutra et al. 2016; Neri-Numa et al. 2018b; Schiassi et al. 2018). Unfortunately, a discrepancy between the number of scientific publications on plants by Brazilian scientists and

the development of new phytotherapeutic agents exists and underlines the need of public policies focused on innovation (Dutra et al. 2016).

The native fruits of the Cerrado are increasingly valued in the world market as functional and nutraceutical foods because of their high nutritional value and attractive sensory characteristics (Arruda et al. 2016; Finco et al. 2012). Agriculturally, many Cerrado species grow spontaneously with amazing adaptability, surviving in soils with little natural fertility and which lack chemical additives (Finco et al. 2012; Haridasan 2008). Further, Cerrado fruits can be employed in multiple food applications (Araújo et al. 2018), and their residues from industrial processing are rich in bioactive compounds that possess many functional properties.

In summary, in view of their economic importance and relatively slight recognition, the aim of this chapter is to review the principal vegetal species of the Cerrado, focusing on their pharmaceutical, cosmetic, and foods potential.

2 Technological Methods to Obtain Products

It is important to highlight that quality control and standardization of all processing stages (Fig. 1) is fundamental and guarantees the reproducibility and safety of the plant-derived product. Initially, plant samples are collected, dried, and processed by comminution or pulverization (by mechanical forces) to achieve fragmentation of the plant material into small particles. Solvent selection for extracts and determination of particle size are key steps in the process of obtaining herbal products. Decoctions, infusions, macerates, and tinctures are used to obtain plant extracts. In general, the liquid extract obtained must be concentrated and standardized to the established control parameters, usually found in different pharmacopoeias (List and Schmidt 1990).

Extract concentration is a key step to obtaining intermediate products and preparing liquid material for the drying process. When the liquid presents alcohol, one approach to concentrate the extract consists in the use of a rotary evaporator system, equipment able to remove the most volatile solvents under reduced pressure. To optimize vaporization, water bath temperature, cylinder immersion depth, and degree of vacuum are the adjustable parameters. The method is widely employed in phyto-pharmaceutical processes (List and Schmidt 1990). Other techniques to concentrate extracts include tube vaporization with auto-circulation, tube vaporization with pumped circulation, falling films vaporization, thin layer vaporization, and centrifugal rotary vaporization. Once the concentrated extract is obtained, various quality parameters are important at this stage for standardization such as pH, solid content, density, chemical markers content, and viscosity (List and Schmidt 1990).

Applied to fruits and vegetables that require chemical and physical stability, drying is the most common preservation method. When water is removed, deterioration due to microbial activity is retarded, yet without causing significant physical, nutritional, or sensory loss. Further, for phyto-medicines, dry plant extracts allow preparation of solid tablets and capsules (Kho and Hadinoto 2011). To obtain plant-derived products, there are many drying methods. Among them, spray-drying

Fig. 1 Principal steps in plant processing. First, the plant is dried in an oven and pulverized (1). Upon obtaining the powder material, the extraction process is performed (2); once the liquid extract is obtained, the material is normally concentrated and submitted to quality control parameters before drying processes (3). When the dried powder is achieved, the material can be employed in final products for the pharmaceutical and food industries (4)

is a robust manufacturing process, often used in the food and pharmaceutical industries (Wang 2015). Spray-drying has various advantages, such as reproducibility, high capacity, fast drying capability, and short exposure time to high temperature processing (Al-Khattawi et al. 2018). Spray-dryer equipment rapidly and efficiently transforms liquids into powders (Schuck et al. 2009). The equipment also can be used to microencapsulate natural products. Microcapsule wall systems consist of polymers with chemical groups presenting hydrophilic or hydrophobic properties, which provide the emulsion characteristics of the system. The polymers must be chemically compatible and nonreactive with the encapsulated component. The approach is used for products with increased stability and flexibility (Maresca et al. 2016; Silva et al. 2020b).

Another drying technique that can be used for coarse particles is spouted bed technology. This technique provides a high solid circulation rate and increases contact between the drying agent and solid particles (Gao et al. 2017; Zhang et al. 2017). Other drying processes that can be used to obtain herbal products are centrifugal atomization, vacuum belt dryers, roller dryers, drying ovens, freeze dryers, and microwave dryers. In summary, dried materials are used to provide finalized products with applications in food, medicine, and cosmetics.

3 Species and Technological Products from the Cerrado

Numerous studies have demonstrated the technological potential of extracts from Cerrado plant species. In this section, we provide a brief review of the best-known and most-used fructiferous species of the Cerrado. Biological properties, intermediate products, characteristics, and potential technological applications for the species presented below are compiled in Table 1. Further, nutritional compositions of the Cerrado plant species highlighted in this chapter are compiled in Table 2.

4 *Anacardium occidentale* L. (Anacardiaceae)

Anacardium occidentale is a tree popularly known as the cashew tree or *cajueiro* (Fig. 2a). The pseudo-fruit, the large pulpy and juicy part commonly referred to as the “cashew apple,” has a fine sweet flavor (Silva et al. 2007). In folk medicine, the cashew leaf and bark teas are used to treat diabetes, muscular debility, urinary disorders, and dyspepsia (Andrade Júnior et al. 2018).

In food applications, *A. occidentale* and *Psidium guajava* (guava) dried bagasse have been used to enrich cookies (Matias et al. 2005). Cashew is a rich source of vitamins, minerals, and other essential nutrients (Omorodion et al. 2017). Cookies respectively enriched with 10% and 5% cashew and guava fibers received a high rating for flavor acceptability (Matias et al. 2005).

Beverages based on *A. occidentale* aqueous extract from the fruits present an adequate concentration of viable probiotics and are lactose-free, which makes them both a functional food and good substitute for those who cannot consume milk (Firmo et al. 2020; Vergara et al. 2010). The *A. occidentale* juice is encapsulated using a spray-drying technique, thus stabilizing it for at least 14 days and protecting sensitive compounds present in the food matrix, like vitamin C (Bastos et al. 2012). By fermentation, a wine has been developed using *A. occidentale* juice and in sensory evaluations was rated as very acceptable as an alcoholic beverage. Significant differences (probably because of high tannin content in the cashew wine) in taste, aroma, flavor, and aftertaste exist between the *A. occidentale* wine and commercially sold grape wines (Mohanty et al. 2006).

In pharmaceutical applications, natural cashew gum has been used in conjunction with phthalocyanines to develop a layer-by-layer film for an electrochemical sensor to detect dopamine, with an acceptable detection limit for the pharmaceutical industry (Araújo et al. 2012). Cashew gum has also been used as a pharmaceutical excipient (a natural muco-adhesive polymer) in dental pastes containing aceclofenac (AC) for pain management in periodontitis (Hasnain et al. 2018); in bucal-adhesive curcumin tablets with the potential to improve the bioavailability of the active ingredient (Gowthamarajan et al. 2012); and in an Orabase formulation for periodontitis treatment (Souza Filho et al. 2018). The dental paste demonstrated sustained AC release over 6 h with good oral mucosa adhesion, resulting in effectual management

Table 1 Products obtained from Cerrado plant species highlighted in this chapter

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
<i>Anacardium occidentale</i> L.							
Cookies	Fruit	Not specified	Drying in fixed bed convective dryer. Blend of cookie ingredients with 5%, 10%, and 15% dry residues of <i>A. occidentale</i>	Cookies with 10% dehydrated bagasse presented a high rate of acceptability	Cookies with 15% of the dehydrated bagasse were not accepted	Food application	Matias et al. (2005)
Drinks	Fruit	Not specified	Fermentation process	The symbiotic drink presented good physicochemical and microbiological characteristics	The acidity value and content of beneficial microorganisms in the probiotic drink were lower than recommended	Beverage application	Firno et al. (2020)
Juice	Fruit	Not specified	Fermentation process	Contained prebiotic oligosaccharides	The yeast extract added as an external nitrogen source presented an unpleasant taste for human consumption	Beverage application	Vergara et al. (2010)
Juice	Fruit	40.7–55.3%	Microencapsulation	Physicochemical stability; high nutritional value	Not specified	Ingredient in the formulation of many food products	Bastos et al. (2012)
Wine	Fruit	Not specified	Fermentation process	Good nutritional and sensory properties and consumer acceptance	Lower acceptance than commercial grape wine	Beverage application	Mohanty et al. (2006)
Electrochemical sensor	Gum (tree exudate)	Not specified	Multilayer deposition	Stable smooth films with well-defined redox processes, punctuated by large globular features and exhibiting low roughness values	Not specified	Nano-biomedical devices	Araújo et al. (2012)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Dental paste	Gum (tree exudate)	19.22%	Conventional triturating method	Good tube extrusion and easily spreadable; sustained releasing of aceclofenac (the active ingredient) over 6 h; good adhesion to the oral mucosa	Not specified	Muco-adhesive dental pastes	Hasnain et al. (2018)
Buccal adhesive tablet	Gum (tree exudate)	70%	Development of a natural buccal adhesive polymer cashew nut tree gum (20% polymer concentration, 0.1% penetration enhancer, 40 mg backing layer, compressed at 2 tons/cm ² for 10 s)	Unidirectional release; the rate of release of the drug substance (curcumin) as well as the bioadhesive bond strength of the formulation can be modulated; easy to formulate; inexpensive; provide easy application; with convenient removal from the mucosal surface	Not specified	Sustained release and muco-adhesive, tablet excipient for a variety of low-molecular-weight drug substances	Gowthamarajan et al. (2012)
Orabase formulation	Gum (tree exudate)	80%	Development of an Orabase gel with cashew gum polysaccharide	High yield; protein-free product; reduced alveolar bone loss and inflammation; nontoxic	Not specified	Potential adjuvant for periodontitis treatment and source of novel biotechnological discoveries	Souza Filho et al. (2018)
Gold nanoparticles	Leaves	Not specified	Green synthesized gold nanoparticle	Size between 10 and 60 nm and spherical in shape; antibacterial effect; permissible levels of cytotoxicity toward normal cells; high cytotoxicity toward MCF-7 cancer cells	Not specified	Antibacterial applications, such as food packing and wound dressing, and as an anthelmintic	Sunderam et al. (2019)

Silver nanoparticles	Testa (cashew nut husk)	Not specified	A simple economic and eco-friendly synthesis of silver nanoparticles	Average size of 25 nm and distorted spherical shape; high stability; good catalytic activity toward the reductive-degradation of azo dyes	Not specified	Catalyst for the reductive-degradation of carcinogenic azo dyes used in many industries such as food and pharmaceuticals	Edison et al. (2016)
<i>Ammonia crassiflora</i> Mart.							
Dehydrated pulp	Fruit	~28.94%	Drying in forced air circulation	Good sensory properties and consumer acceptance	Not specified	Food application	Martineli et al. (2020)
Dehydrated pulp and carpel	Fruit and flower	Not specified	Freeze-drying and convective hot-air drying processes	Sources of alimentary fiber and derivatives from oleic and palmitic acids	Significant difference between fresh and dehydrated <i>marolo</i> , mainly in proteins	Food application	Correia et al. (2011)
Dehydrated pulp	Fruit	Not specified	Thin layer convective air drying using inulin as a drying aid agent	Lower moisture contents; satisfactory wettability results; lower hygroscopicity; better stability; prebiotic and sensory properties	Treatments without inulin produced powders with better solubility.	Food application	Botrel et al. (2016)
Bread	Fruit	Not specified	Drying in forced air circulation. Crushing. Blend of flour with bread ingredients	Good nutritional, sensory properties and consumer acceptance	Not specified	Food application	Villela et al. (2013)
Food bars	Fruit	Not specified	Drying in forced air circulation. Milling. Blend of flour with bars ingredients	Increase in antioxidant activity, vitamin C, and total carotenoids content. Good sensory properties and consumer acceptance	Not specified	Functional food	Silva et al. (2018b)
Liquor	Fruit	50%	Alcoholic infusion. Addition of syrup	Good sensory properties	Not specified	Food and beverage application	Oliveira et al. (2018a)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
<i>Caryocar brasiliense</i> Camb.							
Cookies	Fruit	Not specified	Blend of wheat flour with 10% and 20% <i>C. brasiliense</i> flour	Good nutritional value	Cookies supplemented with flour (20%) presented higher than average moisture values	Food application	Silva et al. (2018a)
Pequi by-product flours	Peel	43.32 ± 0.72 g total dietary fiber/100 g pequi peel flour	Not applicable	Production of flours rich in antioxidant molecules and dietary fibers; total dietary fiber contents are in the same range of commonly employed fiber sources; total amount of extractable phenolics are significantly high in comparison to pequi pulp and almond and other fruit peels; high antioxidant capacity compared to extracts obtained from other tropical fruits	Not specified	Functional food	Leão et al. (2017)
Pectin	Peel	20.79 g/100 g	Microwave heating	Obtained pectins with high degree of esterification; shorter extraction times	Not specified	Functional food ingredient with use as a thickener, emulsifier, gelling agent, and stabilizer	Leão et al. (2018)
Prebiotic yogurt	Fruit	Not specified	Lyophilization	Lower pH, less syneresis, and higher water-holding capacity (characteristics favorable to conservation during storage); good sensory acceptance	Residual bitter taste	Functional prebiotic food	Souza (2015)

Pulp oil	Fruit	53.65 g oil/100 g pequi pulp	Supercritical fluid extraction	Attractive cost of manufacturing in the pilot and industrial scales; acceptable payback time (<1 year)	Not specified	Functional food	Johner et al. (2018b)
Pulp oil	Fruit	55 g oil/100 g pequi pulp	Supercritical fluid extraction assisted by pressing	Faster extraction rate and lower amounts of solvent consumption	Not specified	Functional food	Johner et al. (2018a)
Pulp oil random inter-esterified	Fruit	Not specified	Chemical inter-esterification	Increased thermal stability despite containing high amounts of oleic acid; total carotenoid content remained stable; increased range of applications; increased value along the entire pequi oil value chain	Not specified	Functional food fat,	Guedes et al. (2017)
Freeze-dried fruit pulp	Fruit	30 g/100 ml of extract	Freeze-drying after pretreatment with sucrose and ethanol	Crystalline structures with lower bulk porosity; particles showing uniformity and homogeneity, with a better distribution; good stability, with lower water sorption during storage	Low inter-particle interaction; low total carotenoid content	Food product	Alves et al. (2010)
Concentrated alcoholic and aqueous extracts	Fruit	Not specified	Nano-filtration	Concentration of polyphenols and carotenoids in aqueous extract	Nano-filtration of the alcoholic extract was not acceptable for concentrating carotenoids and polyphenols	Functional food	Machado et al. (2013)
Pequi aqueous extract membrane-filtered	Fruit	Not specified	Ultrafiltration and nano-filtration	Concentration of polyphenols and carotenoids; removal of the solvent from the extract; process not submitted to high temperatures (energy saving); no change in the physical state of the solvent	Not specified	Products with functional properties	Machado et al. (2015)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Vacuum-dried fruit pulp	Fruit	71.78 ± 6.98 mg carotenoid/g pequi pulp	Vacuum drying at low temperatures (~40 °C)	Ascorbic acid and carotenoid contents stability; higher rehydration coefficient; minimal color change; less shrinkage; and reduced drying time	Osmotic dehydration substantially decreased moisture content, drying process time, and volumetric ratio of the dried product; yet also promoted leaching of bioactive constituents	Functional food	Mendonça et al. (2017)
Encapsulated carotenoid extract	Fruit	9.61 µg carotenoids/g pequi pulp	Encapsulation by emulsification (O/W) and foam-mat drying	Raise the bioavailability of carotenoid compounds; encapsulation alternative free of organic solvents, simple and inexpensive	Not specified	Functional food or natural dye	Pinto et al. (2018)
Biosensor for thiocarb determination	Fruit	Not specified	Pequi polyphenol oxidase immobilized on chitosan cross-linked with cyanuric chloride	Construction simplicity; linear calibration range; low detection limit; good repeatability and reproducibility; long-term stability with the sensitivity of the inhibition-based polyphenol oxidase; the results were satisfactory when compared with those obtained using high-performance liquid chromatography	Not specified	Determination of thiocarb in fresh fruits and vegetables	Lima et al. (2010a)
Methylic and ethylic biodiesels	Fruit	Methylic, 96%; ethylic, 80%	Alkaline trans-esterification via the methylic and ethylic routes	Thermally stable; in general, biodiesels emit lower levels of CO ₂ and particulate material and originates from renewable source; it is easy to adapt biodiesel to diesel engines	Not specified	Substituent for conventional mineral diesel	Silva et al. (2014)

Chitosan coating	Fruit	Not specified	Orbital shaker extraction and dip coating application	The combination of <i>C. brasiliense</i> extract with chitosan was suitable as an effective edible coating, improving fresh weight retention and reducing color change in tomatoes together with retaining the benefits of chitosan in delaying fungal growth	Not specified	Preserving tomato quality	Breda et al. (2017)
Supercritical CO ₂ extract	Leaves	Not specified	Supercritical CO ₂ extraction	No cytotoxic and phototoxic hazards	Not specified	Development of cosmetic and/or pharmaceutical products	Amaral et al. (2014b)
Liquid soap and hand lotion	Leaves	Not specified	Supercritical CO ₂ extraction	Antimicrobial and antioxidant activities	Not specified	Development of personal care products, especially antiseptic and anti-aging products	Amaral et al. (2014a)
<i>Dipteryx alata</i> Vog.							
Granola	Almonds	Not applicable	Not applicable	High levels of protein content, dietary fiber, and iron; lower moisture, water activity, sodium, lipids, and energy value; high stability, crunch texture, and consumer acceptability	Not specified	Health-promoting food preparations	Souza and Silva (2015)
Cupcake	Almond flour	Not specified	Blend of wheat flour with 30% <i>D. alata</i> almond flour	Good nutritional and sensory properties; formulation of a “light” product, with reduction of margarine and trans fatty acids; good consumer acceptance	Reduction in water absorption, stability, mixing tolerance index, and extensibility; increase in dough development time and resistance to extension	Reduced fat product. <i>D. alata</i> flour may be used in other food formulations	Paglarini et al. (2018)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Almond oil	Almonds	~22%	Supercritical CO ₂ and/or ultrasound	High concentration of oleic and linoleic acids; same fatty acid profile when compared with oil extraction using organic solvents	Not specified	Fabrication of food and pharmaceutical products (cosmetics)	Santos et al. (2016)
Almond oil	Almonds	36.87% 32.62%	Compressed propane Supercritical CO ₂ with ethanol as co-solvent	High concentration of oleic and linoleic acids; high levels of tocopherol; good antioxidant and antimicrobial activities; same fatty acid profile when compared with oil extraction using organic solvents; residues of the extraction presented high content of proteins (~32%)	Not specified	Food and pharmaceuticals applications	Fetzer et al. (2018)
Almond protein isolate	Proteinaceous cake remaining after almond oil extraction	884 ± 10 g/kg	Sequential extraction of almond defatted flour	High protein content; well-conserved protein arrangement; high in vitro digestibility; water and oil absorption capacity; emulsifying activity; foam formation; stability at mild and neutral pH	Loss of albumins and low-molecular-weight globulins during isolation process; low thermostability	Substitute ingredient in oily food formulations or in development of new products	Nunes et al. (2017)
Cookies	Partially defatted almond flour	53.7 g of cake/100 g of almonds	Continuous screw press; 25% substitution of wheat flour by <i>D. alata</i> almond flour	The flour presents high contents of proteins, calcium, and fibers; few content of carbohydrates; is rich in iron, zinc, and copper; good content of total phenolics, total flavonoids, and condensed tannins; and present antioxidant activity	The flour presents high lipid content. The cookies were hard and brittle when 75% or more of the wheat flour was substituted by <i>D. alata</i> almond flour. The consumer acceptance of the cookies was not good even with only 25% <i>D. alata</i> almond flour wheat flour substitution	Positive enhancement of nutritional and antioxidant characteristics of cookies. <i>D. alata</i> almond flour may be used in other food formulations	Pineli et al. (2015)

Lamellar gel phase emulsion	Oil extracted from almonds	Not specified	10:10:80 <i>D. alata</i> oil/surfactants/purified water. Surfactants used: ceteareth-5 and steareth-2	Stable formulation with anisotropic structures (liquid-crystals); pH ~6.0; particle size ~12µm; structural similarity to <i>Stratum corneum</i> (SC) membranes; increase SC lipid fluidity	Not specified	Delivery system for drugs and cosmetic actives	Moraes et al. (2018)
<i>Eugenia dysenterica</i> DC.							
Wine	Fruit	Not specified	Batch fermentation	The acceptability of wines produced by immobilized cells was greater than 70% for color, flavor, and taste	Not specified	Beverage application	Oliveira et al. (2011)
Jelly	Fruit	Not specified	Blend of two types of pulp (filtered or unfiltered) with two amounts of pulp/sucrose/pectin (50:50:0.2 and 60:40:0.1)	All jelly formulations showed microbiologically safe and good acceptability. The formulation with pulp filtered/sucrose/pectin ratio 60:40:0.1 showed good nutritional value and stood out as a source of vitamin C	After 120 days of storage, the selected formulation presented significant reductions in all chemical parameters	Food application	Santos et al. (2012)
Raisins	Fruit	Not specified	Osmotic dehydration	Good nutritional and sensory properties and consumer acceptance	Not specified	Food application	Silva et al. (2015a)
Spray-dried extract	Leaves	34.64–63.92% (w/w)	Spray-drying	Low moisture contents and water activities; good recuperation ratios for total polyphenols, tannins, and flavonoids; dry product flow and compressibility varied over a range acceptable for pharmaceutical purposes	Not specified	Intermediate phyto-pharmaceutical products	Couto et al. (2013)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Spray-dried extract	Fruit	37–81.20%	Spray-drying	High process yield; high stability; low moisture content and water activity; high glass transition temperatures; low hygroscopicity; high solubility in water; an alternative to reduce transport costs, prevent deterioration or loss of phenolic compounds, and ensure the quality and availability of fruit	Processing temperatures and concentration of carrier agents influenced the physical properties of the powders	Functional food	Daza et al. (2016)
Encapsulated extract	Fruit	Not specified	Spray-drying	Powders were obtained with high total phenolic compounds retention and proanthocyanidins, antioxidant activity, inhibition of α -amylase and α -glucosidase, and antimicrobial activity against <i>S. aureus</i> and <i>L. monocytogenes</i>	Lower total phenolics and proanthocyanidins content than powder obtained by freeze-drying	Functional food	Daza et al. (2017)
Micro-emulsion	Leaves	Not specified	O/W and W/O micro-emulsions	High stability; good penetration into skin; antioxidant activity preservation; low irritability potential	Not specified	Dermatological treatments that require antioxidant action	Ferreira-Nunes et al. (2018)
Emulsion with chitosan microparticles	Leaves	31%	<i>E. dysenterica</i> aqueous extract captured in chitosan microparticles with further incorporation in a dermatologically acceptable formulation	Relative stability for 60 days at 6 °C; high skin penetration; angiogenic action	Not specified	Dermatological treatments	Silva et al. (2020a)

Hancornia speciosa Gomes

Nectar	Fruit	Not specified	Formulations with different concentrations of pulps and sugar	Good sensory properties and consumer acceptance	Not specified	Food application	Assumpção et al. (2013)
Yogurt	Fruit	Not specified	Blend of yogurt ingredients with pulp and jam (0%, 5%, 6%, 7%, and 8%)	Good nutritional and sensory properties and consumer acceptance	Not specified	Functional food	Santos et al. (2017)
Jelly	Fruit	Not specified	Blend of pulp with jelly ingredients	High dietary fiber, total phenolic content, and antioxidant capacity; remained microbiologically stable	Not specified	Functional food	Souza et al. (2018a)
Bio-oil	Seeds	Not specified	Pyrolysis of mangaba seed to obtain bio-oil	Use of the mangaba industrial residues which contribute to environmental conservation	Not specified	Technological application	Santos et al. (2015)
Bio-membrane	Latex and silver nanoparticles	0.1–0.4% of AgNP	Dried at 40 °C	Biomaterial combines angiogenic, anti-inflammatory, and antibacterial properties and might be used to stimulate wound-healing	Not specified	Pharmaceuticals applications	Almeida et al. (2019)

Mauritia flexuosa L.f.

Nectar	Fruits	Not specified	Crushing and sifting formulations with different concentrations of pulp and sugar	Low-calorie product, source of vitamins, good sensory properties and consumer acceptance	Not specified	Functional food	Garcia et al. (2015)
Jelly	Fruit	Not specified	Blend of buri pulp: water (1: 2) with jelly ingredients	Good nutritional and sensory properties and consumer acceptance	The diet pulp jelly requires formulation adjustment for better acceptability by tasters	Food application	Sousa et al. (2020)
Biscuits	Fruit	Not specified	Blend of biscuit ingredients with <i>M. flexuosa</i> flour (10%) and oats (4%)	The addition of oats resulted in cookies with smaller diameters and thicknesses and higher fiber content and consumer acceptability	Not specified	Food application	Santos et al. (2011)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Dehydrated and sprayed product	Fruits	Not specified	Drying in oven with forced air circulation. Crushing and sifting	The dehydrated and sprayed <i>M. flexuosa</i> retained good chemical and microbiological stability for at least 150 days of storage at temperatures of 4 °C and –12 °C	Not specified	Ingredient in formulated foods aimed at supplementation of pro-vitamin A	Aguar and Souza (2017)
Flour	Fruit	Not specified	Lyophilization	Lowered triglyceride and total cholesterol levels and raised HDL levels in Swiss mice	Not specified	Nutraceutical	Pereira-Freire et al. (2019)
Flour	Fruit	2.53–11.84%	Crushing and bleaching. Separation of shell, endocarp, pulp, and seed was selected as a processing option	Peels and defatted pulp flours are highlighted as those with higher antioxidant potential. Carotenoids content was also higher in the peels and flours. All flours showed expressive amounts of total non-extractable proanthocyanidins	Blanching preserved only the extractable polyphenols, not carotenoids or total non-extractable proanthocyanidins	Source of dietary fiber and natural antioxidants in food	Resende et al. (2019)
<i>Myrciaria cauliflora</i> (Mart.) Berg							
Pomace powder	Fruit	Not specified	Freeze-drying, milling, and sieving	The co-product obtained during juice extraction was a source dietary fiber and polyphenols	Not specified	Functional food	Gurak et al. (2014)
Jelly extract	Not specified	~25%	Supercritical fluid extraction	Antioxidant capacity and low cost of manufacturing	Not specified	Food application	Cavalcanti et al. (2011)
Formulation of Bologna-type sausages containing <i>M. cauliflora</i> peel extract	Fruit	Not specified	Lyophilization. Maceration with stirring. Blend of the ingredients and extract (0.25%, 0.5%, 0.75%, and 1%)	The addition of extract protected the samples from color changes during storage, reduced the thiobarbituric acid reactive substance values, and prevented the decrease of sensory acceptance during storage	The extract had no positive effect on microbial stability during storage	Improving shelf life oxidative stability	Almeida et al. (2015)

Fermented dessert	Fruits	Not specified	Blend of fermented dairy dessert with hydroethanolic extract and syrup from <i>M. cauliflora</i> peel	The formulations were low in fat, presenting as acceptable for overall consumption, with attractive color and appreciable texture. Also presented antioxidant capacity	Not specified	Functional food	Almeida Neta et al. (2018)
Integral breads	Fruits	Not specified	Drying with forced air circulation. Crushing. Blend of bread ingredients with <i>M. cauliflora</i> flour (5%, 10%, and 15%)	The addition of flour in the loaves reduced carbohydrate contents, lipids, and caloric value. Fiber content increased by up to three times and phenolics by up to seven times, and consequently, antioxidant activity was higher in breads with <i>M. cauliflora</i> peel flour	In general, acceptance levels and acceptability indexes of the loaves lowered with increases in flour supplementation	Functional food	Ferreira (2017)
Juice	Fruit	Not specified	Maceration and lyophilization	Presence of chemical markers in fresh fruit extract which were not detected in commercial juice. The antioxidant capacity was higher in fresh fruit extract	During processing, anthocyanins and other polyphenols decreased significantly	Functional food	Wu et al. (2012)
<i>Psidium gatajava</i> L.							
Powder	Fruits	Not specified	Hot-air drying and lyophilization	Vitamin C content and antioxidant activity, with the freeze-dried powder showing the highest values and also higher thermal stability. The powders had good nutritional and sensory properties and consumer acceptance	Powder morphologies of indicated possible separation of phases in the solids as a result of dehydration processes	Food with added value	Osorio et al. (2011)

(continued)

Table 1 (continued)

Intermediate product	Part of the plant used	Yield	Technological methods	Favorable characteristics	Unfavorable characteristics	Possible applications	References
Sheep meat nuggets	Fruit	94.89–95.61 %	Incorporation of <i>P. guajava</i> powder (0.5% and 1%) in sheep meat nuggets	Total phenolics and total dietary fiber significantly increased and retarded lipid peroxidation of nuggets	Decreased emulsion stability, nuggets cooking yield; ash and moisture content of emulsion increased	Source of antioxidant dietary fiber in meat foods	Verma et al. (2013)
Treated seeds	Seeds	Not specified	Heat treatments (boiling or autoclaving)	The treatments reduced fat content significantly. Autoclaving at 121 °C for 15 min and germination for at least 7 days, have both been shown in lowering the phytic acid level to an extent that the treated seeds could be feasibly employed as a component of food or animal feed	Germination for 14 days caused a significant reduction in nutrient content in the range of 16–79%. Boiling did not reduce the phytic acid content substantially	Food application	Chang et al. (2014)
Guava cheese	Fruits	Not specified	Blend of softened guava and pectin (0.5%, 1%, and 1.5%). Cooking of the pulp	Addition of pectin to the guava cheese increased the hardness and phytochemical content, enhanced the shelf life stability and antioxidant potential	Not specified	Healthy fruit snack	Patel et al. (2016)
Meat	Not specified	Not specified	Substitution of corn with <i>P. guajava</i> (0%, 20%, 40%, and 60%) formulations in diets	Addition of 40% of <i>P. guajava</i> to the diet of lambs resulted in satisfying meat color, but less intense flavor and tenderness	Not specified	Alternative for the production of sheep meat	Costa et al. (2019)

<i>Pterodon emarginatus</i> Vogel							
Oil	Seeds	Not specified	Cold pressing	The supplementation of <i>P. emarginatus</i> oil (0.03%) in laying diets preserved the quality of the egg albumen and also helped maintain the pH of yolks	The use of the oils in laying diets did not improve the internal quality of eggs stored under refrigeration	Preservation of egg albumen quality	Oliveira et al. (2018b)
Microencapsulated oil	Fruits	84.89–98.63%	Spray-drying	A 1:3:3:6 blend of essential oil/gum arabic/maltodextrin offered the best protection, with 98.63% of essential oil being retained and the same proportion of trapped b-caryophyllene	Not specified	Food and pharmaceutical applications	Alves et al. (2014)
<i>Brosimum gaudichaudii</i>							
Gingerbread	Seed flour	25–30%	Not specified	Improved sensory and nutritional characteristics	Not specified	Food application	Alves et al. (2017)
<i>Byrsonima crassifolia</i>							
Semidry table wine	Fruit	Not specified	Fermentation process of the pulp fruit was performed using <i>Saccharomyces cerevisiae</i>	Good nutritional, antioxidant and sensory properties	Not specified	Food application	Bizinoto (2017)
<i>Campomanesia cambessedesana</i>							
Dried fruit	Fruit	Not specified	Spray-drying	Efficient in increasing pulp shelf life	Changes compared to fresh pulp, such as browning and reduction of the total phenolic compounds content	Food application	Chung (2016)

Table 2 Nutritional composition of Cerrado plant species highlighted in this chapter

Scientific name	Common name	Plant part	Content	Amount (/100 g)
<i>Anacardium occidentale</i>	Cashew	Pulp	Total energy (kcal)	39
			Total energy (kJ)	167
			Humidity (g)	89.8
			Ash (g)	0.20
			Proteins (g)	0.50
			Total fats (g)	0.20
			Total carbohydrates (g)	9.30
<i>Annona crassiflora</i>	Araticum	Raw pulp	Total energy (kcal)	110
			Total energy (kJ)	459
			Humidity (g)	73.9
			Ash (g)	0.74
			Proteins (g)	1.37
			Total fats (g)	2.86
			Total carbohydrates (g)	20.43
<i>Caryocar brasiliense</i>	Pequi	Raw pulp	Total energy (kcal)	277
			Total energy (kJ)	1140
			Humidity (g)	54.6
			Ash (g)	0.80
			Proteins (g)	2.71
			Total fats (g)	25.50
			Total carbohydrates (g)	17.53
<i>Dipteryx alata</i>	Baru	Raw nut	Total energy (kcal)	504
			Total energy (kJ)	2095
			Humidity (g)	5.4
			Ash (g)	3.28
			Proteins (g)	24.21
			Total fats (g)	32.48
			Total carbohydrates (g)	33.72
<i>Eugenia dysenterica</i>	Cagaita	Raw pulp	Total energy (kcal)	36
			Total energy (kJ)	153
			Humidity (g)	90.4
			Ash (g)	0.29
			Proteins (g)	1.36
			Total fats (g)	0.51
			Total carbohydrates (g)	7.64

(continued)

Table 2 (continued)

Scientific name	Common name	Plant part	Content	Amount (/100 g)
<i>Hancornia speciosa</i>	Mangaba	Raw pulp	Total energy (kcal)	60
			Total energy (kJ)	252
			Humidity (g)	84.9
			Ash (g)	0.56
			Proteins (g)	0.88
			Total fats (g)	1.51
			Total carbohydrates (g)	11.56
<i>Mauritia flexuosa</i>	Buriti	Raw pulp	Total energy (kcal)	190
			Total energy (kJ)	786
			Humidity (g)	59.0
			Ash (g)	0.98
			Proteins (g)	2.19
			Total fats (g)	15.42
			Total carbohydrates (g)	25.80
<i>Myrciaria cauliflora</i>	Jabuticaba	Raw whole fruit	Total energy (kcal)	67
			Total energy (kJ)	281
			Humidity (g)	81.2
			Ash (g)	0.53
			Proteins (g)	0.17
			Total fats (g)	0.08
			Total carbohydrates (g)	18.04
<i>Psidium guajava</i>	Guava	Raw whole fruit	Vitamin A ERA (mcg)	68
			Vitamin A RE (mcg)	135
			Retinol (mcg)	0
			β -carotene (mcg)	810
			Lycopene (mcg)	5300

The dataset is available for public consultation on the Brazilian Biodiversity Information System – SiBBR (<https://ferramentas.sibbr.gov.br/ficha/bin/view/FN>)

of dental inflammation and pain through prolonged local delivery of AC in periodontitis treatment (Hasnain et al. 2018). The bucal-adhesive tablet bypasses first pass metabolism and provides sustained release of curcumin, a phenolic compound whose therapeutic effectiveness is often limited due to its poor absorption from the gastrointestinal tract (Gowthamarajan et al. 2012). The Orabase formulation with cashew gum polysaccharide decreased inflammation and bone loss (hallmarks in experimental periodontitis) (Souza Filho et al. 2018).

Fig. 2 Fructiferous species from the Cerrado highlighted in this chapter. (a) *Anacardium occidentale* (cashew); (b) *Mauritia flexuosa* (buriti); (c) *Hancornia speciosa* (mangaba); (d) *Psidium guajava* (goiaba); (e) *Caryocar brasiliense* (pequi); (f) *Myrciaria cauliflora* (jabuticaba); (g) *Pterodon emarginatus* (sucupira); (h) *Dipteryx alata* (baru); (i) *Annona crassiflora* (araticum); (j) *Eugenia dysenterica* (cagaíta). All photographs were obtained from the Herbário da Universidade Estadual de Goiás (HUEG) and are available at <https://www.gbif.org/pt/dataset/bbb1f181-3221-4a10-ad52-14f1da0dca26>

A. occidentale was also used to produce nanoparticles in varied applications. Aqueous cashew leaf extract was used in gold nanoparticle preparation, presenting good antibacterial effect against *Escherichia coli* and *Bacillus subtilis* and demonstrating permissible levels of cytotoxicity toward normal cells and high cytotoxicity toward MCF-7 cancer cells (Sunderam et al. 2019). *A. occidentale* testa (the cashew nut husk) has been used in silver nanoparticles as a catalyst for reductive degradation of carcinogenic azo dyes (Edison et al. 2016).

5 *Annona crassiflora* Mart. (Annonaceae)

The species is popularly known as *araticum* or *marolo* (Fig. 2i). The fruits present unique sensory features such as attractive color, intense flavor, and exotic aroma, as well as a high nutrient content (Arruda et al. 2015). In folk medicine, the leaf infusions are used in oral administrations to treat inflammatory and painful ailments such as wounds, snakebites, diarrheas, malaria, and rheumatism (Formagio et al. 2015; Morzelle et al. 2011; Oliveira et al. 2019). Additionally, the fruits are used as a tonic and as an astringent, and its bark powder has antifungal and antirheumatic properties (Vilar et al. 2011).

The food potential of *A. crassiflora* is mainly associated with the pulps and carpels. The pulp and carpel when dehydrated retain their total carotenoid contents

(Martineli et al. 2020) and were shown to be a good source of alimentary fiber and derivatives such as oleic and palmitic acids (Corrêa et al. 2011). *A. crassiflora* pulp powder when produced by thin layer convective air drying using inulin as a drying aid presents lower moisture content, lower hygroscopicity, and better stability (Botrel et al. 2016).

When breads were enriched with *A. crassiflora* pulp flour, they presented excellent nutritional value, and the formulations were well accepted from a sensory point of view, a good alternative for using the fruit (Villela et al. 2013). Food bars enriched with *A. crassiflora* pulp flour present higher fiber content and a significant increase in antioxidant activity, vitamin C, and total carotenoids. In sensory evaluations, the modified food bar (adding 50% *A. crassiflora* flour) presented higher averages for all evaluated attributes and was the favorite of the evaluators (Silva et al. 2018b).

A. crassiflora pulp liqueur presents a translucent drink, dark yellow to light brown in color, with a strong flavor, and an aroma characteristic of the species. It can be consumed after meals as a digestive and can be used in preparations of drinks, sweets, chocolates, and various desserts (Oliveira et al. 2018a).

6 *Caryocar brasiliense* Camb. (Caryocaraceae)

The *Caryocar* genus presents 16 species, some of which possess economic potential since their fruits are often used as a source of edible oil (Ascari et al. 2013). Among *Caryocar* species, *Caryocar brasiliense* Camb., a native of the Brazilian Cerrado biome, is one of the most studied species. It is called *pequi*, and its fruit is widely consumed in Central Brazil (Fig. 2e). Local communities use *Caryocar* spp. to treat colds, bronchitis, liver disease, skin cancer, and ophthalmological problems, to regulate menstrual flow, and to cure hematomas and bruises as well (Ascari et al. 2013; Lopes et al. 2016). The hepatoprotective, gene-protective, and antioxidant effects of *C. brasiliense* fruits and oil have been scientifically verified (Colombo et al. 2015; Palmeira et al. 2016; Roesler et al. 2008; Torres et al. 2016). Moreover, *pequi* oil intake reduces hepatic triglycerides and improves cardiac function ex vivo in male rats (Oliveira et al. 2017). Toxicological investigations have indicated that oil extracts of *C. brasiliense* pulp present no toxicity, genotoxicity, maternal-embryo-toxic or teratogenic effects in rats (Traesel et al. 2016; Traesel et al. 2017a; Traesel et al. 2017b).

Although *C. brasiliense* has various applications, the principal use of *pequi* is as a food. Its flavor is used to aromatize many foods, especially in Central Brazil (Maia et al. 2008). *Pequi* is very nutritious and contains fibers, proteins, carbohydrates, and minerals (Ascari et al. 2013). *Pequi* flours are of industrial interest. Cookies made with a partial substitution of wheat flour with *pequi* pulp flour have been developed and present good nutritional value, revealing the great potential of *pequi* flour as an alternative for use in new food products (Silva et al. 2018a). The potential of *pequi* by-products (endocarp and mesocarp) as substrates to produce *pequi* flours rich in antioxidant molecules and dietary fibers has also been evaluated. Dietary fibers in *C. brasiliense* residue flour (exocarp and the mesocarp) ranged from 39.8

to 43.3 g/100 g (Leão et al. 2017). The pectin obtained from *C. brasiliense* peel flour is highly esterified (Leão et al. 2018) and can be employed in jams and preserves, as a stabilizer in acidic dairy products, or to promote viscosity in beverages (BeMiller 2019). *C. brasiliense* mesocarp flour has been added to yogurt, decreasing the pH and darkening the color of the final product. The high absorption rate of the flour (1.5%) favors less syneresis and increases water-holding capacity. The formulated prebiotic yogurt was suitable for consumption with viable lactic acid bacteria (Souza 2015). The antioxidant capacities of pequi by-product flours were higher than those of fruits and fruit by-products, such as blackberry and blueberry reported in the literature (Leão et al. 2017). Such results reveal a promising future for pequi peels as a potential source of dietary fiber and natural antioxidants (Leão et al. 2017).

Pequi has been widely used as a source of oil with nutritional and cosmetic value (Ascari et al. 2013), and its oil is high in monounsaturated (especially oleic) fatty acids and carotenoids (Oliveira et al. 2017). Many techniques can be used to extract pequi oil, such as supercritical fluid extraction (Johner et al. 2018b) and cold-press assisted supercritical fluid extraction by (Johner et al. 2018a). An unfavorable aspect of pequi oil in technological applications is that the native oil lacks the melting behavior and thermomechanical properties required for food functionality (Guedes et al. 2017). Thus, pequi oil can be modified through chemical inter-esterification, which increases tripalmitoylglycerol (a completely saturated triacylglycerol) content to ~6%. The inter-esterified oil does not fractionate and is thermally stable to 40 °C, and the total carotenoid content (~390 mg/kg) remains stable (Guedes et al. 2017).

Despite being highly coveted by the food and cosmetic industry (due to exposure to oxygen, light, heat, and the presence of enzymes, metals, and peroxides), carotenoids are highly susceptible to degradation during processing and storage (Boon et al. 2010). To preserve carotenoids, a freeze-dried pequi pulp has been developed (Alves et al. 2010). Membrane separation and vacuum drying to preserve the fruit's bioactive properties have also been tried. Nano-filtration processing has been shown to be efficient in concentrating bioactive compounds from pequi aqueous extracts (Machado et al. 2013, 2015). Low-temperature vacuum drying is recommended for preparing dried sliced pequi because the process retains higher ascorbic acid and carotenoid contents and is associated with a higher rehydration coefficient, minimal color change, less shrinkage, and reduced drying times (Mendonça et al. 2017). Another study proposed carotenoid extract encapsulation of pequi to obtain a powdered product using emulsification (5% emulsifier) with drying (at 60 °C) via the foam mat process (Pinto et al. 2018).

For biotechnological applications, a biosensor based on polyphenol oxidase obtained from *C. brasiliense* pulp was developed and used for thiodicarb pesticide determinations in fresh fruit and vegetable samples. The results were satisfactory (Lima et al. 2010a). *C. brasiliense* pulp has also been used to produce biodiesel. The obtained methyl and ethyl biodiesels by alkaline transesterification of pequi oil presented satisfactory thermal stability and were qualified as potential substitutes of conventional mineral diesel (Silva et al. 2014).

The addition of *C. brasiliense* peel extract into a chitosan matrix reduced weight loss by 22% and total color variation in tomatoes by 50% (*Lycopersicon esculentum*

Mill.). Application of the extract alone was effective in controlling fungal growth on tomatoes, a 70% reduction when compared to uncoated fruits. The combination of the extract with chitosan was suitable as an effective edible coating, improving fresh weight retention and reducing color changes in tomatoes while retaining the benefits of chitosan in delaying fungal growth (Breda et al. 2017).

The antimicrobial and antioxidant activities of *C. brasiliense* leaf extract obtained by supercritical CO₂ extraction were also investigated. Supercritical *C. brasiliense* extractions presented antioxidant activity without cytotoxic or phototoxic hazards (Amaral et al. 2014a, b). Liquid soap and hand lotion containing this extract exhibited antimicrobial activity against *E. coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* (Amaral et al. 2014a). The data reveal that *C. brasiliense* leaf extract may be useful in the development of personal care products, especially for antiseptic skin products, as well as products that minimize damage caused by free radicals (Amaral et al. 2014a).

7 *Dipteryx alata* Vogel (Fabaceae)

Dipteryx alata is an oleaginous species native to the Cerrado known as *baru* that possesses an edible almond (Fig. 2h). Popularly, *D. alata* (*baru*) is used as an antirheumatic, tonic, and anti-ophidian and to regulate menstruation (Dey and De 2012; Sano et al. 2016). Baru almonds possess a high protein content and high in vitro digestibility relative to casein (Cruz et al. 2011). They also present a good essential amino acid composition, an appreciable amount of calcium, and high levels of iron, zinc, dietary fiber, and tannins (Fernandes et al. 2010; Martins et al. 2013). Baru almonds are rich in mono and sesquiterpenes, phytosterols, and tocopherol derivatives (Marques et al. 2015). The introduction of baru almonds into rat diets reduced triglycerides and VLDL and LDL cholesterol, increased HDL cholesterol, and yet did not interfere in weight gain, visceral fat, total cholesterol levels, or oxidative stress (Fiorini et al. 2017). A baru almond-enriched diet for 8 weeks in overweight and obese women reduced abdominal adiposity and increased HDL (Souza et al. 2018b). Some chemical safety assays indicate that *D. alata* bark extract is neither mutagenic (Ames test) nor toxic during pregnancy in rats, with no physical-neurobehavioral consequences on the development of the rats' offspring (Esteves-Pedro et al. 2012). Thus, besides its therapeutic importance, *D. alata* presents nutritional relevance while being chemically safe. This encourages its use, especially the almonds, as a raw material for food, pharmaceutical, and cosmetic industries (Moraes et al. 2018).

In food applications, baru almonds have already been used to produce a cereal supplement called granola (a mixture of cereals, whole grains, dried fruit, and nuts). Granola containing dried *caju-do-cerrado* (*Anacardium othonianum* Rizz) and baru almonds presents high protein levels, dietary fiber, and iron; lower moisture, water activity, sodium, and lipids; and high energy value, stability, crunchy texture, and consumer acceptability, potentially being a good food to bring to market (Souza and Silva 2015). Powdered baru almonds (baru flour) was used to produce reduced fat baru

cupcakes. The flour was characterized as containing more protein, dietary fiber, minerals, and lipids than wheat flour. It was then used in cupcake formulations where 30% of the wheat flour was replaced with baru flour (Paglarini et al. 2018). A reduction in water absorption, stability, mixing tolerance index, and extensibility and an increase in dough development time and resistance to extension for the wheat-baru flour blend were observed. The baru flour mix allowed reduction in margarine use by 75% without reducing consumer acceptance, achieving a “reduced fat” claim (Paglarini et al. 2018).

Baru almonds are also a good source of polyunsaturated fatty acids, which are considered essential since the human metabolism is incapable of synthesizing them. To extract fatty acids from plant sources, organic solvents are normally used. However, severe legal restrictions have been proposed for reducing the use of organic solvents in industrial processes (Santos et al. 2016). Therefore, alternative techniques are being developed to obtain baru almond oil, such as supercritical CO₂ and compressed propane (Fetzer et al. 2018; Santos et al. 2016). The compressed propane technique presents the highest extraction yield (~37%) (Fetzer et al. 2018), and the oil product presents high concentrations of oleic and linoleic acids (Fetzer et al. 2018; Santos et al. 2016). Both supercritical fluid and compressed propane extractions avoid modifying the fatty acid profile of the oil (Fetzer et al. 2018; Santos et al. 2016). The proteinaceous cake remaining after baru almond oil extraction can be transformed into protein concentrates and isolates (adding value to the production chain), bringing new products to the food industry (Nunes et al. 2017). Partially defatted baru almond flour has already been used to produce cookies. Despite not having a good consumer acceptance, the cookies (25% baru almond flour) presented high fiber and bioactive compounds content, leading to higher antioxidant activity (Pineli et al. 2015). Baru almond flour can also be used in other food formulations.

For pharmaceutical and cosmetic applications, a lamellar gel phase emulsion using oil extracted from baru almonds was developed (Moraes et al. 2018). The system demonstrated stability during storage and was able to increase *stratum corneum* lipid fluidity, demonstrating its potential to act as a vehicle for drugs or in skin care (Moraes et al. 2018).

8 *Eugenia dysenterica* DC. (Myrtaceae)

Popularly known as *cagaita*, *Eugenia dysenterica* is a species native to the Cerrado with globular pale-yellow edible fruit highly appreciated by local populations (Fig. 2j). Different parts from this species have been employed in folk medicine to treat various disorders (Silva et al. 2015b; Souza et al. 2007). The leaves of *E. dysenterica* are used to treat diarrhea, cardiac diseases, diabetes, and jaundice and to reduce blood cholesterol. Cagaita fruits present laxative activity, and the flowers are employed to treat skin and bladder infections (Lima et al. 2010b; Lima et al. 2011; Silva et al. 2015b).

As to food applications, a fruit wine was elaborated from *E. dysenterica* pulp. The beverage presented good consumer acceptance for color, flavor, and taste (Oliveira

et al. 2011). Jellies using two types of *E. dysenterica* pulp (filtered or unfiltered) and two different mixtures of pulp, sucrose, and pectin were obtained which were microbiologically safe and well accepted. The formulation with 60:40:0.1 (filtered pulp/sucrose/pectin) presented good nutritional value and was a good source of vitamin C (Santos et al. 2012). *E. dysenterica* raisins obtained using an osmotic dehydration process enjoyed good acceptance during sensory analyses (Silva et al. 2015a).

To prevent deterioration of the bioactive compounds in *E. dysenterica*, spray-drying methodology is used during dehydration of the leaves and fruit (Couto et al. 2013; Daza et al. 2016). The powdered *E. dysenterica* fruit extract can be used as a functional ingredient in food formulations or as an intermediate phyto-pharmaceutical product; it presents antioxidant activity, α -amylase and α -glucosidase inhibitory potential, and antimicrobial activity against *Staphylococcus aureus* and *Listeria monocytogenes* as well (Daza et al. 2017).

E. dysenterica leaf extract has been incorporated in micro-emulsions to develop stable, non-irritant topical formulations, improving cutaneous permeation without compromising its antioxidant activity (Ferreira-Nunes et al. 2018). The extract was also incorporated in chitosan microparticles with further incorporation in a dermatologically acceptable formulation. The emulsion presented relative stability for 60 days at 6 °C, good skin penetration, and angiogenic activity (Silva et al. 2020a). Thus, *E. dysenterica* leaf extract appears to be a promising alternative for dermatological treatments.

9 *Hancornia speciosa* Gomes (Apocynaceae)

Popularly known as mangabeira (Fig. 2c), *Hancornia speciosa* is a native Cerrado tree, and its fruit is called mangaba and is known by its exotic flavor and aroma (Cardoso et al. 2014). Economic interest in this fruit has been growing in recent years, because the pulp is rich in vitamins A, B₁, B₂ and C, as well as iron, phosphorus, and calcium (Narain et al. 2018). Mangaba can be consumed fresh or processed in the form of jelly, sweets, ice cream, juices, soft drinks, liquors, wine, and syrup (Almeida et al. 2016). Phytochemical studies have reported identification of differing classes among *H. speciosa* extract compounds. Flavonoids, catechins, proanthocyanidins, and tannins are present in the bark of the species. Steroids, triterpenes, and tannins are present in the leaves (Moraes et al. 2008), and chlorogenic acid, naringenin-7-O-glucoside, catechin, and proanthocyanidins were identified in the trunk latex (Neves et al. 2016).

With regard to its medicinal potential, the species has long been employed in folk medicine for treating wounds, rheumatism, hypertension, obesity, gastric lesions, and diabetes (Hirschmann and Arias 1990; Macedo and Ferreira 2004; Moraes et al. 2008). In addition to ethnobotanic surveys, certain pharmacological effects have also been associated with the plant extracts. For example, studies have shown that *H. speciosa* leaf extract presents endothelium-dependent vasodilatory effect (Ferreira et al. 2007), which is effective for blood pressure control (Silva et al.

2011). The leaf extract also has antidiabetic potential being able to reduce blood glucose concentration through inhibition of intestinal α -glucosidase and stimulation of glucose uptake by adipocytes (Pereira et al. 2015). Mangabeira bark extract possesses antioxidant activity and inhibits acetylcholinesterase production, which suggests that it can be used in the treatment of Alzheimer's, a disease linked with oxidative stress, acetylcholine deficiency in the brain, and inflammatory processes (Penido et al. 2017). The trunk latex possesses angiogenic (Almeida et al. 2014; D'Abadia et al. 2020), osteogenic (Floriano et al. 2016; Neves et al. 2016), anti-inflammatory (Marinho et al. 2011), and antioxidant (D'Abadia et al. 2020) activities, which may help in wound healing.

In food applications, a mixed nectar of *H. speciosa* and *E. dysenterica* has been developed achieving good acceptance by consumers due to an attractive sensory profile and good nutritional value (Assumpção et al. 2013). Yogurt made of goat's milk and *H. speciosa* pulp presented satisfactory sensory analyses, and the authors highlighted the product as a promising alternative for consumers who are allergic to cow's milk, as well as to those seeking a product with better digestibility (Santos et al. 2017).

A mixed jelly of *H. speciosa* and *Spondias tuberosa* Arr. C. ("umbu") presented high dietary fiber content, total phenolic content, and antioxidant capacity and remained microbiologically stable in moisture and total titratable acidity at 90 days of storage. The jelly presented sensory characteristics similar to commercialized jellies, but with more dietary fiber and functional properties as well (Souza et al. 2018a).

With regard to other technological applications, mangaba seeds can be used to produce bio-oil (Santos et al. 2015). The production of bio-oil from mangaba industrial processing residues can decrease wastes released into the environment. In another application, silver nanoparticles were added to *H. speciosa* latex bio-membrane to develop a new biomaterial, combining angiogenic, anti-inflammatory, and antibacterial properties, which could potentially be used in wound healing (Almeida et al. 2019).

10 *Mauritia flexuosa* L. f. (Arecaceae)

Mauritia flexuosa is a palm that produces a fruit popularly known as *buriti* (Fig. 2b), which has an orange-colored thick mass and spongy endocarp that surrounds a very hard seed (Sampaio et al. 2008). The species presents antitumor (Siqueira et al. 2014), hypoglycemic (Bataglion et al. 2014), hypolipidemic (Aquino et al. 2012), antimicrobial (Koolen et al. 2013), and other healing activities (Batista et al. 2012). Due to its high β -carotene contents, buriti is extremely effective in treatment and prevention of xerophthalmia (Mariath et al. 1989); it also reduces the risk of developing cardiovascular disease (Neri-Numa et al. 2018a; Sandri et al. 2017). Although buriti possesses various ethnobotanical applications, the main use of buriti pulp is as a food, in the form of jams, jellies, juices, and ice creams (Gomes et al. 2011).

In food applications, the nectar obtained from *M. flexuosa* has low calories and presents iron, manganese, and fiber levels that meet daily requirements. It also presents good sensory properties and consumer acceptance (Garcia et al. 2015). *M. flexuosa* jellies in their conventional, light, and diet versions were elaborated (Sousa et al. 2020). The light and diet versions presented physical-chemical alterations in relation to the traditional jelly, yet without compromising quality in the storage periods studied. The conventional and light jelly formulations were well accepted. However, the diet pulp jelly required formulation adjustments for better taste acceptance (Sousa et al. 2020). *M. flexuosa* biscuit flour with addition of oats resulted in cookies with reduced diameters and thickness; higher moisture, lipid, fiber, and caloric contents; and lower protein and carbohydrate contents. Sensory characteristic testing revealed good consumer acceptability (Santos et al. 2011). *M. flexuosa* fruits processed by dehydration and spraying maintained good chemical and microbiological storage stability for 150 days, at temperatures of 4 °C and 12 °C (Aguilar and Souza 2017).

Freeze-dried flours from *M. flexuosa* were produced with its by-products which reduced triglyceride and total cholesterol levels and raised HDL levels in *Swiss* mice (Pereira-Freire et al. 2019). The flours can be used for preparing nutraceuticals with lipid-lowering characteristics and may be useful in support therapy for patients with dyslipidemia. *M. flexuosa* by-product flours present high dietary fiber contents and the presence of pectic polysaccharides, arabinoxylans, and xyloglucans. The peels and defatted pulp flours were highlighted for possessing higher antioxidant potentials as compared to the endocarp and to manually produced bran flours. Carotenoid content was also higher in the peel flours, and all of the flours produced presented expressive amounts of total non-extractable proanthocyanidins (Resende et al. 2019).

Although due to an elevated β -carotene content, *M. flexuosa* is considered a good source of carotenoids, and as a supplement of pro-vitamin A (Aguilar and Souza 2017), its fibers and polyphenols may bind to macromolecular compounds that are not dialyzable, or generate mineral complexes, decreasing their solubility and bio-accessibility (Bouayed et al. 2011).

11 *Myrciaria cauliflora* (Mart.) O. Berg. (Myrtaceae)

Myrciaria cauliflora is a native plant in southern and central South America. The fruit is known as *jabuticaba* and presents a white soft juicy pulp, sweet and acidic flavor, and a dark purple color (Fig. 2f). The pulp is rich in minerals and ascorbic acid (Fortes et al. 2011; Teixeira et al. 2011). The dark peel is rich in polyphenols and anthocyanins. Folk medicine uses *jabuticaba* to treat asthma, throat inflammation, and gastrointestinal and cardiovascular disturbances (Giraldi and Hanazaki 2010). Studies have also demonstrated *jabuticaba* peels significantly reduce blood cholesterol (Dragano et al. 2013), obesity-associated insulin resistance (Araújo et al. 2013), and promote vasorelaxant and hypotensive effects (Andrade et al. 2015).

With regard to food applications, *M. cauliflora* juice extraction yielded three powders obtained from the whole fruit (JWF), peel (JPE), and pomace (JPO). The pomace (JPO) was rich in total dietary fiber, insoluble dietary fiber, and phenolic compounds, especially monomeric anthocyanin, while the peel (JPE) presented a large amount of soluble dietary fiber (Gurak et al. 2014). Supercritical fluid extraction was used to prepare *M. cauliflora* jelly, which presented a good yield of antioxidant compounds (Cavalcanti et al. 2011). The addition of *M. cauliflora* peel extract to Bologna-type sausages decreased the pH at the start of processing and protected the samples from changes in color during storage. However, it had no positive effect on storage microbial stability (Almeida et al. 2015). A fermented dairy dessert containing *M. cauliflora* peel was characterized as a low-fat product, being considered acceptable for overall consumption, with an attractive color and appreciable texture, despite an acidic taste. These formulations are seen as a viable alternative for the use of *M. cauliflora* peel, as well as a potential functional food due to the concentration of lactobacilli, besides the presence of antioxidant phenolic compounds (Almeida Neta et al. 2018). Addition of *M. cauliflora* peel flour to loaves reduced carbohydrate content, lipids, and caloric value while increasing humidity. Fiber content increased up to three times and phenolics up to seven times, and consequently, antioxidant activity was higher in breads supplemented with *M. cauliflora* peel flour. Bread formulated with 5% *M. cauliflora* peel flour presented greater sensory acceptance in overall impression and flavor attributes (Ferreira 2017).

It is important to highlight that certain marker compounds present in the fresh *M. cauliflora* fruit extracts were not detected in commercial juice and jams, and thus, the antioxidant capacity of the fresh fruit extract was higher (Wu et al. 2012).

12 *Psidium guajava* L. (Myrtaceae)

Psidium guajava, popularly known as guava or goiaba (Fig. 2d), is traditionally consumed (fruit) due to its flavor and nutritional value (Satyal et al. 2015). The aqueous extract of guava leaves has been reported to be efficacious in the treatment of various types of gastrointestinal disturbances such as diarrhea, peristaltic reflex inhibition, and gastroenteritis (Gutiérrez et al. 2008). The whole plant is used as a skin tonic and is employed to treat female-related diseases like dysmenorrhea, miscarriage, uterine bleeding, and premature labor (Rishika and Sharma 2012). Various flavonoids such as guajaverin, guayfotavolic acid, guajadial, and guavanoic acid were identified in this plant (Wang et al. 2014).

P. guajava fruit powders, when obtained by lyophilization, present a higher residual content of vitamin C, antioxidant activity, and thermal stability, than when obtained by hot-air drying. Sensory analyses revealed similarities between the two dehydrated powders, but a pleasant guava jelly-resembling flavor was detected for both solids. Both powders enjoyed high consumer acceptance (Osorio et al. 2011).

Incorporation of *P. guajava* powder in sheep meat nuggets resulted in significant decrease in emulsion and nugget pH, emulsion stability, cooking yield, and nuggets' moisture content. Emulsion ash and moisture content increased. Total phenolics, total dietary fiber, and ash content significantly increased in the nuggets with powder added. The powder was also found to retard lipid peroxidation in cooked sheep meat nuggets, did not affect sensory characteristics of the products, and can be used as a source of antioxidant dietary fiber in meat food preparations (Verma et al. 2013).

Heat treatments (boiling or autoclaving) did not affect *P. guajava* seed total dietary fiber or ash contents. Boiling did not significantly reduce phytic acid content, but autoclaving caused a reduction of 91%, a level below the anti-nutritional threshold. Germination for 14 days caused significant reductions in nutrient contents of 16–79% and also reduced the phytic acid content by 90%. Thus, *P. guajava* seeds can be treated thermally or germinated to manipulate their composition and enable their use in both food and feed industries (Chang et al. 2014).

Addition of pectin (0.5%, 1%, and 1.5%) to *P. guajava* cheese, a semisolid concentrated fruit product, increased hardness, phytochemical content, and antioxidant potential while enhancing shelf life stability. The guava cheese formulated presented good nutrition, sensory properties, and consumer acceptance and may well be utilized as a healthy fruit snack when adding alternative sweeteners and functional ingredients to obtain further health benefits (Patel et al. 2016).

The sensory quality and physicochemical characteristics of meat from Santa Inês lambs fed with diets containing *P. guajava* agro-industry by-product were tested. As a result, inclusion of 40% guava in diets (in place of corn) produced meat with satisfactory consumer acceptance in terms of color, yet with a less intense flavor, and tenderness. It was also observed that the animals suffered weight reduction (Costa et al. 2019).

13 *Pterodon emarginatus* Vogel (Fabaceae)

P. emarginatus is a tree popularly known as *sucupira* (Fig. 2g). Its fruits are *cryptosamaras*, which in their central structure present an alveolus filled with bitter oil (Lorenzi 2008). The seeds are commercialized in popular markets, especially for their pharmacological properties. The population makes use of the seeds in hydroalcoholic macerations to treat laryngological diseases, as antirheumatic, anti-inflammatory for spinal problems, depurative, and fortifier (Hansen et al. 2010). Seeds of *P. emarginatus* are also used as raw material to obtain an amber-colored viscous oil that is considered a rich source of vouacapanes diterpenes (Santos et al. 2010).

The effects of dietary supplementation in laying hens of *P. emarginatus* (0.03%) and *Copaifera langsdorffii* Desf (0.03% and 0.06%) oils on the quality of their fresh eggs – stored under refrigeration and at room temperature – were evaluated. Supplementation with these oils helped to preserve the quality of the egg albums (kept at room temperature for up to 14 days), similar to using refrigeration. It also

helped to maintain the pH of the yolks in eggs stored at room temperature for up to 30 days (Oliveira et al. 2018b).

In pharmaceutical applications, microencapsulation of the *P. emarginatus* fruit essential oil (spray-drying) may contribute to the development of an herbal medicine, since 98.63% of the essential oil was retained and the same proportion of β -caryophyllene was captured (Alves et al. 2014).

14 Other Species with Technological Potential

Brosimum gaudichaudii Trécul (Moraceae) is popularly known as mama-cadela. Its roots are traditionally used for the treatment of patients with vitiligo. The activity is attributed mainly to the *furancoumarins* psoralen and bergapten (Jacomassi et al. 2007; Morais et al. 2018). *B. gaudichaudii* seed flour in gingerbread improved the sensory characteristics and may be useful in partial replacement of wheat flour (Alves et al. 2017).

Byrsonima crassifolia (L.) Kunth (Malpigiaceae) is popularly known as murici. Its bright yellow fruit is edible with a sweet taste and a slightly bitter aftertaste (Pereira and Freitas 2002). Its fruits and leaves are used to treat gastrointestinal problems, such as ulcers and diarrhea. Its roots are used to heal wounds and infections of the mouth and throat such as gingivitis, tonsillitis, and pharyngitis (Gellen and Silva 2016). An alcoholic fermented drink from *B. crassifolia* was obtained with physicochemical characteristics in accordance with the Brazilian legislation for grape wines, except for NaCl chlorides, ashes, and total titratable acidity parameters (Bizinato 2017). The fermented alcohol of *B. crassifolia* was classified as a semidry table wine. Fruit-based beverage formulations with *B. crassifolia* and *Spondias mombin* L. (cajá) were well-accepted and presented antioxidant properties (Souza et al. 2020).

Campomanesia cambessedean Berg (Myrtaceae) is popularly known as gabi-roba or guavira. Its fruits are appreciated for their sensory characteristics and nutritional value. Its pulp is succulent, acidic, and slightly sweet (Malta et al. 2012). The leaves and fruits have anti-inflammatory, antidiarrheal, and antiseptic properties in the urinary tract and are also used to prevent rheumatism and liver disorders (Campos et al. 2012). Atomization processing of *C. cambessedean* fruit pulp was efficient in increasing pulp shelf life. However, the powder underwent changes such as browning and reduction of the total phenolic compounds content when compared to the fresh pulp (Chung 2016).

15 Conclusion

Cerrado species have great technological potential as functional foods, and for nutraceutical, cosmetic, and pharmacological applications as well. Yet consumption is normally limited to local communities. This may be due to scarce informa-

tion regarding their potential use, the processing necessary, or the quality of products that can be obtained from these species. In the food industry, the potential of many Cerrado species was demonstrated for cookies, food bars, cupcakes, juices, jellies, liquors, wines, yogurt, and other formulations, which presented good nutritional values and high acceptability in sensory tests. Moreover, Cerrado species can be prospected to produce drugs to alleviate different human diseases such as inflammations, infections, and gastrointestinal disturbances or to produce cosmetics with antiaging or healing properties. Such applications enable commercialization, generate employment and income for the local populations, favor industrial expansion, minimize wastes, and promote the generation of various co-products.

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