Natural Toxins in Brazilian Unconventional Food Plants: Uses and Safety

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1 Are Unconventional Food Plants Toxic?

Brazil presents one of the greatest biodiversities in the world. Whether native, cultivated, or naturalized, over 48,572 species are currently recognized in the Brazilian flora. Data provided by the Brazilian Ministry of the Environment reveals more than 200 thousand registered species in the Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal, and Pampa biomes. This approaches 15% of all plant species on the planet (do Brasil 2020; Flora do Brasil 2020 em construção 2020).

Many of these native Brazilian species can be used as food sources, but their potential is still little known, either due to the lack of common knowledge, to restricted distribution/or use in the country, or to simple negligence. Such plants are currently known as unconventional food plants (UFP). UFP refers to plants that have one or more parts with food potential yet with unusual use; those which are not quickly recognized or acquired by the population of a given community; and plants that generally have no market value, being only sold in small scale, or are discarded, or plants which only possess one quality that is important to the market. These UFP can be described as native or exotic, cultivated or spontaneous, and can be adapted to local environments (Kinupp and de Barros 2007). Taken together, UFP become

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an important strategy towards promoting food and nutritional security, and the sustainable use of such natural resources can guarantee the autonomy of local populations, making it urgent to vindicate and expand our understanding of their potential for rational use (Leal et al. 2018).

In a given population, consumption of certain UFP can occur in times of food scarcity or in emergency situations, when the plants become categorized as “famine food plants.” Native plant species are the most often utilized in such situations, and in some cases there are reports after consumption of undesirable effects such as stomach complaints, constipation, diarrhea, and even signs of intoxication (Guinand and Lemessa 2001; Nascimento et al. 2018).

The substances involved in triggering such undesirable effects are derived from the plant’s biochemical metabolism. Secondary metabolites, or natural products, are so-called because they are not directly involved in the primary processes of basic growth and development but in mechanisms of plant adaptation and defense. These modulate as a way of responding to environmental stress, attracting pollinators or seed dispersers, and defending against herbivores, insects, fungi, and phytopathogenic bacteria (Bennett and Wallsgrove 1994; Shih and Morgan 2020).

Widely used in pharmaceutical research, these natural products determine vegetable taste and odor and can make them unpalatable, with either beneficial or harmful effects on humans and animal health upon ingestion. As an example, plants rich in cyanogenic glycosides or glycosinolates can cause serious problems with ingestion. A traditional plant, manioc (*Manihot esculenta* Crantz) being native to Brazil, is well-known for presenting cyanogenic glycosides which if consumed form hydrogen cyanide, resulting in food poisoning. However, local traditional culture has developed an adequate preparation technique for this species, thus eliminating the natural toxin (Jackson-Malete et al. 2015).

2 Natural Toxins

Natural toxins present wide structural variety; they are toxic compounds produced by plants and can induce various undesirable effects in human health. The toxins are useful for the plants, as adaptations or in defense systems, but they can be harmful to humans when consumed (Jackson-Malete et al. 2015). These natural toxins can also present anti-nutritional properties which can limit the bioavailability of nutrients present in food (Samtiya et al. 2020). The principal classes of secondary metabolites typically present compounds with the characteristics of natural toxins including alkaloids, cyanogenic glycosides, coumarins, tannins, and terpenes, among others (Yamane et al. 2010).

Alkaloids are a diverse group of secondary metabolites, with more than 12,000 molecules reported from about 150 plant families. Their main function is to defend against predators (from vertebrates to fungi) and from other plants, thus being potentially toxic when consumed by humans. Alkaloids are an intrinsic part of the Western diet, and throughout history there have been many case reports of

poisoning, whether accidental or through deliberate food poisonings. The compounds in this class can be derived from ornithine (pyrrolizidine and tropane alkaloids), lysine (piperidine and quinolizidine alkaloids), tyrosine (isoquinoline alkaloids), tryptophan (alkaloids from *b*-carboline, quinoline, and ergot), nicotinic acid (nicotine and myosmine), adenine/guanine (methylxanthine), or glycoalkaloids. Pyrrolizidine alkaloids can bioactivate certain reactive alkylating intermediates, and various quinolizidine, β -carboline, ergot alkaloids, and steroids act as neurotoxins. Despite this, we still lack safe definitions and/or tolerable values for daily intake of many of the alkaloids present in the modern food chain (Cirlini et al. 2018; Koleva et al. 2012).

It is important to differentiate the use of plants that contain natural toxins from the use of these same substances in isolation, since the concentrations they present in the plant define whether they present a health risk or not. This exists in addition to factors such as interaction with other foods and methods of preparation. An example of this tea from the leaves of *Erythroxylum Coca* Lam., whether as food or medicine, being very common in many countries in South America, contains high concentrations of tropane alkaloids, such as those derived from cocaine, tropinone, and calystegines. But is safe given the low concentrations present in the species (respecting moderate use), and the way in which the tea is prepared, which causes degradation of the active substances (Marín-Sáez et al. 2019).

Non-proteic amino acids are often found in vegetables and seeds and can be toxic because they present similar structures, yet lead to production of unnatural proteins that may not work properly. As examples from the UFP species *Canavalia ensiformis* (L.) DC (pig bean), we find the non-proteic amino acid canavanine, an analog of the amino acid arginine; and in *Beta vulgaris* L. (beet), we find azetidine-2-carboxylic acid, an inferior homolog of proline, associated with disorders in neurodevelopment and autoimmune diseases (Rubenstein 2020; Yamane et al. 2010).

When degraded by plant enzymes after maceration (or in the intestinal microbiota after ingesting plant material), cyanogenic glycosides (mentioned above) release hydrogen cyanide (HCN), with a ketone or aldehyde which are highly toxic. Yet glucosinolates are widely distributed in plant tissues. By themselves, they are not toxic to herbivores, but in the presence of the enzyme myrosinase, and depending on the pH, they can degrade into isothiocyanates or nitriles (Kuti and Konoru 2006; Yamane et al. 2010). Certain diseases, such as konzo, tropical ataxic neuropathy, goiter, and cretinism (due to iodine deficiency), are among others associated with chronic food intake involving cyanogenic glycosides. We note indications that individuals with malnutrition are more susceptible to the effects of cyanogenic glycosides (Cressey and Reeve 2019). Almonds, pomegranates, apple and pear seeds, cassava, flaxseed, spinach, lupine, plum, and apricot kernels among others, all contain cyanogenic glycosides.

Phenolic compounds are a class of natural products with great structural diversity, presenting at least one aromatic ring in which at least one hydrogen is replaced by a hydroxyl group. They are widely distributed in the plant kingdom and in many species used as food. The group subclasses of flavonoids, tannins, coumarins, phenolic acids, and lignans serve as examples.

Flavonoids protect plants against UV radiation and pathogenic microorganisms and are also involved in plant pigmentation (Perez-Vizcaino and Fraga 2018). Flavonoids are currently considered safe for consumption, mainly due to their antioxidant properties, and in protection against chronic and cardiovascular diseases. Yet harmful effects have been seen at high doses, most commonly in food supplements enriched with flavonoid compounds (Kozłowska and Szostak-Węgierek 2018; Perez-Vizcaino and Fraga 2018).

Tannins are polyphenols with molecular weights greater than 500 Da and, for the well-known antioxidant potential of phenolic compounds, are believed to improve the oxidative condition present in *diabetes mellitus* (Kumari and Jain 2012). However, tannins have a strong capacity to form complexes with proteins and digestive enzymes, impairing their activity, and thus human digestion. Depending on the dose, interference in the digestive process can seriously affect absorption of nutrients and minerals such as iron and zinc (Higashijima et al. 2019). For this reason, the group is widely recognized as an anti-nutritional factor. As an example of foods rich in these compounds, we have red wines, teas, green fruits, grapes, apples, cocoa, persimmons, and bananas, among others.

Coumarins are a metabolite class that occurs naturally in many plants and consists of molecules carrying a 1,2-benzopyrone nucleus. *Dipteryx odorata* (Aubl.) Willd. (tonka beans or cumaru) is a significant example of a vegetable source of coumarins. In foods, these metabolites commonly bring strong flavors, yet also important hepatotoxic and carcinogenic properties. Furanocoumarins present phototoxicity (Abraham et al. 2010). Coumarins have an important history in health regulation, and additions to food are prohibited in the United States (21 CFR 189.130). The European Union imposes limits on their intake (European Regulation EC 1334/2008). Information such as this alerts us to inappropriate use of coumarins in food, but may not be applied to all representatives of the coumarin group.

Still, certain phenolic groups such as monophenols and diphenols undergo enzymatic oxidation by polyphenols oxidases and peroxidases, to become reactive molecular species that covalently bind to nutritionally important amino acid residues, such as cysteine and lysine, decreasing their nutritional value.

Terpenes, which are derived from isoprene units, present a wide range of biological structures and activities. Phytoecdysteroids, cardenolides, and iridoid glycosides present toxicity to mammals, and quinoa is a food rich in phytoecdysteroids (Yamane et al. 2010).

Carotenoids are found in many vegetables. They are divided into two main groups: carotenes, which are hydrocarbons – such as β -carotene and lycopene – and xanthophylls, which include oxygen in addition to hydrogen and carbon, such as lutein, zeaxanthin, bixin, and norbixin. Lipophilicity and the presence of conjugated double bonds within the molecule cause carotenoids to slow lipid peroxidation and stabilize cell membranes. Carotenoids are molecules with antioxidant potential (Hammond and Renzi-hammond 2013).

Saponins are widely distributed compounds with great structural variety. They consist of a hydrophobic steroid or triterpene aglycone linked to sugar chains (hydrophilic part) (Oleszek and Oleszek 2020). Plants very rich in saponins have

limited use because high concentrations yield a very bitter taste. In addition, it is reported that saponins inhibit certain digestive enzymes. There are also reports in the literature of anti-nutritional effects induced by the formation of iron and zinc complexes which reduce absorption. In addition, by inhibition of digestive enzymes, saponins influence carbohydrate, lipid, and protein bioavailability (Higashijima et al. 2019). For example, saponin extracts from various types of legumes consumed have been reported in China as inhibiting the activity of the pancreatic lipase and α -glycosidase digestive enzymes (Liu and Xu 2015). Depending on consumption, the effects can be harmful since nutrient demand varies by individual; whether one is in post-surgical recovery, a child, or a woman in gestation. Yet, saponins might be interesting in cases of obesity and diabetes. In general, foods rich in saponins present little or low toxicity. The saponin content in foods decreases with cooking; this improves nutritional availability (Samtiya et al. 2020). Examples of plants containing saponins are oats, quinoa, peppers, eggplant, tomato seeds, and yams, among others.

Oxalic acid is considered an anti-nutrient because it prevents calcium absorption and can induce undesirable effects. Reports of excessive intake of foods rich in oxalic acids are relatively uncommon, but their undesirable effects usually involve gastrointestinal effects, hypocalcemia, and renal toxicity (Dassanayake and Gnanathasan 2012). Although the lethal oral dose of oxalic acid is very high (from 5 to 30 g in adults), when absorbed, it can react with calcium in the plasma and form calcium oxalate crystals, inducing renal damage through precipitation in the kidneys (Tsujihata 2008). Oxalic acid can interfere with the absorption of minerals such as magnesium, sodium, and potassium. Examples of oxalic acid-rich food plants are spinach, beets, chard, star fruit, cocoa, sweet potatoes, tomatoes, and black tea, among others (Higashijima et al. 2019).

Nitrites and nitrates interfere with vitamin A metabolism and thyroid gland function. Excessive consumption is associated with hypoxia or acidotic situations, in which nitrite is converted into nitric oxide (NO) (Higashijima et al. 2019). In cell signaling, NO activates soluble guanylyl cyclase to generate the guanosine monophosphate (cGMP) second messenger. Increasing the intracellular concentration of cGMP induces vessel relaxation and better blood distribution in local tissue. cGMP also stimulates mitochondrial biogenesis and oxidation of fatty acids in skeletal muscle; generates energy; and increases metabolic efficiency (Ashmore et al. 2015). These are interesting perspectives for clinical improvement in metabolic syndrome or for aerobic performance in athletes. From a functional perspective, vegetables that are naturally rich in inorganic nitrate positively affect NO biology. A classic example of this is beet juice consumption (Sweazea et al. 2017). Yet, as observed by Santos (2006), cooking of plants in culinary preparations decreases the availability of their nitrates. As studies progress, and when considering the results presented in this chapter (see Table 1), the beneficial and safe effects of nitrate-rich vegetables are better understood.

In a scenario of expanding knowledge concerning the use of UFP in Brazil, the data bring important realizations. Though many foods may contribute to a varied and nutritionally rich diet, preparation for consumption requires special attention to

Table 1 Toxicity reports of unconventional food plants of Brazil

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Araucaria angustifolia</i> (Bertol.) Kuntze (Araucariaceae).	Atlantic Forest	Seed <i>in natura</i> ; boiled or roasted seed (cake, flour, pudding, ice cream, soufflé)	–	–	–	–
<i>Bixa orellana</i> L. (Bixaceae).	Amazon, Cerrado, Atlantic Forest	Seed (condiment, dye)	–	1. Aqueous, ethanolic extract, and chloroform-ethanol (1:3) from the seeds pulp showed no cytotoxic effect (<i>Allium cepa</i>) 2. Aqueous extract from the leaves showed high toxicity and teratogenicity (<i>Zebrafish embryos</i>)	3. Diet with waste seeds showed no liver toxicity (rats) 4. Recommendations for safe doses of bixin and norbixin seed extracts	1. (Joseph and Siril 2010) 2. (De Vera et al. 2016) 3. Valério et al. (2015) 4. EFSA Journal (2016)
<i>Byrsonima crassifolia</i> (L.) Kunth (Malpighiaceae)	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal	Fruit <i>in natura</i> ; fruit pulp (cake, jam, yogurt, liquor, sauce, mousse, pudding, puree, soup, ice cream, juice, pie)	–	–	1. Methanol extract from leaves showed low toxicity, induced constipation and decreased locomotor activity at high doses (mice) 2. Hexane, chloroform and methanolic extracts of the fruit showed low acute toxicity (rats)	1. (Herrera-Ruiz et al. 2011) 2. (Perez-Gutierrez et al. 2010)

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Caryocar brasiliense</i> Cambess (Caryocaraceae)	Amazon, Caatinga, Cerrado, Atlantic Forest	Seed pulp (cake, canned, jam, flour, liquor, oil, ice cream, juice, rice preparations and meat stews)	–	1. Ethanol extract from the fruit showed low cytotoxicity (BALB-C 3T3 mouse fibroblasts) 2. Fruit pulp oil showed no cytotoxic effect (<i>A. salina</i>)	2. Fruit pulp oil showed low genotoxic and clastogenic effects (rats) 3. Ethanol extract from the bark (exocarp and external mesocarp) had a low toxic effect on male reproductive functions (Swiss mice) 4. Fruit pulp oil showed low acute and subchronic toxicity (Wistar rats) 5. Fruit pulp oil showed low maternal and embryological toxicity 6. Hydroalcoholic extract of the bran of the fruit peel showed a toxic effect (Swiss mouse)	1. (Roesler et al. 2010) 2. (Traesel et al. 2017b) 3. (Souza et al. 2019) 4. (Traesel et al. 2016) 5. (Traesel et al. 2017a) 6. (Almeida et al. 2010)

(continued)

Table 1 (continued)

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Genipa americana</i> L. (Rubiaceae)	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal	Crystallized fruit; fruit pulp (cake, jam, syrup, liquor, blue bread/cake, ice cream, juice)	–	1. Extract from green genipap fruits showed genotoxic effect (Chinese hamster ovary cells) 2. Ethanol extract from the fruit showed low cytotoxicity (Hep-G2 liver carcinoma cells, normal fetal lung cells MRC-5 and HT-29 colon carcinoma cells)	–	1. (Neri-Numa et al. 2020) 2. (Tauchen et al. 2016)
<i>Hymenaea courbaril</i> L. (Fabaceae).	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal	Fruit pulp and seeds (biscuit, cake, cream, sweet, flour, bread, pudding, ice cream, pie)	–	1. Fresh xylem sap showed low cytotoxicity (3T3–A31 mouse fibroblast)	2. Sap showed no toxic effects and genotoxic using the micronucleus test (mice)	1. (da Costa et al. 2014) 2. (Vale et al. 2013)
<i>Mauritia flexuosa</i> L. f. (Arecaceae)	Amazon, Caatinga, Cerrado	Fruit peel (tea); fruit pulp <i>in natura</i> ; fruit pulp (sweet, flour, jelly, oil, ice cream, juice); stem marrow (starch)	–	–	1. Diet with crude or refined oil inhibited somatic growth and reflex maturation (rats) 2. Diet with crude or refined oil showed low toxicity (rats)	1. (Medeiros et al. 2015) 2. (De Souza Aquino et al. 2015)

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Pereskia aculeata</i> Mill. (Cactaceae)	Caatinga, Cerrado, Atlantic Forest	Leaves (flour, dough, bread), Leaves/flowers/ young branches (stew, omelet, sauté, salad, pie); Fruit (jam, liqueur, mousse, juice)	–	–	1. Topical application of the hexane fraction from the methanolic extract (leaves) showed low dermal and systemic toxicity in Wistar rats 2. Ethanol extract from leaves showed low acute toxicity in rats	1. (Pinto et al. 2015b) 2. (Silva et al. 2017)
<i>Platonia insignis</i> Mart. (Clusiaceae)	Amazon, Cerrado	Fruit <i>in natura</i> ; fruit pulp (sweet, jelly, yogurt, liquor, sauce, mousse, ice cream, juice, pie)	–	1. Dichloromethane and ethyl acetate fractions from the ethanolic extract of the seeds showed genotoxic effect and low cytotoxicity (<i>A. salina</i> and mammalian V79 cells) 2. Hexane seed extract showed low cytotoxicity (Balb/c murine macrophages and human erythrocytes)	2. Oral administration of the hexane seed extract showed low toxicity in rats	1. (Costa Júnior et al. 2013) 2. (Lustosa et al. 2016)

(continued)

Table 1 (continued)

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Portulaca oleracea</i> L. (Portulacaceae)	Amazon, Caatinga, Cerrado, Atlantic Forest, Pantanal, Pampa	Young leaves and branches (fresh or cooked – cake, stew, pickles, salad, pie); seed (bread)	–	1. Polysaccharide portions of the aerial parts showed low toxicity in normal mouse cells	2. Chloroform extract from aerial parts showed low toxicity in female albino rats, but with anti-fertility effect 3. Chloroformic extracts and methanol-water from the leaves showed anti-fertility effect in rats 4. Hydroalcoholic extract from the whole plant showed low acute and subacute toxicity in Swiss albino mice 5. Methanolic extract from the whole plant showed toxicity in albino rats 6. Fraction 4 methanolic from the whole plant extract showed toxicity in albino rats	1. (Gatea et al. 2017) 2. (Nayaka et al. 2014) 3. (Obinna et al. 2019) 4. (Shafi and Tabassum 2015) 5. (Oyediji and Bolarinwa 2012) 6. (Olusina et al. 2015)
<i>Psidium cattleianum</i> Sabine (Myrtaceae).	Caatinga, Cerrado, Atlantic Forest, Pantanal, Pampa	Fruit <i>in natura</i> ; fruit pulp (sweet, jelly, yogurt, liquor, sauce, mousse, ice cream, juice, pie).	1. Report of heartburn after consumption of fruit <i>in natura</i> by users of medicinal plants in Mauritius	2. Hydroalcoholic extract of the leaves showed low cytotoxicity (LLC-MK2 mammalian fibroblast)	–	1. (Mahomoodally et al. 2018) 2. (Alvarenga et al. 2013)

Species (family)	Biomes ^a	Culinary use ^b	Ethnobotanical studies	In vitro studies	In vivo studies	References
<i>Solanum paniculatum</i> L. (Solanaceae).	Amazon, Caatinga, Cerrado, Atlantic Forest	Fruit with savory dishes, canned, cream, omelet	–	1. Ethanol extract from the fruit and leaves showed cytotoxic activity, but not mutagenic (bone marrow cells of Swiss mice) 2. Ethanol extract from the aerial parts showed low toxicity (red blood cells from Wistar rats)	2. Ethanol extract from aerial parts showed low acute toxicity in Swiss mice	1. (Vieira et al. 2010). 2. (Clementino-Neto et al. 2015)
<i>Spondias mombin</i> L. (Anacardiaceae).	Amazon, Cerrado, Atlantic Forest	Fruit <i>in natura</i> ; fruit pulp (jelly, yogurt, liquor, sauce, ice cream, juice, pie)	–	1. Aqueous and hydromethanol extracts of the leaves did not have a genotoxic effect (<i>A. cepa</i>) 2. Aqueous and crude ethanol extracts from the leaves showed a genotoxic effect (<i>Drosophila melanogaster</i>) 3. Fixed seed oil showed low cytotoxicity (<i>A. salina</i>) 4. Ethanol extract from the bark showed moderate cytotoxicity (<i>A. salina</i>)	5. Aqueous and hydromethanol extracts from the leaves showed mutagenic effect (Swiss albino mice) 6. Aqueous leaf extract showed low acute and subchronic toxicity (rats) 7. Fruit juice showed low toxicity (rats)	1. Oyeiyemi and Bakare (2013) 2. (Senes-Lopes et al. 2018) 3. (De Rezende et al. 2018) 4. (Clementino et al. 2018) 5. (Oyeiyemi et al. 2015) 6. (Goodies et al. 2015) 7. (Akharaiyi et al. 2018)
<i>Sierculia striata</i> A.St.-Hil. & Naudin (Malvaceae)	Amazon, Caatinga, Cerrado, Atlantic Forest	Almond (<i>in natura</i> , cooked, toast, cereal bar, biscuit, oil)	–	–	–	–

^aFlora do Brasil 2020 em construção (2020)^bdo Brasil (2018)

those that contain natural toxins. Though the nutritional aspects of UFP are relatively well documented, the presence of natural toxins still requires attention, especially in areas suffering from food insecurity (shortages) in Brazil. This chapter will further explore Brazilian UFP safety and consumption, known natural toxins, and reported toxicities. We reviewed the use of UFP and reports of undesirable effects with consumption, including information on plant toxicity, through extracts or the toxins themselves.

3 Brazilian UFP: Toxic Potential

In this chapter, we seek to answer the following questions: “Are Brazilian UFP safe for human consumption?” and “What are the principal natural toxins found?”. Our main concern is not to analyze experimental models from the perspective of reproducibility but to record the presence or absence of information on toxicity: which part of the plant was used or which type of extract or preparation used and which are the possible toxins involved. Determining which plants ought to be considered as UFP is not simple since a plant can be widely known and consumed in one region of the country and not in another. Related to geographic and cultural aspects, a species may or may not be considered a UFP because different communities or regions in Brazil have different relationships with plants (Jacob 2020).

For this reason, we chose 14 plant species from different botanical genera that fulfilled the role of UFP according to the concept of “relative non-conventionality.” The 14 plant species were chosen from an initial list of native (socially and biologically diverse) Brazilian plants of interest for consumption and commercialization that the Ministry of the Environment of Brazil had published through an Interministerial Ordinance No. 284/2018. We chose only species from the native Brazilian flora which present greater distributions in Brazilian biomes, in accordance with the Flora do Brasil 2020 database (Flora do Brasil 2020 em construção 2020). This information can be found under the items “origin” and “phytogeographic domains,” and Table 1 summarizes the principal UFP toxicity-related information.

To collect the data, we conducted an updated scientific literature search obeying the following criteria: review articles and original research in Portuguese, English, and Spanish, and (for only current references) those published between 2010 and 2020. We used the following databases for research: Scielo, Embrapa Agricultural Research Databases (BDPA), Web of Science, Medline/PubMed (via the National Library of Medicine), and Scopus. We used as descriptors in the databases the terms “*species name*” and *toxin*, or *toxicity*, or *anti-nutritional*. Initially, the titles and abstracts were submitted to a first screening (paired) in which those which did not meet the eligibility criteria were excluded. The title or abstract needed to cite UFP toxicity in ethnobotanical, in vitro or in vivo studies. Subsequently, a complete reading of the selected articles was carried out to obtain the following information: (1)

parts of the plant used as food, the form of preparation and undesirable effects, and (2) information concerning the toxic effect of the plant or plant extracts. Articles that did not present information on plant toxicity, isolated chemical agents with toxic action, agents stimulating the development and survival of the plant, or pharmacological/therapeutic activity of the plant or its products were excluded.

The toxicity studies were grouped into three types: (1) in vitro assays, using various types of human or other cells in their experimental models; (2) in vivo studies which used mice or rats; and (3) ethnobotanical studies. To evaluate the safety and efficacy of a plant or its products in humans, in vitro and in vivo studies always precede clinical trials. This also applies to research on potential plant food products to obtain more consistent data on food safety for consumption. In addition, ethnobotanical studies help to better understand undesirable effects occurring after consuming the plant or preparations made from them.

In the initial screening stage, the database search resulted in a total of 561 articles (analysis of titles and abstracts) yielding 39 articles for complete reading. In vivo animal studies occupied the largest segment (24), followed by in vitro (17), and ethnobotanical (01) studies. The most studied plants for toxicity were *Caryocar brasiliense* Cambess (pequi), *Portulaca oleracea* L. (beldroega, purslane), and *Spondias mombin* L. (cajá). For the edible plants during the last 10 years, toxicity had not been investigated for *Araucaria angustifolia* (Bertol.) Kuntze (pinhão), *Sterculia striata* A. St.-Hil. & Naudin (chichá), *Hymenaea courbaril* L. (jatobá), and *Platonia insignis* Mart. (bacuri). Below, we provide further details on toxicity for each of the UFP in this chapter.

4 UFP Toxicity

A. angustifolia is an example of gymnosperms present in the Atlantic Forest biome which produce food seeds (popularly known as pinhão). It is widely consumed in Southern Brazil whether baked or roasted, in cakes and flours, in paçoca¹ or puddings, ice creams, or souffle preparations (do Brasil 2018; Kinupp and de Barros 2007). Reports in the literature of its antioxidant properties and on correlated applications for *A. angustifolia* are relatively extensive. However, no reports have been found on undesirable effects with use as food or evidence of toxicity in its products. The few reports that deal with *A. angustifolia* claim toxicity to tumor cells using extracts obtained from non-edible parts of the plant such as the bracts (Souza et al. 2014) or essential oils obtained from leaves of other species of this gender (Elkady and Ayoub 2018). A study with consumers in Curitiba-PR reports that *A. angustifolia* is considered a natural food beneficial to health and that it can be consumed by the whole family (de Godoy et al. 2018).

¹Paçoca de pinhão: a mixture of different spices with cooked and ground seeds of *A. angustifolia* and cooked and ground meat.

H. courbaril is greatly studied in terms of pharmacological potential, with an emphasis on its bark, leaves, seeds, and roots. However, it is the fruits and seeds that have food purposes, because the seeds generate an edible flour of great nutritional value and the fruit pulp can be consumed fresh (do Brasil 2018; Schwartz 2018). Considering this, we sought reports on phytochemical profiles for the seeds and fruits of *H. courbaril*.

The presence of biscumarins has been demonstrated in the seeds, including ipomopsin and hymenain (Simões et al. 2009). Simões et al. (2009) demonstrated the anti-free radical activity of biscumarins isolated from the seeds of *H. courbaril* and suggest that biscumarins have the function of protecting the seeds of the plant during germination. Even if the fruits are traditionally accepted, new studies providing accurate information on the food safety of *H. courbaril* fruits and seeds are much needed. Fresh xylem sap is rich in physetin (a flavonoid), considered a functional ingredient in food due to its inhibitory effects on glucose metabolism and its anti-obesity activity (Im et al. 2016). Its cytotoxic activity was evaluated, and the physetin, together with fresh *H. courbaril* xylem sap, presented good results in a mouse fibroblast cell line. The path is open for the use of the xylem sap or physetin in future food preparations (da Costa et al. 2014).

The fruits of *P. insignis* are highly appreciated by local populations of the Amazon, Maranhão, and Piauí, where the species is easily encountered. The pulp of the fruit is edible (de Carvalho and Nascimento 2017). In chemical-pharmacological studies, the seeds are the most explored, being justified by the presence of bioactive compounds. Studies have evaluated the toxicity of the seeds, yet not the fruit nor pulp. In short, seed extracts present low toxicity in vitro and in vivo (in rats), as shown in Table 1. Justification for the biological potential of *P. insignis* seeds is based on the presence of several metabolites which have already been identified and studied for toxicity such as polyisoprenylated benzophenones and 1,3-distearyl-2-oleylglycerol which presents neither toxicity nor mutagenicity to *Artemia salina* Leach (do Nascimento Cavalcante et al. 2020). Isolation of the garcinielliptone FC (the polyisoprenylated benzophenone) from *P. insignis* seeds spurred studies which reported: (1) low central nervous system toxicity and no genotoxic effects in mice at 28 days of treatment (Coelho et al. 2018); (2) cytotoxic and mutagenic effects in concentration-dependent human hepatoma cells (HepG2) (da Silva Prado et al. 2017); and (3) low acute oral and intraperitoneal toxicity (in mice) up to 2000 mg/kg (da Silva et al. 2016). This information, when combined with records of use of the edible fruit in Brazil, reinforces the idea its consumption is safe.

In some regions of Brazil, *S. striata* use is restricted to traditional communities, especially in the Cerrado, yet it can be found in other biomes such as the Amazon, the Caatinga, and the Mata Atlântica (Atlantic Forest). Its seeds or almonds are eaten roasted, and from these, other preparations are produced (Bortolotto et al. 2015; do Brasil 2018). *S. striata* seeds are rich in proteins, fibers, and bioactive compounds with antioxidant activity. When compared to other Brazilian seeds and the more popular Cashews or Brazil nuts, a great differential is their low-fat content. Their lipid profile is composed mainly of oleic acid (18: 1^{Δ9}), linoleic acid (18: 2^{Δ9,12}), phytosterols, and tocopherols (Policarpi et al. 2018). Normally, because of

high-fat content, it is common to suggest caution in seed consumption because of the risks of intestinal problems and weight gain. This makes *S. striata* seeds different (EMBRAPA 1997). Further, we found no current reports on *S. striata* toxicity, which suggests safe food use.

As will be discussed below, the following species: *Bixa orellana* L. (urucum), *Byrsonima crassifolia* (L.) Kunth (murici), *C. brasiliense*, *Genipa americana* L. (jenipapo), and *S. mombin* presented low toxicity in greatly varied experimental model types (Table 1).

B. orellana seeds are commonly used to produce natural red dyes for application in textile, pharmaceutical, and food products. They are natural dyes and possess recognized antioxidant power, and their main components are bixin (containing a metal ester group) and norbixin carotenoids (containing a carboxyl group) (Nathan et al. 2019). A better analysis of the toxic potential of *B. orellana* and its components has revealed important information. According to the EFSA-European Food Safety Authority (2016), in a scientific safety opinion regarding chemical additives, the use of *B. orellana* seed extract (bixin based and norbixin-based) is safe for intake in general. In Brazil, the National Health Surveillance Agency-ANVISA also recognizes *B. orellana* use as a food additive (INS 160b Urucum, bixin, norbixin, Annatto extract, and Na and K salts). This corroborates studies that compose this chapter (Table 1). Nothing significant has been found related to teratogenicity or embryo toxicity, and only one study reported toxicity for *B. orellana* leaf extract (non-edible) (Table 1). In any case, pregnant women should continue to use the plant with caution. We note that carotenoids originating from *B. orellana* suffer degradation when exposed to light or high temperatures; under these conditions, this helps guarantee their safety in food preparations (Satyanarayana et al. 2006).

B. crassifolia is widely distributed in Central and South America. In North and Northeastern Brazil, its fruits are consumed fresh or in preparations usually sold in markets (Perez-Gutierrez et al. 2010). We note that *B. crassifolia* presents antioxidant and cytoprotective potential because of the carotenoids and flavonoids present in its fruits and other parts (Herrera-Ruiz et al. 2011). *B. crassifolia* fruits are a good source of lutein and zeaxanthin, two important carotenoids for humans for their predominant locations in the macular region of the retina. The protective effects on the retina are believed to be involved with the potent antioxidant activity of these components (Mariutti et al. 2013). In addition to being antioxidants, lutein and zeaxanthin are pro-vitamin A carotenoids. Vitamin A is important in visual processes, regulating and modulating cell growth and differentiation (Yonekura et al. 2016). Phenolic compounds such as the quercetin flavonol, one of the most studied flavonoids in the world, bring recognized antioxidant activity to the fruit of *B. crassifolia*. Due not only to study results, but also to its traditional use, *B. crassifolia* fruit appears to be safe.

The fruit of *C. brasiliense*, being native to the Brazilian Cerrado and found in other biomes such as the Amazon, Caatinga, and Mata Atlântica, is frequently consumed. In the literature, reports concerning the fruit or oil extracts from *C. brasiliense* demonstrate an absence of toxicity. *C. brasiliense* can be considered safe for use. It presents large quantities of antioxidants such as carotenoids and gallic acid

(Rocha et al. 2015; Traesel et al. 2017b). The peel of the fruit is indicated for its nutritional potential and presenting both antioxidant components and many food applications. However, its high tannin concentration requires care concerning the possibility of decreasing nutrient bioavailability (Rocha et al. 2015; Souza et al. 2019). Caution when consuming is suggested, especially in individuals who require greater nutritional demand. To minimize these effects, studies recommend boiling or cooking as viable techniques to control these factors and improve the nutritional value of the food (Samtiya et al. 2020).

The fruits of *G. americana* find culinary use and provide widely known bluish food dyes. It is known in the literature that this coloring potential involves the presence of iridoid components (genipin, genipin 1- β -gentiobioside, geniposide, and genipinic acid). *G. americana* iridoid blue-based pigments are considered a natural alternative additive for food applications (Neri-Numa et al. 2018). Little is known about its properties in food or its undesirable effects on human health. *G. americana* fruit extracts present low in vitro toxicity to normal and tumor cells of humans and mice (Table 1). Though studies evaluating their pharmacological potential have been increasing, safety analyses for the use of iridoid compounds (present in *G. americana*) remain inconclusive. For example, genipin presents low cytotoxicity and genotoxicity when tested in isolation on mouse cells (Tsai et al. 2000). Geniposide, a glycoside of genipin present in the fruits of *G. americana*, presents hepatotoxicity in rats when administered in chronic form in high doses (Tian et al. 2018). However, as with other natural dyes, genipin and iridoid compounds are easily degraded in the presence of light, heat, oxidizing agents, or pH changes; common conditions during culinary preparation (Neri-Numa et al. 2018). Therefore, *G. americana* appears to be safe for culinary use of its fruits.

The research performed for this chapter indicates that consumption of *S. mombin* fruit seems safe, presenting low toxicity in animal models upon administration of fruit juice (Akharaiyi et al. 2018). Yet the in vitro studies are confusing because they point to differing cell toxicities with changes in cell type. Further, no study has studied the principal edible part of the plant (the fruit) to assess cytotoxicity (see Table 1). This is important since fresh *S. mombin* fruit is widely consumed in Brazilian North and Northeastern culinary.

The toxicological aspects of certain of the plants analyzed present relevant questions. More detailed comments concerning *Mauritia flexuosa* L. f. (buriti), *Pereskia aculeata* Mill. (ora-pro-nóbis), *Portulaca oleracea* L., *Psidium cattleianum* Sabine (araçá), and *Solanum paniculatum* L. (jurubeba) are necessary.

The fruits of *M. flexuosa* are sweet to the taste, yet rich in fats. Fatty acid profiles for the mesocarp and seed oils predominantly present palmitic acid (16:0) and oleic acid (18:1 ^{Δ^9}), and *M. flexuosa* also presents carotenoids and phenolic compounds (da Agostini-Costa 2018). Methanol extracts of the fruit present flavonoids (flavones, flavonols, flavononols, flavonones, xanthones, chalcones, catechins, leuco-antocyanidins, and aurones), components with outstanding antioxidant activity that bring added economic value (Nobre et al. 2018). In animal models, most current studies have demonstrated *M. flexuosa* oil as safe for food use. However, it is noteworthy that maternal use of the oil in the diet can cause motor development and

reflex losses in the offspring (Table 1). Based on the above information, we can infer only that consumption of *M. flexuosa* as a food seems safe, yet that pregnant women should be cautious.

The species *P. aculeata* is popularly known in Brazil as ora-pro-nóbis, the only representative of the Cactaceae family in this chapter. It is part of a family of plants very well adapted to arid and hot regions, such as the Caatinga biome of Brazil, and the plant retains its capacity to accumulate water, and supply minerals, antioxidants, and proteins (Takeiti et al. 2009). *P. aculeata* is a plant with more restricted culinary uses; its leaves and fruits are consumed fresh or in preparations made from its by-products such as flours obtained from its leaves or jellies obtained from its fruits (do Brasil 2018). However, it is the uses of *P. aculeata* in traditional medicine from which studies bring information concerning its safety or undesirable effects. The leaves are traditionally used in Brazil in medicinal preparations, as emollients and for wounds, or inflammations on the skin; the fruits are used as expectorants (Pinto and Scio 2014). An important study reported that the hexane fraction of the methanolic extract of *P. aculeata* leaves did not induce signs of topical or systemic toxicity in dermal irritation tests in rats (Pinto et al. 2015b). Although this is not the usual form of the plant as a food, it is an important indication of its safety when there are no reports of toxicity. The second report found in our search confirmed that ethanolic extracts from the leaves of *P. aculeata* are generally safe because the signs of acute toxicity in animal models (rats) were negligible (Silva et al. 2017).

P. aculeata leaves are known to be rich in proteins, especially in tryptophan (Takeiti et al. 2009). Tryptophan is a precursor amino acid for the indole alkaloids which affect biological systems as bioactive amines, such as in adrenergic, serotonergic, dopaminergic, or cholinergic systems related to pain control. In a study developed by Pinto et al. (2015a), various alkaloids with antinociceptive activity were identified in *P. aculeata* leaves, including tryptamine, abrine, mescaline, hordenine, petunidin, di-tert-butylphenol isomers, and quercetin. The alkaloids present in the leaves of *P. aculeata* may well be involved in its analgesic activity. Due to the toxic potential of alkaloids, it is interesting that they are found in low amounts in food preparations. Foods contaminated with certain classes of alkaloids, such as pyrrolizidine alkaloids, are considered a risk to human health (Knutsen et al. 2017).

It has also been reported that the leaves of *P. aculeata* contain important constituents such as oxalic acid, nitrate, and saponins. Oxalic acid is considered an anti-nutrient that compromises calcium absorption and can induce undesirable effects. However, in practical terms, the species is not expected to present enough oxalic acid to significantly impede the absorption of minerals (de Almeida et al. 2014).

The presence of nitrates in *P. aculeata* needs our attention. Nitrates and their derivatives in the human diet are controversial and it is necessary to be aware of these aspects. Normally, dietary nitrate is reduced to nitrite by bacteria in the oral microbiota. Nitrite, in turn, is absorbed and appears to be responsible for systemic effects in humans (Weitzberg and Lundberg 2013). Although both are considered products with limited carcinogenic potential, nitrite in combination with certain amines or amides can potentially form carcinogenic nitrosamines (Chamandoost et al. 2016). There have always been concerns over consumption of processed

animal foods rich in nitrates and its carcinogenic consequences. Also observed in *P. aculeata* is the presence of compounds from the saponin group. High concentrations of saponins give the food a bitter taste, and it is reported that certain digestive enzymes are inhibited in the presence of saponins.

In the context of a varied diet, the consumption of *P. aculeata* is interesting. All these aspects lead us to believe that, even with observed low toxicity concerning the *P. aculeata* leaves, it is necessary, especially for users of centrally acting analgesic drugs, to use caution (in concomitant use of the plant), since analgesic effects may increase.

In the scenario of food preparations with bioactive and functional potential, the species *P. oleracea* is a UFP with increasing prominence. Its stems and leaves are consumed in salads and hot preparations, yet *P. oleracea* also brings applications from traditional medicine, many of them scientifically proven. Its positive effects on the blood biochemistry are emphasized and possibly justified by the high content of omega-3 fatty acids and antioxidant components in its composition (Petropoulos et al. 2016). However, with regard to safety, the studies are sometimes contradictory, and certain reports will be necessary to mention.

In this chapter, all the studies used extracts from edible parts of the plant (aerial parts), but with extractive solvents of different polarities. We noted that the chloroform and hydromethanol extracts induced deleterious effects on the fertility of rats, although being of low toxicity, similar to the hydroalcoholic extracts. The methanolic extracts presented a certain degree of toxicity in rats in a dose dependent manner (see Table 1). Trying to better understand the reason for these effects, we noted that the extractions using the chloroform and chloroform-methanol (v/v) solvents are more efficient and reliably obtain higher concentrations of both phenolic compounds and organic acids (Petropoulos et al. 2016). In addition, it is very common for *P. oleracea* to present in its composition other secondary metabolite classes such as flavonoids and phenolic acids (Gatea et al. 2017). Though many of these components have antioxidant action, depending on the dose consumed, and part of the plant used, they can cause undesirable effects.

In this context, the effects of *P. oleracea* on fertility are more important. In vivo animal studies point to the involvement of flavonoids present in the plant in anti-estrogenic activity and anti-ovulatory activity (Nayaka et al. 2014). Kaempferol, apigenin, luteolin, myricetin, and quercetin are some of the main flavonoids found in *P. oleracea*. The greatest flavonoid content is found in the roots, followed by the stems, and leaves (Gatea et al. 2017; Zhu et al. 2010). Although the leaves are mostly used in cooking, caution is highly suggested when using *P. oleracea* in food preparations for pregnant women.

Gatea et al. (2017) when analyzing the biological potential and phytochemical profile of *P. oleracea*, detected high concentrations of oxalic acid, which deserves attention. This compound acts as a chelator of dietary minerals, especially calcium. Yet even considering this caveat, the use of *P. oleracea* in a balanced and varied diet is strongly suggested, as it provides a variety of bioactive nutrients and is relatively safe. The general toxicity of the plant is not pronounced, but assessing its chronic

toxicity is necessary, and regular use in the human diet should be moderated due to its oxalic acid high content.

Our study did not find reports of toxicity for *P. cattleianum*; only one of the studies reported the low cytotoxicity of a hydroalcoholic extract obtained from the leaves and not the fruits, which is the principal form consumed as food (Alvarenga et al. 2013). An ethnobotanical study performed with users of medicinal plants in the Republic of Mauritius demonstrated that when consumed to prevent fever and flu, *P. cattleianum* fruit causes mild heartburn. Further, there are reports of vomiting when its fruits are consumed after using iron supplements (Mahomoodally et al. 2018). However, of the universe of 307 individuals participating in the research, there were few reports, and the amount consumed until these effects appeared was not reported. The phytochemical profile of the fruit, containing vitamin C between 200 mg and 242 mg per gram of fresh fruit justifies the adverse effect (heartburn) (Pereira et al. 2018). Very high daily doses of vitamin C (2000 mg or more) can cause transient gastroenteritis or osmotic diarrhea in some individuals (da Silva et al. 2016). Thus, for those with previous gastric or intestinal problems, it becomes interesting to moderate consumption of citrus fruits such as *P. cattleianum*.

In traditional medicine, the roots, leaves, and fruits of *S. paniculatum* are used for general inflammations, as a diuretic, and against liver diseases (Agra et al. 2007). However, it is their fruits that have food potential. Considering this, we found a single report on the toxicity of an ethanol extract obtained from the fruits of *S. paniculatum* (Vieira et al. 2010). The authors demonstrated the cytotoxicity of the extract when administered to mice in high doses (above 200 mg/kg of weight) yet with an absence of mutagenicity. *S. paniculatum* has many metabolites that seem to be involved in its discrete toxicity, among them are steroidal sapogenins and steroidal glycoalkaloids (solanine, solasonine, and solamargine). Steroidal sapogenins are non-saccharide portions of saponins, and although less common, they are found in the roots, leaves, and vegetable fruits of the genus *Solanum* (Sobolewska et al. 2020; Vieira Júnior et al. 2015). In vivo studies of steroidal sapogenins have demonstrated low acute toxicity in mice (Wei et al. 2014). In general, consumption of foods containing these compounds presents little toxicity and does not appear to be dangerous for consumers (Oleszek and Oleszek 2020).

In turn, steroidal glycoalkaloids are found in large quantities in the fruits of *Solanum* spp., presenting a bitter taste, and undesirable effects in humans (Knuthsen et al. 2009). The principal effects reported include gastrointestinal problems (abdominal pain, vomiting, and diarrhea), sweating, bronchospasm, confusion, hallucination, heart failure, partial paralysis, seizures, coma, and even death (Mensinga et al. 2005; Sucha and Tomsik 2016). The suggested mechanisms of action include induction of apoptosis or necrosis, inhibition of acetylcholinesterase, and interaction with membrane steroids (affecting the function of plasma membranes). We suggest reading Sucha and Tomsik (2016) for further study.

Studies on the toxicity of these compounds in plants of the genus *Solanum* spp. have been increasing. Principally, reports refer to other members of this genus such as potatoes (*Solanum tuberosum* L.), tomatoes (*Solanum lycopersicum* L.), and eggplant (*Solanum melongena* L.). This is relevant since vegetables are much more

present in the daily world of food than is *S. paniculatum*, yet they share certain glycoalkaloids (Barceloux 2009). We note that glycoalkaloid content varies substantially between different cultivars of the plant and post-harvest conditions (light, mechanical injuries, storage). During cooking, the principal methods used in processing, such as boiling, heating, and frying, do not significantly alter the final glycoalkaloid content of the food (Friedman 2006). Considering the genus *Solanum*, toxic glycoalkaloids are not generally found in the fruit, but are present in greater quantities in other inedible parts such as the leaves (Knuthsen et al. 2009). In this context, cases of glycoalkaloid poisoning are relatively rare, yet they do occur, chiefly with consumption of little known plants considered wild such as *S. paniculatum* (Barceloux 2009). This may be why the only report we found describing the in vitro toxicity of *S. paniculatum* fruit extract cited high concentrations (Vieira et al. 2010).

Finally, we note that the Brazilian UFP in this chapter present diverse spectra of metabolites considered to be natural toxins and which are often present in more than one plant. In view of this great diversity, Fig. 1 summarizes these toxins and associates them with the UFP in which their occurrence was observed.

Fig. 1 Distribution of the main groups of natural toxins present in unconventional food plants of Brazil

5 Conclusions

Understanding the toxic properties of certain plants discussed in this chapter raises important questions that go beyond safe consumption. Reflecting critically on these factors can help to better understand the forms of interactions between humans and plants, especially since UFP represent a potentially relevant contribution to a varied and complete diet.

Initially, the studies included in this chapter present a scenario in which practically all UFP's are of great use to popular medicine, while also presenting nutritional potential. Yet often, depending on the part of the plant used, the form of preparation, dosage, and final distribution of the natural toxins involved in these effects, the plants possess toxic or mutagenic properties. In addition, certain metabolites can be considered anti-nutritional, since they interfere in nutrient (food) bioavailability, causing secondary damage to individuals. All of these factors are important and determine the safety of the plant.

Many of the studies used products from plants that are not associated with their principal forms of culinary use in Brazil. Many of these studies presented as their central objective an investigation into the pharmacological potential of the inedible parts of the plants. Ensuring the correct part of the plant is used is essential since there are variations in the phytochemical profiles of the various plant organs. These phytochemical components perform important functions in the plant, and uneven distribution is an important form of adaptation.

The biological properties of natural toxins observed in many studies (given the isolated metabolite) may not represent the toxic activity of the plant as a whole. When consumed, the plant itself presents a phytocomplex system, and interactions between various such compounds during the digestive process can result in reduced bioavailability for any of them. Combinations with other foods can also cause similar results. The amounts of toxin in the ingested plant are in many cases lower, when comparing similar effects from the use of the isolated substance. It is interesting to note that we are cautious with the consumption of UFP associated with drug therapies, as there are real possibilities of drug-food interactions that are not beneficial for humans. Sometimes information concerning natural toxins and how they work in the body remains unclear. This opens up a promising field for future studies.

In general, the information presented in this chapter reveals various UFP species with relatively low toxicity. However, certain UFPs require greater attention to their toxicological aspects: *S. paniculatum* requires more care with its leaves (for containing glycoalkaloids and steroidal saponins) than with its fruits. Due to the presence of flavonoids involved in fertility (for women), and for containing large amounts of oxalic acid, consumption of *P. oleracea* during pregnancy requires caution. Because of potentially negative consequences for the development of newborns, *M. flexuosa* oil should be treated with caution by pregnant women as well. Due to oxalic acid, saponins, and indolic alkaloids, consumption of *P. aculeata* must be moderate since associations of indolic alkaloids with analgesics may be well be harmful. For those who present stomach problems, *P. cattleianum* appears to cause heartburn and moderate use of the fruit should be considered.

Considering our discussions, when there is a need to seek information on food safety in a given UFP, we emphasize the need to ask the following questions: “Is the part of the plant of interest used in this study the edible part?”, “What is the predominant phytochemical profile (natural toxins)?”, and “Do the current physical processes of culinary practice interfere with either the content or stability of these toxins?” In conclusion, consumption of fresh UFP or derived products, in whole or in part, without adequate knowledge of their botanical, chemical, and toxic characteristics can bring undesirable results. Such knowledge is imperative, especially for plants presenting restricted consumption.

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