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Review article

Biotechnological potential of *Hancornia speciosa* whole tree: A narrative review from composition to health applicability

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ABSTRACT

Mangabeira (*Hancornia speciosa*) is a Brazilian tree and a socioeconomic key due to the commercialization of its food products and tree parts to treat health conditions empirically. This review gathers the main chemical, and microbiological characteristics of the mangabeira tree parts (leaves, fruits, tree bark, latex, and seeds), emphasizing its applicability in food science and focusing on its bioapplicability in health conditions. Leaves, fruits, and tree bark can be used to develop functional foods, and phytochemical products; the tree latex have great potential in the bioengineering material field; and the seeds in sustainable energy production. Leaves and fruits were the main samples bioapplied in health conditions *in vitro* (oxidative stress and chemopreventive effect) and *in vivo* (gastrointestinal and cardiovascular health, anti-inflammatory, and antidiabetic effect), whereas tree bark and latex also exhibited health effects and seeds showed low cytotoxicity. All parts of the mangabeira tree can be explored by extractivist families and industries from a sustainable point of view.

1. Introduction

The mangabeira tree belongs to the *Eudicotiledoneas* group, *Gentianales* order, *Apocynaceae* family, and *Hancornia speciosa* Gomes species. It is a native plant found in the North, Northeast, Middle West, and part of Southeast regions of Brazil, covering Brazilian biomes such as Cerrado, Pantanal, and part of Atlantic Forest. It also grows in some countries of South America, e.g., Peru, Bolivia, and Paraguay [1].

The extractivism is the main exploration use of *H. speciosa* tree parts (Figure 1), in some periods of the year, uncountable families have on its harvest and commercialization an important occupation and financial source [1]. The plant fruits are largely used in local culinary, being consumed both *in natura* and in preparations like desserts, jams, liqueur, vinegar, juice, and ice cream [2]. Also, mangabeira fruit has been explored by diverse emerging technologies to develop functional foods improving the health quality of consumers [3, 4].

Studies have shown that the plant is a source of several nutrients and bioactive compounds, especially the phytochemicals rutin and chlorogenic acid [5, 6, 7, 8]. In addition, recently, has been discovered that the different parts of the mangabeira tree (leaf, fruit pulp, latex, and bark) presents pharmacological benefits on common health conditions, such as hypertension [9, 10, 11], diabetes [12], and inflammation [5, 8, 13].

Lastly, the mangabeira tree has shown a great potential to contribute to sustainable development, being used as raw matter for innovative products focusing on minimizing environmental impact caused by large-scale industry production [14, 15]. Thus, the objective of this study is to build a complete review of the mangabeira tree, approaching its characteristics regarding composition, medicinal properties–biotechnological

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Figure 1. *H. speciosa* tree parts: (A) leaves, (B) seeds, fruit pulp, and whole fruit, (C) tree bark, and (D) latex.

applications. To the best of our knowledge, this study is the first narrative review about the *Hancornia speciosa*: which comprises the potential and uses of all mangabeira tree.

2. Materials and methods

This manuscript is a narrative review derived from a systematic literature survey guided by Prisma Group [16]. In the identification step, the terms "*Hancornia speciosa*" and "mangaba" were used to obtain all content at Science Direct, PubMed, and Scielo web database, since the tree is native from Brazil, we included its scientific platform. No filter of type of material, language, nor timespan was applied, although the literature survey was carried in July 2020. At the screening step, after excluding all duplicated material, all the records related to physico-chemical, chemical, macro, and micro -nutrients characterization; *in vitro*, and *in vivo* assays; and product development from any part of the mangabeira tree were included. The exclusion criteria were the type of material (review articles, and book chapters), subject matter (agriculture, ecology, plant physiology, morphology, socioeconomics, and anthropological), and lack of information (omission of methods, and the number results). All the steps including eligibility, and included, were confirmed by the consensus of three reviewers, which integrated the whole literature survey (Figure 2).

Some of the values at the Characterization of *H. speciosa* section are presented as minimum–maximum found value, each single value from every single study is displayed in the supplementary material (Table S1).

3. Characterization of the *Hancornia speciosa*

In this section are described all the information related to the chemical, physicochemical, and microbiological composition of the different parts of the mangabeira tree.

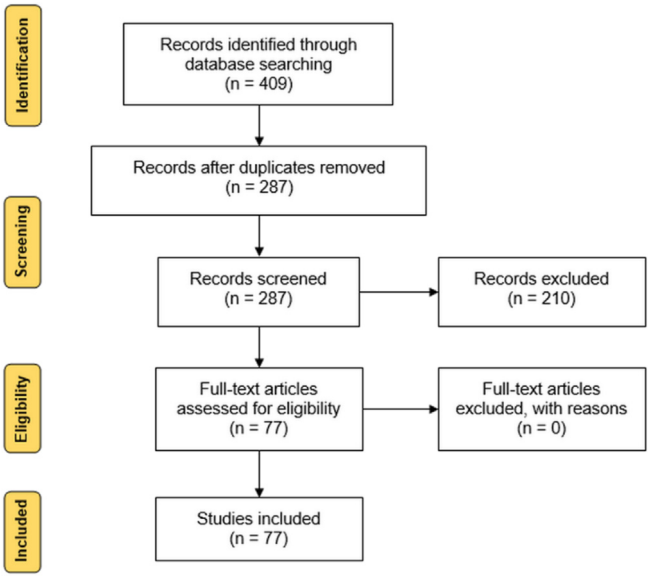

Figure 2. Flow chart of literature survey.

3.1. Nutritional, physico-, and chemical components

From the data presented in Table 1, we can say that the mangabeira leaves are mostly composed of carbohydrates followed by proteins; its fruits, on the other hand, are formed of water, followed by carbohydrates and lipids; while the latter predominates in the chemical composition of the fruit seeds. Is worth mentioning that

Table 1. Main macro and micro nutrients found in different parts of *Hancornia speciosa*.

Nutritional parameter	Part of the plant					
	Leaves	Ref	Fruit	Ref	Seeds	Ref
Ashes (g/100 g)	2.2	[17]	0.3–0.8	[7, 94]	1.87	[14]
Moisture (g/100 g)	-	-	82.4–90.8	[63, 95]	7.78	[14]
Lipids (g/100 g)	0.14	[17]	1.4–2.3	[94, 95]	27.33	[14]
Protein (g/100 g)	14.7	[17]	0.6–2.3	[19, 96]	12.10	[14]
Carbohydrate (g/100 g)	82.9	[17]	6.2–11.5	[7, 19]	-	-
Total fiber (g/100 g)	-	-	1.3–17.4	[43, 94]	11.98	[14]
Soluble fiber (g/100 g)	-	-	6.9	[43]	-	-
Insoluble fiber (g/100 g)	-	-	10.5	[43]	-	-
Cellulose (g/100 g)	-	-	-	-	17.07	[14]
Hemicellulose (g/100 g)	-	-	-	-	22.57	[14]
Lignin (g/100 g)	-	-	-	-	10.16	[14]
Total pectin (g/100 g)	-	-	0.4–1.2	[43, 97]	-	-
Soluble pectin (g/100 g)	-	-	0.21	[43]	-	-
Energy (calories/100 g)	392.0	[17]	58.5–67.1	[30, 43]	-	-
Calcium (mg/100 g)	4.0	[98]	8.5–130	[99, 100]	-	-
Phosphorus (mg/100 g)	2.10	[98]	6.05	[100]	-	-
Magnesium (mg/100 g)	1.0	[98]	70.27	[100]	-	-
Sodium (mg/100 g)	-	-	33.78	[100]	-	-
Potassium (mg/100g)	7.0	[98]	110 - 1,030	[7, 99]	-	-
Zinc (mg/100 g)	7.0	[101]	0.1–2.1	[7, 100]	-	-
Iron (mg/100 g)	41.0	[101]	0.8–7.9	[95, 99]	-	-
Manganese (mg/100 g)	20.0	[101]	1.5	[99]	-	-
Copper (mg/100 g)	8.0	[101]	0.08–0.6	[99, 100]	-	-
Selenium (mg/100g)	-	-	0.8	[100]	-	-
Sulfur (mg/100 g)	1.3	[98]	-	-	-	-
Boron (mg/100 g)	2.0	[101]	-	-	-	-
Cobalt (mg/100 g)	-	-	20.93	[100]	-	-
Bromine (mg/100 g)	-	-	0.4	[99]	-	-
Nickel (mg/100 g)	-	-	13.66	[100]	-	-
Carbon (mg/100 g)	-	-	-	-	58.07	[14]
Hydrogen (mg/100 g)	-	-	-	-	8.19	[14]
Nitrogen (mg/100 g)	10	[98]	-	-	4.61	[14]

Ref: references (leaves n = 3 [17,98,101]; fruit n = 11 [7,19,100,30,43,63, 94–97,99]; Seed n = 1 [14]).

few articles sustain the composition of leaves and seeds, so we suggest that future researches involving these samples explore their composition.

Table 2. Physicochemical characteristics of *Hancornia speciosa* fruits.

Parameter	Mangaba	Ref.
Water activity	0.99	[102]
pH	2.8–3.9	[27, 30]
Titratable acidity (mgCA/100 g)	0.5–3.1	[87, 103]
Soluble solids (°Brix)	9.1–18.1	[87, 104]
Total soluble sugar (mg/100 g)	9.2–16	[105, 106]
Reducing sugar (mg/100 g)	5.1–9	[30, 106]
Non-reducing sugar (mg/100 g)	4.13	[106]

Ref: references - fruit n = 8 [27,30,87,102–106]. CA: Citric acid.

Given such chemical characteristics were obtained, the approximate energy values that the leaves and fruits of the mangabeira tree offer us; where the leaves have a relevant caloric amount of approximately 3.9 calories per gram [17], while its fruits bring on average 0.6 calories per gram.

Regarding the dietary fibers present in the mangabeira fruits, the average value obtained by this work was 13%, with individual values ranging from 1 to 38% [18, 19]. Taking into account that the recommendation of dietary fiber intake for women between 19 and 50 years old is 25 g per day [20], the consumption of 100g of mangabeira fruits supplies 51% of the reference value, while its seeds alone supply 47%.

When observing the composition of micronutrients present in the mangabeira leaf, notably calcium, iron, manganese, and copper exceed the respective recommended daily values of 1, 18, 1.8 mg/day, and 900 μg/day [21] in 400, 200, 1000, and 800%. However, only manganese exceeds the tolerable upper intake level of 11 mg/day for women between 19 and 50 years of age by 180% [22].

Manganese is an important element in enzymatic reactions of a redox character, it is also involved in bone and cartilage formation when ingested in adequate amounts [22]. The main toxic effects of manganese are caused to the brain, generating signs and symptoms similar to Parkinsonian syndromes, normally neurotoxicity is irreversible and progressive in the face of causal exposure [23].

Regarding the minerals present in the fruits of the mangabeira tree, those that stand out are selenium, manganese, and copper, which offer 1400, 80, and 40% of the daily values recommended for women aged 19 to 50 (55, 1800, and 900 μg/day). In contrast, only selenium exceeds the tolerable upper intake level value (400 μg/day) by 200%, when ingested by the same group of people [22].

Selenoproteins are derived from selenium, where we can emphasize the glutathione peroxidases that act on the human antioxidant system, associating this element to the prevention of some types of cancer, cardiovascular diseases, and diabetes. However, it is also reported that excess selenium stimulates the generation of reactive oxygen species making its toxicity a relevant cyto- and genotoxic factor, resulting in a close relationship with carcinogenesis, diabetes, and neurodegenerations [24].

The only physicochemical information found was regarding the mangabeira fruits (Table 2), where these characteristics attribute particular sweetness and mild acidity tastes derived from the high amount of sucrose, and total sugars and also from low pH, and organic acids. Despite the low acidity, the mangaba also has high water activity, favoring the metabolism of the post-harvest fruit, as well as the development of microorganisms.

A single mangabeira tree can produce more than 100 kg of fruit per harvest [25], and when we consider its parameters of water activity and soluble solids, it is essential to apply technologies to maintain the nutritional, microbiological, and safety quality of this food. Fresh fruit is the most cited form of consumption in the literature, followed by instantly frozen pulps or by conventional freezing [7, 26, 27].

The use of technological methods of processing foods aiming the extension of shelf life of this fruit and its derived food products are needs

resulting from its high production and physicochemical peculiarities; In addition to freezing, pasteurization is a technology widely used by the industry to inactivate deteriorating food enzymes and microorganisms, such process can cause sensory changes in mangaba, however, these changes do not influence the sensorial acceptability of the (un) pasteurized fruit pulp for up to one year of freezing storage [26].

The use of fruits in product development is an alternative form of food preservation, the most common products developed from mangabeira trees are further detailed in Section 5. However, taking into account the acidity, total sugars and even the amount of pectin present in mangaba make it a great candidate in the manufacture of jams, as this type of product has a low cost of manufacture, processing, transportation, storage, and extends the offer of the fruit after the harvest period [28].

The application of different technologies in the post-harvest of fruits generates a socioeconomic impact on the populations that survive from their extractivism, valuing the biodiversity of native plants and fruits, contributing to the spread of popular knowledge around this tree with biotechnological applications, and generating complementary income to small producers [25, 29].

Furthermore to the characteristics of sugars, water, and organic acids, other phytochemicals also contribute significantly to the particularities of fruit flavor, and consequently of their derived products [28]. Among them are the volatile compounds, present in the fruits of *H. speciosa*, being respectively esters (30%), alcohols (21%), aldehydes (18%), hydrocarbons (13%), terpenes (10%), and ketones (6%); 77 different volatile compounds have been identified by gas chromatography on the fruits of the mangabeira tree, and they are all listed in the supplementary material (Table S1) [30, 31, 32].

Additionally, ascorbic acid and phenolic acids are also relevant in the sensory perception of bitter and acidic tastes, and astringent flavor, depending on their concentrations present in food [33]; In fresh fruits, phytochemicals are transformed according to their metabolism, where post-harvest applied technologies help to maintain beneficial characteristics of these compounds, mainly the antioxidant capacity, therefore increasing appreciable characteristics by the food industry in the development of functional products and with greater stability/durability [34].

In the leaves of the mangabeira tree, the water-soluble phytochemical compounds predominate, with intermediate levels of total phenolic content [35] where 8% of these are flavonols. Among the 35 compounds identified by liquid chromatography, the most cited in the literature are rutin, quinic, and chlorogenic acids; it is also important to mention L (+) bornesitol due to its therapeutic action, which is better detailed in the next section [36, 37]; the hydro solubility of this class of compounds explains the popular knowledge of using this material in infusions [38] and scientific research exploring hydrophilic extracts (Section 4).

Although the lipid composition is close to zero, the polyunsaturated, saturated, and monounsaturated fatty acids present in the leaves of mangabeira correspond to 48, 39, and 11%; Therefore, fat-soluble phytochemicals (carotenoids and chlorophyll) [17] also contribute to the therapeutic antioxidant capacity (Section 4) and the stability/development of food products due to their low concentrations [39].

The highest concentrations of phytochemicals are present in the fruits of the mangabeira tree (Table 3) and similar to the leaves, most compounds have water-soluble characteristics; the most mentioned are chlorogenic acid, rutin, quercetin, and kaempferol, in addition to these other 23 were identified by liquid chromatography.

Another water-soluble compound concentrated in the mangaba is vitamin C (ascorbic acid). The daily recommendation for vitamin C intake is 75 mg/day for women over 19 years of age [21], then 100 g of mangaba offers 270% of this value, not exceeding the UL. This was one of the first vitamins studied due to diseases related to its deficiency, however, current research is associating it with the prevention of neurodegeneration, inflammation [40], bioapplication in the development of microcapsules for the treatment of cancer, and others [41]. However, like chlorophylls, vitamin C is an unstable molecule, which when added to the physicochemical characteristics of mangaba results in its oxidation [41].

Regarding the lipophilic phytochemicals present in mangaba, there are the carotenoids with variations from 0.18 to 1.26 mg [42, 43], and also some of the volatile compounds mentioned above. The carotenoids and anthocyanins, both present in the fruit, are natural plant pigments, thus giving them yellowish and pinkish colorings, besides their antioxidant capacity and therapeutic action [44].

Table 4. Microorganisms isolated from different parts of *H. speciosa*.

Part of the plant	Isolated microorganism	Ref.
Fruit	*Candida bombicola-like; C. gropengiesseri-like; Candida krusei; Candida parapsilosis; Candida spandovensis; C. spandovensis-like; Candida sorbosivorans; C. stellata-like; Candida spp; Geotrichum sp.; Kluyveromyces marxianus-like; Metschnikowia-like; Pichia membranifaciens; Pichia spp.; Saccharomyces bayanus; Saccharomyces cerevisiae; Saccharomyces sp.; Torulaspora delbrueckii-like; Trichosporon spp*	[45, 47]
Tree bark	*Aspergillus flavus Link; Aspergillus niger Tiegh; Cladosporium cladosporioides (Fresen.) G.A. de Vries; Colletotrichum gloeosporioides (Penz.) Penz. & Sacc.; Fusarium lateritium Nees; Fusarium solani (Mart.) Sacc.; Lasiodiplodia theobromae (Pat.) Grif. Maubl.; Mariannaea elegans G. Arnaud; Mycelia sterilia; Nigrospora sphaerica (Sacc.) Mason.; Penicillium fellutanum Biourge; Phoma cava Schulzer; Phomopsis archeri B. Sutton.; Trichoderma harzianum Rifai.; Tritirachium oryzae (Vincens) de Hoog*	[49]
Tree latex	*Enterobacter, Escherichia, Klebsiella, and Bacillus**	[52]
Seeds	*Aspergillus spp.; Chaetomium spp.; Cladosporium sp.; Fusarium spp.; Paecilomyces sp.; Penicillium spp.; Pestalotiopsis sp.; Phomopsis sp.; Aureobasidium pullulans*	[53]

*taxonomic level: Genera.

Table 3. Chemical components in different parts of *Hancornia speciosa*.

Phytochemical	Part of the plant							
	Leaves	Ref.	Fruit	Ref.	Tree bark	Ref.	Tree latex	Ref.
Ascorbic acid (mgAA/100 g)	-	-	80.2–431	[106, 107]	-	-	-	-
Total phenolic content (mgGAE/100 g)	179	[60]	0.3–440	[32, 105]	60.2	[108]	37.4	[109]
Flavonols (mgQE/100g)	2.7–29	[36, 60]	6.6–15	[63, 110]	8.6	[108]	-	-
Pro-anthocyanidins (mgCE/100 g)	-	-	4.2	[110]	-	-	-	-
Total anthocyanins (mgTA/100 g)	-	-	0.4–0.7	[63, 64]	-	-	-	-
Total carotenoids (mgTC/100g)	0.62	[17]	0.1–1.2	[42, 43]	-	-	-	-
Chlorophyll (mg/100 g)	1.75	[17]	-	-	-	-	-	-

Ref.: references - leaves n = 8 [17,36,37,60,72,74,111,112]; fruit n = 20 [5,6,38–41,46,47,50,55–57,7,8,19,22,24,26,35,37]; tree bark n = 1 [108]; tree latex n = 1 [109]. AA: Ascorbic acid. GAE: Gallic acid equivalent. QE: Quercetin equivalent. CE: Catechin equivalent. TC: Total carotenoids. TA: Total anthocyanins.

Phenolic compounds are also present, in low concentrations [35], in the bark and latex of the mangabeira tree, and so both also demonstrate therapeutic activities (Section 4).

3.2. Microbiological components

In Table 4, we represent all the microorganisms that were isolated from the different parts of the mangabeira tree. Most studies identified at least nine species of fungi, and only in the tree's sap were identified as 4 species of bacteria. Among the fungi most commonly found in food are *Aspergillus*, *Paecilomyces*, *Cladosporium*, *Fusarium*, *Penicillium,* and *Trichothecium*; and *Saccharomyces* species are among the yeasts.

Nine different strains of *Candida sp*. were detected from frozen mangaba pulps, the authors suggest that extrinsic factors to the fruit/plant are responsible for the presence of these microorganisms in sample [45]. Not being associated with the fungus causing the sexually transmitted infection (*Candida albicans*) [46], the found *Candida sp*. demonstrate high killer activity against fungi other than their colonies, which are appreciated by the pharmaceutical industry in the development of antimicrobial drugs; plus, observed proteolytic, pectinolytic, and arbutin-reducing actions by these microorganisms are also appreciable biotechnologies to improve the taste and flavor of juices and wines, by the food industry [47].

The fungi *Kluyveromyces*, *Torulaspora*, and *Saccharomyces*, are known for the fermentation of oat polysaccharides and fructans; In particular, *Torulaspora* are used in the manufacture of traditional Austrian bread, and *Saccharomyces* are used in alcoholic fermentation to obtain beers and fuel alcohol [48]. Therefore, these identified microorganisms (if isolated and bioapplied) can help in the development of new antimicrobial drugs/compounds, the production of fermented food products, and even fuel. In addition, they can influence the perishability of the mangaba fruit in the post-harvest period, causing sensory and chemical alterations that may be unwanted in the development of new food products (Section 3.1).

In the bark of the mangabeira tree, endophytic fungi producing bioactive compounds with antimicrobial capacity against pathogens [49] have been reported, despite their endosymbiosis with the plant, some fungi mentioned (such as *Aspergillus*) produce mycotoxins that cause damage to the health of human beings [50]; in contrast, the bark of the tree is commonly used in the preparation of infusions, where the temperature reaches 100 °C, thus inactivating both the aflatoxins and the microorganisms that produce them, but they remain in the product [51].

Four bacteria genera were isolated from the tree's sap; through the use of this material in the empirical treatment against pulmonary and sexually transmitted fungal infections, the authors isolated the bacteria and measured their respective antifungal potential without success, concluding that the therapeutic effect has no bacterial but possibly chemical origin [52].

Regarding the fungi identified in the seeds of the mangaba fruit, the authors state that studies with a larger sample size need to be carried out, to confirm the phytopathogenicity caused by the fungi isolated from the sample (*Pestalotiopsis sp*., *Phomopsis sp*. And *A. pullulans*) to inoculated mangabeira trees [53].

For many years we believed that the goal was food free of microorganisms, however, after the Human Microbiome Project [54], we started to understand our real interaction with microorganisms and how they can determine the state of health or disease in the host.

Despite this being a milestone for biomedicine, the food science/industry has already used microorganisms in product development since 1850 [55]; from then on, new food products began to appear using different strains of microorganisms, and substrates to stimulate their growth/metabolites, until we arrive at the most recent definitions of parabiotics (fragment of non-viable microorganism cell that when administered in sufficient quantity, confers benefits to the consumer) [56], and postbiotics (metabolites of microorganisms released from the food matrix or microbial origin, including non-viable cells that, in sufficient quantity, confer benefits to the consumer) [57].

The high hydrostatic pressure (HHP), an emerging food technology, consists of a non-thermal technology that subjects the food to a pressure ranging from 100 to 690 Mpa through fluid injection or mechanical compression, ensuring sanitary quality through the lysis of microorganisms, increasing the shelf life of the product without causing significant changes in the nutritional and sensory composition of the food [58].

Thus, HHP in addition to using fewer energy resources such as electricity and water, when compared to classic technologies such as pasteurization, provides safe and high-quality food products causing less environmental impact [59]; and through cell lysis it generates cells and/or fragments of non-viable microorganisms, which when ingested might bring beneficial effects to the consumer, defining postbiotic foods [56].

In this way, all parts of mangabeira classical or emerging technologies are applied [38], and bacterial or fungal microorganisms have been identified (Table 4), can be considered a candidate for a natural biotic product, meeting food trends such as functional, plant-based, sustainable, and -biotic foods.

4. Health effects of *Hancornia speciosa*

After describing the main characteristics that compose the different parts of the mangabeira tree this section details the health effects of each of these parts *in vitro* (Table 5) and *in vivo* (Table 6) assays. Figure 3 briefly illustrates the main findings of this section.

4.1. In vitro studies

4.1.1. Leaves

Most of the *in vitro* studies using mangabeira tree leaves have explored its antioxidant and anti-inflammatory potential. Two of the assays to determine antioxidant activity were conducted using human erythrocytes, however, testing different concentrations of *H. speciosa* leaves ethanolic extract (EEHS). Santos et al. [60] evaluated hemolytic activity in doses of 50–125 μg/mL, while Santos et al. [17] used a smaller dose of 20 μg/mL. In both cases, EEHS was able to prevent APPH-induced hemolysis on erythrocytes, being that doses of 100 and 125 μg/mL preserved the effect during the incubation period for a longer time (240 min) [60].

More studies were conducted using the ethanolic extract and its fraction [61] evaluated the chemopreventive activity and discovered a potent NF-kB-inhibitory action on EtOAc, EtOAc: MeOH (1:1), MeOH, and MeOH: H2O (1:1) fractions, tested in human hepatic tissue cells. Data presented in this study also confirms the plant's ability to put an end to inflammation conditions. Analysis to support mangabeira leaves ethanolic extract fraction and isolated compound healing character also demonstrated positive results on inflammatory process control. Following this, Geller et al. observed a significant decrease of proinflammatory cytokines (TNF-α) release on human acute monocytic cells (THP-1) stimulated by lipopolysaccharides (LPS) [62].

4.1.2. Fruits

In vitro experiments conducted with *H. speciosa* fruit assessed the pulp properties both *in natura* and in extracts, being this one focused on the antioxidant activity analyzed by ABTS, FRAP, and DPPH test [6, 42, 63, 64]. Dutra et al. determined the pulp phenolic profile and antioxidant activity using methanolic and acetonic extracts, and also determined their bioavailability on frozen pulps exposed to induced gastrointestinal conditions [6].

Satisfactorily, the study led to a significant increase in frozen pulp phenolic compound concentration (33,6%) and a higher capacity of iron reduction developed by dialysate after gastrointestinal digestion simulation. In addition, there was an increase in rutin concentration and

Table 5. *In vitro* studies regarding the health effects of *Hancornia speciosa*.

Part of the plant	Experimental assay	Product used	Dosage	Method	Effect	Ref.
Leaves	Chemopreventive	Fractions of ethanolic extract	20 μg/mL	Aromatase, NF-κB, and ornithine decarboxylase inhibition; antioxidant response elements (ARE) induction; and cell proliferation assays (MCF-7, LNCaP, HepG2, or LU-1)	Chemopreventive and anti-inflammatory	[37]
	Cytotoxicity	Methanol/hexane extract	50 μg/mL	Cells exposure to the extract (HCT-8 colon carcinoma, MDA-MB-435 melanoma, SF-295 glioblastoma, and HL-60 promyelocytic leukemia)	No expressive antiproliferative potential	[113]
	Chemopreventive	Ethanolic extract and fractions (hexane; DCM; DCM/EtOAc; EtOAc; EtOAc/MeOH; MeOH; Hydro/MeOH)	20 μg/mL	NF-κB inhibition; ARE induction; inhibition of COX-1 activity; TPA-induced ODC activity	Anti-inflammatory and antioxidant	[61]
	Antioxidant and antimicrobial capacity	Crude extract (hexane; EtOAc; Hydro/EtOH)	300 μL	DPPH	Antioxidant and antimicrobial	[36]
			250–500 μg/mL	Antimicrobial susceptibility		
	Antidiabetic	Crude extract and fraction (EtOH)	0.3 to 1,000 μg/mL	α-glucosidase inhibition;	Hypoglycemic effect	[74]
			100 μg/mL	adipocytes glucose uptake		
	Tissue repairing	Ethanolic extract	10, 30, and 100 μg/mL	TNF-α release; wound-healing activity	Anti-inflammatory and wound healing effect	[62]
		fraction (MeOH/EtOH)	50 and 100 μg/mL			
	Antioxidant, antidiabetic, and antimicrobial capacity	Ethanolic extract	10 to 1,000 μg/mL	Microbiological plating	Antidiabetic, antimutagenic, antioxidant, and anti-inflammatory effects	[17]
			20 μg/mL	Antihemolytic		
			5–15 μg/mL	Antimutagenic		
			50 μL	cholinesterase-inhibiting		
			25 μL	tyrosinase-inhibiting		
			25 μL	hyaluronidase-inhibiting		
			20–100 μg/mL	α-amylase-inhibiting		
			10 μL	α-glucosidase-inhibiting		
			2.5–35 μg/mL	lipase-inhibiting activities		
	Antioxidant, antimicrobial, and cytotoxicity capacity	Ethanolic extract	0.78 and 100 mg/mL	Microbiological plating	Antioxidant, antimicrobial, and cytotoxic activity	[60]
			25–200 μg/mL	cytotoxicity (leukemia cell line Kasumi-1)		
			100 μg/mL	Inhibition of malondialdehyde production		
			200 μL	DPPH		
			50–125 μg/mL	hemolysis		
	Antioxidant and cytotoxicity	Ethanolic extract'	0.1 mL	DPPH	Antioxidant and cytotoxicity effects	[30]
			100–300 μg/mL	inhibitory effect of the extract on *Artemia salina*		
Fruit	Antioxidant capacity	Methanolic/acetonic extract	30–400 μL/mL	DPPH; ABTS; FRAP; ORAC, and; β-Carotene bleaching	Avoid the oxidation	[63]
	Antioxidant capacity	Methanolic/acetonic extract	100 μL	DPPH	High antioxidant capacity	[6]
			200 μL	FRAP		
	Antioxidant capacity	Pulp juice	30 μL	ABTS, and DPPH	High antioxidant capacity	[64]
	Antioxidant capacity	Ethanolic extract	50 μL	Cellular viability (mononuclear, and MCF-7); superoxide anion release; CuZn-superoxide dismutase	Antioxidant effect	[114]
	Catabolism	Fruit pulp	60 μL	Pancreatic α-amylase; salivary α-amylase; trypsin inhibitory activity	Inhibitory effect on protein metabolism	[96]
	Antioxidant capacity	Methanolic/acetonic extract	30 μL	DPPH; ABTS	Antioxidant effect	[42]
			90 μL	FRAP		
Tree latex	Cytotoxicity	Aqueous extract	1.5–10%	Mitotic and micronuclei evaluation of *Allium cepa*	No cytotoxic and genotoxic effects	[65]
	Angiogenic, cytotoxic, and genotoxic capacity	Aqueous extract	50%	Cellular viability, cytotoxicity, and genotoxicity (NIH3T3); angiogenic potential (chorioallantoic membrane) and histology of vessels	Angiogenic effect	[66]
Tree bark	Antioxidant capacity	Ethanolic extract	3–100 μg/mL		Antioxidant effect	[67]

(*continued on next page*)

Table 5 (*continued*)

Part of the plant	Experimental assay	Product used	Dosage	Method	Effect	Ref.
				DPPH; ABTS; antioxidant activity of β-carotene/ linoleic acid, and; acetylcholinesterase inhibitory activity		
	Antimicrobial	Ethanolic extract	5000 μg/mL	Antimicrobial plating	Anti- bacterial, and fungi capacity	[68]
	Gastroprotection	Ethanolic extract and infusion	250, 500 or 1000 mg/kg	Inhibition of isolated *Helicobacter pylori*	Antibacterial effect	[69]
Seeds	Cytotoxicity	Thermal treated crude extract	100 μL	Inhibitory effect on *Artemia salina*	Low cytotoxicity	[71]
	Cytotoxicity	Crude extract	100 μL	Letal dose of *Artemia salina*	Cytotoxic effect	[70]

bioavailable content on mangaba pulp after gastric digestion simulation [6].

Almeida et al., when evaluating pulp antioxidant capacity, found a positive response in DPPH (5.27 ± 0.34) and ABTS (10.84 ± 0.13) tests, placing mangaba in a highlight spot among to murici for being reported as good sources of antioxidants, compared to 11 other analyzed fruits. Analysis conducted with ethanolic and methanolic extracts also presented a satisfactory antioxidant capacity [42].

4.1.3. Tree latex

Similarly, Ribeiro et al. and Almeida et al. verified that the mangabeira tree latex aqueous extract diluted in different proportions, 1, 5, and 10% and 50%, respectively, do not cause cytotoxic effects [65, 66].

In addition, it was noticed that mangabeira tree latex, besides presents good cellular viability tested on mice fibroblasts NHI (NIH3T3), the aqueous extract (1:1) showed to be capable of increase vascularization, compared to a negative control (water) and inhibitor (dexamethasone). In this case, the latex extract also demonstrated a potential angiogenic effect under comparations to positive control Regederm, however, the difference was not significative [66].

4.1.4. Tree bark

Ethanolic extract prepared using *H. speciosa* tree bark in different proportions (3.125, 6.25, 12.5, 25.0, 50.0 and 100 μg/mL) were tested regarding its antioxidant capacity, demonstrating that other parts of the plant also present antioxidant effect [67], not only pulp and leaves, as previously cited. Still, about Penido et al. study, the antioxidant potential presented by the extracts achieved better results about anticholinesterase activity, when compared to other 11 species [67].

Other analyses conducted using ethanolic extract attested antimicrobial activity against gram-positive species and antifungal potential [68]. Moraes et al. also evaluated the ethanolic extract in *Helicobacter* Pylori communities obtained from patients with duodenal ulcers, resulting in excellent antimicrobial activity and no toxic effect [69].

4.1.5. Seeds

Few tests were conducted using *H. speciosa* seeds aqueous extract to evaluate its cytotoxic potential. Fonseca et al. confirmed mangabeira seeds' toxic potential when exposed to *Artemia salina* communities [70]. High temperatures exposure induced different results. Batista et al. exposed the seed to 78°–110 °C and, then, prepared the aqueous extract, which was added into the *Artemia salina* sample in the dose of 100 μL. As the result, the sample exposed to the temperature of 78 °C for 2 min showed to be capable of inactivating toxins [71].

4.2. In vivo studies

4.2.1. Leaves

Regarding plant leaves, stand out studies related to the cardiovascular system and glycemic control. Ferreira et al. evaluated the *H. speciosa* leaves ethanolic extract vasodilator effect on the superior mesenteric artery rings [72] and on descending thoracic aortic rings [73] and observed that, in both studies, the 100 μg/mg dose was capable to induce a concentration-dependent relaxant effect in vessels containing a functional endothelium. Moreover, to identify which endothelium-derived relaxing factors were the vasodilator effect of HSE dependent on, they evaluated the *H. speciosa* leaves extract vasodilator effect on the presence of atropine, indomethacin, and L-NAME, and found out that only this last one was capable of inhibiting *H. speciosa* leaves extract vasodilator effect, suggesting that its effects were due to nitric oxide production (NO).

Also using the ethanolic extract, Silva et al. found out that it induces a potent and long-lasting reduction in the systolic blood pressure of normotensive–hypertensive animals, under the dose of 1 mg/kg [9, 10]. This hypotensive effect indicated for the *H. speciosa* leaves is due to its main component, a cyclitol named Bornesitol, as demonstrated by Moreira et al. [11].

The *H. speciosa* leaves ethanolic extract has also shown a potent effect on reducing glucose serum levels in normoglycemic animals. Pereira et al. presented positive results for a dose of 300 mg/kg in Swiss mice, in acute treatment [74]. This data was then confirmed by Santos et al., but with a lower dose of 200 mg/kg [17]. They also evaluated this effect on induced diabetic animals, and none of the doses showed to be capable of reducing blood glucose levels, whether in acute or chronic treatment [17]. In contrast, the aqueous extract induced a significant decrease in fasting glucose serum levels and hyperglycemia after the oral glucose tolerance test in treated diabetic animals, as shown by Neto et al. [12].

As demonstrated in session 3.1, mangabeira leaves possess a high content of bioactive compounds, and some of them could be related to their hypoglycemic character. Doses of 50 mg/kg of quercetin–quinic acid, either isolated or associated, showed to be capable of reducing blood glucose levels in animals treated for 21 days, and also alleviating structural degeneration in the liver, kidney, and pancreas tissues [75]. In addition, the treatment with quinic acid for 12 weeks increased insulin release by pancreatic cells and the dietary supplementation for 2 months improved glucose tolerance [76]. Finally, studies about chlorogenic acid also suggest an ability to reduce glycemic levels [77, 78].

4.2.2. Fruits

H. speciosa fruit pulp has predominantly shown anti-inflammatory properties. Torres-Rêgo et al. evaluated different doses of *H. speciosa* pulp aqueous extract and some isolated compounds (rutin and chlorogenic acid) against induced peritonitis, ear edema, and air pouch models [8]. The results showed significant inhibition of cell migration, as well as the production of proinflammatory cytokines, standing out the treatments with aqueous extract at a dose of 50 mg/kg, rutin at 2.5 mg/kg, and chlorogenic acid at 10 mg/kg.

Later, Bitencourt et al. also evaluated different doses of rutin, chlorogenic acid, and *H. speciosa* pulp aqueous extract plus its fractions on peritonitis caused by scorpion envenomation in BALB/c mice of both sex [13]. All of the groups showed anti-inflammatory activity, largely reducing the number of leukocytes and cytokines IL-1β, IL-6, and IL-12, especially the group treated with chlorogenic acid. Also, Yamashita

Table 6. *In vivo* studies regarding the health effects of *Hancornia speciosa*.

Part of the plant	Experimental model	Product used	Dosage	Biomarker	Effect	Ref.
Leaves	Vasodilatation; Wistar rats	Ethanolic extract	0.1–100 μg/mL; Intravenous administration; Acute (once)	Percentage of vasodilatation	Vasodilatation effect	[72]
	Vasodilatation; Wistar rats	Ethanolic extract	0.1 to 100 μg/mL;	Vasorelaxation of aortic ring	Vasodilatation effect	[73]
	Hypertension; Swiss mice	Fraction (EtOAc/MeOH) of Ethanolic extract	1, 10, and 100 mg/kg; Gavage; Acute (once)	Systolic blood pressure; heart rate; serum ACE activity; plasmatic angiotensin II levels; serum nitrite dosage	Hypotensive effect	[9]
	Hypertension; Swiss mice	Ethanolic extract and fraction (DCM/EtOAc)	0.03, 0.1 or 1 mg/kg; Gavage; Acute (once)	Blood pressure; serum nitrite dosage; myograph studies; indirect measurements of NO production in the small mesenteric artery; H2O2	Anti-hypertensive effect	[10]
	Hypertension; Wistar rats	Isolated bornesitol	0.1, 1, 3 mg/kg; Intravenous administration; Acute (once)	Blood pressure; pulsatile arterial pressure; serum nitrite; ACE plasmatic activity; vascular reactivity	Hypotensive effect	[11]
	Glycemic control; Swiss mice	Ethanolic extract and fraction	300 mg/kg; Gavage; Acute (once)	Serum glycemia; glucose tolerance test	Hypoglycemic effect	[74]
	Glycemic control; Diabetes; Wistar rats	Ethanolic extract	200 and 400 mg/kg; Acute (once), and chronic (28 days)	Serum glycemia; glucose tolerance test	Hypoglycemic effect	[17]
	Glycemic control; Diabetes; Wistar rats	Aqueous extract	400 mg/kg; Gavage; Chronic (21 days)	Glucose tolerance test; Serum glycemia, proteins, total cholesterol, triglycerides, HDL, non-HDL, ALT, and AST	Hypoglycemic effect	[12]
	Gestational diabetes; Wistar rats	Aqueous extract	600 mg/kg; Chronic (20 days)	Maternal glycemia; fetal weight; preimplantation loss rate; skeletal anomalies	Impaired reproductive outcome, and teratogenic effect in non-diabetic rats	[115]
Fruit	Inflammation; Swiss mice	Freeze dried juice	100–200 mg/kg; Intra-gastric; Acute (once)	Relative lung weight; myeloperoxidase enzyme; IL-1β, IL-6, TNF-α; vascular permeability; nitric oxide; TBARs; AST; ALT; LDH; CK; serum urea, creatinine, albumin, and amylase levels	Anti-inflammatory effect	[5]
	Inflammation; BALB/C mice	Aqueous extract	20, 30, and 40 mg/kg; Intravenous administration; Acute (once)	Histopathology; peritonitis; IL-1β, -6, and -12	Anti-inflammatory effect	[13]
		Fractions (DCM, EtOAc, *n*-BuOH)	20 mg/kg; Intravenous administration; Acute (once)			
	Inflammation; BALB/C, and Swiss mice	Freeze dried aqueous extract	20, 30, and 40 mg/kg; Intravenous administration; Acute (once)	Peritoneal inflammation (leucocytes count, cytokines IL-6, -1β, -12, and TNF-α);	Anti-inflammatory effect	[8]
			40, 50, and 60 mg/kg; intraperitoneal administration; Acute (once)	Edema; air pouch;		
	Antimutagenicity; Swiss mice	Pulp in natura	10, 20, and 40 mL/kg; Gavage; Chronic (15 days)	Liver lipid, and protein oxidative stress; antimutagenic/mutagenic effect in bone marrow, and intestinal cells	No toxic/mutagenic effects	[7]
	Bowel motility, Wistar rats	Pulp in natura	5, 10, and 15 mL/kg; Gavage; Chronic (14 days)	Bowel motility; ionic balance; liver, and intestinal histology	Local anti-inflammatory, and laxative effect	[18]
Tree latex	Inflammation; BALB/C mice, and Wistar rats	Aqueous extract	0.06–1.3mg of protein/kg; Gavage; Acute (once)	Acetic acid-induced abdominal writhing; inflammatory response (formalin test); hot plate test; paw edema; subcutaneous air pouch; anti-inflammatory proteins (IL-6, TNF-α, PGE2); nitrate levels; COX2, and iNOS enzyme expression	Anti-inflammatory effect	[82]
	Bone formation; Wistar rats	Aqueous extract	3, and 50%; Gavage; Chronic (15–30 days)	Bone formation	No bone formation effect	[116]
	Osteogenic potential; Wistar rats	Latex gel	5%; Topical use; Chronic (5–30 days)	Bone healing; histology	Healing effect	[109]
Tree bark	Gastroprotection; Swiss mice, and Wistar rats	Ethanolic and aqueous extracts	250, 500, and 1000 mg/kg; Gavage; Acute (once)	Histopathology, gastric secretions (pH and mucus)	Gastroprotective effect	[69]

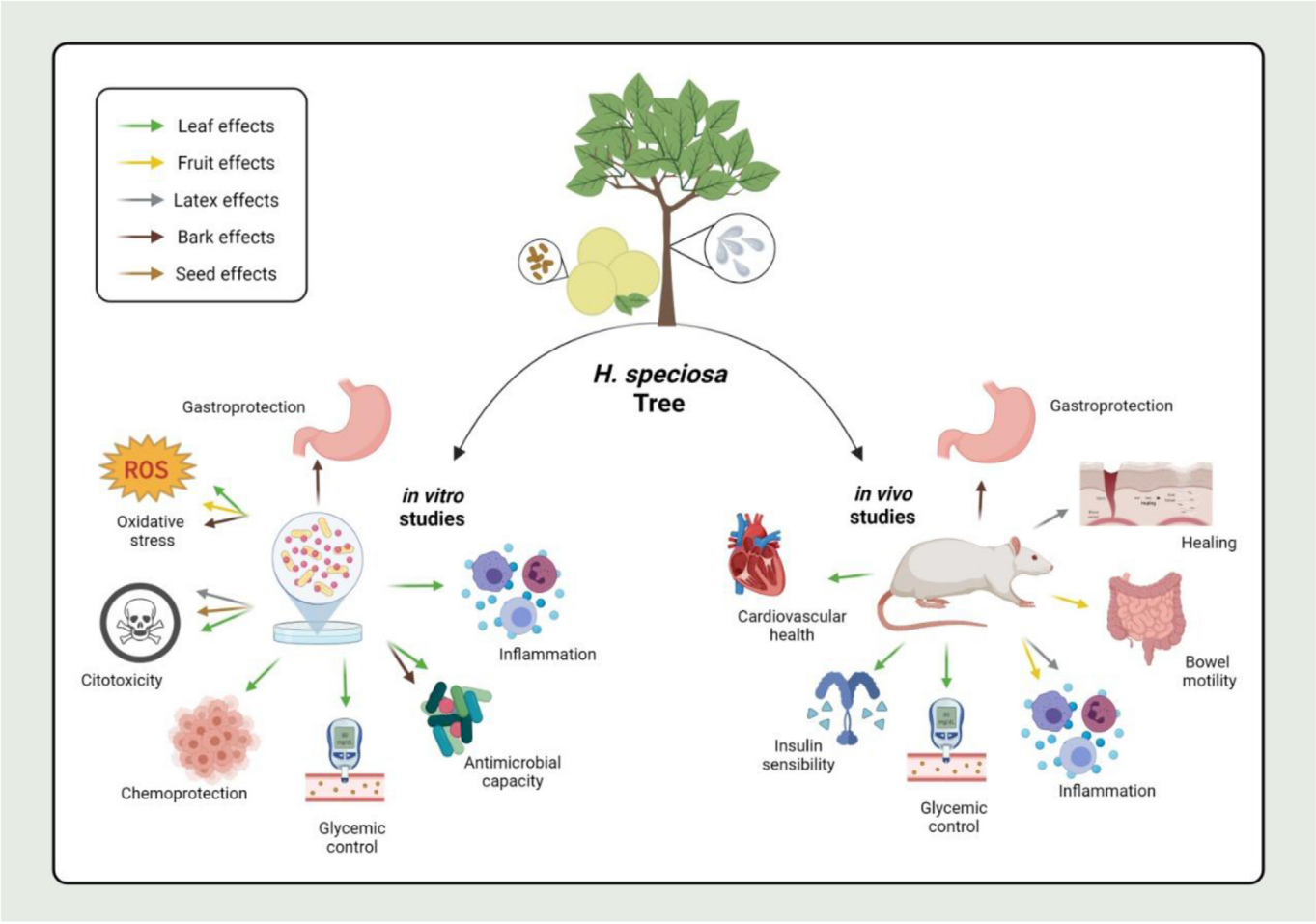

Figure 3. Graphical review of the bioapplicability of different parts of the mangabeira tree in in vitro and in vivo assays. Created with BioRender.com.

et al. [5], evaluated the effect of a dried juice of *H. speciosa* against lung edema similarly induced by scorpion envenomation. The results showed that doses of 100 and 200 mg/kg of *H. speciosa* juice improve inflammation parameters, such as IL-6 and TNF-α. Consisted to this, several studies have assigned an anti-inflammatory character to quercetin, which was previously cited as one of the bioactive compounds found in *H. speciosa* fruit pulp [79, 80].

Regarding safety, *H. speciosa* pulp has indicated no toxicity or mutagenic effects [7]. The treatment with the pulp *in natura* shows a protective effect over bone marrow and gut cells, by reducing the micronucleated cells and apoptosis index [7].

Reis et al. also evaluated the pulp *in natura* on animal bowel motility and observed an improvement in intestinal transit and a decrease of pro-inflammatory cells on gut tissue, owing to a 14 days treatment [18]. This data suggests that *H. speciosa* fruit pulp carries a laxative capacity and fortifies its anti-inflammatory property. Mangabeira fruit pulp carries a high content of rutin, as shown in Section 3.1. This flavonoid was reported to improve intestinal inflammation markers on a colitis model, reducing myeloperoxidase and alkaline phosphatase activities on the intestinal mucosa, STAT4 and NFκB signaling in spleen cells, and secretion, expression, and plasma levels of pro-inflammatory cytokines, specially IFN-γ and TNF-α [81].

4.2.3. Tree latex

The anti-inflammatory property was also observed on *H. speciosa* latex. Marinho et al. evaluated the effect of the latex on a formalin-induced paw inflammation and noticed a dose-dependent inhibition on animals treated with doses of 0,06 and 1,3 mg/kg. Later, they induced paw edema on the animals, and the pre-treatment with latex was shown to be capable of reducing the formation of edema. Finally, they, subcutaneously, injected carrageenan into the animals, inducing the formation of an air pouch, and the pre-treatment with both doses of latex (0,06 and 1,3 mg/kg) decreased the volume of exudate and protein leakage. Besides, the pre-treatment with latex caused a reduction in iNOS and COX2 enzyme expression, PGE2 levels, and IL-6 and TNF- α production.

Regarding safety, the dose of 1,5 g/kg showed no lethality effects of toxic symptoms, indicating no toxicity from the *H. speciosa* latex [82].

4.2.4. Tree bark

There are few studies about *H. speciosa* tree bark. Moraes et al. evaluated the effect of different doses of the bark ethanolic extract and infusion on gastric ulcers induced by several damage agents. The treatment with the extract at the dose of 1000 mg/kg showed notable results against nonsteroidal anti-inflammatory drugs (NSAIDs) and hydrochloric acid (HCl)/ethanol agents, reducing ulcer formation in 53,5%–68%, respectively. Furthermore, the treatment with the extract at the dose of 500 mg/kg was significantly shown to protect the gastric mucosa, by inhibiting its depletion and decreasing acid secretion. Besides, the treatment with the extract at the dose of 5 g/kg, for 14 days, indicated no toxic effects on the animals [69].

The pharmacological findings presented in this section may characterize the mangabeira tree as a potential treatment agent for multiple health conditions that affect a large portion of the population and require intensive and expensive care. The leaves extract and infusion preparations, such as tea, may help control glucose levels and blood pressure in diabetic and cardiovascular disease patients. Also, the hypoglycemic and

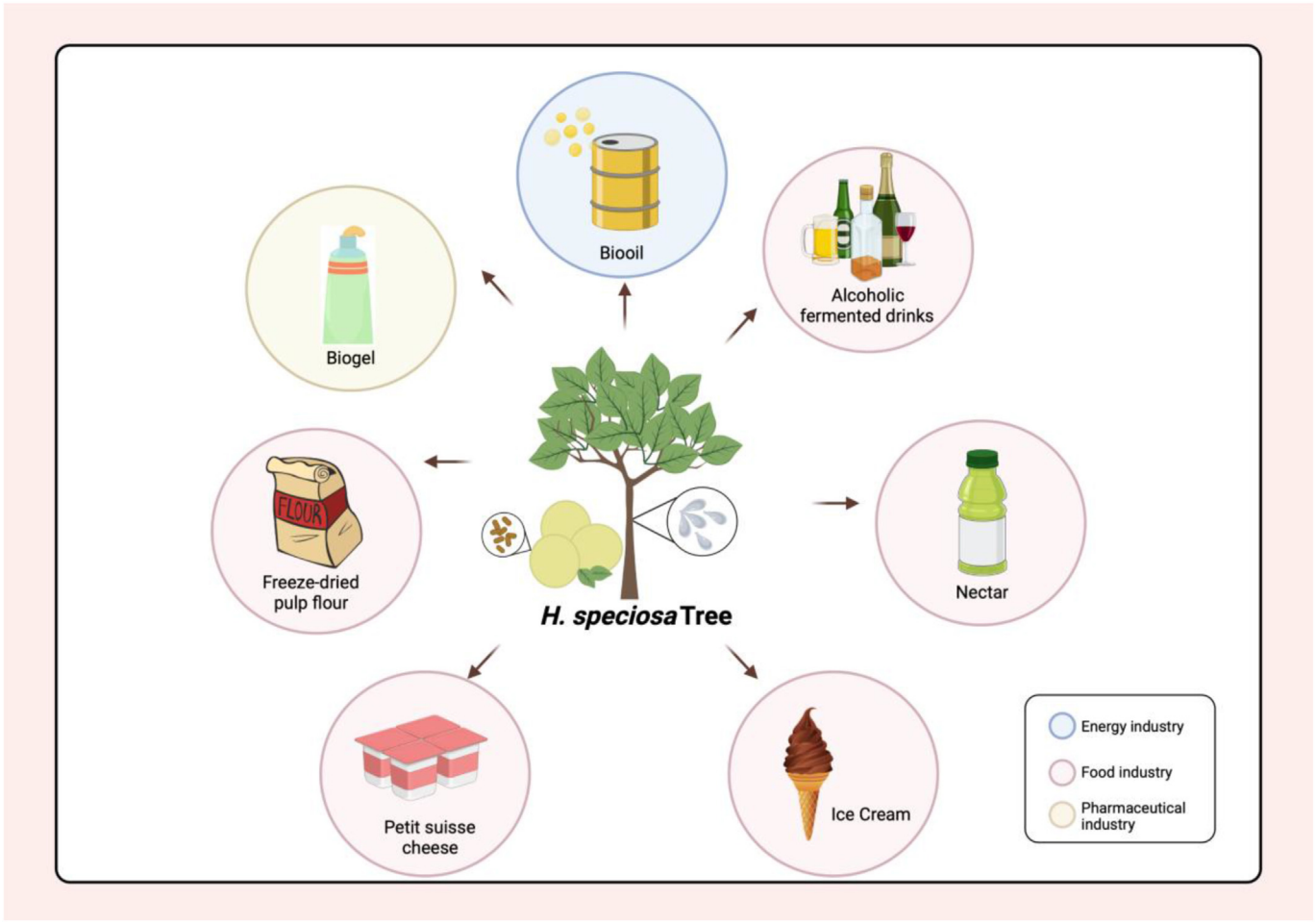

Figure 4. Graphical review of the biotechnological applicability of mangabeira tree. Created with BioRender.com.

hypotensive effects may be considered on metabolic syndrome patients [83].

On the other hand, there are a lot of inflammatory conditions that might be benefited from the anti-inflammatory property found on the mangaba pulp, such as chrons disease, colitis, rheumatism, and others. Also, the antioxidant capacity found on the leaves and pulp extract may help to reduce the production of reactive oxygen species and improve the oxidative stress commonly linked to inflammatory conditions [84]. As mentioned before, mangaba pulp can be used in many culinary preparations, such as juices, ice creams, jelly, desserts, and also *in natura*, facilitating its consumption and maybe helping to relieve inflammatory symptoms. Further studies are needed to prove this theory.

Despite the popular use of mangabeira tree latex for gastric symptoms, the tree latex is the one that presents scientific evidence of its property. Again, extract and infusion preparations, such as tea, may be helpful to improve gastric health.

Finally, clinical studies are needed to evaluate those theories and applications and standardize plant extracts formulations and other products derived from the mangabeira tree for human consumption, to promote and improve health conditions.

5. Known biotechnological applications of *Hancornia speciosa*

Up to date, more than 20 patents are registered to utilize mainly the mangabeira's tree leaves or fruits. This section's goal is to summarize the main products obtained by different parts of the mangabeira tree, as a result of the literature survey; it also seeks to highlight the different industrial sectors involved in the use of these materials. Figure 4 briefly illustrates the main findings of this section.

5.1. Food industry

The mangabeira's fruits are widely used in the manufacture of food products, and due to their chemical characteristics (Section 3) they can be classified as functional foods (Section 4) and be used as health claims by food marketing [85].

Four of the food products developed and published aim at the chemical, sanitary, sensorial, and consumer acceptance description, being foods like alcoholic fermented drink [86], nectar [87], ice cream [88], "Petit Suisse" cheese [4], and fruit pulps with different thermal technologies applied [26]. Only one study describes no longer than the physicochemical characteristics of the mangaba sherbet [3]. Aware of the nutritional and cultural importance of mangaba was developed a freeze-dried mangaba pulp flour with incorporated maltodextrin, which maintained the physicochemical and sensory characteristics of the fruit for up to 90 days, making it possible and easier to use it in the development of food products after the harvest period [89, 90]. Yamashita et al. [5], developed a juice from the fruit of the mangabeira tree, the characteristics of the product developed help in the treatment of scorpionism, recurrent in sub- and tropical countries (such as Brazil), classifying the product as a functional food protected by patent.

After using the fruits to obtain the aforementioned products and several others protected by a patent not included in this survey, the remaining biomasses are considered industrial waste. Regarding the biomass composed of parts of leaves, pulps, and seeds, Lima et al. [91]

emphasize obtaining the tannase enzyme from this residue; This enzyme is used in the clarification of products derived from grapes, such as juices and wines, tannase derives from fungi used technologically, but which are also present in the composition of mangaba (*Penicillium*), and through the degradation of compounds such as proanthocyanidins/tannins (also present in mangaba), produce the enzyme through a solid-state fermentation process, without the use of high amounts of water, generating a positive environmental impact [91].

5.2. Pharmaceutical industry

More than 10 patents are filed within the pharmaceutical industry, delimiting extracts, fractions, and isolated compounds applied in the treatment of pathological and or preventive processes. A single article [15] was found in the literature that demonstrates the capacity to form bio gel based on the chemical characteristics of the mangabeira tree's latex; besides, the authors indicate that the developed biomaterial can be used as a substitute for damaged organic tissues, and thanks to its polymeric matrix it can store and release silver nanoparticles that accelerate the recovery of injured tissues, through angiogenic, anti-inflammatory activity, and antibacterial.

5.3. Energy industry

As previously mentioned, the other industries widely use the mangaba pulp as raw material, generating the seeds as waste. Concerned with reducing the environmental impacts of industrial residues and the thermochemical process that emit gases, the authors describe the use of this specific biomass in the production of bio-oil through pyrolysis; describing the whole process and critical points to be improved in the use of this product for its use as biofuel [14]. There is also a patent that uses the same biomass as a raw material for a bio adsorptive product that removes contaminants from water and effluents [92].

6. Conclusions

This narrative review brings the state of the art concerning the main characteristics of the most popularly used parts of the mangabeira tree, and which, through the scientific evidence presented, emphasize new and confirm some powers of traditional knowledge associated with it.

We conclude that the leaves, fruits, and seeds are composed of macro and micro -nutrients, and appreciable phytochemicals; the fruits have relevant physicochemical characteristics for product development, and; the fruits, the peel, the latex, and the seeds have particular microorganisms intrinsic to them. In a broader view, the mangabeira tree can be considered a nonconventional edible plant, except for its latex, all its parts when used in various preparations bring health benefits through its ingestion. Thus, observational studies on adverse and toxic effects from their consumption must be performed to ensure safety for consumers.

It is also important to highlight that the biotic and functional products are in rapid commercial expansion, and here, phytochemicals involved in the prevention and treatment of diseases have been observed [56, 85]; additionally, reported microorganisms intrinsic to the mangabeira tree parts can be explored by pharmaceutical, food and fuel industries. We suggest a new field of research aimed at microorganisms naturally present in food, and how emerging technologies can assist in the development of functional and/or -biotic foods, generating and potentiating the positive effects to health by eating these foods, while at the same time causing less environmental impact and stimulating their commercialization through sustainable production.

Scientific evidence, both *in vitro* and *in vivo*, confirms some popular medicinal effects of mangabeira tree, which are the antimicrobial activity, glycemic and hypertensive control, and general anti-inflammatory action, and also in the gastrointestinal system; however, some models remain unexplored, such as diarrhea, inflammation, and infections of epidermal, auditory, ophthalmic, analgesic capacity, the health of the female reproductive system and attached systems, and hepatic metabolism. *In vitro* tests show evidence of the ability to reduce oxidative stress and chemopreventive effects, however, no animal model has been tested to confirm such mechanisms of action. Emphasized that clinical trials are necessary to determine the dosage of therapeutic mechanisms already elucidated in favor of the commercialization of medicines of natural origin and the search for alternative treatments to pharmacological ones.

As the main result of this review, we highlight the sustainable development of healthy diets [93], where the mangabeira tree (as well as other similar trees) jumps from a mere Brazilian native fruit tree to a potential instrument of food security, biodiversity, and ecological sustainability, sustainable communities, industrial innovation, source of clean energy, economic development, and good health and well-being.

Declarations

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

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Data included in article/supp. material/referenced in article.

Declaration of interest's statement

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