

# Cactaceaes of the brazilian semi-arid: source of bioactive compounds

## ABSTRACT

The semi-arid region of Brazil stands out as one of the spaces with the highest diversity of plant species in the world, being the Cactaceae family the one that best represents the Brazilian semi-arid. However, although there are many species of cacti in Brazil, their chemical potential are little known. In view of this, the present review aims to record the bioactive metabolites of native cactaceaes or not in Brazil, encompassing a description of its habitat and traditional uses. Compilations of ethnobotanical studies point to the importance of cacti species in the daily life of local cultures. Cactaceaes are used for food, economic, ornamental, mystical purposes, among others, and stand out for their importance in traditional medicine, used to treat various diseases. Bioactive compounds in this family belong mainly to alkaloid groups, betalain, phenolic acids, terpenes and fatty acids. This review displays the relevance of cactaceaes in the face of the remarkable production of bioactive compounds.

**Keywords:** Cacti; Ethnobotanical; Bioactive metabolites; Caatinga.

## 1.0 INTRODUCTION

Cactaceae is the term of the Latin language attributed to the family of plants that belong the cacti. This family has approximately 1.500 species and 130 genera, divided into four subfamilies, of which three, Pereskioideae, Opuntioideae and Cactoideae occur in Brazil [1]. Cactaceaes are native to the American continent, having their largest distribution in the arid and semi-arid regions of the Americas. In the Brazilian territory, 37 genera and 275 species are recognized so far, of which 14 genera and 188 species are endemic [2].

The geographical space of the semi-arid, where it has the largest distribution of cactaceaes in Brazil, extends to eight states in the Northeast Region (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe) plus the north of Minas Gerais [1]. In this area, the dominant biome is caatinga, characterized by low precipitation, high temperature and xerophyte vegetation [3].

Anatomical, ecological and physiological aspects peculiar to the Cactaceae family are responsible for adapting it to the semiarid climate. Its efficiency in water use

is based on the Specialized Photosynthetic mechanism CAM (Crassulacean Acid Metabolism), where the stomata open at night, with the lower temperatures, and keep them closed during the day, enabling high efficiency of the use of water [4].

Cactus species are usually xerophytic, succulent and perennial. They have arboreal, shrubby, subshrub, climbing, epiphyte or geophyte strata and fibrous or tuberous roots [5]. They have a photosynthetically active stem, of variable color, shape and size, forming cladodes, which can be smooth, cylindrical, columnar or globular and are usually covered with thorns [6].

The various cactaceae found in the Brazilian semi-arid are used and known for a variety of purposes, such as food, medicinal, forage, religious mystical, for ornamentation, conservation of biodiversity and as a rain bioindicator [7]. In the scope of traditional medicine, *Cereus jamacaru* (mandacaru), *Opuntia ficus-indica* (palm), *Melocactus zehntneri* (friar's crown), *Pilosocereus gounellei* (xique xique), *Pilosocereus pachycladus* (facheiro) and *Opuntia palmadora* (palmadora), used by rural communities for back problems, diabetes, rheumatism, urinary tract infections, kidney problems, appendicitis, bronchitis and flu [8,9]. The traditionally used parts are mainly the cladodes and roots, in the form of infusion and decoction [10].

Em consonância com sua aplicabilidade na medicina tradicional, these plants have important metabolic characteristics, such as the production of bioactive compounds. The accumulation of these compounds is one of the response mechanisms to biotic agents and abiotic stresses, which, as stimuli, trigger the synthesis of alkaloids, terpenes, betalains, phenolics and nitrogenous compounds [11].

However, although there are many species of cacti in the Brazilian semi-arid region, their phytochemical potential is still little known, and this topic should, therefore, be the subject of study given the importance that these plants play. In this sense, the present review aims to record the bioactive metabolites of cacti, whether or not native to Brazil, encompassing a description of their habitat and traditional uses. In this sense, the present review aims to record the bioactive metabolites of cacti, whether or not native to Brazil, encompassing a description of their habitat and traditional uses. To this end, a search was carried out in scientific databases, where important publications concerning cacti were extracted.

## 2.0 CAATINGA

The Caatinga Biome has its central area located in the northeastern region of Brazil, covering about 844.453km of seasonally dry tropical forests with deciduous shrub vegetation. This area represents one of Brazil's six major ecological regions, and it is the only one restricted to the Brazilian territory, not shared with any other country [12]. The Caatinga is characterized by a semi-arid climate, with high average temperatures (between 25° and 30°C) and low rainfall (between 400 and 1.200 mm per year). However, average temperatures can be lower in the highlands, and rainfall can reach 1.800 mm per year. Thus, the Caatinga is considered as a very heterogeneous Biome [13].

From a biogeographic point of view, the Caatinga is home to a large number of endemic species, i.e., that are not found in any other region of the world. According to Silva *et al.* (2017a) [14], this biota comprises about 3.150 species of vascular plants, 276 ants, 386 fish, 98 amphibians, 191 reptiles, 548 birds and 183 mammals, giving the Caatinga the title of the richest dry forests in the world.

The Caatinga is characterized by extensive flat surfaces with altitudes ranging from 300 to 500 m covered by dry forests, whose leaves are lost during the dry season. With greyish-white trunks and branches, this leafless vegetation was called by native peoples as the white forest or "Caatinga", in the Tupi-Guarani language. However, interspersed with this description, it is also possible to find plateaus that can reach up to 1.000 m. On the slopes and tops of the plateaus, the vegetation is very distinct, being composed of humid forests, savannas and rocky fields [13].

The diversity of this vegetation is mainly composed of xerophytic plants formed by species that have developed mechanisms for survival in a dry climate with little rainfall. Low trees and shrubs are common in the biome, often thorny and deciduous, which lose their leaves in the dry season [13,15]. The flora of the Caatinga is very rich, with a relatively high proportion of endemic species, including many Asteraceae (24), Bromeliaceae (14), Cactaceae (9), Fabaceae (9), Xiridaceae (7) and Melastomataceae (6) [14].

This vegetation is part of another global biome called Seasonally Dry Tropical Forests - SDTFW at an international level [14]. Relevant areas of this biome can be found in South America, including northeastern and northwestern Argentina, southeastern Bolivia, the Andean dry valleys from Bolivia to Colombia, the coastal region of Ecuador and Mexico [13].



**Figure 1.** Caatinga - deciduous shrub vegetation.

In the economic context, the use of this biome is based on extractive processes to obtain products of pastoral, agricultural and wood origins. A large part of the population in the Caatinga exploits its biodiversity to survive, obtaining food, medicine, fodder for different types of herds, wood for construction, among others [8,14].

Given its immense plant diversity, this biome's importance and economic potential are notorious. According to Araújo (2013) [16], the plants in this region are producers of wax, oils and tannins. They are also forage, bear fruit, shelter bees and produce ornaments, fiber, medicinal products and timber. However, this region is still little explored scientifically and, therefore, several biological groups remain unknown and many plant species still need to be described. Along with that, a growing number of species threatened with extinction is worth noting, mainly due to the degradation of the environment resulting from deforestation[17].

On the other hand, a little-known collection of plant species has been studied for medicinal use and raw materials for the chemical, food, cosmetics and pharmaceutical industries [15]. We are highlighting in this way the cactaceae, one of the most diverse families of the Caatinga biome with several endemic species [14]. However, some studies have evaluated the functional potential of the different species of plants, especially the *C. Jamaru*, belonging to this family. This plant traditionally stands out with a diversity of uses, representing an essential resource for different purposes in the caatinga region [8,10].

### **3.0 CACTACEAE FAMILY - HABITAT AND TRADITIONAL USES**

The Cactaceae family belongs to the Angiosperms group, divided into three subfamilies: Opuntioideae, Pereskioideae and Cactoideae – the latter is the most numerous in genera [18]. However, a fourth subfamily, Maihuenioideae, has also been recognized by some authors, being restricted to South America (Argentina and Chile) [19]. This family is native to the American continent, where it occurs with high richness and abundance of species, from British Columbia and Alberta in Canada to Patagonia in Argentina, including the island regions of the continent. Few cactus species are seen occurring naturally on other continents [20].

Four areas in the world are identified as having high richness and endemism of species; they are: 1) Mexico and the southwest of the USA; 2) the central Andes region involving Peru, Bolivia, southern Ecuador, northeastern Chile and northwestern Argentina; 3) Eastern Brazil, covering the northeastern region and part of the southeastern region, excluding the southern portion of the State of Rio de Janeiro and the entire State of São Paulo; and 4) the region that includes Paraguay, Uruguay, northern Argentina and Brazil [1].

The term cactus is used to designate the group of species belonging to the Cactaceae family, which have morphological and physiological adaptations that collaborate with the conservation of species diversity in northeastern Brazil. In general, cacti have a thick cuticle, mucilaginous tissues, succulent and thorny stem, leafless branches and areolas producing thorns [3,21].

As these plants develop in adverse environments, the accumulation of secondary metabolites is one of the response mechanisms to environmental stress. Thus, the water deficit, the high saline concentration in the soil and the light stress are stimuli that trigger the synthesis of compounds such as terpenes, phenolics and nitrogen compounds [21].

The Caatinga species of Cactaceae are classified as xerophilous; they have specific characteristics for semiarid regions, such as the ability to tolerate water scarcity and resist the drought period [3]. Therefore, these plants have a specialized survival mechanism, with physiological adaptations to high temperatures. These adaptations are related to the ability of cacti to convert water into dry matter through a specialized photosynthetic mechanism called MAC (Crassulacean Acid Metabolism), which allows them to remain succulent during the dry season [22,23].

Crassulacean Acid Metabolism (CAM) is one of three possible types of atmospheric carbon (CO<sub>2</sub>) assimilation via photosynthesis. The CAM plants have

increased water use efficiency, constituting a necessary physiological adaptation that allows the plants to occupy habitats characterized by intermittent water availability [22,23].

The Cactaceae is among the most used plants by man, mainly in the semiarid region. The diversity of uses brings it into four categories: medical, aesthetic, domestic and trophic [8]. In this way, one can notice that this botanical group has a great economic, biological and ecological value, mainly because they always remain green, even with water stress conditions and under high temperatures[24].

The robust structure of several cacti, such as *C. jamaicaru* DC. and *Echinopsisattacamensis*(Phil.), makes them suitable for building fences, battens, boards, doors and windows [25,9]. Other uses, such as the mucilage of the cactus *Opuntia ficus* and *Pereskia aculeata*, have been applied in the food packaging industry as a raw material for films and coatings. It has been used, more recently, as a food preservative [26].

One of the prominent uses for Cactaceae species is in folk medicine, food and forage [27,28]. According to Andrade *et al.* (2006b)[27], traditional medicine using cactus is ancient in the semiarid region and is based on traditional knowledge passed down through generations. In the same study, the author mentions the use of cactus for 21 health problems recorded by the research participants, namely: "heat", vaginal inflammation, urinary infection, flu, inflammation in the uterus, bellyache, "choking", "dryness", back pain, syphilis, kidney problem, urethra problem, colic, bowel problem, prosthesis problem, toothache, "swollen belly" and dysentery".

In human food, the ingestion of fruits can be mentioned, mainly of the genera *Cereus* and *Pilosocereus*. Their consumption can be for the generation of some products or in nature[29,30]. Given that, Mizrahi (2014) [29] conducted a study with the fruits of *Cereus peruvianus*, using the ripe fruit for the development of jam, dried fruit and aromatic liqueur.

Furthermore, according to Shetty *et al.* (2012) [28], cacti have excellent properties; they have flavour, are nutritious and can be eaten fresh, as vegetables and in salad dishes. Food products such as cookies, candies, puddings and cakes have also been developed using the cactus. In addition, other commercial products can be mentioned, such as shampoos and soaps, produced from different species of this family[9,24]. Cactaceae is also used in animal feed, such as cattle and goats. The high

content of vitamin A and iron present in these plants can meet the nutritional needs of animals in the region, especially in times of drought [8].

However, due to the popularity of Cactaceae as a medicinal plant, studies have been developed to evaluate the chemical composition of these plants. Since then, alkaloids, carbohydrate polymers, phenolic compounds, carotenoids, natural pigments and terpenes have been described in Cactaceae, especially those belonging to the subfamilies of Cactoideae [24,31].

Considering the great diversity of use and the variety of cactus species, studies that focus on the biochemical characterization of this family are of paramount importance since factors such as habitat destruction threaten these species, putting them in danger of extinction [32]. The Red List of Threatened Species of the International Union for the Conservation of Nature (IUCN) includes about 139 cactus species as vulnerable to extinction [33], highlighting the subfamilies Cactoideae and Opuntioideae with the most significant number of species represented on the IUCN Red List. Brazil has the highest proportion of threatened species on a global scale with 18%, followed by Mexico (10%), Ecuador (9%) and Peru (7%) [20].

#### **4.0 BIOACTIVE COMPOUNDS OF CACTACEAE**

Cacti contain many chemical substances with pharmacological and biological relevance, synthesized in response to biotic and abiotic factors. The main compounds produced are alkaloids [34], betalains [35] and phenolic compounds [36], terpenes [37] and fatty acids [38].

##### *4.1 Alkaloids*

Alkaloids are a heterogeneous group of nitrogenous substances, of fundamental character and pharmacological action, generally of plant origin. Approximately 12,000 compounds are present in plants and act as the defence mechanism against herbivores and some species of pathogens. Notably, the concentration of alkaloids in plants can be highly variable. Several factors such as genetics, environment, age, climate, time of year or time of day, growth stage and wild or cultivated plant are considered capable of influencing the content and/or composition of alkaloids in plants [21].

Several alkaloids with important biological properties have already been identified in cacti. Among them is mescaline, present mainly in *Lophophora williamsii*,

*Lophophoradiffusa*, *Trichocereuspachanoi*, *Trichocereusperuvianus* and *Trichocereusbridgesii*; pelletine, present in *Lophophoradiffusa*, and hordenine, present in the genera *Turbiniacarpus*, *Mammillaria* and *Ariocarpus*. These alkaloids have been widely investigated due to their hallucinogenic properties, among other biological effects of interest [34]. However, these species and genera are not native to Brazil, and they are not cultivated in the country [1].

Other alkaloids have been identified in cacti, about 50 phenethylamines and about 80 isoquinolines, N-methyltyramine, tyramine and macromerine, which are the most commonly found in these plants [34]. In the genus *Cereus*, common in the Brazilian semi-arid region, the most abundant alkaloids are N-Methyltyramine (an adrenergic agonist), hordenine (stimulating norepinephrine) and tyramine (precursor of dopamine) (Fig.2) [21]. N-Methyltyramine has also been identified in the species *Turbiniacarpusalonsoi*, *Obregoniadenegri* and *Lophophora williamsii*. This compound is related to its beneficial effect on treating gastrointestinal disorders [39,40].

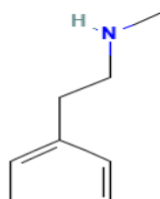
In the species *Cereus jamacaru*, endemic to Brazil, with greater geographic distribution in the northeast region, hordenine, tyramine, N-methyltyramine, Tyrosine and phenethylamine have already been reported [41].

#### 4.2 Betalains

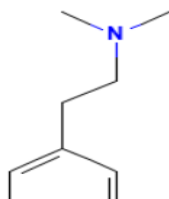
Betalains are nitrogenous and water-soluble substances that belong to alkaloids consisting of betacyanins and betaxanthins and classified as vacuolar pigments. These compounds have many applications in the food, cosmetics and pharmaceutical industries, and can be used as a natural dye, constituting an alternative to synthetic dyes [42].

These compounds are mainly produced by the genus *Opuntia*, and by other genera such as *Hylocereus*, *Mammillaria* and *Schlumbergera* [35,43]. The betalain profile of *O. ficus-indica var sanguigna* was described by Melgar et al. (2017) [44] using the LC-DAD-ESI/MS technique. The authors identified seven betalain fractions, two betaxanthins (indicaxanthin isomer I, indicaxanthin isomer) and five betacyanins (Betanidin-5-O- $\beta$ -sophoroside, Betanidin-5-O- $\beta$  glucoside (betanin), Isobetainin, Gomphrenin I and Betanidin) (Fig.2).

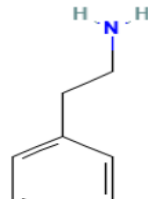
Betalains were also identified in fruits of the species *Stenocereuspruinosis* and *S. stellatus* by HPLC-DAD ESI/MS, revealing the predominance of indicaxanthin,



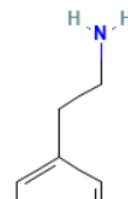
N-  
Methyltyramine  
(C<sub>9</sub>H<sub>13</sub>NO)



Hordenine  
(C<sub>10</sub>H<sub>15</sub>NO)



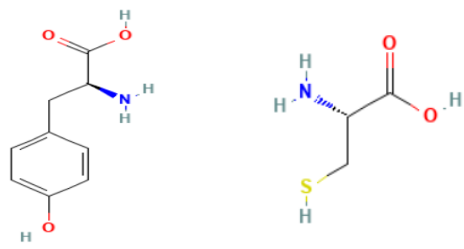
Tyramine  
(C<sub>8</sub>H<sub>11</sub>NO)



Phenethylamine  
(C<sub>8</sub>H<sub>11</sub>N)

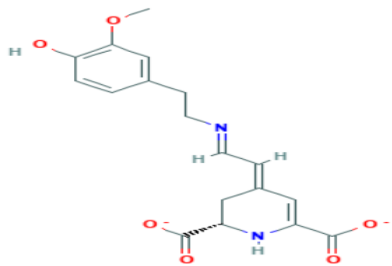
gomprenin I, phyllocacthin and their isomers, with betaxanthin content being higher than that of betacyanins in both species [45].

Studies demonstrate that cactus fruits have a greater predominance of betalainsthanclododium and seeds. For example, the fruit of *Hylocereus polyrhizus*, specifically in the fruit peel, were identified as betanin, isobetanin, phyllocactin, butyrylbetanin, hylocerenin, isophyllocactin, isobutyrylbetanin, 20-apiosyl-phyllocactin and 20-apiosyl isophyllocactin[46]. In fruits of *Mammillaria spp.*, the presence of betacyanins has been described, such as: betanidin 5-O-β-sophoroside, isobetanidin 5-O-β-sophoroside, betanin, isobetanin, betanidin 5-O-(60-O-malonyl)-β sophoroside, isobetanidin 5-O-(60-O-malonyl)-β-sophoroside, betanidin 5-O-(40-Omalonyl)-β-sophoroside, isobetanidin 5-O-(40 Omalonyl)-β-sophoroside, phyllocactin, isophyllocactin, 40-O-malonyl-betanin, 40-O-malonylisobetanin, 20-O-apiosyl-phyllocactin and 20-Oapiosyl-isophyllocactin [47].



Tyrosine  
( $C_9H_{11}NO_3$ )

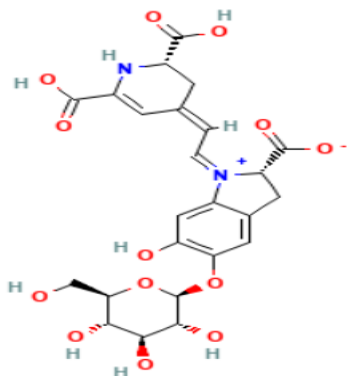
Cysteine  
( $C_3H_7NO_2S$ )



Betaxanthin  
( $C_{18}H_{18}N_2O_6^{-2}$ )

### Betaxanthin

indicaxanthin  
isomer I,  
indicaxanthin  
isomer



Betacyanin  
( $C_{24}H_{26}N_2O_{13}$ )

### Betacyanin

Betanidin-5-O- $\beta$ -  
sophoroside,  
Betanidin-5-O- $\beta$ -  
glucoside  
(betanin),  
Isobetainin,  
Gomphrenin I e  
Betanidin

Fig.2: Chemical structures of the main nitrogen-containing compounds identified in the genera *Cereus* and *Opuntia*.

### 4.3 Phenolic compounds

The main phenolic compounds described in the cactus are phenolic acids, flavonoids, tannins, coumarins, lignans and stilbenes. These compounds have essential biological functions related to their chemical structure, consisting of a benzene ring with one or more hydroxyl groups [48,36,49].

A wide variety of phenolic compounds has already been described in the genus *Opuntia*, such as catechin [36,50], chlorogenic acid [36,50), ferulic acid [36], p-coumaric acid, quercetin, and its derivatives [51], kaempferol, isorhamnetin, gallic acid

[52,51], protocatechuic acid, salicylic acid, rutin [51], kaempferol-3-O-rutinoside [52] (Fig.3). *Opuntia ficus-indica* is one of the most studied species due to its metabolite profile; phenolic compounds are present in the cladode, fruits, and flowers, both in wild and cultivated species [52].

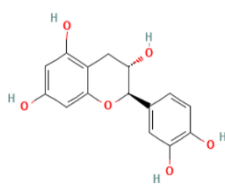
Mena et al. (2018) [49] analyzed the presence of phenolic compounds, through liquid chromatography-mass spectrometry (UHPLC-ESI-MS), in the cladodium and fruit of *Opuntia ficus-indica* (L.) Mill. of different cultivars. The results showed that the highest content of phenolic compounds was identified in young cladodes, with 26 compounds, with flavonoids (in particular, flavonols) being the leading group of polyphenolics. It was also possible to identify isorhamnetin, rutin and ferulic acid-hexoside derivatives. Regarding the peel and pulp of the fruits, 26 phenolic compounds were identified in the peel, with a predominance of phenolic acids in detriment of flavonols; in the pulp, the amount was smaller, with 21 phenolic compounds, with a ferulic acid derivative being the major representative. In the fruit peel of most cultivars, the following compounds were identified in high concentrations: ferulic acid hexoside, sinapic acid-hexoside, dihydrosinapic acid hexoside and isorhamnetin-rutinoside.

The fruits of *Pilosocereusarrabidae* were also evaluated for the composition of phenolic compounds. Gonçalves *et al.* (2015) [48] evaluated the peel and pulp of *Pilosocereusarrabidae* by HPLC-MS, identifying the presence of important flavonoids: Catechin, Dihydrokaempferol, Quercetin, Quercetin 3 or 4'-O-glucoside and Rutin, in both botanical parts (Fig.3). The high rutin content was found in the pulp of *Stenocereuspruinosis* and *S. stellatus* fruits [45], as well as in the peel of fruits of *Hylocereus undatus*[53].

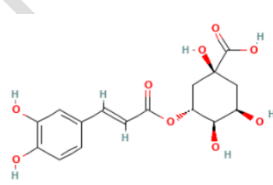
The main phenolic compounds present in cactus flowers are phenolic acids and flavonoids. Ammar *et al.* (2018) [54] evaluated the flowers of *Opuntia ficus-indica* using the LC-MS/MS technique, identifying quinic acid as the main phenolic acid, followed by gallic, protocatechuic, chlorogenic, 4-O-caffeoylquinic, caffeic, p coumaric, trans ferulic and rosmarinic acids. Among the flavonoids, they identified kaempferol-3-O-rutinoside, rutin, hyperoside, 4,5-di-O-caffeoyl quinic acid, quercetin-3-O-rhamnoside, isorhamnetin-3-O-rutinoside, isorhamnetin, 3-O-glucoside, apegenin and kaempferol 3-O-arabinoside. It is important to note that most studies have focused on the cladode and fruit, with few studies focused on flowers.

Despite the presence of polyphenols being reported mainly in *Opuntia* species, particularly in *O. ficus-indica*, in other genera such as *Hylocereus*[55], *Pereskia*[31] and

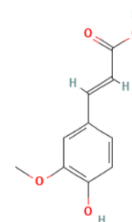
*Coryphantha*[56], the presence of these compounds is also described. Gallic, vanillic, syringic, protocatechuic, p-hydroxybenzoic, p-coumaric and caffeic acids have been described in the species *Hylocereus undatus* and *Hylocereus polyrhizus*[55,45].



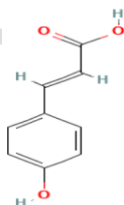
Catechin  
(C<sub>15</sub>H<sub>14</sub>O<sub>6</sub>)



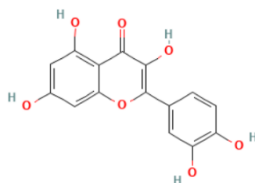
Chlorogenic acid  
(C<sub>16</sub>H<sub>18</sub>O<sub>9</sub>)



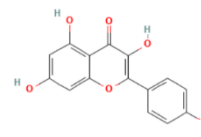
Ferulic acid  
(C<sub>10</sub>H<sub>10</sub>O<sub>4</sub>)



P-Coumaric acid  
(C<sub>9</sub>H<sub>8</sub>O<sub>3</sub>)



Quercetin  
(C<sub>15</sub>H<sub>10</sub>O<sub>7</sub>)



Kaempferol  
(C<sub>15</sub>H<sub>10</sub>O<sub>6</sub>)

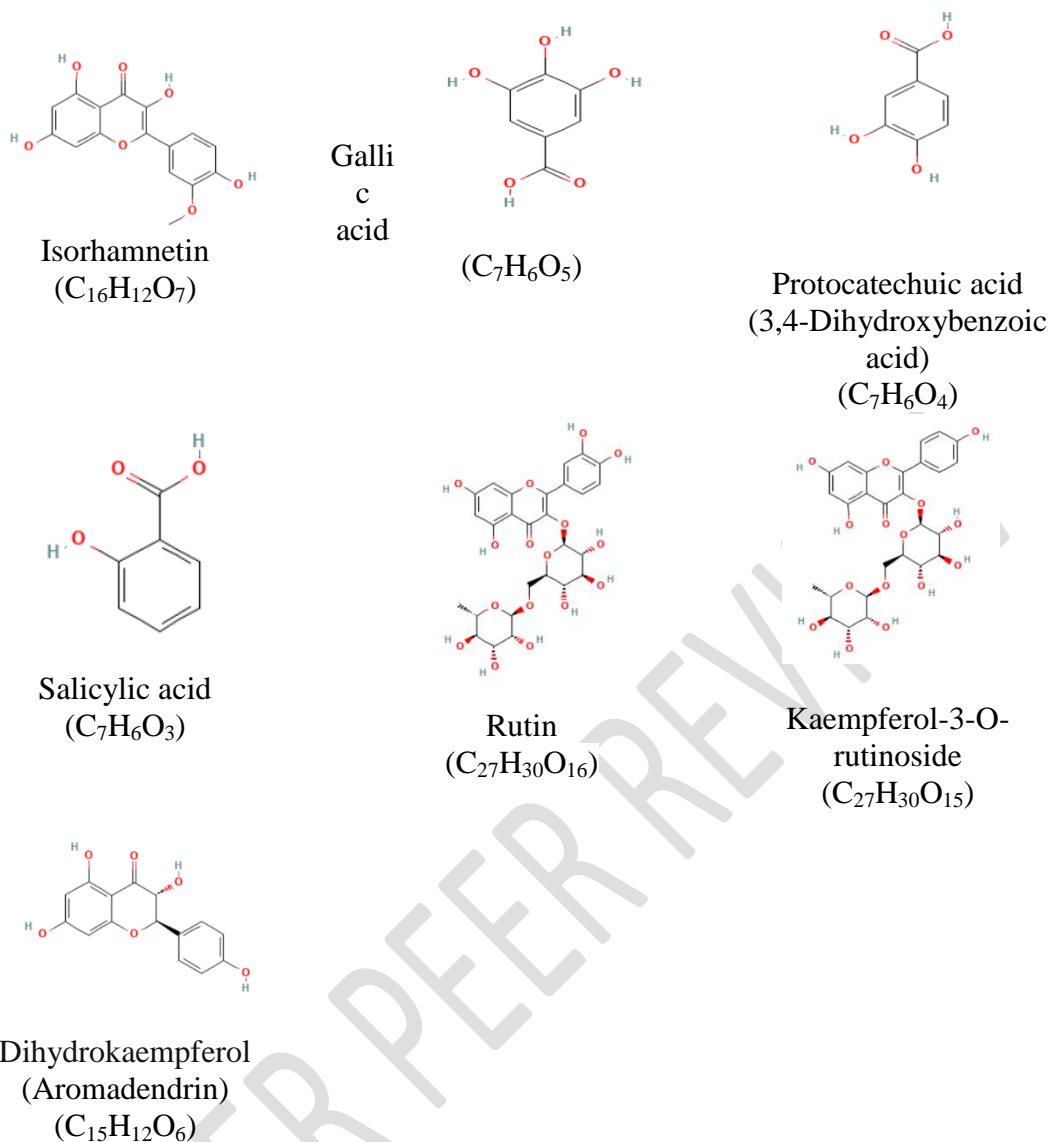


Fig.3: Chemical structures of the main polyphenols identified in the Cactaceae family, which occur in the Caatinga.

#### 4.5 Terpenes

*Terpenes* can be defined as “natural alkenes”, that is, they have a carbon-carbon double bond and are characterized as an unsaturated hydrocarbon. Despite having structural differences, all terpenes/terpenoids are structured in five-carbon blocks – isoprene units ( $C_5H_8$ ) – usually linked together in the “head-to-tail” order (link 1-4) [21].

Many terpenes have already been identified in cacti - in the cladode, stem, peel, seed and fruit, especially in the genus *Opuntias*, mainly in the species *Opuntia comondensis*[57], *Opuntia dillenii*[58], *Opuntia ficus-indica* [36], *Opuntia humifusa*[57], *Opuntia littoralis*[37], *Opuntia macrorhiza*[59], *Opuntia polyacantavar. arenaria*[60]and *Opuntia phaeacantha*[60]. However, the presence of terpenes has also

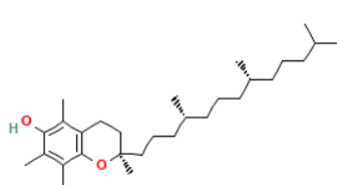
been reported in other genera, such as *Echinopsis*[57], *Hertrichocereus*[61], *Isolatocereus*[61], *Machaerocereus*[62], *Hylocereus*[55], *Pereskia*[31] and *Trichocereus*[61].

In the cladode of *Opuntia ficus-indica*, the presence of  $\alpha$ -Tocopherol,  $\beta$ -tocopherol,  $\gamma$ -tocopherol, linoleic acid, palmitic acid, lauric acid and myristic acid (Fig.4) was identified with HPLC-UV [37,36].

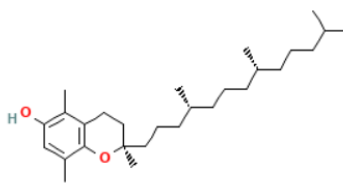
Linoleic, oleic, palmitic acids, cholesterol, campesterol, stigmasterol, and  $\beta$ -sitosterol have been described in *Hylocereus* seeds [55]. In the whole plant of *Isolatocereusdumortieri*, the presence of Dumortierinoside A (sapogenin), dumortierinoside A methyl ester, pachanoside I1 and pachanoside D1 was reported [63,64]. In the genus *Echinopsis*, specifically in the stem, there has already been the identification of: pachanosides C1, E1, F1 and G1 (1–4), bridgesides A1, C1, C2, D1, D2, E1, E2, 24-Methyl-cholesterol and sitosterol [57]. Bridgesigenin A and bridgesigenin B have also been described in the stem of the genus *Trichocereus*[61].

One can notice a wide variety of terpenes in Cactaceae species, as a diversity of triterpenoids, including unusual sterols, pentacyclic triterpenoids and saponins. These compounds have been studied for their biological activity, such as the terpenes of *Pereskia grandiflora*. Sri Nurestriet *al.* (2009) [65] demonstrated that terpenes from the leaves of this species had an *in vitro* cytotoxic effect against five human carcinoma cell lines: nasopharyngeal, cervical, colon (HCT 116), hormone-dependent breast (MCF7) and lung (A549).

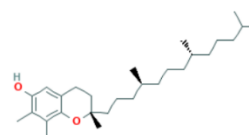
*Isolatocereusdumortieri* and *Stenocereusalamosensis* were also evaluated, demonstrating that triterpene saponins were related to type I antiallergic activity, detected by the inhibitory activity of the  $\beta$  hexosaminidase release from RBL-2H3 cells [64].



$\alpha$ -Tocopherol  
(C<sub>29</sub>H<sub>50</sub>O<sub>2</sub>)



$\beta$ -tocopherol  
(C<sub>28</sub>H<sub>48</sub>O<sub>2</sub>)



$\gamma$ -tocopherol  
(C<sub>28</sub>H<sub>48</sub>O<sub>2</sub>)

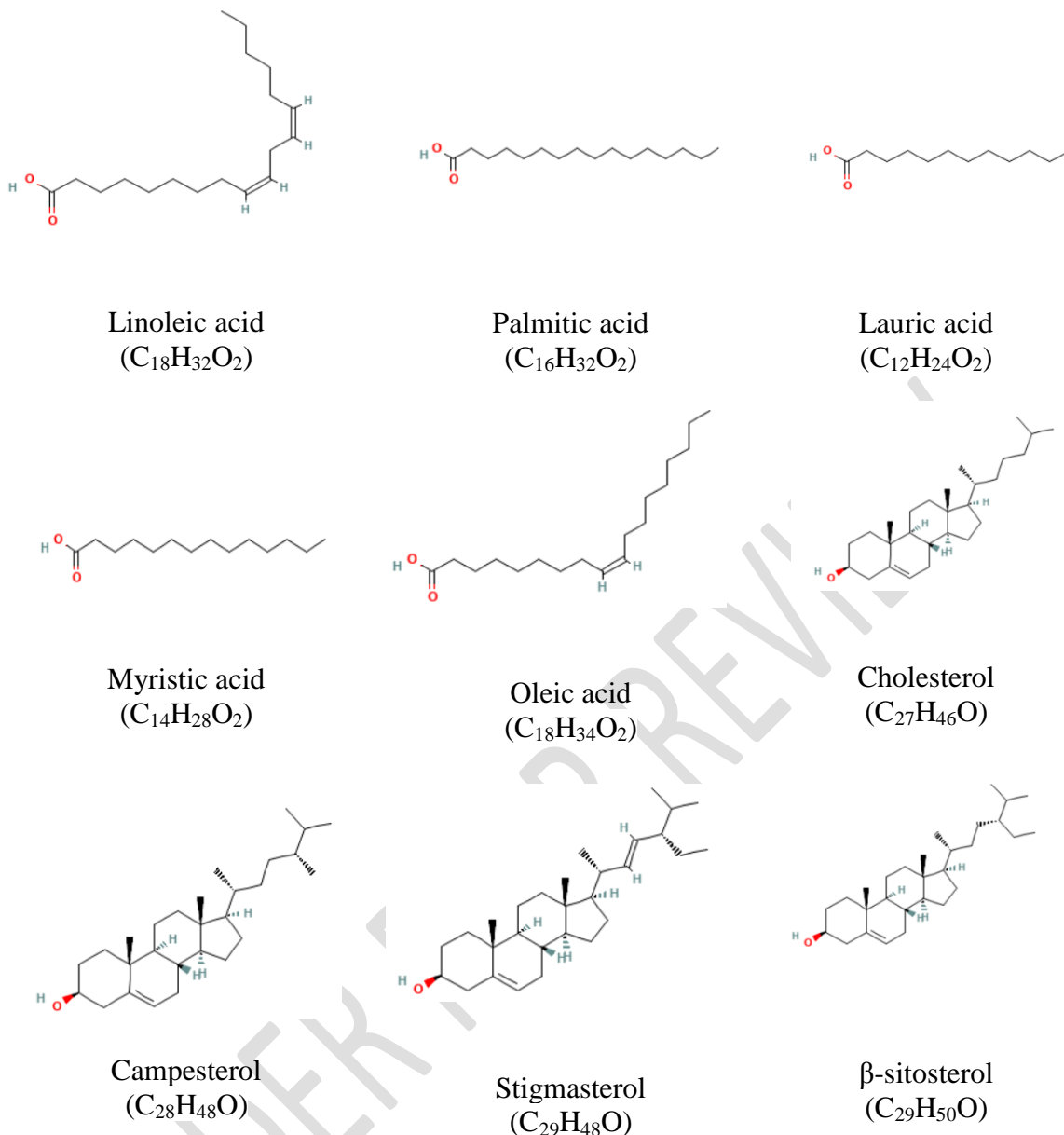


Fig.4: Chemical structures of the main terpenes and fatty acids identified in the Cactaceae family, which occur in the Caatinga.

#### 4.6 Other compounds

Besides the compounds mentioned above, other biocompounds such as saponins, carotenoids, carbohydrate polymers and unsaturated fatty acids were detected in cactus plants [64,31,66,38].

Cacti, particularly from the Cactioideae family, are rich in saponins. Kakuta *et al.* (2012) [64] isolated three triterpenoid saponins in *Isolatocereus dumortieri* Backbg, being dumortierinoside A methyl ester, pacanoside II and canoside D1, in addition to

two more saponins isolated from *Stenocereus alamosensis* A. C. Gibson & K. E. Horak, being gummy side A and gummy methyl ester A. Other saponins such as stellatocide (sapogenin glycosides) have been identified in *Stenocereus stellatus* [67] and stellatocide B and erucasaponin A (betulinic acid glycoside) in other species of the genus *Stenocereus* [68].

The presence of carotenoids was reported mainly in the species *Pereskia aculeata* Mill and *Pereskia grandifolia* Haw, highlighting high levels of  $\beta$ -carotene and  $\alpha$ -carotene in berries of *Pereskia aculeata*, and high levels of  $\beta$ -carotene and xanthophylls (lutein and xanthophylls) in leaves of both species [31]. *Pereskia leiolepis*, lutein and zeaxanthin were also identified in berries [69].

The Cactaceae family is especially rich in mucilage, with a high content of carbohydrates along with water-soluble O-glycosides (such as flavonols and saponins). Arabinogalactans-like polymers, pectin and oligosaccharides have already been described in cacti [70]. Martin *et al.* (2017) [70] evaluated the mucilage of the leaves of *Pereskia aculeata* using the GC-MS and NMR technique, revealing the presence of galactose, arabinose, rhamnose, fucose and partially esterified galacturonic acid, making it possible to characterize a type I arabinogalactan.

Studies have also reported the presence of fatty acids in cacti. Benattia *et al.* (2019) [38] analyzed the fatty acids in *Opuntia ficus-indica* seeds by GC-MS, revealing the presence of linoleic (C18:2) and oleic (C18:1) fatty acids. The presence of these fatty acids was also reported by Ciriminna *et al.* (2017) [66] in the seed oil of *Opuntia ficus-indica*, who also identified the presence of Sterols, such as  $\beta$ -sitosterol, Campesterol and Stigmasterol, in addition to Vitamin E (g-tocopherol).

## 5.0 CONCLUSION

There is much to be explored with the cacti of the Brazilian semi-arid region, both with the cladodes and with the fruits and flowers. These plants have phytochemical potential for obtaining bioactive compounds of interest.

Among the cacti evaluated in this review, the genera *Opuntia*, *Pereskia* and *Pilosocereus* are the most studied and documented for their antioxidant capacity and biological properties. The presence of phenolic compounds, betalains and terpenes, in addition to saponins, carotenoids, carbohydrate polymers and unsaturated fatty acids, confers its effectiveness as a medicinal/functional and food plant.

The *Opuntia ficus-indica* species is one of the most investigated, demonstrating a promising profile of bioactive compounds, especially phenolics and Betalains. *Cereus jamacaru*, native to Brazil, also stands out with a range of bioactive compounds, which are related to antioxidant, antitumor and antimicrobial activities.

However, among the vast universe of cacti that occur in the caatinga biome, it can be considered that there are few species that have already been studied and documented in the literature. Many of these may also present functional properties.

Studies that evaluate the functional potential of this family can certainly contribute to adding knowledge and value to the species. Because they are mainly rich in phenolic compounds and betalains, cacti have recognized antioxidant action and are related to health promotion. Thus, further scientific investigations can contribute to characterizing the plant and consequently stimulating the production and consumption of cacti as food.

Finally, the present review highlighted the variety of uses of the cactus, provided a broad view of its habitat and explored the immense phytochemical potential of these plants. Particularly notable are the bioactive compounds reported here, however, more in-depth studies, in vivo, are still needed to prove their efficacy and safety of use.

## **CONSENT**

It is not applicable

## **ETHICAL APPROVAL**

It is not applicable

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UNDER PEER REVIEW