Acta Botanica Brasilica - 33(2): 191-197. April-June 2019.
doi: 10.1590/0102-33062018abb0352

Cereus jamacaru DC. (Cactaceae): From 17th century naturalists to modern day scientific and technological prospecting

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Received: October 3, 2018
Accepted: October 30, 2018

ABSTRACT

Mandacaru (*Cereus jamacaru* DC - Cactaceae) possesses peculiar physiological and morphological characteristics that allow it to withstand long periods of scarcity and to adapt to different environments. Several uses have also been reported for the species from the 17th century to the present day. Given this history and the importance of the usage of mandacaru, the present investigation aimed to gather information about its uses from different documentary sources, and to perform a comparative analysis between past and present uses. *Historia Naturalis Brasiliae* by Piso and Marcgrave (17th century) served as the primary source, while information on labels of exsicates in botanical collections, basic scientific literature, and applications for patent filing at INPI, EPO, USPTO, WIPO (until October 2017), served as secondary sources. According to established categories of use, both the primary source and secondary sources revealed that mandacaru has had several applications, among which use for food and medicinal purposes stand out. Other uses, such as ornamental, magical-religious, civil construction and rural fences, were also reported. Despite the numerous references of usage in the documentary sources, knowledge about the potential use of *C. jamacaru* is not widely spread nor well protected.

Keywords: *Cereus jamacaru*, mandacaru, medicinal potential, forage use, seventeenth century, patents, historical ethnobotany

Introduction

Cereus jamacaru, commonly known as 'mandacaru' or 'cardeiro', is a native species of the Caatinga biome. It belongs to the family Cactaceae (Bahia *et al.* 2010), which has more than 125 genera and 2,000 species distributed almost exclusively in the Neotropics (Davet 2009; Rêgo *et al.* 2009). Mandacaru grows on stony soils and, along with other species of cacti, forms the typical landscape of the semi-arid region of Northeast Brazil. Its geographic distribution includes the states of Northeast Region (i.e., Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Piauí and Ceará), as well as part of the Southeast Region, specifically north of Minas Gerais (Almeida 2011).

According to Sbrissa & Melo (2012), cacti are endowed with peculiar features that allow them to withstand periods of scarcity and adapt to places that are poor in nutrient and water availability and/or have intense solar radiation and high temperatures. These plants are generally xerophytic perennial succulents that are adapted to semi-arid regions (Sbrissa & Melo 2012; Souza & Calvente 2013). These characteristics of *C. jamacaru* represent morphological and physiological adaptations, such as the presence of a

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photosynthetically active stem and a superficial root system, which facilitates rapid water uptake that supports the plant through periods of prolonged drought (Sales *et al.* 2014).

Mandacaru is arboreal and can reach a height of up to 10 meters, depending on the environment (Sales *et al.* 2014). Its fruits are orange or red with white mucilaginous pulp composed of innumerable miniature, black, edible and sweet seeds (Landgraf & Paiva 2009; Meiado *et al.* 2010). It also possesses an elongated green stem with spines, longitudinal buds and large colorful flowers (Sales *et al.* 2014).

According to Sales *et al.* (2014), mandacaru has great medicinal importance and is widely used in popular medicine in Northeast Brazil, mainly by local populations of the semi-arid region for which it is often one of the few therapeutic resources available. According to Paulino *et al.* (2011), mandacaru roots and stem are used by local populations in the Northeast as an infusion in the treatment of renal problems, to stimulate menses, as an antihypertensive and antirheumatic, and to treat constipation, nausea and vomiting. Guedes *et al.* (2009) also reported the use of stem infusion as a treatment of diseases such as diabetes, and vesicular and respiratory problems, such as cough and bronchitis. There are also records of this species being used as an ornamental plant and in civil construction in regions where it occurs naturally (Lucena *et al.* 2012b).

The first record of the use of mandacaru for treating diseases was in the 17th century by the naturalists Guilherme Piso and George Marcgrave in their *Historia Naturalis Brasiliae* (Natural History of Brazil), originally published in 1648 by the Elsevier fem Amsterdam workshop. According to Medeiros & Albuquerque (2014), this work is considered the first scientific treaty of the Americas and, with regards to Brazil, is the first report on Brazilian botanical flora and botany. It has since become a fundamentally important source for research in historical ethnobotany. For Medeiros (2010), the analysis of this reference allows information to be transfered, thus enabling society to reflect on how natural resources were and are used. According to Silva & Medeiros (2015), research that takes this historical bias stimulates the exchange of knowledge between the scientific universe and the empirical universe, and thus contributes to knowledge about the use of plants by human populations.

Considering the historical importance of the use of the mandacaru cactus by different human communities in the semi-arid region of Brazil, reports scattered throughout the literature about its use, and the need to gather more information for a better understanding of the species, the present study aimed to undertake a scientific and technological survey based on different documents about the species. The work *Historia Naturalis Brasiliae* (1648) is used as a primary source, with the intention of recovering information on mandacaru cited therein by Guilherme Piso and George Macgrave, and performing a comparative analysis of uses registered by naturalists of the 17th century with uses reported in other records. It is expected that this prospection will stimulate other scientific research on the benefits of this cactus.

Materials and methods

The prospection involved a search and documentary analysis of the use of the species *Cereus jamacaru* De Candolle, following four stages: (1) analysis and data collection using *Historia Naturalis Brasiliae* (Brazilian Natural History); (2) analysis and data collection using botanical collections; (3) analysis and data collection using the scientific literature; and (4) analysis and data collection using patent filing applications.

The first stage invovled reading, interpreting and data collection regarding the use of *C. jamacaru* reported by the naturalists Guilherme Piso and George Marcgrave (1648) in *Historia Naturalis Brasiliae*, the primary source in this research. This stage also considered the revision of this primary source entitled *Flora do Nordeste do Brasil segundo Piso e Marcgrave no século XVII* (Flora of Northeast Brazil according to Piso and Marcgrave in the 17th century) written by Dom Bento José Pickel (2008), which provided additional information on taxonomy and actual botanical commentaries for some of the species cited by Piso & Marcgrave (1648).

The second stage involved analysis and data collection using botanical collections. Information was acquired from the labels of botanical material provided online by several herbariums as part of the speciesLink network (http://www.splink.org.br/).

The third stage invovled the collection of documents, analysis and recording of information in the scientific literature, including books, articles, monographs, dissertations and theses. The search for these documents employed the following databases: Scientific Electronic Library Online (SCIELO), Medical Literature Analysis and Retrieval System Online (MEDLINE), Latin American and Caribbean Literature in Health Sciences (LILACS) and Scopus, updated to October 2017. The documents were selected based on the keywords: "Cereus jamacaru", "mandacaru", "cardeiro", "application", "herbal uses", "utility", "medicinal use" and "ethnobotanical study" conjugated by the AND connector. No time limit was set for in-depth reading and data collection of the selected documents. This survey was not intended to be exhaustive, but instead followed the criterion of access to information (available on the internet or in libraries) to perform this scientific and technological prospection.

Stage four involved the search for patents, which was based on applications filed with the National Intellectual Property Institute (INPI), the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO), and the World Intellectual Property Organization (WIPO). Searches were performed using the keywords "Cereus jamacaru", "mandacaru" and "cardeiro". Patents

that mentioned the species in both the abstract and the title were included, as well as all patent applications filed since the first registration until October 2017. For more advanced research, the connectors "AND", "OR" and "NOT" were applied to the combinations of keywords whenever necessary.

All the data collected in the four stages were organized into Excel® databases. These databases included all the information found regarding the species *C. jamacaru*, such as popular name, indicated use, part of the plant used, geographic distribution, and other data concerning the plant. Indications of use were classified into seven categories: accidents with venomous animals, food, rural fences, civil construction, magic-religious, medicinal and ornamental.

Results and discussion

According to information reported by Piso and Marcgrave in *Historia Naturalis Brasiliae* (1648), *C. jamacaru* was popularly known as 'mandacaru', 'cardeiro', 'cardo', 'iamacarú', 'caxabú', 'wild fig tree' or 'indica fragant fig tree', and was a well-known plant in Northeast Brazil where it was found from the coast into the interior. In the 17th century it was used as a food and medicinal resource, mainly for the treatment of stomach diseases, fever and bile, as well as to relieve heart and stomach problems.

According to Pickel (2008), *C. jamacaru* was described wery well by Marcgrave in *Historia Naturalis Brasiliae* (1648). On the other hand, Piso confuses this species with *Cereus fernambucensis*, considering them the same thing, although Pickel (2008) reports that his descriptions of the flower and fruit are certainly for *C. jamacaru*.

The survey of botanical collections found 568 labels of material related to *C. jamacaru*, of which 555 were considered acceptable; the other 13 records were not in agreement with the status of the scientific name recognized by the speciesLink network because only names with correct spellings are recognized.

Review of distribution records for each region of Brazil revealed that most of the specimens were collected in the Northeast Region (87.5 %, n = 497 records), followed by the Southeast (7.9 %, n = 45), Centrer-West (1.4 %, n = 8), North (0.9 %; n = 5) and South (0.3 %, n = 2) regions. Regions were not identified for 11 records (2 %).

Of the 568 records found in the speciesLink network and distributed among the states of Brazil, 115 were from the Caatinga (20.3 %), eight from the Cerrado (1.4 %), and four from the Atlantic Forest (0.7 %), while the biome was not reported for 441 (77.6 %) of the records.

Only 22 (3.8 %) of the 568 consulted labels had information about the use of *C. jamacaru*. All of these reported for medicinal uses, while two labels also indicated use as forage (food) (Tab. 1). Although the collectors reported the uses of mandacaru, none of them provided data on the modes of preparation and administration, nor the part of the plant used (Tab. 1). The diseases cited as treated with *C. jamacaru* included: high or low blood pressure, heart complications, diabetes, influenza, fever, spinal pain, respiratory problems, dry skin, skin dehydration, cough and kidney disease (Tab. 1).

Table 1. Information on category of use, description of use, collector, year, herbarium and registration number of the botanical collection for *Cereus jamacaru* DC. in the speciesLink network (2017) and citations in the scientific literature. Caption: Col. = Collector.

Category of Use/ Use description	Col./ Year/ Voucher/ Citations
Medicinal	
Urinary system diseases	Albuquerque & Andrade 2002; Andrade 2002; Andrade *et al.* 2006; Roque *et al.* 2010; Lucena *et al.* 2013; 2014; Cordeiro & Félix 2014; Sales *et al.* 2014; Silva 2015
Digestive system diseases	Roque *et al.* 2010; Vatta *et al.* 2011; Lucena *et al.* 2012a; 2014; Ribeiro *et al.* 2014; Sales *et al.* 2014; Silva 2015; Ferreira *et al.* 2016
Cardiovascular system diseases	Andrade 2002; Andrade *et al.* 2006; Pickel 2008; Messias *et al.* 2010; Lucena *et al.* 2012a; 2014; Sales *et al.* 2014
Respiratory system diseases	Carneiro 2009; Andrade *et al.* 2006; Lucena *et al.* 2012a; 2013; 2014; Cordeiro & Félix 2014; Silva 2015
Female reproductive system diseases	Andrade 2002; Andrade *et al.* 2006; Roque *et al.* 2010
Rheumatological diseases	Carneiro 2009; Lucena *et al.* 2013; Pereira Júnior *et al.* 2015
Skeletal system diseases	Andrade 2002; Andrade *et al.* 2006; Lucena *et al.* 2014
Antimicrobial action	Davet 2005; Davet *et al.* 2009; Pires *et al.* 2015
Nervous system diseases	Queiroz *et al.* 2011; Sales *et al.* 2014
Antioxidant action	Morais 2013; Santana 2016
Antiproliferative action	Lucena *et al.* 2013; Silva *et al.* 2015
Traumas	Roque *et al.* 2010
Plant used in folk medicine	Rocha, E.A./ 1998/ UFP 22219
	Rocha, E.A./ 1998/ UFP 22776
	Neves, M. C. A./ 2013/ HDELTA 813
Used in regional folk medicine	Rocha, E.A./ 1998/ PEUFR 26726
	Rocha, E.A./ 1998/ UESC 10708

Table 1. Cont.

Category of Use/ Use description	Col./ Year/ Voucher/ Citations
Plant used in medicine	Rocha, E.A./ 2004/ JPB 36855
	Rocha, E.A./ 2006/ UFP 44422
	Rocha, E.A./ 2004/ UESC 11833
	Rocha, E.A./ 1998/ UESC 11831
	Torres, W. et al./ 2015/ IPA91006
	Almeida, C./ 2006/ UFP 45664
	Rocha, E.A./ 1998/ UFP 22221
	Rocha, E.A./ 2005/ IPA 84554
	Rocha, E.A./ 2006/ IPA 81655
	Rocha, E.A./ 1998/ IPA 57103
	Rocha, E.A./ 2007/ UESC 15505
	Rocha, E.A./ 2007/ IPA 85114
Used as medicinal plant in Afro-Brazilian cults	Albuquerque, U.P./ 1993/ UFP 8753
Plant with medicinal property; diuretic; kidney diseases; spine and cough	Miranda, I.R./ 1985/ UFP 4368
Used in the treatment of high or low pressure, heart complications, diabetes, influenza, fever, back pain, respiratory problems, and dry skin	Londoño, P.A./ 2010/ UFP 61186
Medicinal and Forage	
Plant used as forage and in medicine	Teixeira, G./ 1965/ PEUFR 15075
	Gomes, M.L./ 1996/ IPA 58067
Accidents with venomous animals	
Snake bite	Cordeiro & Félix 2014; Silva 2015
Food	
Human food	Santos *et al.* 2007; Silva & Alves 2009; Lucena *et al.* 2012b; 2016; Oliveira *et al.* 2013; 2015; Roque & Loiola 2013; Medeiros & Albuquerque 2014; Farias *et al.* 2015; Lima 2016
Animal food (forage)	Albuquerque *et al.* 2002; Cavalcanti & Resende 2006; Santos *et al.* 2007; Araújo *et al.* 2010; Damasceno *et al.* 2010; Silva *et al.* 2011; Lucena *et al.* 2012b; 2015; Pereira Filho *et al.* 2013; Roque & Loiola 2013; Silva *et al.* 2013; Alves *et al.* 2014; Sales *et al.* 2014; Pereira Júnior *et al.* 2015; Santana Neto *et al.* 2015; Silva 2015; Souza & Cruz 2015; Gomes 2016; Santos & Souza 2016; Dantas *et al.* 2017
Ornamentation	
Housegardens	Lucena *et al.* 2012b; 2015; Rodrigues 2013; Dantas *et al.* 2017
Civil construction	
Building houses	Lucena *et al.* 2012b; Alves *et al.* 2014; Sales *et al.* 2014; Silva 2015
Magic-religious	
Mystic and religious practices	Lucena *et al.* 2012b; 2015; Dantas *et al.* 2017
Hedge	
Rural constructions	Lucena *et al.* 2012b; Alves *et al.* 2014

Specimens registered in the speciesLink network were collected between the years 1900 and 2017, with the greatest number of collections being deposited in the last 27 years (1990 to 2017; 70.7 %, n = 402) (Tab. 1).

Among the scientific literature considered, there were 18 indications of uses for *C. jamacaru*. The most important category was food (43 %, n = 29), followed by medicinal (35 %, n = 24), ornamental, civil construction (6 %, n = 4 each), magic-religious (4 %, n = 3), and accidents with venomous animals and hedge (3 %, n = 2 each).

The use of mandacaru for food included both non-human animals (see, for example, Albuquerque *et al.* 2002; Cavalcanti & Resende 2006) and humans (for example, Santos *et al.* 2007; Silva & Alves 2009; Oliveira *et al.* 2013; Lucena *et al.* 2012b; Roque & Loiola 2013) (Tab. 1). The medical category includeded treatments of several diseases, with emphasis on those of the urinary system (for example Cordeiro & Félix 2014; Lucena *et al.* 2014; Sales *et al.* 2014; Silva 2015) with 41.7 % of the citations; followed by diseases of the digestive system (Lucena *et al.* 2014; Ribeiro *et al.* 2014; Silva 2015; Ferreira *et al.* 2017, among others) with 33.3 %; the cardiovascular system (Ribeiro *et al.* 2014; Sales *et al.* 2014; Silva 2015; Ferreira *et al.* 2017, among others) with 29.1 %; the respiratory system (Andrade *et al.* 2006; Cordeiro & Félix 2014; Lucena *et al.* 2014; Silva 2015, among others) with 29.1 %; and the female reproductive system (Andrade 2002; Andrade *et al.* 2006; Roque *et al.* 2010) with 20.8 % (Tab. 1).

Mandacaru is one of the main forage resources for ruminant animals during the prolonged drought periods in Northeast Brazil. Because of this, many agriculturalists of this region cultivate mandacaru to support their herd

and to sell to other ranchers (Sales *et al.* 2014). According to the uses reported in the scientific literature, mandacaru also serves as food for fruit-eating wasps and bats that feed on fruit pulp, and for honeybees that use pollen as food (Santos *et al.* 2007). According to Davet *et al.* (2009), mandacaru is also used as a food resource by poor families who consume cooked or *in natura* cladodium, as well as fruits and flowers.

With regard to popular medicine, Lucena *et al.* (2012a) reported that *C. jamacaru* is used for the treatment of various diseases such as cough, spinal problems, wounds, boils, urinary tract infection, renal inflammation, rheumatism and urethra infection. Actions against cardiovascular diseases, cholesterol, gastritis, respiratory infections, and flu were also mentioned for mandacaru by Sales *et al.* (2014). In a preliminary *in vitro* study of the anti acetylcholinesterase activity of ethanolic extracts of plants as possible alternatives in the treatment of Alzheimer's disease, Queiroz *et al.* (2011) found mandacaru to exhibit inhibitory action against acetylcholinesterase (AChE), the enzyme that inactivates acetylcholine, which is considered as the main therapeutic strategy for the symptomatic treatment of Alzheimer's disease. The use of this cactus in the treatment of liver diseases, for relief from symptoms of menopause (Lucena *et al.* 2013) and for care after snake bites have also been reported (Cordeiro & Félix 2014).

Other works, such as that of Messias *et al.* (2010), reported that the mandacaru stem has antimicrobial and vasodilator activity in rodents. In a study with mammals, Andrade *et al.* (2006) observed that the *in natura* stem of this species has an anti-inflammatory property. Vatta *et al.* (2011) verified that the consumption of the stem of mandacaru by sheep has an anthelmintic action.

Mandacaru has a very thick woody cladode, which makes it useful for the construction of doors, spoons, windows, foundations and roofs of houses by low-income people (Aragão *et al.* 2000; Alves *et al.* 2007; Lucena *et al.* 2012b; Sales *et al.* 2014). Mandacaru is also used for other types of rural construction, such as hedges (Lucena *et al.* 2012b). In addition to these uses, there are also reports in the literature that this cactus is used as an ornamental plant in gardens or backyards, and in religious-magical practices (Rodrigues 2013; Lucena *et al.* 2015; Pires *et al.* 2015; Dantas *et al.* 2017).

The survey of patent applications for *C. jamacaru* uncoverd the same two records in INPI and WIPO.

The two records refer to the use of *C. jamacaru* in the treatment of diseases, and were deposited in the years 2009 and 2010. The 2009 application refers to the invention of a new nutraceutical composition formed from the extracts of *C. jamacaru* and other species of the genus *Cereus*, for use in regular diets, in diets for weight loss and in the treatment of diseases. Although Davet *et al.* (2009) reports human ingestion of this cactus, the scientific literature does not report the use of mandacaru by local populations for weight loss.

The 2010 patent is a protection claim for an invention of an herbal compound for the treatment of menopausal disorders, such as hot flashes, irritability, tingling and dizziness. The compound was produced in the form of capsules and tincture, and obtained by hydroalcoholic extraction. It is interesting to note that this patent, related to the use of this cactus for menopausal disorders, involved the same local use that appeared in the study of Lucena *et al.* (2013).

According to International Patent Classification (IPC) evaluation, the found patent applications relate to Section A - Human needs; A23L - Food, food products or non-alcoholic beverages, their preparation, modifications of the nutritional quality and its processing; A61P - Specific therapeutic activity of chemical compounds or medicinal preparations; and A61K - Preparations for medical, dental or hygienic purposes.

Based on the information acquired from the selected documentary set, it is clear that *C. jamacaru* has many applications. The main applications, however, are as a food resource for animals and humans during drought, and in folk medicine for the treatment of several diseases by the poorer families of the regions where cactus is present, and where it is often one of the most accessible therapeutic resources available. Comparison of past and present uses of *C. jamacaru* reveals that knowledge about its use has not been lost over time. In *Historia Naturalis Brasiliae*, for example, Piso and Marcgrave mention the use of cactaceae as a food resource and for the treatment of diseases of the heart, stomach, fever and bile. In other words, the diseases mentioned by naturalists in the 17th century that were treated with the use of mandacaru, were also reported in other documents of the documentary set analyzed in this work.

In spite of the innumerable indications of uses for *C. jamacru* presented in the present study, more in-depth studies confirming the reports made by local populations, especially regarding medicinal action, are still very scarce. The uses are also mostly unprotected, as evidence by the search for patents uncovering only two applications.

From a negative point of view, the few records of patents for tecnologies and innovations associated with local knowledge of *C. jamacru* means that most knowledge reported in the scientific literature can be accessed in a free way. In this sense, local knowledge that has historical confirmation of existance among local populations of the Northeast Region can be protected by anyone who has access to published information about the use of mandacaru, and who then can develop a process and product based on this original information.

In a positive way, local populations may have the opportunity to negotiate sharing in the benefits associated with traditional knowledge, considering the context of tecnological innovation and conservation of natural resouces and associated knowledge. From this perspective of bioprospecting, these local populations have, in patent

warehouses, a legal way to guarantee their rights for economic development associated with biodiversity.

In all cases of bioprospecting, local knowledge is valued and is the basis of patented and commercialized products. But regardless of the market value, all local knowledge has economic value, including all the social benefits of a product (Príncipe 1989). Thus, given that local knowledge is legally unprotected, there remains the possibility it being of great value in the future by demonstrating an important applicability. However, the use of natural resources and associated local knowledge are still incipient in Brazil.

Intellectual capital is a critical resource in today's global economy. Brazil not only holds great biodiversity within its borders, but is also home to numerous human communities with diverse cultures and knowledge about the applicability of a large number of plant species. Local knowledge is commonly disregarded as a fundamental part of a larger body of knowledge when market value and economic value are confused. The act of protecting local knowledge that has developed from historical use prevents illegal, injurious or unauthorized actions and recognizes the right of these communities to fully exercise decision regarding the use of their knowledge.

Considering all the information presented here on mandacaru, and the scarcity of studies that confirm the uses indicated in the literature, further studies need to be developed, especially those that demonstrate the true medicinal properties of this species. Likewise, researche aimed at optimizing the use of mandacaru as food are also needed, since this was the most cited use in the documentary set analyzed. It is expected, therefore, that the present work will support future scientific research into discovering and demonstrating the benefits of *C. jamacaru*.

Acknowledgements

We thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the master's scholarship granted to the student master and first author.

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