Knowledge, use, and management of *pequi* (*Caryocar coriaceum* Wittm.) in the region of the Sete Cidades National Park (Piauí, Brazil)

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Research

Abstract

Background: This study aimed to identify and characterize the knowledge and forms of use and management of *Caryocar coriaceum* Wittm. in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Methods: The data were collected through semi-structured interviews. The questionnaire sought information on knowledge of the species, forms of use and management, period, areas, and forms of collection, transport, storage, processing, and commercialization of the resource, as well as socio-economic data, such as age, marital status, level of education of the informants, and length of residence in the community.

Results: A total of 375 use citations were recorded across the following categories: food (84), construction (81), technology (62), medicinal (57), fodder (50), veterinary (21), fuel (15), magico-religious (4), and others (1). Food and construction had the highest use diversity value (UDV). Pequi oil stood out in the medicinal category due to its commercialization. A gender-based analysis indicated men knew more uses than women. The primary forms of management were collection (27) and protection (8). The results suggest overexploitation of *C. coriaceum*, putting local availability at risk.

Conclusions: Considering the use pressure on *C. coriaceum*, studies for investigating possible anthropogenic impacts caused by the unsustainable management of *pequi* in the region should be conducted, seeking more information for the development of conservation strategies for this species.

*Keywords***:** Ethnobotany, Local Knowledge, NTFP, Extractivism.

Background

Traditional communities around the world have a rich connection with nature, depending directly on the resources it offers for their subsistence and well-being (Laws, 2013; Campos *et al*., 2019; Souza *et al*., 2023). In this context, species of cultural value play a fundamental role as they have symbolic and practical meanings for these communities, being used in religious practices, rituals, traditional medicine, construction of houses and artifacts, handicrafts, and other aspects of everyday life (Platten and Henfrey, 2009; Souza *et al*., 2024). Furthermore, these species are intrinsically linked to cultural identity and the preservation of ancestral knowledge transmitted over generations, being crucial to value and preserve them as a way of ensuring the maintenance of traditions, socio-environmental balance, and the cultural heritage of traditional populations (Cristancho and Vining, 2004; Garibaldi and Turner, 2004).

Caryocar coriaceum Wittm. (Figure 1) is among these species and belongs to the Caryocaraceae family, which has a total of 25 species, including only two genera, *Caryocar* L. and *Anthodiscus* G. Mey. *Caryocar* species are found in different phytophysiognomies such as the Cerrado, Caatinga, Amazon and Atlantic Forest (Nunes and Gil, 2016; Guedes *et al*., 2017; Almeida Bezerra *et al*., 2022).

C. coriaceum is widely distributed in the states of Ceará, Pernambuco, and Piauí (Costa *et al*., 2004). Due to its useful potential, this species can be classified in different categories of use, such as medicinal (Conceição *et al*., 2011; Sousa-Júnior *et al*., 2013; Almeida Bezerra *et al*., 2022), food (Sousa-Júnior *et al*., 2013), fodder (Oliveira *et al*., 2008), technology (Fonseca-Filho *et al*., 2016), fuel (Oliveira, 2008), construction (Meireles *et al*., 2018; Oliveira *et al*., 2008), veterinary, magico-religious, among others.

This species produces a resource of cultural and socio-economic relevance for several human communities: the "*pequi*" or "*piqui*", popular names given to its fruit, commonly sold in the form of derivatives; among which, the *pequi* oil stands out as a product that contributes significantly to the local economy (Sousa-Júnior *et al*., 2013; Sobral *et al*., 2024). It is a non-timber forest product (NTFP) whose extractivism is a common activity in regions where this species occurs. The fruit is collected mainly by residents of rural communities. Despite its ecological, cultural, and socio-economic relevance, studies addressing the forms of use and management of this species have been conducted mostly in the Chapada do Araripe, in the state of Ceará, where there is a greater predominance of the species (Sousa-Júnior *et al*., 2013; Cavalcanti *et al*., 2015; Sobral *et al*., 2024). In addition to this region, there are other potential areas for conducting research with this focus, such as the region of the Sete Cidades National Park (PNSC), in the state of Piauí, where the present research was conducted.

The communities surrounding the PNSC exploit *C. coriaceum* for various purposes and supplement their income by selling the *pequi in natura* and the oil, made of fruits collected in the region, which lacks studies on the use and management of this species. From a management perspective, measures such as protection, tolerance, transplantation, and sowing reflect the knowledge and wisdom of traditional communities. Protection consists of adopting measures to preserve the species and their habitats, preventing excessive exploitation and promoting natural regeneration. Tolerance consists of allowing moderate use of resources, respecting natural reproduction cycles and ensuring long-term sustainability. Transplantation and sowing aim at the active management of the species, making possible their reproduction and dissemination in appropriate areas, favoring regeneration and genetic diversity. These actions of protection, tolerance, and transplantation reflect, for example, studies like Tomasini *et al*. (2019), which demonstrated that the ecological knowledge of local communities is extremely effective in monitoring the conservation status and population changes of beneficial species.

Our research considers that uses of *C. coriaceum* may be influenced by gender for including several categories, such as medicinal, food, and construction, among others, and the collection of fruits for commercialization of derivatives may be the most relevant activity from the perspective of species management, and the management attitudes are seen by the communities as a crucial tool in the conservation and sustainable use of the species, from the perspective of economic sustenance. (Sousa-Júnior *et al*., 2013; Albuquerque *et al*., 2021; Sobral *et al*., 2024)

Based on these viewpoints, this research aimed to identify and characterize the knowledge and forms of use and management of *C. coriaceum* Wittm. in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil), evaluating these conditions in a buffer zone of a Conservation Unit, as well as investigating the existence of management attitudes by traditional populations, such as protection, tolerance, transplantation, and sowing, from a quantitative and qualitative perspective.

The cultural and socio-economic value of *pequi*, the potential impacts of its extractivism, as well as the lack of information on the person-plant relationship, involving *C. coriaceum*, justify the development of this research, which can provide subsidies to develop conservation strategies for the study species.

Figure 1. General aspects of *Caryocar coriaceum* Wittm. (Caryocaraceae). A. Adult individual; B. Detail of the open fruits, exposing the pulp and seed; C. Flower and floral buds; D. Pequi oil; E. Fruits of *Caryocar coriaceum* Wittm.

Material and Methods

Study area

This study was carried out in seven communities surrounding the Sete Cidades National Park (PNSC), which is located between the municipalities of Piracuruca and Brasileira, geologically inserted in the northeastern portion of the Parnaíba Basin (Barros *et al*., 2011). This conservation unit covers an area of 6,221.48 ha and has a perimeter of 36.2 km (04º05' S to 04º15' S and 41º30' W to 41º45' W). The study area included the following communities: Cachoeira, Água da Abelha, Palmeira da Emília, Morada Nova, Santa Isabel, Santo Expedito, and Todos os Santos (Figure 2). The economy in these communities is mainly based on agriculture, livestock, and extraction of plant resources for commercialization, especially *pequi*.

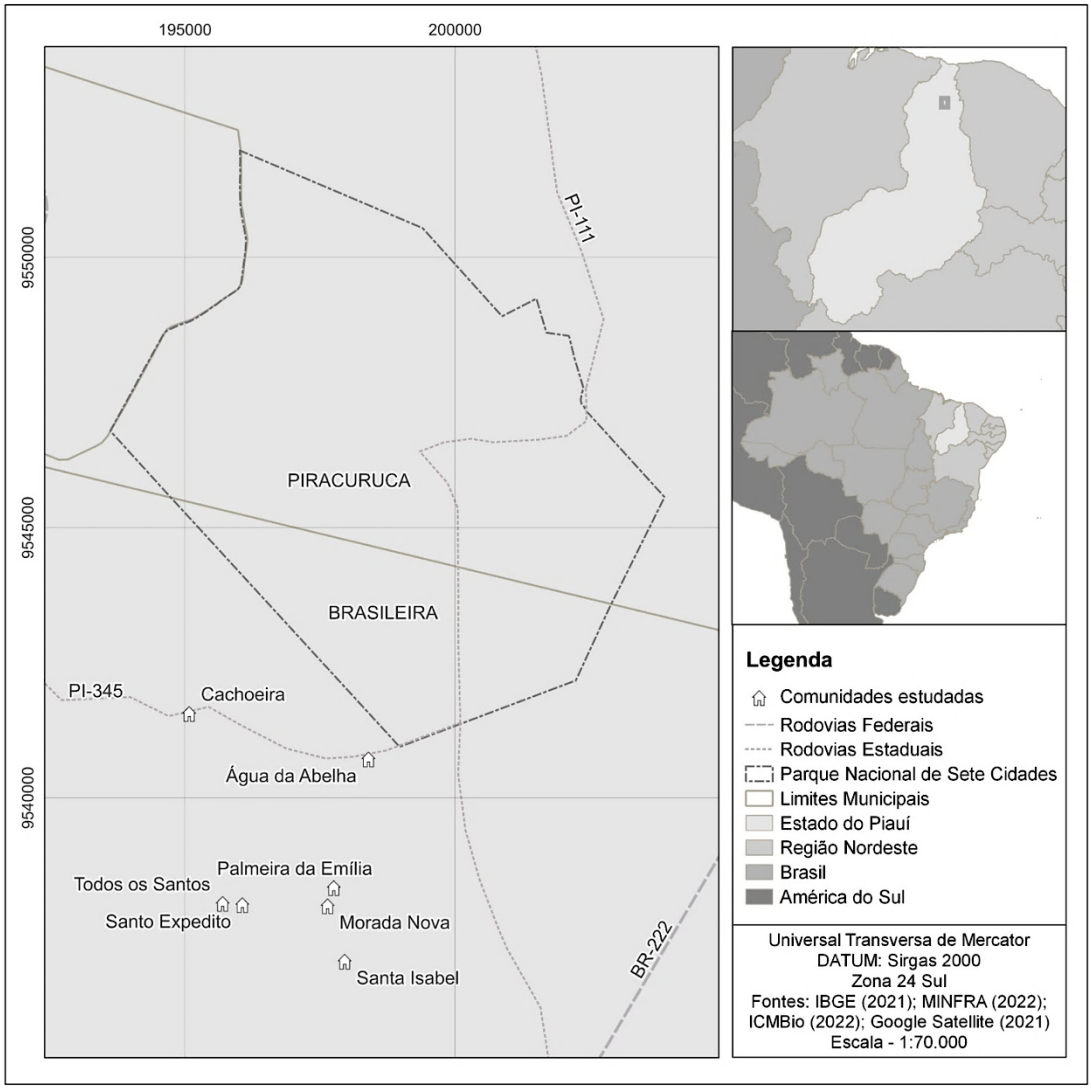

Figure 2. Location map of the study communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Legal aspects

Before data collection, residents were informed about the objective of the research and invited to sign the Free and Informed Consent Form (TCLE) (Resolution CSN 466/2012), agreeing to participate. This study was submitted to the Ethics Committee for Research with Human Beings of the Health Sciences Center of the Federal University of Paraíba (CCS/UFPB) and approved under opinion No. 4,615,045.

Data collection

The data were obtained through semi-structured interviews carried out with the breadwinners of the families (men and women) (Albuquerque *et al*., 2010), in addition to direct observation throughout the fieldwork, aiming to collect information about the daily lives of the residents and their relationships with the study species.

The interviews were conducted between May and June 2018. The questionnaire sought information on traditional knowledge, use, and management of *C. coriaceum*, collection period, areas and forms of collection, number of fruits extracted per tree and per collection, and forms of transport, storage, processing, and commercialization of the resource, in addition to socio-economic data, such as age, marital status, education level of the informants and length of residence in the community.

Data collection began in the community of Cachoeira, applying the snowball method (Biernacki and Waldorf, 1981). This method consists of asking interviewees to nominate another person who holds the knowledge investigated (expert). From the first indication, a "chain reaction" begins to collect information, in which each informant indicates another at the end of the interview. When indications begin to be repeated, without new nominations, it means that there are no more people of interest to be interviewed. This method was used to identify a larger number of people who performed fruit collection, commercialization, and other forms of management of the species. Those considered as *pequi* extractivists were the social agents of our research.

Seven residents (2 men and 5 women), who reported collecting *pequi*, were interviewed in the community of Cachoeira. Based on their indications (snowball), other 20 collectors (10 men and 10 women) were identified in six other rural communities: Água da Abelha (4), Palmeira da Emília (1), Morada Nova (8), Santa Izabel (2), Santo Expedito (3) and Todos os Santos (2) (Figure 2). Thus, a sample composed of 27 collectors (12 men and 15 women) was obtained.

Data analysis

For the comparative analysis of the informants' local knowledge of *C. coriaceum*, the following indices were used: use diversity value (UDV), informant diversity value (IDV), and informant equitability value (IEV) (Byg and Balslev, 2001).

The UDV index is calculated by dividing the number of times the species was mentioned in each category (food, medicinal, construction, etc.) (U_{CX}) by the total number of use citations in all categories (U_{CT}) (UDV = U_{CX}/U_{CT}). Based on this index, the importance of use categories and how they contribute to the local use value can be determined.

The IDV refers to the number of use citations mentioned by a given informant (U_X) divided by the total number of citations of the species (U_T) (IDV = U_X/U_T). This index is used to calculate the number of informants who use a given species and how this knowledge is distributed among them.

The IEV is calculated by dividing each informant's IDV by the highest IDV found (IDV_{max}) (IEV = IDV/IDV_{max}). This index measures the degree of homogeneity of informants' knowledge.

The above-mentioned indices were used considering the gender of the informants to identify how knowledge regarding the use of *C. coriaceum* is distributed between men and women in the study region.

To verify the relationship between gender and the number of citations in each category, T-tests were performed, comparing the number of uses cited by men and women. To verify whether the data met the parametric assumptions, data distribution was visually analyzed (Quinn *et al*., 2002), assessing its normality. Then, the homogeneity of data variance was verified using Levene's test.

Monte Carlo simulations were applied using 5,000 randomizations to assess the effect of gender in samples that did not meet the assumptions of normality or homogeneity of variance.

All analyses were performed in the R development environment (R Core Team, 2021). Values of $p<0.05$ were considered significant.

Results

Knowledge and use of *Caryocar coriaceum* Wittm.

All informants (N = 27) stated that they use the species as food (100%) and for medicinal purposes (100%). The fodder category was indicated by 96.3% of informants, followed by construction (81.5%), technology (74.1%), veterinary (51.9%), fuel (33.3%), magico-religious (14.8%), and others (3.7%) (Table 1).

Table 1. Percentage of informants who cited *Caryocar coriaceum* Wittm. in the categories of use recorded in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

	Use categories								
Informant (N = 27)	Food	Construction	Technology	Medicinal	Fodder	Veterinary	Fuel	Magico-religious	Others
	100%	81.5%	74.1%	100%	96.3%	51.9%	33.3%	14.8%	3.7%

The residents of the PNSC region use *C. coriaceum* for a variety of purposes, whether for timber or non-timber purposes. A total of 375 use citations of the species were recorded, distributed in the following categories: food (84), construction (81), technology (62), medicinal (57), fodder (50), veterinary (21), fuel (15), magico-religious (4), and others (1) (Table 2).

Table 2. Use citations (No. and %) of *Caryocar coriaceum* Wittm. in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil). Constr. = construction, Techn. = technology, Med.= medicinal, Vet. = veterinary, M. Rl = Magico-Religious.

Communities	**Number and percentage of citations per use category**									**Total**
	Food	Constr.	Techn.	Med.	Fodder	Vet.	Fuel	M. Rl.	Others	
Cachoeira	22	12	17	14	14	3	1	1	0	**84**
	(5.9)	(3.2)	(4.5)	(3.7)	(3.7)	(0.8)	(0.3)	(0.3)	(0.0)	**(22.4%)**
Água da	10	11	13	10	9	3	4	1	0	**61**
Abelha	(2.7)	(2.9)	(3.5)	(2.7)	(2.4)	(0.8)	(1.1)	(0.3)	(0.0)	**(16.3%)**
Palmeira da	5	7	2	2	2	2	0	0	0	**20**
Emília	(1.3)	(1.9)	(0.5)	(0.5)	(0.5)	(0.5)	(0.0)	(0.0)	(0.0)	**(5.3%)**
Morada Nova	23	32	19	15	14	6	3	1	0	**113**
	(6.1)	(8.5)	(5.1)	(4.0)	(3.7)	(1.6)	(0.8)	(0.3)	(0.0)	**(30.1%)**
Santa Izabel	4	4	5	9	4	3	4	0	0	**33**
	(1.1)	(1.1)	(1.3)	(2.4)	(1.1)	(0.8)	(1.1)	(0.0)	(0.0)	**(8.8%)**
Santo	13	13	3	5	5	3	3	0	1	**46**
Expedito	(3.5)	(3.5)	(0.8)	(1.3)	(1.3)	(0.8)	(0.8)	(0.0)	(0.3)	**(12.3%)**
Todos os	7	2	3	2	2	1	0	1	0	**18**
Santos	(1.9)	(0.5)	(0.8)	(0.5)	(0.5)	(0.3)	(0.0)	(0.3)	(0.0)	**(4.8%)**
Total	**84**	**81**	**62**	**57**	**50**	**21**	**15**	**4**	**1**	**375**
	(22.4%)	**(21.6%)**	**(16.5%)**	**(15.2%)**	**(13.3%)**	**(5.6%)**	**(4.0%)**	**(1.1%)**	**(0.3%)**	**(100%)**

Based on the number of citations, use diversity value (UDV) was calculated for each category (Table 3), which included 30 types of uses (purposes) from different parts of the plant (pulp, seed, bark, flower, and wood) (Table 4).

Table 3. Use diversity value of the use categories indicated for *Caryocar coriaceum* Wittm. in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Use categories	**Use diversity value (UDV)**
Food	0.224
Construction	0.216
Technology	0.165
Medicinal	0.152
Fodder	0.133
Veterinary	0.056
Fuel	0.040
Magico-religious	0.011
Others	0.003

Table 4. Types of uses and used parts of *Caryocar coriaceum* Wittm. in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil). [No.] = number of use citations.

Categories	Used part	Product and/or forms of use/consumption/preparation	Types of Use / Purpose [30]
Food [84]	Fruit (pulp) [60]	▪ *In natura* [27] – The "rapa" (pulp) is consumed with flour, rapadura/sugar. ▪ Cooked [26] – With water and salt; cooked accompanied by beans and/or rice, chicken, beef, flour, and sugar/rapadura. It can be prepared (cooked) with beans, rice, chicken, beef/bone, and chicken. ▪ Processed [7] – Sweet [4], cake [2], pizza dough [1].	Human food [84]
	Fruit (no peel) [8]	▪ Oil [8] – Used for frying [6], cooking [1], and as a seasoning [1]. For frying, the oil is heated until it starts to smoke, becoming yellowish. This process softens the odor of the product.	
	Seed [16]	▪ Roasted [9] – Chestnut [7], macerated chestnut mixed with flour [1], preparation of "farofa" [1]. ▪ Oil [4] – Used for frying [4]. The chestnut is macerated to produce oil; the chestnut oil is different, it curdles; the "butter" turns white, looking like lard. ▪ Processed [3] – Cake [1], "paçoca" (a traditional Brazilian ground peanut candy) [1] and "chestnut milk" [1].	
Construction [81]	Wood [81]	▪ Stakes [18], fence posts [19], gates [9]	Fences [46]
		▪ Boards [4], rafters [2], beams [1], fork [1], door and window linings [6], doors [10], windows [10], batten (floor) [1].	Houses [35]
Technology [62]	Wood [51]	▪ Handles for axes [5], sickle [1], adze [1], digger [1], hoe [1], broom [1], "cipio" (tool used to smooth wood) [1].	Tool handles [11]
		▪ Trowel [1], "catitú" ball (a tool used to grate/saw cassava to make flour) [2].	Tools [3]
		▪ Chairs [2], stools [3], tables [2], wardrobes [1].	Furniture [8]
		▪ Trough for the production of flour [10] or rapadura [1], pestle [7], meat cutting board [1], brush [1], trough (Feeder) [4].	Domestic or field utensils [24]
		▪ Canoes [3], boats [2].	Transport [5]
	Fruit [11]	▪ Soap [11].	Hygiene [11]
Medicinal [57]	Fruit (Pulp/Almond) [56]	▪ Oil (orally) [43] – Mixed with bee honey (1:1) in PET bottles that can vary from 250 mL to 2 L. Other ingredients can be added to the mixture, such as white onion, lemon, garlic, mallow, and mint. It can also be ingested pure or with salt. Dosage: 1 to 3 tablespoons daily. Note: Larger doses can cause diarrhea [1].	Flu [27], cough [6], expectorant [3], pneumonia [1], tiredness [1], constipation [1], diabetes [1], heart problems [1], cancer prevention [2]
		▪ Oil (topical use) [13] – Apply to wounds. For body pain, apply it on the painful area, massaging.	Healing [8], pain [1], toothache [2], burns [1], repellent [1].
	Fruit (pulp) [1]	▪ *In natura* – Liquid ("milk") extracted from the raw endocarp. Dosage: 1 to 2 tablespoons daily.	Flu [1].

Fodder [50]	Fruit peel [23]	▪ *In natura* – Used to feed goats and cattle.	Animal feed [50]
	Fruit [18]	▪ *In natura* – Consumed by cattle, goats, and pigs, as well as by wild species, such as armadillo, agouti, paca, "peba" (*Euphractus sexcinctus*), "preá" (*Galea spixii*), "rabudo", parrot, "jacu" (Penelope) and "lambu" (*Crypturellus parvirostris*).	
	Fruit (pulp) [4]	▪ "Borra" – Consists of a residue derived from cooking the fruit (pulp) during oil production. It is used to feed pigs and chickens.	
	Flower [5]	▪ *In natura* – Consumed by goats and wild species, such as deer, "peba" (*Euphractus sexcinctus*), armadillo, and parrot.	
Veterinary [21]	Fruit (no peel) [18]	▪ Oil [18] – Topical use.	Healing [9] and repellent [9].
	Fruit (pulp) [2]	▪ "Borra" [2] – Topical use.	Healing [1] and repellent [1].
	Seed [1]	▪ Smoke – The seeds are burned to release smoke	Repellent [1].
Fuel [15]	Wood [15]	▪ Firewood [8] and charcoal [7]. Note: They use firewood and charcoal from the pequi tree, although these resources are not good fuels.	Domestic use for food preparation [15].
Magico-religious [4]	Fruit (no peel) [4]	▪ Oil [4] – The production process can be influenced by the phases of the moon [3] and by "negative" people [1].	No purpose [3], Indirect indicator of "negative energy" [1]
Others [1]	Fruit peel [1]	▪ *In natura* [1] – Used as a natural fertilizer.	To fertilize the soil for planting [1]

Both the pulp and the seeds can be used in the form of oil, which was recommended in our research for frying and as a seasoning. The oil extracted from seeds is more appreciated in frying than the oil from the pulp, due to the peculiar flavor left in the food.

The technology category (UDV_T = 0.165) included timber and non-timber uses, in which *C. coriaceum* wood can be used to produce household utensils, furniture, tool handles, and boats, and the pulp is used to make soap. To produce soap, the pulp is mixed with potassium hydroxide (potash); the mixture is cooked for around two hours, stirring it until "apurar", i.e., reducing the liquid present in the preparation, through slow and prolonged cooking, to concentrate and intensify the final product. Then, the soap is cut into bars. Other products can be added to the mixture, such as washing powder and bleach.

The use of *pequi* oil stands out in the medicinal category, being common in the study communities, obtained from cooking the fruit pulp (most common form) or seeds. Due to the oil properties, it is a product widely used in traditional medicine and much appreciated by residents and people from Piracuruca and Brasileira, as well as other surrounding municipalities.

In our research, the medicinal use of *pequi* oil included the following therapeutic indications: flu [27], cough [6], expectorant [3], pneumonia [1], tiredness [1], constipation [1], diabetes [1], heart problems [1], cancer prevention [2], healing [8], pain [1], toothache [2], burns [1], and repellent [1] (Table 4).

For the veterinary category (UDV_V = 0.056), most informants cited the use of oil as a repellent and healing agent. The "borra" and seed were also cited in this category, the first as healing and repellent and the second as a repellent when releasing smoke.

The use of *C. coriaceum* wood was also associated with the fuel category, such as firewood and charcoal, with UDV_{Fuel} = 0.040, lower than that found by Susa-Júnior *et al*. (2013) (UDV = 0.055). Oliveira (2008) also recorded the use of this species for energy production. Some informants explained that *C. coriaceum* wood is not good for charcoal production, which may justify its low UDV_{Fuel}.

Regarding the magico-religious category (UDV_{MR} = 0.011), some informants mentioned the oil as an indicator of "negative energy". According to them, if any "negative" person appears during the oil production, the quality of the product is affected. Some residents associated the yield of oil with the phases of the moon, explaining that the oil production, when the moon is "good" (full or waxing), results in a better yield of the product, whereas, when the moon is "bad" (new or waning), oil production is lower.

For the category "others" (UDV_O = 0.003), fruit peel was cited as fertilizer. This category includes uses that generally do not fit into the other categories. Some particular uses of *C. coriaceum* have already been classified in this category, such as melliferous and ornamental.

Management of *Caryocar coriaceum* Wittm.

In the study on the management of *C. coriaceum,* 27 informants were identified who either currently practiced or had previously practiced at least one type of management for the species. Collection was the predominant form of management, performed by 27 collectors, followed by protection (8), tolerance (7), transplantation (3), and sowing (1). Informants reported that *C. coriaceum* rarely grows when planted, suggesting a lack of knowledge about planting techniques and incentives to cultivate the species (Figure 3).

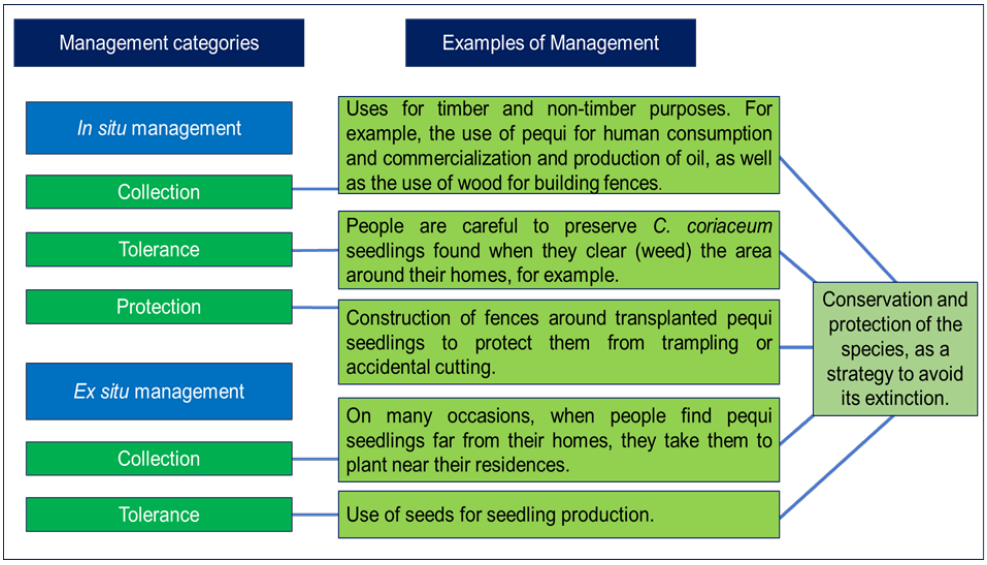

Figure 3. Scheme showing the types of management of *Caryocar coriaceum* Wittm. recorded in the communities surrounding the Sete Cidades National Park – PNSC (Piauí, Brazil).

The germination of *C. coriaceum* seeds is slow and may take around a year, which exacerbates the species' conservation issues. Increased extractivism, the decrease in dispersing animals, deforestation, and fires in the Cerrado currently threaten the species, which is highly valued in both cuisine and traditional medicine. To prevent local extinction, measures such as reducing fruit collection and regenerating populations in deforested areas should be considered. The development of public policies for the protection of pollinating and dispersing animals could also contribute significantly to the species' maintenance. The enactment of Law 9,985 in 2000 by the Brazilian Institute of Environment and Renewable Natural Resources – IBAMA, which prohibits practices affecting the natural regeneration of ecosystems, including the introduction of cattle into forests, marked a significant milestone in conservation.

Collection and post-collection of *Caryocar coriaceum* Wittm.

Pequi collection is performed from december to march, with february being the most productive month. This practice is preferably carried out in the morning and/or afternoon. Some collectors stated that they need to start their activities early, around 4:00/6:00 a.m., so that they can obtain a good quantity of fruits. This is due to the high number of collectors, including those from nearby municipalities, such as Piripiri, Brasileira, and Piracuruca. If collection starts too late, there may be a low quantity of fruit available.

The informants explained that only the fruits from the ground are collected because when the *pequi*s are collected directly from the tree, they do not release the peel and are bitter, and, sometimes, even those collected from the ground do not release the peel. The fall of the fruit indicates its ripening stage appropriate for collection.

The collection areas correspond to the communities (Figure 2). The communities of Água da Abelha and Morada Nova are the areas most explored by collectors (20 and 12 citations, respectively), followed by the areas in Santa Izabel (2), Santo Expedito (1) and Palmeira da Emília (1). None of the informants mentioned the community of Cachoeira as a collection area.

The residents said that collection areas are selected according to their proximity and number of trees. Thus, the areas located in Água da Abelha and Morada Nova are most explored because these communities are home to a larger number of collectors (14.8% and 29.6%, respectively). Moreover, these areas have a higher density of specimens. Due to the lack of collection areas in Cachoeira, the collectors who live there (26%) collect the fruits in Água da Abelha.

Collection is carried out, on average, twice a day and four times a week. Each person collects around 200 – 500 *pequi*s per collection. Thus, considering the number of collectors (27), it can be estimated around 18,900 fruits per day (75,600/month).

The majority (78%) of collectors transport the fruits in bags (200 – 400 *pequi*s), and the others use hand trucks (11%), buckets (7%), and cans (4%). One can hold approximately 500 peeled *pequi*s. The *pequi* peel is removed at home or in the collection area. The following means are used to transport the fruits: motorcycles (11%), bicycles (4%), and carts (4%); 81% transport the fruits on foot.

After collection, the fruits are stored inside the collectors' houses, in piles, generally in the living room or service area. There is no specific place for storage. According to informants, *pequi*s must be stored outside the bags to prevent fruit rot and it is common to store some fruits in the refrigerator to extend their shelf life.

The fruits are used to produce oil, which is commonly used in the study communities and the surrounding municipalities. Due to its medicinal properties, *pequi* oil is highly appreciated in the region and can be obtained by cooking the fruit (most common form) or the seed.

Before starting fruit processing, it is common to wait for the *pequi*s to wither because, according to informants, withered fruits release a greater amount of oil. The fruits are generally cooked in cans (18 L) after removing the peel, a process known as "rolar" (peeling), mentioned as being a difficult activity. The *pequi*s are subjected to wood cooking, which can last around 12 hours. The collectors generally start the cooking process and go collect more fruits. There are cases of leaving the *pequi*s to cook overnight, collecting the oil at dawn. An informant reported that cooking could last days, depending on production. The product reaches the ideal point when "squeaks", indicating the absence of water and that cooking can now be ended.

Pequi oil production was recorded as a practice carried out only by women (11). Men's participation only occurs during collection. To obtain 1 L of oil, according to the producers, around 200 – 500 peeled *pequi*s are needed. Both fruits *in natura* and the oil are sold locally or in nearby municipalities (Piripiri, Brasileira, Piracuruca, São Luiz, and Domingo Mourão), in fruit stores, markets, highways, and/or to specific customers.

A can containing around 200 *pequi*s costs R$20.00 – R$30.00 (on average US$4.0 to US$6.0, exchange rate on June 26, 2023). When the fruits are sold in units, five *pequi*s cost R$1.00. Oil is sold in PET or glass bottles and the price can range from R$30.00 to R$50.00 per liter. The oil is also sold in 250 mL PET for about R$15.00.

Comparison of knowledge between men and women about *Caryocar coriaceum* Wittm.

The comparative analysis of knowledge of *C. coriaceum*, according to gender, indicated a significant difference, suggesting that men know more forms of use than women (Table 5, 6 and 7).

Table 5. Measurements of knowledge distribution of *Caryocar coriaceum* Wittm. between men and women, considering the total number of use citations, in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Use categories	9
Total of informants	27
Total of citations	375
Gender	**Mean**
Men	17.00[a]
Women	11.40[b]

Means followed by different letters in the columns differ from each other by the T-test ($p<0.05$).

Table 6. Measurements of knowledge distribution of *Caryocar coriaceum* Wittm., between men and women, considering the number of use citations per category, in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Use categories	5	
Total number of informants	27	
Total citations	334	
Categories	**Mean**	
	Men	**Women**
Food	2.75[a]	3.27[a]
Medicinal	2.00[a]	2.13[a]
Fodder	2.25[a]	1.57[a]
Construction	4.58[a]	2.36[b]
Technology	4.09[a]	1.89[b]

Means followed by different letters in the lines differ from each other by the T-test ($p<0.05$).

Table 7. Measurements of knowledge distribution of *Caryocar coriaceum* Wittm., between men and women, according to the IDV and IEV, in rural communities in the region of the Sete Cidades National Park – PNSC (Piauí, Brazil).

Informants	27
Use citations	375
Use categories	9
Informant Diversity Value (IDV)	**Mean**
Total IDV	0.037
Total IDV for women	0.030
Total IDV for men	0.045
Informant Equitability Value (IEV)	**Mean**
Total IEV	0.537
Total IEV for women	0.441
Total IEV for men	0.657

Discussion

Knowledge and use of *Caryocar coriaceum* Wittm.

The Use Diversity Value (UDV) of *C. coriaceum* in the food category (UDVFood = 0.224) stood out as the highest in our study, even surpassing the value found by Sousa-Júnior *et al*. (2013), who recorded a UDVFood of 0.213. This category includes both the fruit (pulp) and the seed (nut) of *C. coriaceum*. The pulp was identified as the most frequently mentioned part, reflecting the results of Sousa-Júnior *et al*. (2013), and is consumed in various ways, both raw and cooked. It can be combined with other foods, such as flour, rapadura/sugar, beans, rice, or meat, and is also widely used in sweet preparations, such as cakes and pizza dough, a use also supported by Coradin *et al*. (2018). The seed, or *pequi* nut, is enjoyed roasted or incorporated into "farofas" and cakes. The oil extracted from the pulp, considered the most economically and socially significant product, is particularly valued for its milder flavor and aroma, attributes linked to its lauric oil content, in contrast to the oleic oil found in the pulp, as noted by both Coradin *et al*. (2018) and Sousa-Júnior *et al*. (2013). These comparisons emphasize the importance of *C. coriaceum* in the diet and economy of the studied communities.

In the construction category, *C. coriaceum* had a UDV of 0.216, which is significantly higher than the 0.075 reported by Sousa-Júnior *et al*. (2013). This elevated value underscores the wood's widespread use in building structures such as fences (stakes, posts, gates) and houses (rafters, beams, windows, doors). This usage aligns with the findings of Jenrich (1989) and Oliveira (2008), who also highlighted its application in carpentry, particularly for fence posts and rural construction. While Fonseca-Filho *et al*. (2016) noted that *C. coriaceum* is indeed used for timber, they observed that it is not among the most preferred species for this purpose. Additionally, an ethnobotanical study in northeastern Brazil recorded its use in cosmetics (Pereira *et al*., 2016), classifying it under the technology category and non-timber uses. Meireles (2012) further expanded on its utility by noting that the wood is also employed in boat construction by local fishermen, reinforcing its importance within the construction category.

In the medicinal category, *C. coriaceum* had a UDV of 0.152, the fourth highest value, although Sousa-Júnior *et al*. (2013) reported a slightly higher UDV of 0.181. Their study also included categories such as "derivatives" and "trade," highlighting *pequi* oil as significant for both food and medicinal uses. Previous research (Jenrich, 1989; Souza and Felfili, 2006; Agra *et al*., 2007; Oliveira *et al*., 2007; Lorenzi and Matos, 2008; Oliveira, 2008; Conceição *et al*., 2011; Sousa-Júnior *et al*., 2013; Ribeiro *et al*., 2014; Saraiva *et al*., 2015) confirms the medicinal use of *C. coriaceum*. While most medicinal uses reported in our study align with these findings, treatments for bronchitis, rheumatism, and other conditions documented elsewhere were not observed. *Pequi* oil, used both orally and topically, is the main medicinal application. Although our study did not record the use of fruit peel or stem bark for antipyretic or diuretic infusions, one informant mentioned a liquid extracted from the raw endocarp for flu. Pre-clinical trials support the medicinal value of *pequi* oil, highlighting its gastroprotective, anti-inflammatory, and antioxidant properties (Penha, 2007; Quirino *et al*., 2009; Batista *et al*., 2020; Oliveira *et al*., 2010; Saraiva *et al*., 2011a; Oliveira *et al*., 2015; Leite *et al*., 2009; Figueiredo *et al*., 2016). Additionally, extracts from the fruit peel and plant show potential against various pathogens (Alves *et al*., 2017; Lacerda-Neto *et al*., 2018; Costa *et al*., 2011; Saraiva *et al*., 2011b).

The fodder category in our study showed a UDV of 0.133, a significant increase compared to the 0.024 reported by Sousa-Júnior *et al*. (2013). The most frequently cited parts of *C. coriaceum* for animal feed were the epicarp, mesocarp, and endocarp of the fruit, with some informants also mentioning the use of flowers and "borra" (oil residue) to feed pigs, goats, cattle, and chickens. This use of *C. coriaceum* as fodder is supported by previous studies (Oliveira, 2008; Oliveira *et al*., 2008; Coradin *et al*., 2018), which similarly emphasize its importance in traditional animal husbandry practices.

Additionally, our study revealed gender-based differences in knowledge about *C. coriaceum,* particularly in the construction and technology categories. Men, for example, demonstrated broader knowledge in these areas, an observation consistent with Sousa-Júnior *et al*. (2013), who also reported that men have greater familiarity with timber uses. This highlights a pattern seen in various studies where men tend to have more knowledge of timber and construction-related applications (Sousa-Júnior *et al*., 2013).

Furthermore, the diversity and equitability values among informants suggested that men possess a wider range of knowledge about *C. coriaceum*, indicating an uneven distribution of knowledge. This contrasts with the findings of Sousa-Júnior *et al*. (2013), where knowledge distribution appeared more balanced among informants. These comparisons underscore the complexity of local ecological knowledge, which varies not only across use categories but also by gender, reinforcing the importance of considering social dynamics in ethnobotanical studies.

Management of *Caryocar coriaceum* Wittm.

In our study on the management of *C. coriaceum*, the practices of collection and protection were predominant, with 27 informants involved in collection and 8 in protection. These findings are consistent with Sousa-Júnior *et al*. (2013), who also identified collection and protection as the primary management strategies. However, a notable difference emerged in the practice of sowing. While Sousa-Júnior *et al*. (2013) found sowing or planting to be the third most cited form of management, it was less prominent in our study. This disparity may be attributed to the informants' indication that *C. coriaceum* rarely grows when planted, suggesting both a lack of knowledge about proper planting techniques and insufficient incentives to cultivate the species.

One key challenge in the propagation of *C. coriaceum* is the slow germination of its seeds, which can take approximately a year due to endogenous dormancy (Silva & Medeiros-Filho, 2006; Sobral *et al*., 2017; Almeida-Bezerra *et al*., 2022). This biological constraint further complicates efforts to encourage sowing, as it requires long-term commitment and specialized understanding of germination processes. Thus, while collection remains the most accessible form of management, the

underutilization of planting as a strategy highlights an area where future conservation efforts could focus on enhancing local knowledge and providing resources for effective cultivation. By addressing these gaps, it may be possible to foster greater sustainability in the management of *C. coriaceum.*

The threat to *C. coriaceum* is intensified by a combination of factors, including increased extractivism, a decline in animal species like the agouti that help disperse seeds, deforestation, and frequent fires in the Cerrado. This growing anthropogenic pressure is particularly alarming given the high demand for *C. coriaceum* fruits, which are prized both in regional cuisine and traditional medicine. Without proper regulation and control over extractivism, the species could face a significant decline.

Our findings echo concerns raised in previous studies (Bezerra *et al*., 2020; Peres *et al*., 2003), which highlight the low recruitment of seedlings due to extractive pressure and a diminished availability of diaspores. This issue is especially troubling in ecosystems where *C. coriaceum* already has low frequency and a restricted distribution. In comparison, Peres *et al*. (2003) also emphasized the risks posed by habitat fragmentation and defaunation, which further reduce seed dispersal.

The combined impact of these factors underscores the urgent need for sustainable management practices that go beyond immediate extractive benefits, focusing instead on the long-term survival of the species. Measures such as regulating harvest levels and restoring habitats may be essential to counteract the growing threats to *C. coriaceum* and ensure its continued presence in the ecosystem.

To prevent local extinction, it is necessary to reduce the number of fruits collected to allow for species propagation and to consider regenerating populations in deforested areas. Additionally, developing public policies aimed at protecting pollinating and dispersing animals could be crucial for maintaining the species (Almeida-Bezerra *et al*., 2022). Animals such as birds and bats are pollinators, while the agouti and beetles from the Scarabaeidae family act as dispersers, aiding seed germination. Unfortunately, these arthropods are vulnerable to climate change and habitat loss, and the agouti is also hunted locally (Azevedo *et al*., 2011; Sousa-Júnior *et al*., 2015; Santos *et al*., 2016; Albuquerque *et al*., 2018).

Collection and post-collection of *Caryocar coriaceum* Wittm.

Pequi oil commands a higher price due to its role as a form of profit storage, as it can be preserved for extended periods, unlike the fruit, which is highly perishable (Pereira *et al*., 2014). This long shelf life makes *pequi* oil particularly valuable during the off-season when its commercial value surpasses that of the fruit itself (Oliveira *et al*., 2009). The oil's ability to be stored and sold throughout the year offers producers a more stable income stream compared to the seasonal and short-lived sales of fresh fruit.

In our study, the average oil production per interviewee was 9 liters in 2018, resulting in a collective total of 99 liters. Unlike the spontaneous sales of fresh fruit, oil transactions tend to be more structured, as consumers often contact producers directly to inquire about availability. Once an order is placed, customers either pick up their oil in person or request home delivery, underscoring the personalized and on-demand nature of *pequi* oil sales.

This pattern reflects broader findings by Oliveira *et al*. (2009) and Pereira *et al*. (2014), who noted the higher demand for *pequi* oil during periods of fruit scarcity. The ability to store and distribute the oil over time provides an economic buffer for producers, highlighting its importance as a culinary and medicinal product, it becomes vital for the livelihood of rural communities.

Pereira *et al*. (2014), in their analysis of *C. coriaceum* extractivism in the Chapada do Araripe, found that 44% of *pequi* extraction is used for oil production, which is the main process carried out in the communities. Similarly, our research observed a high demand for *pequi* oil, and group work is common during both the collection and production phases to meet this demand. The oil produced is divided among the group members, highlighting the communal nature of the activity.

Although selling *pequi* oil is more profitable than selling the fruit, supplementing family income, the production process is arduous. Producers (73%) reported that the smoke and high temperatures during fruit cooking damage their health, and 36% mentioned developing bursitis due to the physical effort involved in oil production. These health issues related to the strenuous work in *pequi* oil production align with findings from other studies on extractivists of açaí (Canto, 2001), *pequi* in the Flona Araripe-Apodi (Augusto and Góes, 2007), Brazil nut (Silva-Jean *et al*., 2016), and fava d'anta (Dimorphandra gardneriana) (Alcantara *et al*., 2020).

Despite being viewed as a practice that helps reduce poverty in remote areas and promotes forest conservation (Veiga *et al*., 2017), combining socio-economic development with low environmental impact (Brites and Morsello, 2016), extractivism of non-timber forest products (NTFPs) is still classified as an informal activity, lacking institutional support and labor legislation. This lack of formal support does not ensure rights or assistance to the communities dependent on these resources.

In addition to issues in the oil production process, other difficulties were observed, including a lack of financial support, protective equipment, and appropriate collection tools, group disorganization, and a lack of incentives to formalize and expand the activity. These challenges underscore the precarious nature of the production chain, even given the high demand and economic potential of *pequi* oil.

Conclusion

The multifaceted uses of *C. coriaceum* highlight its integral role in the daily lives and economies of the rural communities in the PNSC region. Beyond merely cataloging its applications and economic value, this study underscores the complex interplay between traditional knowledge and contemporary conservation challenges.

The extensive knowledge about *C. coriaceum* across various domains, ranging from food to construction and medicine, demonstrates the species' deep-rooted cultural significance. However, the evident gender-based disparities in knowledge, particularly in the construction and technology categories, point to a nuanced understanding of how different community members interact with and utilize the species. This disparity calls for more inclusive approaches in knowledge sharing and education, ensuring that all community members have equal opportunities to learn about and benefit from the species' diverse uses.

The management practices observed, with a predominant focus on collection and protection, reveal a critical gap in the sustainable cultivation and regeneration of *C. coriaceum*. The challenges faced in planting and propagating the species indicate a need for enhanced training and resources to support effective cultivation practices. Given the slow germination and high demand pressures, immediate attention must be directed towards developing and implementing sustainable harvesting strategies and conservation measures.

To effectively conserve *C. coriaceum* and ensure its continued availability for future generations, a multi-pronged approach is required. This includes integrating ecological research to monitor and model the species' population dynamics, expanding conservation areas, and fostering community involvement in sustainable practices. Enhanced environmental education and the development of supportive policies will be vital in bridging the gap between traditional knowledge and modern conservation needs.

In summary, while *C. coriaceum* remains a vital resource for local communities, the path forward must involve a balanced approach that respects traditional practices while addressing contemporary ecological and economic challenges. Emphasizing community education, sustainable management, and ecological research will pave the way for preserving this specie for the long term.

Declarations

Ethics approval and consent to participate: We have previously informed consent, as detailed in the manuscript.
Conflict of interests: The authors declare no conflicts of interest.
Author Contributions: RSO, RFPL: conceptualization of the study, RSO, RFPL, AC, ASS, CML: writing – original draft preparation, ASS, CML, AC: writing – review and editing.

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