Review Article
Food Science and Technology
ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
DOI: https://doi.org/10.5327/fst.00389

Pequi fruit: nutritional properties, sustainable potential, and derived products

Julio Cesar Colivet BRICENO[1,2*], Dennia Pires de Amorim TRINDADE[1], Julião PEREIRA[1], Bruna Melo MIRANDA[3], Alessandra Lopes de OLIVEIRA[4], Tatianne Ferreira de OLIVEIRA[1], Flávio Alves da SILVA[1]

Abstract

The pequi fruit, endemic to the Brazilian Cerrado, has been historically valued in gastronomy and traditional medicine, yet its full potential remains underexplored. This article emphasizes the importance of sustainable practices for leveraging pequi's benefits, particularly in the food sector, while preserving biodiversity and traditional knowledge. The study highlights the challenges of deforestation and poor management in the Cerrado, advocating for agroecosystems and sustainable harvesting to protect both the pequi and its ecosystem. Local awareness, education, and policies like the Minimum Price Guarantee Policy (PGPM-Bio) are essential for conservation and economic growth. The pequi fruit, significant in culinary uses, biodiesel production, and medicine, faces hurdles like market informality and the need for state intervention to formalize the market. Sustainable exploitation of pequi offers prospects for the Cerrado, promoting biodiversity conservation, income generation, and socioeconomic development. The study underscores the necessity of integrating sustainable practices, traditional knowledge, and conservation policies to ensure the future of the pequi fruit and the Cerrado biome. Conscious government initiatives are vital to safeguarding these resources, highlighting the broader implications for environmental and economic sustainability in the region.

Keywords: sustainable practices; cerrado biodiversity; traditional knowledge.

Practical Application: Pequi is a key for food, cultural, environmental, and economic treasure in Cerrado.

1 INTRODUCTION

1.1 Pequi context in the cerrado

The Cerrado, an expansive savanna covering around 2 million square kilometers, represents the largest savanna ecosystem in South America, constituting approximately 22% of the total land area of Brazil (Figure 1) (Damasco et al., 2018). The examined geographic region displays a wide range of savanna vegetation types, including riparian forests, gallery forests, woody savannas, and grasslands (Guilherme et al., 2022). The Cerrado region encompasses a significant expanse of land, extending from the northern sector of Maranhão state to the southern area of Mato Grosso do Sul. In the present perspective, it is pertinent to acknowledge the pequi tree (*Caryocar brasiliense*) as a notable species within the region. The pequi tree is distributed in different parts of the Cerrado biome, including densely populated areas with fewer populations. It is prevalent in locations characterized by deep soils with a high siliceous clay content. The pequi tree shows excellent growth in subtropical or tropical environments with reduced rainfall. The cultivation of the pequi tree is primarily focused on the production of its fruit, known as pequi (de Oliveira et al., 2008). The pulp of this fruit holds significant importance in the culinary traditions of the Cerrado area (MMA, 2017). Pequi has incalculable commercial value due to its versatility of applications due to its composition of oil and fleshy pulp. This composition lends itself to a variety of uses, including preparing seasoning, producing liqueurs, manufacturing lubricants, and developing cosmetic items such as soaps, shampoos, and creams. Almonds are used in the preparation of various culinary dishes, including tamale-type cakes, conventional cakes, sauces, and in raw and roasted form (Torres et al., 2016). Furthermore, pequi has significant importance in traditional medicine due to its therapeutic properties in the treatment of respiratory diseases (Pereira et al., 2020).

Numerous families derive their income by engaging in the trade of fruits harvested from the fields. According to data from the Brazilian Institute of Geography and Statistics (IBGE) (Embrapa, 2021), the national pequi production exceeded 74 thousand tons in 2021, with the state of Minas Gerais taking the lead, responsible for over half of this total. Nevertheless, these figures have the potential for further growth, given that the majority of fruit commerce occurs within the informal market. Minas Gerais and Goiás emerge as the predominant

Received: 22 Aug., 2024.
Accepted: 18 Set., 2024.
[1]*Universidade Federal de Goiás, Goiânia, GO, Brazil.*
[2]*Instituto Federal de Educação, Ciência e Tecnologia de Goiás, Inhumas, GO, Brazil.*
[3]*Universidade Federal da Bahia, School of Nutrition, Department of Food Science, Salvador, BA, Brazil.*
[4]*Universidade de São Paulo, Faculdade de Zootecnia e Engenharia de Alimentos, Pirassununga, SP, Brazil.*
*Correspondence author: julio_colivet@ufg.br
Conflict of interest: nothing to declare.
Funding: National Council for Scientific and Technological Development and Fundação de Amparo à Pesquisa do Estado de Goiás.

pequi-producing regions in the country. In terms of sales and distribution, however, Ceasa Goiás (State Supply Centers) holds the forefront. In the year 2021 alone, this Goianian supply center received an impressive 7,191.84 thousand tons of pequi. The sales from the latest harvest contributed to a financial value exceeding $2 million. Notably, Ceasa trades a notably larger quantity of pequi than the amount extracted within the state. Among the 7,191.84 thousand tons sold in 2021, a mere 2,036.96 thousand tons hailed from Goiás (Goiás, 2022). This accentuates the paramountcy of Goiás as the primary consumer of the fruit and Ceasa/GO as the preeminent hub for pequi trade in Brazil. The pequi season takes off in September, with the inaugural shipment from Tocantins accounting for approximately 30% of the total product volume in the Goianian market.

Considering the socioeconomic and cultural importance of pequi. The aim of this review article is to explore opportunities to sustainably harness pequi, emphasizing its ability to provide advantages for both the industry and the local population by providing circular economy strategies, while contributing to the preservation of the Cerrado biome and the recognition of traditional practices.

2 METHODS

For the literature selection in this review, searches were conducted in scientific databases such as PubMed, Scopus, Web of Science, and Google Scholar. A purposeful selection of search terms, directly associated with pequi, sustainable utilization, Cerrado, and its diverse applications. The study incorporated a comprehensive review of scholarly articles published in international scientific journals, as well as dissertations, theses, and other pertinent papers. The inclusion criteria encompassed publications up until the period of investigation.

The criteria for inclusion that were utilized were as follows: (1) scholarly publications, including scientific papers, written in English or Portuguese, that have explored subjects pertaining to pequi and its sustainable application; (2) research investigations elucidating the nutritional, functional, and medicinal attributes of pequi, along with its prospective utilization in the realms of food and pharmaceuticals; (3) scholarly publications deliberating on the cultivation, harvesting, processing, and storage techniques pertaining to pequi, with an emphasis on sustainable methodologies; and (4) research endeavors investigating the cultural and economic implications of pequi for indigenous people within the Cerrado region.

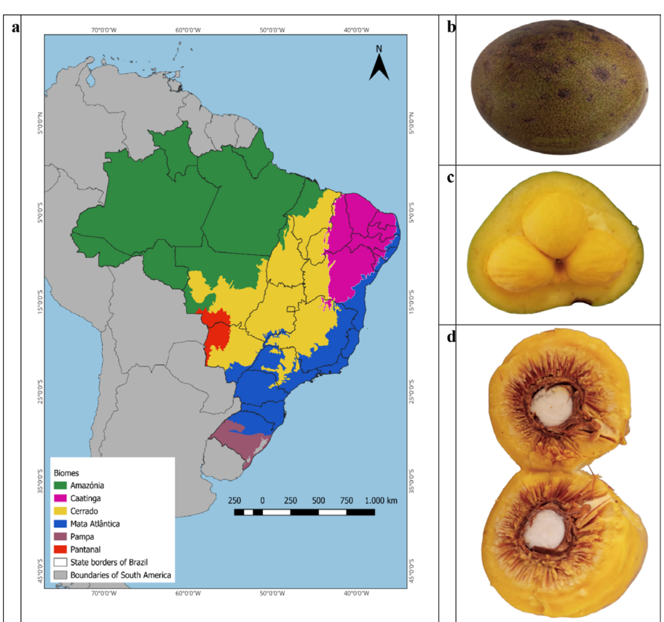

Figure 1. (a) Map of Brazil's biomes (IBGE, 2004). (b) Whole pequi fruit. (c) Internal structure of the pequi fruit. (d) Structure of the pequi seed.

3 BIBLIOMETRIC ANALYSIS

The analysis of the 317 publications about "pequi," focusing on the years from 2013 to 2023 (Figure 2), reveals a steady increase in interest and research about the fruit. The number of publications gradually rose, reaching a peak of 47 in 2022 before dropping to 15 in 2023. The diversity of areas covered in the publications suggests that "pequi" has been studied across various disciplines, providing a more comprehensive understanding of its benefits and applications.

In relation to the dataset regarding the volume of research publications centered around "pequi," categorized across various subject areas, it offers intriguing insights into the dissemination of scholarly interest (Table 1). Predominantly, these publications are concentrated within the realm of Agricultural and Biological Sciences, accounting for a substantial 28% of the total corpus, indicative of a profound emphasis on understanding the botanical and ecological facets of the "pequi" fruit. An equal enthusiasm for the chemical and molecular aspects of "pequi" is reflected in the sizeable representation of chemistry and biochemistry, genetics, and molecular biology, contributing 10 and 7%, respectively. This dedication underscores a pronounced inclination toward comprehending its genetic traits and chemical composition, potentially opening avenues in domains such as nutraceuticals, pharmaceuticals, and food sciences. The intersection of research in chemical engineering (6%) underscores its industrial potential and processing possibilities, signifying its relevance in varied product development processes. Likewise, the presence of research within medicine (5%) and pharmacology, toxicology, and pharmaceutics (also 5%) signifies an exploration into the therapeutic potential and pharmaceutical attributes of "pequi."

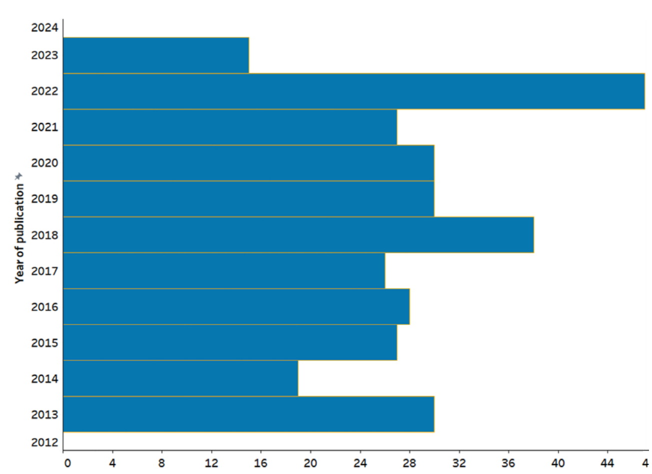

Figure 2. Publication trends per year related to pequi (research done in the Scopus database during August 2023 using the term "pequi" in the topic).

Table 1. Publication areas, organizations, and countries that have published the most.

Ranking	Name	Number	Percentage (%)
	Countries		
1	Brazil	306	85.71
2	United States	11	3.08
3	United Kingdom	5	1.40
4	France	4	1.12
5	Portugal	4	1.12
6	Australia	3	0.84
7	Canada	3	0.84
8	Italy	3	0.84
9	Cuba	2	0.56
10	Saudi Arabia	2	0.56
11	Other countries	14	3.92
	Organizations		
1	Universidade Federal de Minas Gerais	58	7.64
2	Universidade Federal de Goiás	53	6.98
3	Universidade Federal de Viçosa	47	6.19
4	Universidade de Brasília	39	5.14
5	Universidade Federal de Lavras	35	4.61
6	Universidade de São Paulo	33	4.35
7	Universidade Estadual de Campinas	26	3.43
8	Universidade Federal do Ceará	24	3.16
9	Universidade Federal dos Vales do Jequitinhonha e Mucuri	21	2.77
10	Universidade Estadual Paulista Júlio de Mesquita Filho	19	2.50
11	Other institutions	404	53.23
	Publications areas		
1	Agricultural and biological sciences	178	28
2	Chemistry	61	10
3	Biochemistry, genetics, and molecular biology	47	7
4	Chemical engineering	38	6
5	Medicine	31	5
6	Pharmacology, toxicology, and pharmaceutics	31	5
7	Engineering	23	4
8	Environmental science	22	4
9	Veterinary	19	3
10	Physics and astronomy	15	2
11	Other subareas	88	14

The dimensions of engineering (4%) and environmental science (4%) underscore the conscientious exploration of the sustainable applications of “pequi” and its ecological implications. Similarly, the foray into veterinary research (3%) points to its potential impact on animal health, possibly extending to areas such as livestock nutrition or veterinary medicine. Considering the global perspective, the distribution of publications across countries underscores Brazil’s predominant role (85.71%), where “pequi” holds cultural and ecological significance. Concurrently, international interest from the United States (3.08%), the United Kingdom (1.40%), France (1.12%), and Portugal (1.12%) is evident, indicating cross-border collaborations, trade-related research, or participation in international scientific networks.

Institutions within Brazil notably contribute extensively, with Universidade Federal de Minas Gerais (7.64%), Universidade Federal de Goiás (6.98%), and Universidade Federal de Vicosa (6.19%) emerging as leading contributors. This substantial involvement underscores the local commitment to researching the diverse dimensions of “pequi.”

The inclusive engagement of varied institutions and countries demonstrates the fruit’s significance across diverse scientific disciplines, fostering comprehensive exploration into its intrinsic attributes, potential applications, and cross-disciplinary contributions. The substantial number of publications emanating from other institutions (53.23%) signifies an overarching curiosity and engagement that extends beyond the primary contributors.

4 CHARACTERISTICS AND COMPOSITION OF PEQUI: EXPLORING ITS TRAITS AND MAKEUP

4.1 Nutritional profile

Pequi (*C. brasiliense*) boasts an interesting and diverse nutritional profile, serving as a rich source of nutrients and bioactive compounds (de Santana Magalhães et al., 2019). The edible part of pequi, its pulp and almond, carries a high content of lipids, primarily monounsaturated and saturated fatty acids (Cornelio-Santiago et al., 2022; Miranda-Vilela et al., 2009).

Additionally, it contains proteins, carbohydrates, fibers, and minerals such as calcium, magnesium, phosphorus, iron, zinc, and potassium (Table 2).

One of the nutritional highlights of pequi is its high content of carotenoids, such as beta-carotene, a precursor to vitamin A, giving the characteristic yellow-orange color to its pulp (Pinto et al., 2018). Pequi is also known to contain antioxidant compounds like phenolic compounds, quercetin, epicatechin, chlorogenic acid (Brito et al., 2022), and tocopherols and tocotrienols (Ketenoglu et al., 2020), which work to neutralize free radicals and contribute to the prevention of chronic diseases. On the contrary, it is important to mention that pequi is a calorie-dense food due to its high lipid content. Therefore, its consumption should be moderate, especially for individuals who need to manage calorie intake. However, some authors highlighted that replacing lard with pequi oil in a Western diet prevented the accumulation of visceral fat and contributed to reducing inflammation in adipose tissue and oxidative stress in the liver, improving obesity-related insulin resistance (Moreno et al., 2024). Beyond its nutritional profile, pequi also exhibits functional and medicinal properties.

4.2 Volatile organic compounds of pequi

Due to its aromatic properties, pequi is used to enhance the flavor of many culinary preparations. Maia et al. (2008) demonstrated that the olfactory characteristics of pequi are mainly characterized by the presence of ethyl esters, saturated fatty acids, and long-chain hydrocarbons. The primary component identified in pequi is ethyl hexanoate, constituting 52.9% of the total composition. Subsequently, smaller amounts of ethyl octanoate (4.6%), tetrahydrofurfuryl alcohol (4.3%), ethyl butanoate (4.1%), butyl palmitate (3.7%), isobutyl isobutyrate (2.6%), and 3-methylvaleric acid (2.6%) were also detected. In relation to fatty acids, C-8 (caprylic acid and ethyl octanoate) to C-18 (e.g., stearyl acetate and isobutyl isobutyrate) can contribute to aromatic properties. Furthermore, Belo et al. (2013) observed that there are variations in the composition of volatile organic compounds (VOCs) among pequi fruit, depending on the growing region and the type of tree. In total, 77 volatile compounds were identified, including esters, hydrocarbons, terpenoids, ketones, lactones, and alcohols. The total amount of volatile compounds and their individual levels varied between plants, allowing their classification. Regarding the pequi pericarp, Santos et al. (2020) identified that most volatile compounds were terpenes (65.71%) and esters (14.29%). In total, 35 VOCs were identified in pequi pericarp. The predominant compounds were pentyl octanoate, 2-ethylhexyl salicylate, and 1,8-dimethyl-8,9-epoxy-4-isopropyl-spiro[4,5]decan-7-one. Hexyl salicylic acid and (E)-3-methyl-4-(1,3,3-trimethyl-7-oxabicyclo[4.1.0]heptan-2-yl)but-3-en-2-one have also been identified in significant amounts.

4.3 FUNCTIONAL AND MEDICINAL PROPERTIES

C. brasiliense is used traditionally to treat tummy troubles and the flu. Leaves and flowers of *C. brasiliense* are used as an energy booster, tonic, aphrodisiac, and for liver problems (de Oliveira et al., 2018). The pequi fruit has many helpful properties like fighting off bad stuff in the body, stopping cancer (Silva, J. N. B. et al. (2022), easing swelling (Miranda-Vilela et al., 2009), and killing (Almeida-Bezerra et al., 2022; Alves et al., 2017).

The pequi fruit is a drupe. It can be up to 10 cm. It is heavy, about 104 g on average. Inside, there are usually one to five seeds, each weighing around 14.2 g (Correa et al., 2008; Mariano-da-Silva et al., 2009). The seeds are covered by a woody endocarp that has spines on the outside, completely surrounded by a yellow, fleshy layer (Figure 1d). The pulp stands out for its high lipid content, of which around 60% is represented by unsaturated fatty acids. The almond portion is characterized by a high concentration of monounsaturated fatty acids, mainly oleic acid (Carneiro et al., 2023; Paula de Almeida et al. (2022).

Additionally, other parts of the plant exhibit nutraceutical and medicinal properties that have potential for utilization in the functional food and pharmaceutical industries (Table 3). Overall, various parts of the plant are subject to extractions using different solvents and, in some cases, transformed into different products for use in the pharmaceutical and food industries.

Table 2. Nutritional profile of pequi (*Caryocar brasiliense*).

Nutrient	Quantity (/100 g)	Bibliography
Calories	185 kcal	Paula de Almeida et al. (2022); TBCA (2023).
Carbohydrates	4–13 g	Carneiro et al. (2023); TBCA (2023)
Proteins	2–3 g	Paula de Almeida et al. (2022); Santos et al. (2010); TBCA (2023)
Total fat	18–28 g	Paula de Almeida et al. (2022); Santos et al. (2010); TBCA (2023)
Saturated fats	3–8 g	Paula de Almeida et al. (2022);
Monounsaturated fats	12 g	Paula de Almeida et al. (2022)
Polyunsaturated fats	5 g	Paula de Almeida et al. (2022)
Fiber	9–19 g	Carneiro et al. (2023); Paula de Almeida et al. (2022); TBCA (2023).
Calcium	38–173 mg	Ramos and Souza (2011); TBCA (2023).
Magnesium	38–147 mg	Ramos and Souza (2011); TBCA (2023).
Phosphorus	63–106 mg	Ramos and Souza (2011); TBCA (2023).
Iron	0.6–3.6 mg	Ramos and Souza (2011); TBCA (2023).
Zinc	1–2.29 mg	Ramos and Souza (2011); TBCA (2023).
Potassium	167–554 mg	Ramos and Souza (2011); TBCA (2023).
Vitamin A (β-carotene)	58 µg	TBCA (2023)

These products can possess functional activity, including against cancerous cells. Ombredane et al. (2022) demonstrated that nanoemulsions developed from pequi pulp oil exhibited activity against the proliferation of malignant cells and organelles involved in the production of various diseases.

5 TRADITIONAL UTILIZATION OF PEQUI

According to Nascimento et al. (2016), the principal output obtained from pequi is its pulp, which is located in the inner mesocarp and is connected to the pit. The primary use of this pulp is observed within regional gastronomy, specifically in

Table 3. Bioactive compounds present in the pequi fruit.

Plant part	Functional properties	Bioactive compounds	Concentration	Bibliography
Peel	Antimicrobial and antiparasitic activity.	Total phenolics Flavonoids Rutin Isoquercetin	56 mg/g 3.8 mg/g 4.1 mg/g 129.2 mg/g	Alves et al. (2017)
Pulp	Antimicrobial activity against bacteria and fungi	Phenolic compounds and flavonoids	11.26 mg/g 5.98 mg/g	Almeida-Bezerra et al. (2023)
Pulp	Antimicrobial and antiparasitic activity.	Total phenolics Flavonoids Rutin Quercetin Isoquercetin.	24.5 mg /g 1.3 mg/g 5.02 mg/g 1.96 mg/g 47.62 mg/g	Alves et al. (2017)
Pulp	Antioxidant activity	Gallic acid Cathechins Chologenic acid	2.64 mg/g 2.14 mg/g 0.15 mg/g	Guimarães et al. (2023)
Pulp	Antioxidant activity	Poliphenols Carotenoids Ascorbic acid	1.65 mg/g 0.64 mg/g 0.39 mg/g	Pinto et al. (2022)
Oil extracted from the pulp	Anti-inflammatory activity and blood pressure reduction	Oleic acid Palmitic acid	0.54 g/g 0.42 g/g	Miranda-Vilela et al. (2009)
Peel	Anticancer and antioxidant activity	Chiquimic acid Gallic acid Myo-inositol Sarotrin	0.37 g/g 0.05 g/g 0.04 g/g 0.03 g/g	Silva, J. N. B. et al. (2022)
Leaves and skin	Antifungic activity	Gallic acid Quinic acid Elagic acid	Qualitative analysis using mass spectrometry	Breda et al. (2016)
Leaves and skin	Neuroprotective activity Antioxidant activity	Gallic acid	1.2–4 mg/mL	De Oliveira et al. (2018)
Nanoencapsulated pulp oil	Anti-arthritic activity	Oleic acid Palmitic acid	0.72 g/g 0.28 g/g	De Faro Silva et al. (2022)
Seed	Antioxidant activity	Phenolics compounds β-carotene	0.39 mg/g 0.89 mg/g	de Barros et al. (2021)
Pulp and seed	Antibacterial activity	Oleic acid Palmitic acid	0.48–0.72 mg/g 0.28–0.46 mg/g	Pereira et al. (2020)

the states of Minas Gerais, Goiás, Mato Grosso, Mato Grosso do Sul, and the Federal District. The pulp is noteworthy due to its inclusion of oils utilized as flavorings in the manufacturing of alcoholic beverages, in the lubricant sector, and in cosmetics (including soap, shampoo, and lotions). Additionally, it holds significance in folk traditions for its purported effectiveness in resolving respiratory ailments. Table 4 displays a selection of culinary items that are derived from the pequi fruit.

The high concentration of monounsaturated fatty acid is of interest for applications in the food, cosmetic, and oleochemical industries. Additionally, pequi oil contains about 35% palmitic acid (C16:0), making it suitable for applications in margarines and vegetable fats (Guedes et al., 2017). Both fatty acids can influence the physical stability of the oil in tropical regions. Pequi oil is regularly marketed in the Brazilian Cerrado region through specialized stores offering Cerrado products or online shops. However, these products face the issue of tendency to fractionate during storage (Guedes et al., 2017). Another product of great relevance in the Brazilian market is pickled pequi. This product is obtained through heat treatment of the fruit in preheated water (blanching), followed by cooking at 80°C for periods of 25–35 min. After the heat treatment, the product is packaged using oil or vinegar as a covering liquid.

The act of consuming dried pequi nuts is often regarded as a gastronomic delicacy. A diverse range of purchasing alternatives for these items is offered, encompassing those seasoned with a spice combination as well as those that are just salted. It is noteworthy to highlight that these items exhibit a comparatively higher price point in relation to other possibilities that are now accessible. Among the most produced pequi-based foods, creams, which consist of a mixture of water and/or vinegar, pequi pulp, preservatives, and stabilizers are widely sold and used in the Cerrado region, which includes salads, burgers, and a variety of other culinary inventions.

Due to the functional properties of pequi, which include a high content of phenolics, carotenoids, tocopherols, and tocotrienols, several studies report that it can play a major role in mitigating oxidative stress and combating free radicals, which are implicated in several diseases. Pequi extracts and derivatives have been investigated for their potential to present anti-inflammatory (Coutinho et al., 2020), antimicrobial, and even anticancer properties (Silva, L. M. S. F. et al. (2022). In addition, capsules and supplements, which are marketed as sources of antioxidants and bioactive compounds. Among these products, gelatin capsules containing pequi extracts are sold in health food stores. Other products include pequi oil with anti-inflammatory properties, pequi-based syrups with anti-flu properties, and cosmetic products such as shampoos, massage ointments, and soaps.

5.1 Sustainable potentials of pequi utilization

5.1.1 Waste utilization

The use of pequi waste can also bring economic and environmental benefits. The waste recovery process aims to reduce waste and use all parts of the fruit, maximizing its value and minimizing

Table 4. Foods derived from pequi processing.

Part used	Product	Characteristics	Bibliography
Peel	Flour	High concentration of phenolic compounds, antioxidant activity, and bioaccessibility.	Santos et al. (2022).
Defatted pulp residue	Cookies	High protein content and low-calorie content.	De Sousa et al. 2021).
Pulp	Sauce	High stability during storage.	Souza et al. (2014).
Pulp	Fermented beverage like kefir	Distinct sensory attributes and high nutritional quality.	Gomes et al. (2020).
Pulp	Liqueur	High physicochemical and sensory qualities.	Leite et al. (2019).
Pulp	Flour	Flavoring ingredients with high sensory acceptability.	Santos et al. 2010).
Pulp	Flour	High nutritional potential due to its lipid content.	Silva, L. M. S. F. et al. (2022).
Pulp	Oil	Physicochemical parameters comparable to commercial oils.	Colares et al. (2021).
Almond	Cereal bar	Improvement in sensory evaluations as the concentration of pequi almonds increased.	Ramos et al. (2021).
Pulp	Sweet bread	Improvement in sensory evaluations as the concentration of pequi almonds increased.	Cunha et al. (2023).
Pulp	Cocoa butter equivalent	Improve the crystallization properties in binary mixtures with Kpangnan butter.	Ghazani et al. (2022).
Pulp	Dark chocolate with pequi	Improvement of nutritional properties and the content of phenolic compounds.	Lorenzo et al. (2022).

environmental impact. Pequi waste constitutes lignocellulosic materials (Ghesti et al., 2022), and its disposal represents a significant burden on the environment; pyrolysis is a safe alternative for these processes. Pyrolysis and gasification are thermal processes considered alternatives to incineration in waste management. Pyrolysis of food waste at temperatures between 400 and 800°C converts solid material into a liquid and/or gaseous product that can be used as fuel or raw material for subsequent industrial or chemical production (Gonçalves Martins et al., 2021). Pyrolysis allows the partial production of gaseous fuels, which are used to generate energy in engines and gas turbines, or as raw material for chemical production. Miranda et al. (2020) researched the potential of pequi seed residues as a sustainable source for combined heat and power generation using gasification technology. The study evaluated the characteristics of pequi seeds, derived charcoal, and bio-oil obtained by slow pyrolysis conversion. According to the authors, the results demonstrated that the slow pyrolysis of pequi seeds produced high-quality charcoal with up to 60% fixed carbon, bio-oil, and light gases. Gasification of high-carbon coal has resulted in a gas that is virtually tar-free, making it suitable for heat engine applications.

Pequi waste, such as peels and seeds, can be composted to produce an organic fertilizer rich in nutrients. Silva et al. (2018) investigated the effect of organic compounds derived from pequi residues on the control of the nematode *Meloidogyne javanica* in okra plants. The biofertilizer was formulated by mixing cattle manure, sugarcane straw, and pequi peel in a 1:1:1 ratio and tested on okra seedlings. According to the authors, the incorporation of pequi residues into the soil resulted in an increase in the dry mass of the aerial and root parts of the plants.

Regarding obtaining ingredients with potential use in the pharmaceutical and food industry, Leão et al. (2018) obtained pequi peel extraction yields of 10–20% using processing techniques that included microwave-assisted heating. The pectins obtained exhibited a high degree of esterification comparable to other commercially available pectins. In the same order of ideas, Siqueira et al. (2012) applied pectin extracted from pequi peels in the production of mango-based jelly with positive results in gelling characteristics and organoleptic properties.

Pequi residues can present a significant concentration of oil (around 10% m/m), it is a notable reservoir of antioxidant compounds with functional properties (Pegorin Brasil et al., 2022). The residual oil exhibits potential utility across several sectors, including but not limited to cosmetics, soaps, and the biofuel industry. The incorporation of these areas not only contributes to the economic value but also serves as a deterrent against improper disposal methods. Souza et al. (2019) assert that biodiesel has garnered considerable attention as a biofuel in several nations owing to its renewable and biodegradable attributes, which are firmly entrenched within the domains of the environment, society, and energy. Although biodiesel production through esterification and cracking routes shows potential, they still face challenges of technical and economic viability. It's emphasized that utilizing waste vegetable oils and fats for biofuel production is feasible but requires investment and workforce training to operate the proposed new plant. Thus, the study demonstrated that using pequi waste for biofuel production is possible when utilizing acid catalysts capable of reducing acidity and achieving high biofuel conversion. The fact that pequi's fatty material is an agro-industrial residue with suitable composition renders the entire process economically viable.

On the contrary, some parts of pequi, such as unused peels and pulps, can be utilized in animal feed, providing additional nutrients for locally raised animals. Cruvinel et al. (2023) determined the antioxidant protective effect of pequi oil against cyclic thermal stress in broiler chickens and highlighted the potential application as a promising additive in the feed for these animals. Oliveira et al. (2016) determined that the inclusion of pequi shell flour in the diet of Japanese quails affected the physicochemical characteristics of the eggs produced. According to the study, despite conventional diets showing similar results, the supplementation led to a significant increase in the content of carotenoids present in eggs. Furthermore, due to the presence of unsaturated fatty acids in the pequi fruit, it has beneficial effects on animal nutrition. In this context, Bezerra et al. (2020) evaluated the effects of supplementation with pequi oil and sunflower oil on physiological settings in nursery piglets. According to the authors, the results revealed that both pequi and sunflower oil produced specific results in terms of systemic inflammatory response. This was evidenced by a reduction in total leukocyte count and neutrophil/lymphocyte ratio. However, supplementation with pequi and sunflower oils also influenced the quality of weight gain and feed consumption of nursery pigs.

5.1.2 Socioeconomic, cultural, and sustainability aspects

Pequi plays a central role in the culture and economy of the Brazilian Cerrado, with community practices and traditions shaping the collection and use of the fruit. Silva and Tubaldini (2014) described that pequi extraction plays a crucial role as a source of income in the northern region of Minas Gerais, especially in the informal economy, as well as in supporting farmers in Minas Gerais and other regions, where regional events are held as the National Festival. The fruit is intrinsically intertwined with local music, poetry, legends, stories, art, and crafts. The cultivation of pequi in the northern region of Minas Gerais is of considerable importance, covering economic, culinary, cultural, and environmental aspects. The acquisition and use of pequi are subject to the effects of community dynamics, family connections, and geographic location, where the fruit is seen as a community resource and its use is shared collaboratively among farmers. However, the study also draws attention to many challenges, including the possible influence of capitalist pressures on traditional methods of harvesting and using pequi.

On the contrary, Souza and Lima (2019) reported that pequi plays a significant role in the food, cuisine, and local economy of the Cerrado. According to the authors, in the State of Mato Grosso, pequi tree cultivation is promoted as a strategy for economic development and conservation of the biome. Pequi extraction is practiced by rural communities as an economic alternative, contributing to the preservation of native areas and generating income for farming families. At the same time, due to the sociocultural importance of pequi in the Cerrado region, the Brazilian government promotes some government initiatives with the aim of promoting the cultivation and commercialization of pequi, which include the Price Guarantee Program for Family Farming (PGPAF) and the Food Acquisition Program

(PAA). The main objectives of these initiatives are to improve the general well-being of the population and facilitate the processing and commercialization of resources with the aim of preserving the commercial value of this type of food in the region and keeping the income of rural producers stable.

6 ENVIRONMENTAL AND CONSERVATION ISSUES

Unsustainable pequi harvesting can put pressure on the biodiversity of the Cerrado, leading to a decrease in the population of pequi trees and consequently the loss of species related to this ecosystem. According to Oliveira (2010), almost 50% of the Cerrado's vegetation has been degraded in the last four decades, mainly due to the expansion of pastures and large-scale agriculture, which represents a risk, with these activities being dangerous for essential water resources, as Cerrado rivers play a crucial role as tributaries of Brazil's main watercourses, such as the São Francisco, Tocantins, and Paraná. While large agricultural properties bring benefits, these gains are often concentrated among a few individuals, excluding the majority, especially those most dependent on the land, thus compromising their livelihoods.

The action of removing pequi trees to establish large-scale agricultural operations can have detrimental effects on the environment, including deforestation and degradation; these activities affect negatively the natural habitats of the Cerrado ecosystem. In this sense, the Brazilian government has implemented several protection measures and laws aimed at conserving the environment and its constituent species (Brasil, 2019). One of these actions is the restriction on the cutting of pequi trees, according to the ordinance in question, authorization for the removal of the pequi tree is limited to situations in which there is a need to plant new specimens or when there are no technical or locational alternatives. available for projects that require cutting down trees.

According to da Silva et al. (2020), currently, there are several initiatives that strengthen the production chain of pequi and other fruits in the Cerrado, although they have isolated impacts without changes in food production. The National Supply Company (CONAB) of the Brazilian government, located as a strategy "The policy of minimum prices, such as the Family Farming Price Guarantee Program (PGPAF)," which presents as a production strategy for producers to maintain native forests and contribute to sustainability. This policy includes a diverse range of 17 extractive products, including açaí, babaçu, Brazil nuts, pequi, and managed pirarucu, among others, which play a fundamental role in maintaining national biomes (CONAB, 2017). In addition to guaranteeing a minimum price for products from the cerrado's socio-biodiversity, the preservation of biomes and the reduction of deforestation are intrinsic goals, as the economic valorization of extractive products provides a direct incentive for the maintenance of the ecosystems from which they originate these resources. Promoting education and awareness could be adopted as valuable strategies in conserving these resources. In this sense, encouraging sustainable harvesting of pequi fruits and sustainable management practices, together with tree replanting, could play an important role in the natural regeneration of the ecosystem.

6.1 Preservation of traditional knowledge

According to Sobral et al. (2024), the decisions related to natural resource planning and management are more effective when Indigenous Peoples and local communities are included as stakeholders. Preserving traditional knowledge related to pequi plays a crucial role in conserving this valuable resource and maintaining the culture of local communities. Traditional knowledge about pequi covers a range of aspects, from cultivation, harvesting, and management techniques to medicinal, culinary, and uses associated with this plant. The transmission of this knowledge from generation to generation has been a fundamental practice in communities that rely on pequi for their subsistence and cultural identity. However, the advancement of modernization and the loss of contact with traditions can threaten the continuity of this knowledge. Therefore, preserving this traditional knowledge is vital not only for the conservation of pequi itself but also for the preservation of the rich cultural heritage of local communities.

In this sense, initiatives that aim to provide communities with technical knowledge for the production, use, and commercialization of traditional foods are important and can bring about a significant change in reality. Therefore, educational institutions (universities and research institutes) can play a fundamental role in this scenario, both in the dissemination and production of knowledge, with and for communities, and in supporting public policies aimed at this public (Borges et al., 2021).

6.2 Economic and market aspects

Pequi plays an important role in generating income for rural communities that depend on the harvest and sale of fruit, as well as small producers who produce products through the production of derivatives such as oils (Guedes et al., 2017) and pickles (Silva et al., 2021). Furthermore, the local and regional market is bolstered by the traditional consumption of pequi, driving the economy in areas where it is a fundamental part of culinary culture. In the market sphere, pequi is highly demanded in regional cuisine, imparting a distinctive flavor to many dishes. This domestic demand stimulates the creation of pequi-derived products such as oils, pulps, and seasonings, finding space in natural and gourmet food markets where the search for healthy and authentic options is growing. Moreover, the increasing interest in biome and biodiversity conservation further enhances the value of native products like pequi, driving a quest for sustainable harvesting and management practices.

According to CONAB (2022), the pequi fruit market extends across the states of Minas Gerais, Goiás, and Tocantins. Through bibliographic review, the aim is to comprehend the cultural and economic importance of pequi and investigate price fluctuations impacting the fruit market. Pequi, a symbol of Cerrado diversity, plays a crucial role in these regions in terms of cultural and socioeconomic value (Costa & Costa, 2023), creating employment opportunities and generating income in communities facing economic challenges. The pequi market presents price variations in different states in Brazil, with special emphasis on the states of Minas Gerais, Goiás, and São Paulo, which have significant consumer markets. Pequi experiences significant price variations at different times of the year (Cerqueira

& Gomes, 2021), which may be influenced by factors such as product availability, seasonality, and weather conditions. According to CONAB (2022), for the year 2020, pequi production reached approximately 63,520 tons and prices ranged from $0.1 to $0.37 per kg, and these fluctuations may occur depending on each harvest, due to adverse conditions, such as drought—which influences the flowering of the plant—and fires, and the seasonality of the pequi tree.

Government programs such as the Direct Subsidy to Extractive Producers (SDPE) and the Food Acquisition Program (PAA) play a significant role in the economies of pequi-producing regions. Extractivists, many of them located in areas with low HDI, access the SDPE, contributing to the improvement of their living conditions, and for 2020 the total amount subsidized was approximately $3.7 million of reais and 57.5 thousand tons. In relation to the PAA, approximately 26 thousand kilograms of pequi were purchased, with a total value of $17,500, with the average value received by the supplying producer being $0.65 per kg. In this sense, the pequi trade not only generates income but also promotes the appreciation of the Cerrado, stimulating the local economy (CONAB, 2022).

The international market also has potential, whether for Brazilian communities abroad or for markets looking for exotic and authentic ingredients. In this sense, although exports are still incipient, pequi has been exported to Asian and European markets (Alencar, 2023). However, to be able to place pequi on international markets, it could be necessary to obtain certifications of origin, quality seals, or even organic product labels that can add value to pequi products, enabling access to more demanding markets.

7 CONTRIBUTIONS TO SUSTAINABILITY IN THE FOOD INDUSTRY

7.1 Environmental and social benefits

Pequi offers a series of environmental and social benefits, playing an important role in the regions where it is found. In the environmental area, pequi stands out for conserving the Cerrado biome. Furthermore, it has ecological importance as a key component of Cerrado food chains. Its seeds and fruits serve as a food source for several animal species, including birds, mammals, and insects (Almeida & Silva, 1994). Preserving the pequi and its habitat is essential to maintaining the balance and health of Cerrado ecosystems (Buzin et al., 2009). From a social point of view, pequi plays a significant role in local communities. Fruit collection and processing generate employment and income for many families residing in regions with a low human development index. The fruit is an essential component of local cuisine, used in traditional dishes and festivities. Its presence in culinary and cultural traditions reinforces community identity and promotes the appreciation of local biodiversity. Therefore, the environmental and social benefits of pequi are intrinsically interconnected (Filippin dos Passos Santos, 2022).

7.2 Market potential and added value

Pequi has substantial market potential and the ability to add value in several areas. In the food market, pequi stands out as a unique ingredient, used in traditional cuisine in the Cerrado regions. Its fruits are used in various dishes, sauces, and seasonings, providing a distinct flavor and strong aroma. The growing demand for regional ingredients and the search for new culinary experiences have increased interest in pequi, providing opportunities for the creation of differentiated products with greater added value. Furthermore, pequi has potential in the cosmetics and personal care industry (Beraca, 2016). Its extracts and oils are rich in antioxidant compounds and nutrients beneficial for the skin and hair. In the health area, pequi has also demonstrated therapeutic and nutritional properties. Its bioactive components have been associated with benefits for cardiovascular health and anti-inflammatory and antioxidant effects (Torres et al., 2016). These characteristics aroused the interest of the food supplement industry and natural medicine, expanding the scope of the application of pequi beyond the culinary domain.

8 CONCLUSION

Pequi is more than a fruit native to the Brazilian Cerrado. It is a cultural, environmental, and economic treasure that challenges society to find a balance between its exploration and conservation. It is a valuable product from a nutritional, medicinal, and cosmetic point of view, and the waste generated during its processing can be used to generate energy and obtain natural ingredients for human and animal consumption.

The pequi tree plays a fundamental role in communities in the Brazilian Cerrado, contributing to the family economy and the economic livelihood of the population. Given this context, there are several challenges that surround the sustainable use of pequi, there is an urgency to adopt strategies that raise awareness about the importance of pequi for Cerrado communities. Education about responsible billing, appropriate management techniques, and the potential for added value provides a path to transforming current practices. The establishment of sustainable production chains and encouraging the development of pequi by-products enriches commercialization, benefiting local communities and the environment.

Joint action between governments, research institutions, nongovernmental organizations, the private sector, and local communities is vital to face the challenges and implement the outlined strategies. The preservation of traditional knowledge and scientific innovation must go hand in hand, offering better cultivation methods and technological solutions for the conservation and processing of pequi. The future of pequi in the Cerrado is intrinsically linked to the ability to recognize the importance of its conservation and to collaboratively face existing challenges.

ACKNOWLEDGMENTS

The authors extend their gratitude to the following institutions for their invaluable support through the Young Doctor Researchers' Support Scholarship Program in Brazil: National Council for Scientific and Technological Development—CNPq and Fundação de Amparo à Pesquisa do Estado de Goiás—FAPEG.

REFERENCES

Alencar, G. (2023). Japonvar exporta pequi para Japão e Europa. *Rede Gazeta de Comunicação*. Retrieved from https://gazetanm.com.br/japonvar-exporta-pequi-para-japao-e-europa/

Almeida, S. P. da, & Silva, J. A. (1994). Piqui e buriti: importância alimentar para a população dos cerrados. *Embrapa-Cpac*, 38.

Almeida-Bezerra, J. W., Bezerra, J. J. L., da Silva, V. B., Coutinho, H. D. M., da Costa, J. G. M., Cruz-Martins, N., Hano, C., de Menezes, S. A., Morais-Braga, M. F. B., & de Oliveira, A. F. M. (2022). Caryocar coriaceum Wittm. (Caryocaraceae): Botany, Ethnomedicinal Uses, Biological Activities, Phytochemistry, Extractivism and Conservation Needs. *Plants*, *11*(13), 1685. https://doi.org/10.3390/plants11131685

Almeida-Bezerra, J. W., Pereira da Cruz, R., Silva Pereira, R. L., Bezerra da Silva, V., de Oliveira Bezerra de Sousa, D., Da Silva Neto, J. X., Lopes de Souza, L. A., Salgueiro Araújo, N. M., Gomes Silva, R. G., Lucetti, D. L., Melo Coutinho, H. D., Bezerra Morais-Braga, M. F., & Morais de Oliveira, A. F. (2023). Caryocar coriaceum fruits as a potential alternative to Combat fungal and bacterial infections: In vitro evaluation of methanolic extracts. *Microbial Pathogenesis*, *181*, 106203. https://doi.org/10.1016/j.micpath.2023.106203

Alves, D. R., Maia De Morais, S., Tomiotto-Pellissier, F., Miranda-Sapla, M. M., Vasconcelos, F. R., Silva, I. N. G. Da, Araujo De Sousa, H., Assolini, J. P., Conchon-Costa, I., Pavanelli, W. R., & Freire, F. D. C. O. (2017). Flavonoid composition and biological activities of ethanol extracts of Caryocar coriaceum Wittm., a native plant from caatinga biome. *Evidence-Based Complementary and Alternative Medicine*, *2017*. https://doi.org/10.1155/2017/6834218

Belo, R. F. C., Augusti, R., Lopes, P. S. N., & Junqueira, R. G. (2013). Characterization and classification of pequi trees (Caryocar brasiliense Camb.) based on the profile of volatile constituents using headspace solid-phase microextraction - gas chromatography - mass spectrometry and multivariate analysis. *Food Science and Technology*, *33*(Suppl. 1), 116-124. https://doi.org/10.1590/S0101-20612013000500018

Beraca (2016). Beraca introduces natural pequi oil with antifrizz effect at in-cosmetics 2016. *Focus on Surfactants*, *2016*(5), 4. https://doi.org/10.1016/j.fos.2016.05.017

Bezerra, B. M. O., Parente, R. A., Andrade, T. S., Watanabe, P. H., Evangelista, J. N. B., & Nunes-Pinheiro, D. C. S. (2020). Suplementação com óleos ricos em ácidos graxos poli-insaturados na dieta de leitões na fase de creche: efeitos no desempenho, na resposta inflamatória, no perfil lipídico e no "status" oxidativo. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *72*(3), 1009-1016. https://doi.org/10.1590/1678-4162-11144

Borges, T. C., Olin Silva, P., de Andrade Cardoso Santiago, R., & Tronco Monego, E. (2021). Food and use of Cerrado fruits in quilombos of Goias. *Segurança Alimentar e Nutricional*, *28*, e021022. https://doi.org/86.57920/san.v28i00.8657920

Brasil (2019). *Portaria nº 32, de 23 de janeiro de 2019*.

Breda, C. A., Gasperini, A. M., Garcia, V. L., Monteiro, K. M., Bataglion, G. A., Eberlin, M. N., & Duarte, M. C. T. (2016). Phytochemical analysis and antifungal activity of extracts from leaves and fruit residues of Brazilian savanna plants aiming its use as safe fungicides. *Natural Products and Bioprospecting*, *6*(4), 195-204. https://doi.org/10.1007/s13659-016-0101-y

Brito, R. M., Barcia, M. T., Farias, C. A. A., Zambiazi, R. C., de Marchi, P. G. F., Fujimori, M., Honorio-França, A. C., França, E. L., & Pertuzatti, P. B. (2022). Bioactive compounds of pequi pulp and oil extracts modulate antioxidant activity and antiproliferative activity in cocultured blood mononuclear cells and breast cancer cells. *Food and Nutrition Research*, *66*, 1-13. https://doi.org/10.29219/fnr.v66.8282

Buzin, E. J. W. K., Parreira, I. M., & Figueiredo, R. S. (2009). Simulação da produção de pequi no território kalunga. *Enciclopédia Biosfera*, *5*(7), 1-25. Retrieved from https://conhecer.org.br/ojs/index.php/biosfera/article/view/4874

Carneiro, C. R., Alhaji, A. M., da Silva, C. A. S., de Sousa, R. de C. S., Monteiro, S., & Coimbra, J. S. dos R. (2023). Potential challenges of the extraction of carotenoids and fatty acids from pequi (Caryocar brasiliense) oil. *Foods*, *12*(9), 1907. https://doi.org/10.3390/foods12091907

Cerqueira, E. B., & Gomes, J. M. A. (2021). Operacionalização da política de preços mínimos para os produtos da sociobiodiversidade. *Multitemas*, *25*(61), 177-202. https://doi.org/10.20435/multi.v25i61.2718

Colares, L. M., Moreira, L. O., Dias, D. B., Ribeiro, G. A. C., Castilho, Q. G. da S., Nunes, V. L. N. D., & Moreira, L. R. de M. O. (2021). Avaliação química e microbiológica do óleo de Pequi (Caryocar brasiliense) comercializado em feira de São Luis - MA / Chemical and microbiological evaluation of Pequi oil (Caryocar brasiliense) marketed at São Luis fair - MA. *Brazilian Journal of Development*, *7*(9), 86836-86852. https://doi.org/10.34117/bjdv7n9-036

Companhia Nacional de Abastecimento (CONAB) (2017). *Política de Garantia de Preços Mínimos para os Produtos da Sociobiodiversidade (PGPM-Bio)*. Conab. Retrieved from https://www.conab.gov.br/precos-minimos/pgpm-bio

Companhia Nacional de Abastecimento (CONAB) (2022). *Boletim da Sociobiodiversidade*, *6*(1), 28-32.

Cornelio-Santiago, H. P., Bodini, R. B., Mazalli, M. R., Gonçalves, C. B., Rodrigues, C. E. C., & Lopes de Oliveira, A. (2022). Oil extraction from pequi (Caryocar brasiliensis Camb.) and sacha inchi (Plukenetia huayllabambana sp. Nov.) almonds by pressurized liquid with intermittent purge: The effects of variables on oil yield and composition. *Journal of Supercritical Fluids*, *182*, 105527. https://doi.org/10.1016/j.supflu.2022.105527

Correa, G. C., Naves, R. V, Rocha, M. R., Chaves, L. J., & Borges, J. D. (2008). Determinações físicas em frutos e sementes de baru (Dipteryx alata Vog.), cajuzinho (Anacardium othonianum Rizz.) e pequi (Caryocar brasiliense Camb.), visando melhoramento genético. *Bioscence Journal*, *24*(4), 42-47.

Costa, M. L. X., & Costa, M. D. (2023). Caracterização bioquímica e nutricional do pequi (Caryocar Brasiliense): uma breve revisão. *Revista Científica Rural*, *25*(1), 287-302. https://doi.org/10.29327/246831.25.1-19

Coutinho, D. de S., Pires, J., Gomes, H., Pohlmann, A. R., Guterres, S. S., E Silva, P. M. R., Martins, M. A., Ferrarini, S. R., & Bernardi, A. (2020). Pequi (Caryocar brasiliense cambess)-loaded nanoemulsion, orally delivered, modulates inflammation in lps-induced acute lung injury in mice. *Pharmaceutics*, *12*(11), 1075. https://doi.org/10.3390/pharmaceutics12111075

Cruvinel, J. M., Groff Urayama, P. M., Oura, C. Y., de Lima Krenchinski, F. K., dos Santos, T. S., de Souza, B. A., Kadri, S. M., Correa, C. R., Sartori, J. R., & Pezzato, A. C. (2023). Pequi oil (Caryocar brasiliense Camb.) attenuates the adverse effects of cyclical heat stress and modulates the oxidative stress-related genes in broiler chickens. *Animals*, *13*(12), 1896. https://doi.org/10.3390/ani13121896

Cunha, M. C., Terra, L. H., Campos e Sousa, P., Vilela, D. R., Oliveira, A. L., Silva, J. S., Simão, S. D., Pereira, J., Alves, J. G. L. F., Carvalho, E. E. N. de, & Vilas Boas, E. V. B. (2023). Physical, chemical and sensory implications of pequi (Caryocar brasiliense Camb.) sweet bread made with flour, pulp and fruit by-product.

Anais da Academia Brasileira de Ciências, *95*(2), 1-17. https://doi.org/10.1590/0001-3765202320201550

da Silva, L. H. P., Pinto, L. C. L., de Melo Teixeira, S. A., & Drumond, M. A. (2020). Pequi fruit (Caryocar brasiliense) in Minas Gerais: Commercialization and public policy. *Floresta e Ambiente*, *27*(2), e20171129. https://doi.org/10.1590/2179-8087.112917

Damasco, G., Fontes, C., Françoso, R., & Haidar, R. (2018). The cerrado biome: a forgotten biodiversity hotspot. *Frontiers for Young Minds*, *6*, 1-9. https://doi.org/10.3389/frym.2018.00022

de Barros, H. E. A., Alexandre, A. C. S., Campolina, G. A., Alvarenga, G. F., Silva, L. M. dos S. F., Natarelli, C. V. L., Carvalho, E. E. N., & Vilas Boas, E. V. de B. (2021). Edible seeds clustering based on phenolics and antioxidant activity using multivariate analysis. *Lwt*, *152*, 112372. https://doi.org/10.1016/j.lwt.2021.112372

de Faro Silva, R., Barreto, A. S., Trindade, G. das G. G., Lima, C. M., Araújo, A. A. de S., Menezes, I. R. A., Candido, E. A. F., Santana, É. T. N., Silva-Júnior, W. M., Quintans, J. S. S., Coutinho, H. D. M., Kim, B., & Quintans-Júnior, L. J. (2022). Enhancement of the functionality of women with knee osteoarthritis by a gel formulation with Caryocar coriaceum Wittm ("Pequi") nanoencapsulated pulp fixed oil. *Biomedicine and Pharmacotherapy*, *150*, 112938. https://doi.org/10.1016/j.biopha.2022.112938

de Oliveira, M. E. B. de, Guerra, N. B., Barros, L. de M., & Alves, R. E. (2008). Aspectos Agronômicos e de Qualidade do Pequi. *Embrapa*, *113*, 33. Retrieved from http://qualittas.com.br/uploads/documentos/Aspectos Nutricionais e de Qualidade do Leite - Alexandre Negrao Gadelha.PDF

de Oliveira, T. S., Thomaz, D. V., da Silva Neri, H. F., Cerqueira, L. B., Garcia, L. F., Gil, H. P. V., Pontarolo, R., Campos, F. R., Costa, E. A., dos Santos, F. C. A., de Souza Gil, E., & Ghedini, P. C. (2018). Neuroprotective effect of Caryocar brasiliense Camb. leaves is associated with anticholinesterase and antioxidant properties. *Oxidative Medicine and Cellular Longevity*, 1-12. https://doi.org/10.1155/2018/9842908

de Santana Magalhães, F., de Souza Martins Sá, M., Luiz Cardoso, V., & Hespanhol Miranda Reis, M. (2019). Recovery of phenolic compounds from pequi (Caryocar brasiliense Camb.) fruit extract by membrane filtrations: Comparison of direct and sequential processes. *Journal of Food Engineering*, *257*, 26-33. https://doi.org/10.1016/j.jfoodeng.2019.03.025

De Sousa, E. O., Moreira dos Santos, A. M., Da Silva Duarte, A. M., & Gonçalves da Silva, M. T. (2021). Uso da farinha da torta residual da polpa do pequi (Caryocar coriacium wittm) no desenvolvimento e caracterização de biscoito tipo sequilho. *Revista Brasileira de Engenharia de Biossistemas*, *15*(4), 632-643. https://doi.org/10.18011/bioeng2021v15n4p632-643

Empresa Brasileira de Pesquisa Agropecuária (2021). *Pesquisas com espécies nativas contribuem para conservação do Cerrado*. EMBRAPA. Retrieved from https://www.embrapa.br/en/busca-de-noticias/-/noticia/83349424/pesquisas-com-especies-nativas-contribuem-para-conservacao-do-cerrado?p_auth=GsJ6lR9I

Filippin dos Passos Santos, A. M. (2022). Economias da floresta em Mato Grosso: produtos florestais não-madeireiros e a exploração de madeira em tora. *Boletim Do Observatório Ambiental Alberto Ribeiro Lamego*, *16*(2), 140-161. https://doi.org/10.19180/2177-4560.v16n22022p140-161

Ghazani, S. M., Guedes, A. M. M., Antoniassi, R., Chiu, M. C., & Marangoni, A. G. (2022). Cocoa butter equivalent from Kpangnan butter and Pequi oil. *JAOCS, Journal of the American Oil Chemists' Society*, *99*(9), 739-746. https://doi.org/10.1002/aocs.12630

Ghesti, G. F., Silveira, E. A., Guimarães, M. G., Evaristo, R. B. W., & Costa, M. (2022). Towards a sustainable waste-to-energy pathway to pequi biomass residues: Biochar, syngas, and biodiesel analysis. *Waste Management*, *143*, 144-156. https://doi.org/10.1016/j.wasman.2022.02.022

Goiás (2022). Ceasa promove 2ª edição de Festa do Pequi. *Portal Goiás*. Retrieved from https://www.goias.gov.br/servico/43-economia/128085-ceasa-promove-2a-edição-de-festa-do-pequi.html

Gomes, F. de O., Silva, M. da C. M., Sousa, P. B., Freitas, T. K. T., Silva, D. J. S., & Araújo, R. S. dos R. M. (2020). Avaliação físico-química de uma bebida à base de kefir saborizada com pequi. *Brazilian Journal of Development*, *6*(3), 10755-10762. https://doi.org/10.34117/bjdv6n3-084

Gonçalves Martins, J. P., Setter, C., Ataíde, C. H., Pires de Oliveira, T. J., & Magriotis, Z. M. (2021). Study of pequi peel pyrolysis: Thermal decomposition analysis and product characterization. *Biomass and Bioenergy*, *149*, 106095. https://doi.org/10.1016/j.biombioe.2021.106095

Guedes, A. M. M., Antoniassi, R., & De Faria-Machado, A. F. (2017). Pequi: A Brazilian fruit with potential uses for the fat industry. *Oilseeds and Fats, Crops and Lipids*, *24*(5), D507. https://doi.org/10.1051/ocl/2017040

Guilherme, F. A. G., Júnior, A. F., Pereira, F. C., Silva, G. E., & Maciel, E. A. (2022). Disturbances and environmental gradients influence the dynamics of individuals and basal area in the Cerrado complex. *Trees, Forests and People*, *9*, 100298. https://doi.org/10.1016/j.tfp.2022.100298

Guimarães, A. C. G., de Souza Gomes, M., Zacaroni Lima, L. M., Sales, P. F., da Cunha, M. C., Rodrigues, L. J., de Barros, H. E. A., Pires, C. R. F., dos Santos, V. F., Lima Natarelli, C. V., & Vilas Boas, E. V. de B. (2023). Application of chemometric techniques in the evaluation of bioactive compounds and antioxidant activity of fruit from Brazilian cerrado. *Journal of Food Measurement and Characterization*, *17*(3), 2095-2106. https://doi.org/10.1007/s11694-022-01736-0

Instituto Brasileiro de Geografia e Estatística (IBGE) (2004). *Biomes*. IBGE. Retrieved from https://www.ibge.gov.br/en/geosciences/maps/brazil-environmental-information/18341-biomes.html

Ketenoglu, O., Kiralan, M., & Ramadan, M. F. (2020). Cold pressed pequi (Caryocar brasiliense Camb.) almond oil. *Cold Pressed Oils: Green Technology, Bioactive Compounds, Functionality, and Applications*, 356-372. https://doi.org/10.1016/B978-0-12-818188-1.00033-5

Leão, D. P., Botelho, B. G., Oliveira, L. S., & Franca, A. S. (2018). Potential of pequi (Caryocar brasiliense Camb.) peels as sources of highly esterified pectins obtained by microwave assisted extraction. *Lwt*, *87*, 575-580. https://doi.org/10.1016/j.lwt.2017.09.037

Leite, T. F., Lima, J. P. De, & Paiva, C. L. (2019). Elaboração e análise físico-química de licor de Pequi com variações na extração alcoólica e concentração de calda. *III Simpósio de Engenharia de Alimentos – Interdisciplinaridade e Inovação na Engenharia de Alimentos*, 1251-1258.

Lorenzo, N. D., Vasconcelos, O., & Caetano, S. (2022). Structure and nutrition of dark chocolate with pequi mesocarp (*Caryocar villosum* (Alb.) Pers.). *Food and Science Technology*, *42*, e88021. https://doi.org/https://doi.org/10.1590/fst.88021

Maia, J. G. S., Andrade, E. H. A., & da Silva, M. H. L. (2008). Aroma volatiles of pequi fruit (Caryocar brasiliense Camb.). *Journal of Food Composition and Analysis*, *21*(7), 574-576. https://doi.org/10.1016/j.jfca.2008.05.006

Mariano-da-Silva, S., Brait, J. D. de A., Faria, F. P. de, Silva, S. M. da, Oliveira, S. L. de, Braga, P. F., & Mariano-da-Silva, F. M. de S. (2009). Chemical characteristics of pequi fruits (Caryocar brasiliense Camb.) native of three municipalities in the State of Goiás

- Brazil. *Ciência e Tecnologia de Alimentos*, *29*(4), 771-777. https://doi.org/10.1590/s0101-20612009000400011

Ministry of the Environment (MMA) (2017). *Brazil's Forest Reference Emission Level for Reducing Emissions from Deforestation in the Cerrado biome for Results-based Payments for REDD+ under the United Nations Framework Convention on Climate Change.* MMA.

Miranda, M. R. da S., Veras, C. A. G., & Ghesti, G. F. (2020). Charcoal production from waste pequi seeds for heat and power generation. *Waste Management*, *103*, 177-186. https://doi.org/10.1016/j.wasman.2019.12.025

Miranda-Vilela, A. L., Pereira, L. C. S., Gonçalves, C. A., & Grisolia, C. K. (2009). Pequi fruit (Caryocar brasiliense Camb.) pulp oil reduces exercise-induced inflammatory markers and blood pressure of male and female runners. *Nutrition Research*, *29*(12), 850-858. https://doi.org/10.1016/j.nutres.2009.10.022

Moreno, L. G., César, N. R., Melo, D. S., Figueiró, M. T. O., dos Santos, E. C., Evangelista-Silva, P. H., de Sousa Santos, C., Costa, K. B., Rocha-Vieira, E., Dias-Peixoto, M. F., Castro Magalhães, F. de, & Esteves, E. A. (2024). A MUFA/carotenoid-rich oil ameliorated insulin resistance by improving inflammation and oxidative stress in obese rats. *Molecular and Cellular Endocrinology*, *581*, 112110. https://doi.org/10.1016/j.mce.2023.112110

Nascimento, S. L., Pereira, A. V., Pereira, E. B., Carvalho Martins, E. R., & Fernandes, R. C. (2016). Caryocar brasiliense. *Rede de Catálogos Polínicos Online*, 190-202. Retrieved from http://chaves.rcpol.org.br/

Oliveira, M. C. de, Silva, D. M. da, Marchesin, W. A., Attia, Y. A. E.-W., Lima, S. C. O., & Oliveira, H. C. (2016). Pequi peel flour in diets for Japanese quail. *Acta Scientiarum. Animal Sciences*, *38*(1), 101. https://doi.org/10.4025/actascianimsci.v38i1.28381

Oliveira, W. L. (2010). *Boas práticas de manejo para o extratiivismo sustentável do Pequi*. Embrapa.

Ombredane, A. S., Silva, L. R. A., Araujo, V. H. S., Costa, P. L., Silva, L. C., Sampaio, M. C., Lima, M. C. F., Veiga Junior, V. F., Vieira, I. J. C., Azevedo, R. B., & Joanitti, G. A. (2022). Pequi oil (Caryocar brasilense Cambess.) nanoemulsion alters cell proliferation and damages key organelles in triple-negative breast cancer cells in vitro. *Biomedicine and Pharmacotherapy*, *153*, 113348. https://doi.org/10.1016/j.biopha.2022.113348

Paula de Almeida, D., da Capela, A., Martins, A. F., Costa, N., & Lelis, C. (2022). Biological activities of pequi (Caryocar brasiliense Camb.) pulp oil. *Multiple Biological Activities of Unconventional Seed Oils*, 257-267. https://doi.org/10.1016/B978-0-12-824135-6.00015-5

Pegorin Brasil, G. S., Borges, F. A., Machado, A. de A., Mayer, C. R. M., Udulutsch, R. G., Herculano, R. D., Funari, C. S., dos Santos, A. G., & Santos, L. (2022). A sustainable raw material for phytocosmetics: the pulp residue from the Caryocar brasiliense oil extraction. *Revista Brasileira de Farmacognosia*, *32*(5), 827-833. https://doi.org/10.1007/s43450-022-00319-w

Pereira, F. F. G., Feitosa, M. K. S. B., Costa, M. do S., Tintino, S. R., Rodrigues, F. F. G., Menezes, I. R. A., Coutinho, H. D. M., da Costa, J. G. M., & de Sousa, E. O. (2020). Characterization, antibacterial activity and antibiotic modifying action of the Caryocar coriaceum Wittm. pulp and almond fixed oil. *Natural Product Research*, *34*(22), 3239-3243. https://doi.org/10.1080/14786419.2018.1552955

Pinto, M. R. M. R., Paula, D. de A., Alves, A. I., Rodrigues, M. Z., Vieira, É. N. R., Fontes, E. A. F., & Ramos, A. M. (2018). Encapsulation of carotenoid extracts from pequi (Caryocar brasiliense Camb) by emulsification (O/W) and foam-mat drying. *Powder Technology*, *339*, 939-946. https://doi.org/10.1016/j.powtec.2018.08.076

Ramos, K. M. C., & Souza, V. A. B. de. (2011). Características físicas e químico-nutricionais de frutos de pequizeiro (Caryocar coriaceum Wittm.) em populações naturais da região meio-norte do Brasil. *Revista Brasileira de Fruticultura*, *33*(2), 500-508. https://doi.org/10.1590/s0100-29452011005000072

Ramos, R. de O., Pertuzatti, P. B., Gomes, I. M., Santana, M. B., Brito, R. de M., Tussolini, M., Miguel, T. B., & Tussolini, L. (2021). Chemical and antioxidant characterization, sensory and shelf-life analysis of cereal bars with almonds from pequi (Caryocar brasiliense camb.). *Food Science and Technology*, *41*(Suppl. 1), 368-374. https://doi.org/10.1590/fst.29218

Santos, B. O., Augusti, R., Melo, J. O. F., Takahashi, J. A., & Araújo, R. L. B. de. (2020). Optimization of extraction conditions of volatile compounds from pequi peel (Caryocar brasiliense Camb.) using HS-SPME. *Research, Society and Development*, *9*(7), e919974893. https://doi.org/10.33448/rsd-v9i7.4893

Santos, B. O., Tanigaki, M., Silva, M., Ramos, A. L., Labanca, R., Augusti, R., Melo, J., Takahashi, J., & de Araújo, R. (2022). Development and chemical characterization of pequi pericarp flour (Caryocar brasiliense Camb.) and effect of in vitro digestibility on the bioaccessibility of phenolic compounds. *Journal of the Brazilian Chemical Society*, *33*(9), 1058-1068. https://doi.org/10.21577/0103-5053.20220022

Santos, P., Porto, A. G., Silva, F. S., & Furtado, G. F. (2010). Avaliação físico-química e sensorial do pequi (Caryocar brasiliensis Camb.) submetido à desidratação. *Revista Brasileira de Produtos Agroindustriais*, *12*(2), 115-123. https://doi.org/10.15871/1517-8595/rbpa.v12n2p115-123

Silva, F. de J., Ribeiro, R. C. F., Xavier, A. A., Santos Neto, J. A., Silva, C. M. da, & Mizobutsi, E. H. (2018). Management of meloidogyne javanica in okra using compost of pequi fruit waste. *Journal of Agricultural Science*, *10*(7), 258. https://doi.org/10.5539/jas.v10n7p258

Silva, J. N. B., Guimarães, V. H. D., Marinho, B. M., Machado, A. S., Santos, A. R., David, L. R. de S., Melo, G. A., de Paula, A. M. B., & Santos, S. H. S. (2022). Caryocar brasiliense Camb. fruit peel butanolic fraction induces antiproliferative effects against murine melanoma cell line. *Phytomedicine Plus*, *2*(2), 100273. https://doi.org/10.1016/j.phyplu.2022.100273

Silva, J. P., Tejerina, G., Barreira, S., & Souza, C. (2021). aspectos da comercialização do pequi (Caryocar brasiliense Camb.) no Estado de Goiás, Brasil. *Enciclopédia Biosfera*, *18*(37), 530-543. https://doi.org/10.18677/EnciBio_2021C6

Silva, L. M. S. F., Pereira, G. S. L., Ribeiro, I. G., Braga-Souto, R. N., Teixeira, M. G., Vieira, C. R., & de Lima, J. P. (2022). Production, characterization and shelf-life evaluation of Caryocar brasiliense pulp flour. *International Journal of Gastronomy and Food Science*, *28*, 100512. https://doi.org/10.1016/j.ijgfs.2022.100512

Silva, M. N. S. da, & Tubaldini, M. A. dos S. (2014). O pequi como recurso de uso comum e patrimônio cultural sertanejo. *Geo UERJ*, *1*(25), 161-182. https://doi.org/10.12957/geouerj.2014.5994

Siqueira, B. dos S., Alves, L. D., Vasconcelos, P. N., Damiani, C., & Soares, M. S. (2012). Extracted pectin of "pequi" peel and application in light mango jam. *Revista Brasileira de Fruticultura*, *34*(2), 560-567. https://doi.org/10.1590/S0100-29452012000200030

Sobral, A., Feitosa, I. S., Torre-Cuadros, M. de los Á. La, Alves, R. R. N., Brito-Júnior, V. M., Moura, J. M. B. de, Silva, T. C. da, & Albuquerque, U. P. (2024). Perceptions of pequi (Caryocar coriaceum Wittm) decline: Insights from extractivist communities in the Araripe-Apodi National Forest, Brazil. *Journal for Nature Conservation*, *77*, 126538. https://doi.org/10.1016/j.jnc.2023.126538

Souza, J. P. de, Alves, R. E., Brito, E. de S., Lucena, M. N. G. de, & Rufino, M. do S. M. (2014). Estabilidade de molho de pequi (Caryocar coriaceum Wittm) armazenado à temperatura ambiente. *Revista Brasileira de Fruticultura*, *36*(2), 425-432. https://doi.org/10.1590/0100-2945-127/13

Souza, L., & Lima, L. (2019). *A cultura do pequi e sua importância socioeconômica para a agricultura familiar* [Unifama]. Retrieved from https://sophiauta.s3.amazonaws.com/Agronegócio/Tcc+pdf+Lucas+Araujo+e+Lilian+Juliane.pdf

Souza, M. G. S., Guimarães, M. G., Macedo, J. L., Rodrigues, J. P., & Ghesti, G. F. (2019). Caracterização e utilização de óleo residual de pequi (*Caryocar brasiliense*) na produção de biocombustíveis líquidos. *Revista Interdisciplinar de Pesquisa Em Engenharia*, *2*(5), 41-49. https://doi.org/10.26512/ripe.v5i2.28222

Tabela Brasileira de Composição de Alimentos (TBCA) (2023). Universidade de São Paulo (USP). Food Research Center (FoRC). Versão 7.2. São Paulo. Retrieved from http://www.fcf.usp.br/tbca

Torres, L. R. O., Santana, F. C. d., Torres-Leal, F. L., Melo, I. L. P. d., Yoshime, L. T., Matos-Neto, E. M., Seelaender, M. C. L., Araújo, C. M. M., Cogliati, B., & Mancini-Filho, J. (2016). Pequi (Caryocar brasiliense Camb.) almond oil attenuates carbon tetrachloride-induced acute hepatic injury in rats: Antioxidant and anti-inflammatory effects. *Food and Chemical Toxicology*, *97*, 205-216. https://doi.org/10.1016/j.fct.2016.09.009