Revista ARACÊ
ISSN: 2358-2472

TECHNOLOGICAL PROSPECTION OF THE USAGE OF BARU FRUIT (DIPTERYX ALATA VOG.) TO IMPROVE THE LIVING CONDITIONS OF QUILOMBOLAS, EXTRACTIVIST COMMUNITIES IN BRAZIL

https://doi.org/10.56238/arev6n3-342

Date of submission: 27/10/2024 **Date of publication:** 27/11/2024

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ABSTRACT
Barueiro (Dipteryx alata Vog.) is an arboreal plant species native to Brazil's fertile Cerrado region. holds great promise for cultivation and technological development due to its versatile uses and the complete reuse of its parts. Given its local significance, increased research support is essential, as the species has the potential to generate high-value products and offer a sustainable income source for its producers. This study is a prospective analysis of articles and patents on barueiro (baru fruit), highlighting that most technologies have low technological readiness levels (TRL 3-4) and remain at the bench stage, with most patents filed by universities. Collaboration between extractive communities and academia is crucial for knowledge transfer, cooperative creation, and project development for processing centers, training, and decentralized energy generation, thereby supporting SDGs and circular economy principles by adding value and improving community well-being. Once these cooperatives and processes are established, applying for geographical indication could further enhance the value of baru-based products.

Keywords: Technological Prospecting. New Food Products. Baru. Dipteryx Alata Vog.

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ISSN: 2358-2472

INTRODUCTION

The "barueiro" (*Dipteryx alata Vog*.) is a tree species that belongs to fertile regions of Brazilian cerrado, which is considered to be the second largest biome in Brazil, responsible for hosting about 5% of the world's flora, and one-third of the national biodiversity (Pineli et al., 2015). Depending on the geographical location where this species is found, it may be known by different names, such as: barujó, baruzeiro, baruí, coco-feijão, cumbaru, cumaru, pau cumaru, and baru (Botezelli et al., 2000). This plant bears the "baru" fruit, whose pulp has a sweet flavor that surrounds an edible almond (Da Cruz et al., 2011).

Currently, the baru nut is harvested through extractivism by Quilombola communities, ethnic-racial groups primarily descended from enslaved Africans who escaped slavery. Recognized by the Brazilian state, they hold special territorial rights under the 1988 Federal Constitution and Decree No. 4.887/2003, which grants them property rights over their traditional lands. Historically marginalized, these communities have faced limited resources and opportunities, leading to socio-economic disparities compared to other regions (Pineli et al., 2015).

Many Quilombola communities still face limited access to essential services like healthcare, education, sanitation, and infrastructure. These challenges stem from factors such as racial discrimination, restricted economic and territorial resources, insufficient government policies, and limited political representation. It's also essential to acknowledge that Quilombola communities are diverse, with differing realities influenced by location, history, and local policies. (Evaristo et. al., 2021).[4].

With its diverse applications, baru is a highly promising species for cultivation and technological advancement, as all its parts can be reused. Its dense wood is utilized for constructing fences, posts, beams, rafters, and floorboards, as well as in the manufacturing of bodyworks and agricultural tools (Sano et al., 2004). The peel contains three valuable pentacyclic triterpenes—lupeol, lupen-3-one, and betulin—used to treat back pain (Sano et al., 2004). The edible pulp and almond are nutrient-rich, and the almond, making up 5% of the fruit's yield, is economically viable for oil extraction, serving the food, chemical, and pharmaceutical industries due to its high lipid content (Brandão & CEMIG, 2001; Lemos, 2012). The widespread presence of the baru nut in the Cerrado and its use as a dietary supplement by rural communities have sparked technological interest in developing new, high-value food products from this species, such as . Its local cultivation offers a sustainable

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income source and health benefits to consumers (Hiane et al., 1992; Jesus et al., 2011; Magalhães, 2011).

Using new natural raw materials enhances existing food products, ensuring low-cost nutritional enrichment and promoting product reuse (Bowles & Demiate, 2006) . Cereal bars, bread, cakes, yogurts, and ice creams are popular, convenient options for incorporating regional fruits like baru, which can boost nutritional value, raise the fruit's market value, and support species preservation and sustainable regional development (Soares Júnior et al., 2007).

Given the potential of baru (Dipteryx alata Vog.), this study conducted a prospective analysis of research on the fruit up to 2020. Articles were reviewed for key research areas, promising food sector applications, main funding sources, and related patents. A bibliographic review was carried out on databases such as Scopus, Web of Science, and Capes Periodicals, and patents were reviewed on INPI, WIPO, and Questel Orbit. The study aimed to explore technologies that can increase income for Quilombola extractive communities through value-added baru processing, supporting circular economy principles, reducing greenhouse gas emissions, and aligning with SDG goals.

METHODS AND MATERIALS

Technological foresight, through qualitative and quantitative methods, supports strategic planning by envisioning future scenarios based on socio-economic, cultural, legal, and environmental factors. This study used foresight as a tool to monitor ongoing research and patents, conducting searches in databases like Capes Periodicals, Web of Science, and Scopus with keywords "Baru" and "Dipteryx alata”.

Patent research involved databases like INPI (National Institute of Industrial Property), WIPO, and Questel Orbit, analyzing titles, abstracts, and claims to map technological developments, patenting companies, and inventors.

Searches were conducted between January and may of 2024, considering results from the first recorded research (1999) to the present time. The prospect was done through the data collection, processing, and analysis.

RESULTS AND DISCUSSION

The results from various databases regarding articles on the research topic are summarized in Table 1. A total of 1,112 articles were identified in the national database

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Capes Periodicals for the keyword "Baru" in the title, but only 103 were relevant. About 385 articles were in Indonesian, where "baru" means "new." The remaining 727 articles are not solely related to the topic, as they also reference a volcano named "Barú" in Panama and various places in Malaysia. Additionally, Capes Periodicals includes different reference management software, resulting in duplicate entries. In contrast, the other databases provided more refined results, with 112 articles in Web of Science and 179 in Scopus, although some were not pertinent to the research topic.

Baru, scientifically named *Dipteryx alata*, is a fruit native to the Brazilian cerrado, and this specific term was used to refine search results. In Periódico Capes, 152 results were found related to the studied technology, with 90 in Web of Science and 94 in Scopus. When the search was expanded to include abstracts, the number of results increased, as many studies evaluate multiple plant species for their similarities in regionality, phytochemical properties, or applications. However, combining keywords from both titles and abstracts led to a reduction in results, as some articles were excluded, making this approach less effective for searches. The database responses are summarized in Table 1..

Table 1: Scope of articles search

		Database		
		Capes Periodicals	Web of Science	Scopus
TITLE	Baru	1112	237	413
	Dipteryx alata	267	142	94
ABSTRACT	Baru	13509	635	1087
	Dipteryx alata	438	133	199

As scientific development and technological expansion continue to grow, protecting intellectual property through patents has become increasingly important for safeguarding rights and encouraging investment. Patents were searched using keywords in the title, abstract, and claims, similar to the approach used for articles. It was necessary to include patent claims, as some studies might reference Baru *(Dipteryx alata)* even if it wasn't the primary focus.

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The number of patents found was notably low, as research on Baru only began in 1995. Each patent was carefully analyzed due to the limited number of responses, resulting in a refined count of those relevant to the research. Ultimately, a total of 22 documents were identified across all databases, as detailed in Table 2.

Table 2: Scope of Patent Search

		Database		
		INPI	WIPO	Questel Orbit
TITLE	Baru	16	1534	290
	Dipteryx alata	8	3	4
ABSTRACT	Baru	20	5033	69
	Dipteryx alata	11	5	6
CLAIMS	Baru	-	5	17
	Dipteryx alata	-	3	3

The annual evolution of articles and patents, represented by Figures 1 and 2 respectively, confirm that Baru (*Dipteryx alata*) is a recent concept technology, with a strong growth tendency in the scientific aspect.

The first article emerged in the 1990s when funding projects in the central region of Brazil began investing in research identifying plant species and fruits with socioeconomic potential (Sano et al., 1999).

Research on *baru* (Dipteryx alata) is increasing due to factors such as public policies that improve access to higher education, notably the social inclusion law ("Law No. 12.711 of 29/08/2012"), which has boosted the number of graduates conducting valuable research. Additionally, "Law No. 11,097, of January 13, 2005," promoting biodiesel from biomass, has spurred studies on suitable biomasses. Consequently, over 40% of *baru* publications are in the agricultural sector, reflecting these influences.

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Figure 1: Articles annual evolution

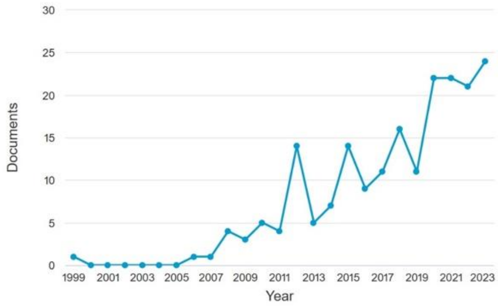
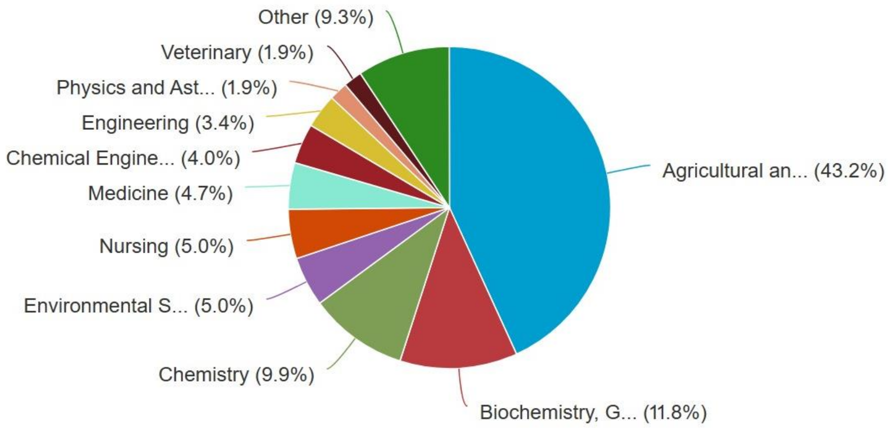


Figure 2. Area of the knowledge of the articles



Considering that not all inventions can be patented; to qualify, they must exhibit novelty, industrial applicability, and inventive activity. This explains why the first patent related to Baru *(Dipteryx alata)* was filed nearly a decade after the publication of the first article (Figure 3). Filing a patent requires expertise in the species, including knowledge of its handling, composition, and uses. The first patent, titled "Machine for extracting almonds from fruits with woody pericarp," (Udonor, 2003), focuses on extracting almonds from Baru and other similar fruits with minor adaptations. This patent was filed in 2003 but was revoked in 2012.

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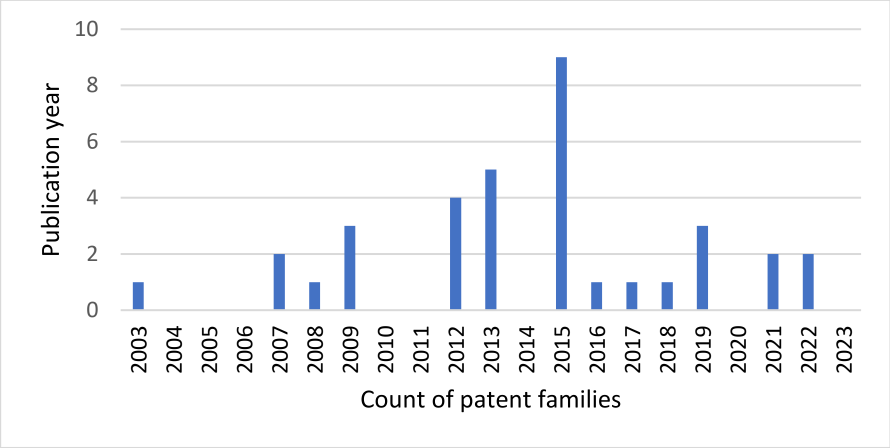
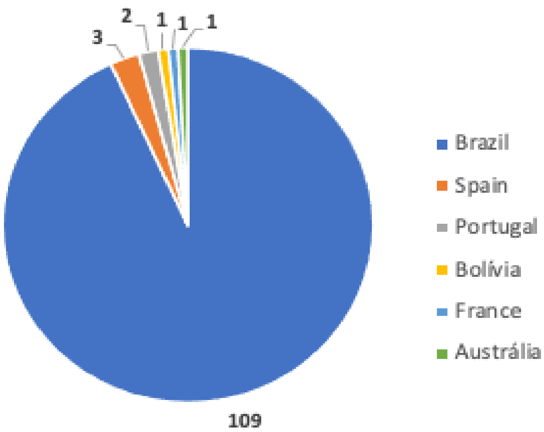
Figure 3: Annual evolution of evaluated patents.



After the initial patent filing, progress in the technology related to Baru was slow until a breakthrough in 2013. This advancement was linked to food scientist Miriam Rejane Bonilla Lemos from the University of Brasília in 2012 (Lemos, 2012), who demonstrated that Baru is not only tasty and nutritious but also possesses significant antioxidant properties that can help combat inflammatory and chronic-degenerative diseases, including arthritis, cancer, diabetes, hypertension, and cardiovascular issues (Ignat et al., 2011). She also discovered that Baru almond oils are rich in essential health compounds such as omega 3, 6, and 9.

Analysis of the documents revealed that Brazil is the leader in publishing articles and patents on Baru, as shown in Figure 4, followed by Spain and Portugal, which are not comparable in terms of research output. Brazil dominates the production of scientific articles and holds all the patent deposits, highlighting its accessibility to research on this topic.

Figure 4: Published articles locations about Baru



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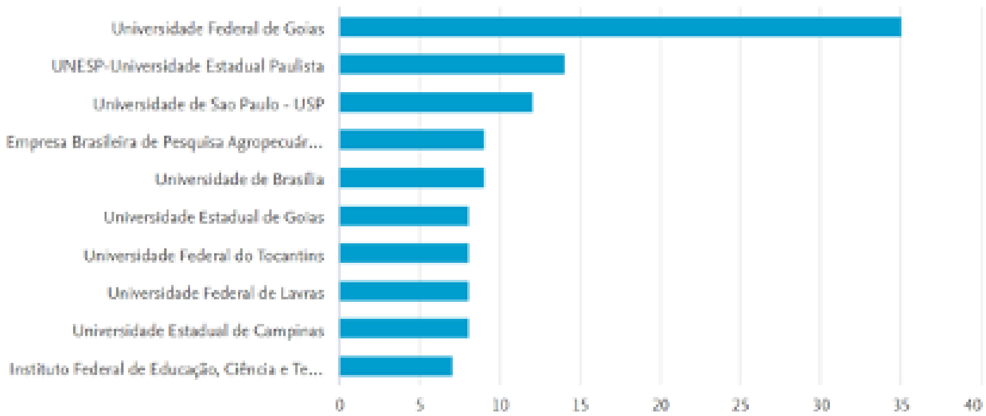
In Brazil, article publications are predominantly produced by institutions in the Midwest and Southeast regions, as illustrated in Figure 5. Most of these publications come from research institutions, particularly Brazilian universities that promote research aimed at enhancing the country's socio-economic development. Notably, the University of São Paulo (USP) and the State University of Campinas (Unicamp) are recognized as significant influencers in entrepreneurship development within the country. (Brasil Júnior/AIESEC/BRASA/enactus/RedeCsF, 2016).

Among the institutions, EMBRAPA (Brazilian Agricultural Research Corporation) ranks as the fourth largest publisher of articles. EMBRAPA is a public research organization linked to the Ministry of Agriculture, focusing on technological innovation in Brazilian agriculture.

Figure 5: Articles documents by affiliation.



Brazilian universities are the primary holders of patents and lead in academic publications, as illustrated in Figure 6. Notably, two patentees are outside academia: Cardoso da Conceição Edemilson, who holds a patent for a moisturizing cream with Baru seed oils (Conceição et al., 2007), highlighting unique sensory qualities, and Castanheira Produtos Alimentícios ME, which owns a patent for a process to create edible frozen desserts using Baru pulp (Martins, 2010),marking an innovative use of this ingredient in frozen treats.

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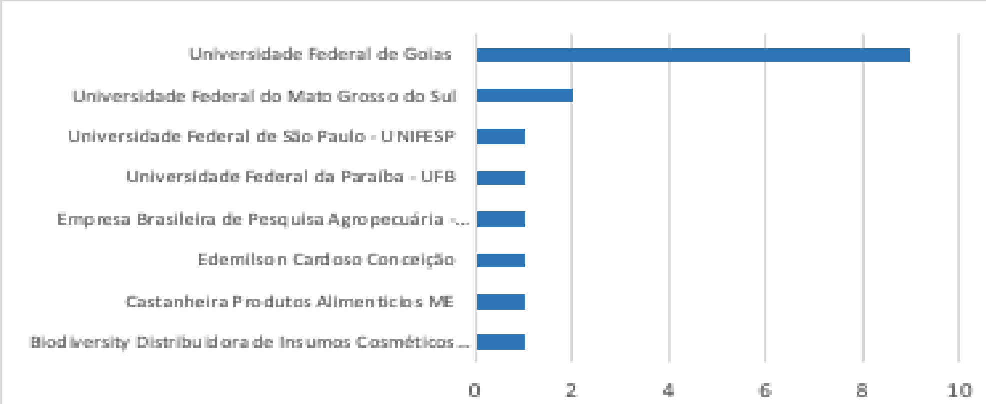
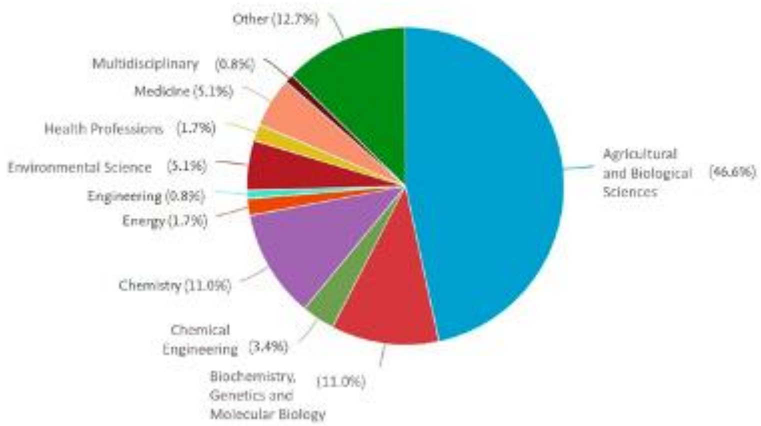
Figure 6: Major patent holders



Regarding the main studies areas related to the search topics (Figure 7), it is noted the environmental, sustainable, social, and economic aspects of the fruit as a sustainable alternative for extraction (Magalhães, 2014), including its various techniques (Fetzer et al., 2018), given its common occurrence in the Brazilian cerrado region, thus exploring the possibility of income generation for local producers. Additionally, articles were related to aspects such as the characterization of different parts of this fruit (pulp, endocarp, and seeds), its phenology, as well as the nutritional content in its tissues, to be used in various sectors, primarily in the food industry, since the oil from its seeds is comparable in fatty acid content to olive oil (Siqueira et al., 2016), and its flour is capable of reducing fat content when substituted in recipes that call for wheat flour (Paglarini et al., 2018).

Figure 7: Fields of study of Baru ((*Dipteryx alata*)



Evaluating the toxicity of new technologies is crucial, especially for medicinal and food products. Research on the baru plant includes in vitro and in vivo safety assessments. (Alonço & Candalaft, 2015; Nazato et al., 2010).

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Baru's productive potential lies in its lipid and protein content, comparable to that of true nuts (almonds, hazelnuts, chestnuts, cashews, Brazil nuts, macadamias, walnuts, and pistachios), making it suitable for culinary use in products like paçocas, biscuits, cereal bars, granola, cakes, and bread (Naves, 2010).

Baking is one of the oldest culinary methods, and the essential ingredients are usually wheat flour, water, salt, and yeast, along with enriching ingredients like sugar, fat, eggs, flavorings, and spices (Brasil, 2017). As technology has advanced, many of these ingredients have been replaced to enhance the nutritional profile of baked goods and attract consumer interest (Miamoto, 2008). Consequently, numerous studies have explored the use of baru flour as a substitute for traditional ingredients, leading to the creation of products with significantly improved nutritional value.

Soares (Soares, 2018) developed biscuits developed biscuits with 20% baru flour, finding increased lipids, proteins, fibers, and minerals compared to commercial biscuits. The protein content rose significantly from 2.75 g to 4.02 g per 100g, with strong consumer acceptance and over 30% intent to purchase. Biscuits with baru almond flour offer both nutritional and sensory benefits, supporting their promotion to consumers.

Demonstrating the feasibility of preparing these recipes, Rocha & Cardoso Santiago (Rocha & Cardoso Santiago, 2009) demonstrated the feasibility of using baru husk and pulp in bread, successfully replacing regular flours to create a product with good texture and appearance, reduced energy content, and a 58.2% increase in dietary fiber.

Similarly, Lima (Lima et al., 2010) developed cereal bars with baru pulp and seeds, achieving dietary fiber levels (15g/100g) that surpass commercial bars, which contain around 6g/100g. This highlights baru's potential in the cereal bar market.

With rising consumer health consciousness, the food industry is innovating healthier options. Rojas et. al. (Rojas et al., 2018) developed a mayonnaise enriched with polyunsaturated fatty acids (PUFAs) using microencapsulated chia seeds, pumpkin seeds, and baru oil, producing a healthier mayonnaise that maintains commercial texture.

In summary, as baru shows potential in the food market, it is necessary to estimate its shelf life, that is, to evaluate the period in which changes in its composition that may be harmful to health may occur. Alves et al. (Alves et al., 2010) examined baru's shelf life, finding it is climacteric (continues to ripen after harvest). They observed that anti-nutritional substances like tannins and phytic acid decrease over time, while nutritional content remains stable.

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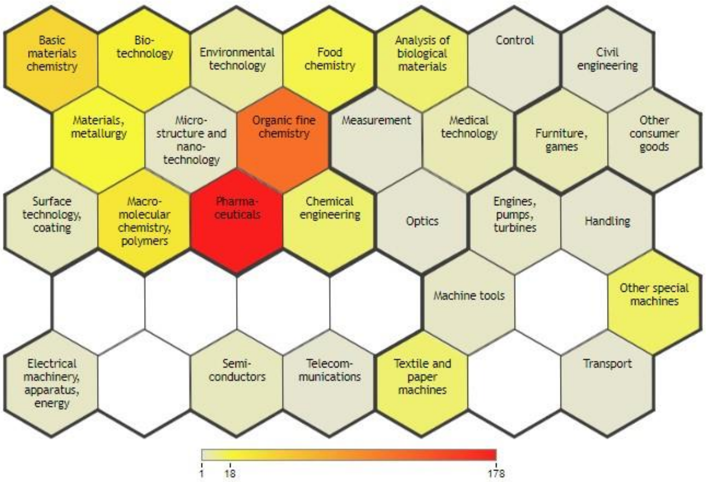
Sousa et al. (Sousa et al., 2012) recommend baru seeds as a nutritious addition to a balanced diet, providing superior protein quality and food efficiency compared to other edible seeds, indicating their economic potential.

Given baru's versatile uses, its technological potential is significant. Intellectual property protection is recommended for these opportunities. In this sense, the present work evaluated the existing patents in this topic.

This study reviewed relevant patents, identifying applications across five sectors: chemical industry, machinery, fine organic chemistry, biotechnology, and pharmaceuticals (Figure 8).

Figure 8: Areas of operation of patents that employ the Baru fruit (Dipteryx alata).



As previously portrayed, food chemistry sector is dominant in baru-related patents, covering products like Baru pulp frozen desserts (Martins, 2010), frozen yogurt (Candido et al., 2018), gluten-free brownies with Baru flour (Pereira et al., 2017), and caramelized/non-caramelized canjicas with baru almonds, in various dietary forms (regular, diet, or lactose-free) (Damiani et al., 2013a; Damiani et al., 2013e)

Functional foods, known for health benefits beyond basic nutrition (Europe et al., 1999; Oliveira et al., 2016) are gaining popularity, especally gluten and lactose-free options. Functional foods can act in the nervous system by regulating appetite and are also associated with the prevention of diseases such as diabetes, hypertension, cancer, anemia, and platelet aggregation (Mitsuoka, 2014).

Probiotic foods, such as milk, support health by providing beneficial microorganisms (Ferreira et al., 2014). Considering the potential applications of baru, Arelhano et al., in collaboration with the Federal University of Mato Grosso do Sul, developed a frozen yogurt from milk fermented with roasted baru nuts, resembling ice cream but with added nutritional value.

Currently, with the increase in the number of intolerant individuals, there is a greater concern regarding the development of products that meet consumer needs, as up to 66% of consumers claim they would pay more for food without undesirable ingredients (Nielsen, 2017). Seizing the market opportunity, Borges et al. developed gluten-free brownies with baru flour, offering high nutrition and superior texture and flavor. This product utilizes residues from cold-pressed oil extraction, supporting sustainable, low-cost production.

Likewise, Damiani et al. (Damiani et al., 2013a-f) produced canjica desserts, a traditional Brazilian treat, with baru almonds in lactose-free and sugar-restricted options, including caramelized varieties, providing a suitable choice for those with dietary restrictions.

In the food industry, Baru almonds are highly valued, but extraction poses a challenge. The difficulties faced by extractors in cutting the fruit and extracting the almond have led to research into the development of techniques to make the pulping process more effective and efficient, as the pulp, being very dry, is difficult to be removed, explaining why the machinery sector ranks second in research areas. Among the patents found are a "Baru nut sheller" (Guimarães, 2012), a "semi-automatic electric machine for cracking and processing Baru (Rodrigues, 2010), and an "almond extractor machine for fruits with woody pericarp" (Udonor, 2003), aimed at improving the efficiency of almond extraction.

Other baru technologies focus on baru oil's properties, which include high antioxidant and anti-inflammatory activityand rich phenolic compounds, recognized as natural antioxidants, capable of preventing various chronic-degenerative diseases (Ignat et al., 2011. These attributes make baru oil promising for the cosmetics industry, exemplified by patents for "antimicrobial liquid soap" (Soares et al., 2016 and "nutritional moisturizing cream" (Conceição et al., 2007).

In biotechnology, one patent describes a process for creating an alcoholic fermented beverage from baru pulp (Ferreira et al., 2013) which mixes baru pulp with sucrose, water, and yeast to produce a drink similar to wine.

Another patent, "Process for obtaining a gel from the ozonation of vegetable oils" (Beatriz et al., 2017) is innovative for creating an organogel with pharmaceutical, cosmetic, and sanitizing applications. This ozonated oil gel has antimicrobial and regenerative properties, suitable for direct skin or wound application without needing additional pharmaceutical bases.

Of the 22 patents found, all are Brazilian, with depositors mainly from the Midwest region, including universities, research centers, and companies. Most patents (56%) are pending, likely due to the bureaucratic hurdles in Brazil's patenting process, while 44% were revoked, possibly for lacking innovative qualities. Food industry patents are still under review by the National Institute of Industrial Property (INPI).

So, add to that, the number of patents is lower than that publications due to Brazil's patentability requirements (Law nº 9.279/1996), limited patent culture, and the low technological readiness level (TRL) of these innovations.

The technologies have low TRL (between 3-4) and the studies are only at the bench level, since most of the Brazilian patents were filed by universities. Therefore, collaboration between extractive communities (notably Quilombola communities) and academia is crucial. Such partnerships could foster cooperatives and develop projects for processing centers, community training, and decentralized energy generation, improving quality of life. Communities currently sell only baru nuts, but new products like nutraceuticals, low-glycemic flour, and lactose-free milk could be produced to target the vegan and lactose-intolerant markets (Borges et al., 2024). Additionally, using baru husks as biofuel through gasification could create a sustainable energy source, reducing environmental impact. Evaristo and co-authors found enough biomass in Brazil's Midwest for decentralized energy generation, potentially improving community living conditions and reducing environmental liabilities (Evaristo et al., 2022).

A comprehensive analysis of the technical, economic, and social aspects of this project would be beneficial, along with exploring partnerships with research institutions, governmental agencies, and local businesses. This collaboration could support the project's implementation and ongoing development. Initially, using energy from baru mesocarp could meet the extractive community's energy needs affordably and reliably. However, flexibility should be maintained to adapt as new uses for mesocarp, such as food or advanced energy applications, emerge.

A sustainable baru production model aligned with the Sustainable Development Goals (SDGs), green chemistry principles, and a circular economy framework could maximize benefits. Using mesocarp for energy not only minimizes waste in baru production but also ensures energy generation is renewable and eco-friendly. This sustainable

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approach could support the development of the Quilombola community while setting an example for other rural and sustainable production initiatives globally.

Figure 9: Circular economy to Baru extrativism community

CONCLUSIONS

The studies indicate that Baru *(Dipteryx alata Vog.)* is an underexplored resource in both academic and economic contexts, presenting significant potential for new ventures and technological development. Despite Brazil's prominent role in this sector due to its accessibility to the species, the results have been modest, as evidenced by the limited number of patents filed since the first published article.

The research highlights that there are few applications for Baru as a raw material, emphasizing the need to promote new information and research in emerging economic fields. This is essential to attract investments that could enhance Brazil's science and technology landscape, social research and development, and the use of government policies that support isolated communities, like Quilombolas. Findings suggest that public policies, such as integrating other biomass into the energy matrix and improving educational access for the Quilombola community, have led to increased research outputs and patents for this previously lesser-known fruit.

Consequently, a model for sustainable Baru nut production is proposed, aligned with the Sustainable Development Goals (SDGs), green chemistry, and circular economy principles. This model envisions utilizing the mesocarp for energy generation within a circular economy framework. Such an approach could not only foster sustainable development within Quilombola communities but also serve as an inspiring example for other rural communities and sustainable production initiatives globally.

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ACKNOWLEDGMENTS

The authors acknowledge the National Council for Scientific and Technological Development (CNPq), the Decanato de Pesquisa e inovação (DPI/UnB) and Pós-graduação da Universidade de Brasília (DPG/UnB) for financial support. We also would like to thank CAPES, Finep, IQ/UnB, FORTEC, PROFNIT, the Network Marketing Partnership of Family Farmers and Gatherers of the savanna, known as Cerrado Emporium.

DECLARATIONS

There is no conflict of interest.

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