Heliyon 9 (2023) e22060

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Exotic fruits patents trends: An overview based on technological prospection with a focus on Amazonian ☆

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ARTICLE INFO

Keywords:
Amazonian fruits
Bioactive compounds
Patents

ABSTRACT

The Amazon rainforest encompasses one of the largest biodiversities of the world and is home to a wide variety of food and therapeutic plants. Due to the diversity of components, the fruits of the Amazon biome possess essential physicochemical, nutritional, and pharmacological properties, strengthening the idea that fruit consumption may provide benefits to human health. Thus, the objective of this study was to investigate the current scenario of the use of Amazonian fruits on the development of food, pharmaceutical, nutraceutical, or cosmetic products through the study of filed patents. A prospecting strategy conducted focusing on patents was used to investigate the application of the following fruits: *Euterpe oleracea*, *Oenocarpus bacaba*, *Caryocar brasiliense*, *Garcinia gardneriana*, *Nephelium lappaceum*, and *Astrocaryum vulgare*. A total of 264 patent documents were found. In 2016, a peak of 33 applications was reached, followed by a peak in 2019 with 32 applications. The study is distributed in three main application areas: cosmetics, pharmaceuticals, and food. The Asian continent was the region with the world leadership in this theme, followed by Brazil. Thus, technological prospection studies can foster investments in translational research to elucidate the effects and properties of Amazonian fruits, which can generate sustainable development of new products with industrial potential.

1. Introduction

Brazil has several species of native and exotic fruits that are underexploited. Fruit exploitation occurs through family farming with sales in the local market, scientific research, and small industries where fruits are processed as jelly, pulp, and juices [1–3]). A large proportion of these fruits, an estimated 44 %, are located in the Amazon, making this region a valuable natural reserve of food and

☆ Not applicable.

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https://doi.org/10.1016/j.heliyon.2023.e22060
Received 18 April 2023; Received in revised form 1 November 2023; Accepted 3 November 2023
Available online 4 November 2023
2405-8440/

medicinal plants worldwide [3,4]. The Amazon rainforest encompasses one of the largest biodiversities of the world and is home to a wide variety of food and therapeutic plants. The Brazilian Amazon biome is the world's largest intact forest and the largest biome in Brazil (accounting for 49.29 % of the Brazilian territory and approximately 40 % of the South American continent). It contains over 13.000 tree species, 2.956 of these being endemic species [5].

According to Pallet, 2002 [6], Amazonian fruits can be considered excellent sources of macro- and micronutrients, valued in the current context as health foods or natural foods. Nevertheless, appreciation for Amazonian fruits is subject to restrictions in regional development [7], among which, we can highlight the açaí (*Euterpe oleracea*), tucumã (*Astrocaryum vulgare*), bacaba (*Oenocarpus bacaba*), pequi (*Caryocar brasiliense*), bacupari (*Garcinia gardneriana* Mart.) and rambutan (*Nephelium lappaceum*), as species of great relevance to local communities. Although some of them do not originate from this region of South America, it has been noted that over the years they have adapted very well to the climate, soil conditions and ecosystems unique to the Amazon rainforest, which has allowed their crop cultivation and socio-economic importance [8].

The oil extracted from pequi has stood out as a useful raw material for the food and pharmaceutical industries due to its high levels of unsaturated fatty acids, predominantly oleic acid (60.6 %), and carotenoids, such as beta-carotene, a precursor of vitamin A [8,9]. Bacaba and tucuma are also oil seeds from the Amazon rainforest region and are recognized sources of omega-3 and -6 fatty acids, as well as relevant bioactive compounds and other micronutrients and macronutrients [10]. Studies report a high content of bioactive compounds (flavonoids, anthocyanins) and high antioxidant activity in bacaba, which has the potential to be used as a functional ingredient for food and pharmaceutical applications [11]. Tucumã fruit possess considerable amounts of bioactive compounds, mainly carotenoids, dietary fibers, fatty acids, and polyphenols, which have shown beneficial effects in the management of human diseases [12–15]. They have generated great scientific interest due to their anti-inflammatory, cardioprotective, gastro-protective, and pro-vitamin A effects [16,17].

Rambutan is made up of a diverse composition of micro and macronutrients, such as sugars, fiber, vitamin C, and minerals [14], resulting in cytoprotective, antiulcer, neuroprotective, antioxidant, antiviral, and antimicrobial properties as well as potential for use in prevention and treatment of osteoporosis [15]. In recent years, the peel and seeds have been the subject of studies by different groups due to their rich mineral composition, thus representing the possibility of application in a balanced diet with less waste [16]. Additionally, the bacupari is a plant native to the Amazon and commonly known for having antioxidant components that provide it with rich herbaceous properties [17]. However, among the fruits mentioned, açaí takes precedence as one of the most consumed fruits, not only in the Amazon region, but in the whole of Brazil [18]. A quick search on international platforms with the keywords açaí powder, açaí puree or açaí oil reveals the worldwide commercial accessibility of this fruit and its wide availability for consumption [10]. Açaí fruits are a rich source of anthocyanins and other flavonoids, phenol acids, lignans, and stilbenes, as well as an important source of fibers [19]. Thus, the açaí berry is promoted as a super-fruit, along with pomegranate, black berries, and blueberries, due to its chemical composition, nutritional value, and biological properties [20].

Due to their vast diversity, the fruits of the Amazon biome possess essential physicochemical, nutritional, and pharmacological properties which strengthen the idea that fruit consumption benefits human health [21]. Fruits and vegetables, in general, have been shown to play an important role in the prevention of non-communicable diseases [22]. Several evidence-based studies indicate the influence of oxidative stress in the pathophysiology of obesity and several chronic diseases, such as atherosclerosis, cancer, diabetes, and degenerative diseases [23–26]. Therefore, the use of foods with antioxidant action and phytochemical protectors may be relevant for the prevention of diseases related to increased oxidative stress [27]. It is also noteworthy that Amazonian fruits have not only demonstrated potential in the prevention and control of chronic diseases, but also have an interesting applicability in the realm of infectious diseases, such as COVID-19, responsible for the greatest health crisis in recent history of humanity [28]. The immuno-modulatory, antioxidant, and anti-inflammatory actions of these fruits have already been demonstrated [28,29]. The potential utility of these fruits against the sequelae of infectious diseases becomes especially important in countries such as Brazil, where these diseases have great epidemiological relevance.

Most Brazilian fruits are consumed in their natural forms, but they can also be found as juice, ice cream, jellies, and other food products. This variety in preparation diversifies the consumer market and, consequently, contributes to economic improvement. Amazonian fruits are of great relevance to local populations, being widely found in local and regional markets, but are also present in commercial establishments throughout different Brazilian states [30]. A great example of this is the açaí, which is considered a model of the globalization of Amazonian plants [31]. Despite its nutritional and economic potential [32], a critical and comprehensive assessment of its health benefits will be necessary for the development of novel products, as well as the establishment of a proper consumer market [33]. Moreover, there is a growing interest in nutritious ingredients rich in bioactive compounds that can be easily produced, stored, and transported for use in developing healthier products [34].

The growing desire for more nutritious food is a prime illustration that compels the food industry to innovate. As indicated by the Euromonitor's reports and Mintel's 2030 Global Food and Drink Trends, a rising count of customers are gaining consciousness about functional foods with the aspiration of attaining added health advantages [35]. These advantages might mitigate specific risks of illnesses or enhance overall wellness. As per the findings of the Brazil Food Trends analysis conducted in 2020, the emphasis on health and well-being is also gaining traction within the nation's food industry. This underscores the fact that individuals in Brazil hold the consumption of foods with potential health advantages in high regard [36].

The richness of biodiversity in Brazil is linked to an extensive array of natural compounds, offering a broad potential for the creation of novel pharmaceuticals, agrochemicals, fragrances, cosmetics, components, and dietary supplements [37,38]. This treasure trove of possibilities presents a catalogue of avenues for biotechnological breakthroughs and an unparalleled edge in terms of competitiveness. Sustainable exploitation of the Amazon rainforest can have positive impacts on both the development of Brazil and the Amazon region, Sustainable exploitation of the Amazon rainforest can have positive impacts on both the development of Brazil and the Amazon region, and this trend has been observed elsewhere in the world [39,40] Through the responsible extraction of its diverse natural resources - ranging from timber and minerals to valuable biodiversity - economic and scientific growth can be significant. In addition, such efforts can trigger technological innovations, especially in areas such as biotechnology and pharmaceuticals [41,42].

Therefore, intellectual property and patents play a pivotal role in the food and beverage industry, fostering innovation, safeguarding creativity, and stimulating economic growth. In this fast-paced and competitive landscape, companies invest substantial resources in research and development to create novel products, cutting-edge processes, and distinctive branding [43]. Intellectual property rights, such as patents offer crucial protection, allowing businesses to maintain a competitive edge and recoup their investments [44]. Understanding Industrial Property, patents, specifically, offer exclusive rights to inventors for a limited time, encouraging them to disclose their groundbreaking technologies and inventions to the public, which ultimately drives further advancements in the industry. These protections foster a culture of innovation and encourage collaboration between industry players, leading to improved food safety, enhanced nutrition, sustainable production methods, and ultimately a more diverse and appealing array of products for consumers worldwide.

Even with this relevance, most of the studies available in the literature have directed their efforts to the analysis of specific species [45,46], without performing a critical analysis on a group of fruits with socioeconomic relevance, especially focusing on the largest forest in the world. In addition, an important scenario to be highlighted is the perspective of environmental changes, many of which are driven by extractive human activities [47]. Activities such as deforestation and burning to open up illegal mining areas, crops, or pastures in the Amazon biome have gained a large proportion in recent years, directly impacting plant diversity [48]. Consequently, this scenario also has a direct impact on ecosystem productivity and the geographical distribution of exotic fruits from the region. Thus, prospective studies can be considered a fundamental tool to support the elucidation of innovation indicators from this perspective.

Thus, the aim of this work was to demonstrate the innovation scenario involving exotic fruits relevant to the Amazon biome (açaí, tucumã, bacaba, pequi, bacupari, and rambuta), elucidating the perspectives that can interfere in this context.

2. Materials and methods

This study was an exploratory search to collect technological information in patent documents. The technological search was carried out on December 19, 2022, in the Derwent Innovation Index (DWPI), Thomson Innovation©, licensed for use by SENAI CIMATEC University Center. After the refinement (data not shown), keywords and Boolean operators were adopted to build the search strategy used in the prospection:

Fruits AND amazon AND bioactives OR Euterpe AND oleracea OR Oenocarpus AND bacaba OR Caryocar AND brasiliense OR Garcinia AND gardneriana OR Nephelium AND lappaceum OR Astrocaryum AND vulgare.

The database was searched in the title, abstract, and claims fields of the patent documents, with no restriction on the period of data collection. For the construction of the graphics, the GraphPad Prism 9.2 (San Diego, CA, USA) software, also licensed for use by the SENAI CIMATEC University Center, was used to report the temporal analysis of the patent documents (year of priority and year of expiration), main applicants and inventors of the technologies, and the International Patent Classification (IPC) codes assigned to the document indicators. The results pertaining to the geographical distribution of the main applicant countries/regions, the main potential markets for the technologies, and the main technological areas related to the inventions were obtained directly from the DWPI database (with adaptations).

3. Results and discussion

The use of patents is an important tool in the development and innovation process, directly supporting the analysis of technologies and innovative activities. In this study, patent prospecting was used to evaluate the possibilities of application of the fruits açai,

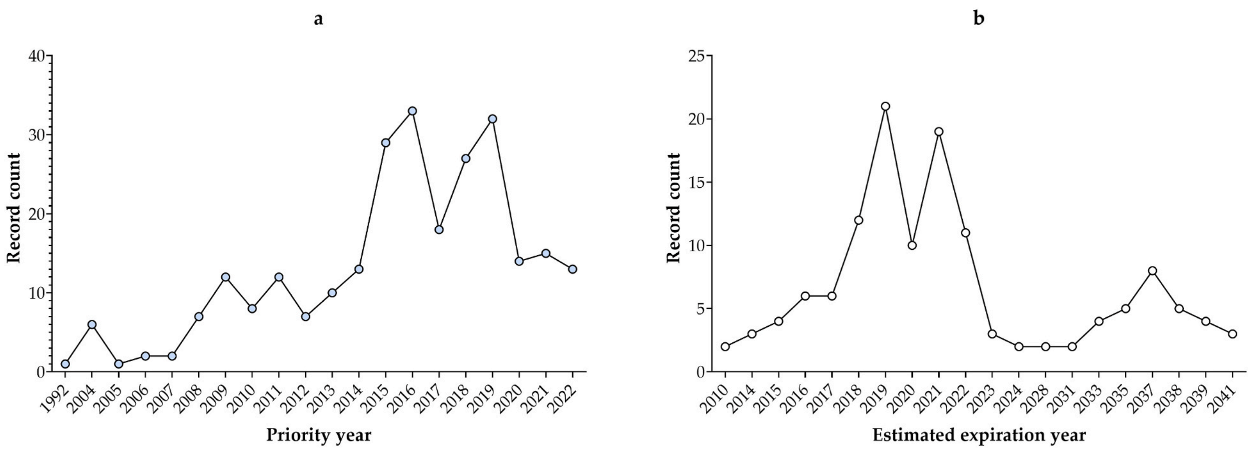

Fig. 1. Temporal analysis of number of patents: (a) evolution per priority year; (b) estimated year for patent expiration.

tucumã, bacaba, pequi, bacupari, and rambutan. As a result of the technology search, 264 individual patent documents and 264 DWPI families were identified. Fig. 1 shows the annual distribution of patent applications related to the subject described, with the first applications beginning in the year 1992 (Fig. 1a). Fig. 1b presents the expiry year of patent applications according to the protection period of each country. According to the results, documents should expire between 2035 and 2038 according to the legal validity related to invention patents, which usually last 20 years. The applications for patent documents were more significant in 2016, reaching a peak of 33 applications, followed by a peak of 32 applications in 2019. The evolution of the number of patent applications may be related to the fact that in recent years, there has been a greater awareness of wellness and health, and this has generated a demand for nutritious and quality food because of the search for a longer and healthier life. Additionally, it is worth noting that we are currently seeing a growing market for bioactive compounds recovered from natural sources that can be applied in the food, cosmetic, and pharmaceutical industries [3]. Results of this search revealed a 3-times increase in the number of related patents from the year 2013 to the year 2016. Given the increasing demand by the consumer market for products that have a natural origin, especially those that contain bioactive components, it is expected that this trend will also be reflected in patent indicators [49]. This behavior may also have implications in the consumption of the amazon fruits, since they present bioactive properties.

It is worth noting that, in 2020, the World Health Organization recommended a daily intake of 400 g of fruits and vegetables to prevent the development of malnutrition and non-communicable diseases. Essential components of a healthy diet, fruits and vegetables have in their composition important vitamins, minerals, fiber, and bioactive compounds. These components are widely known for their antioxidant properties which have important general health benefits, such as strengthening the immune system [50]. Moreover, an adequate daily intake of fruits can prevent major health problems, such as cardiovascular diseases, cancer, type 2 diabetes, and even premature mortality. Bioactive compounds, such as phenolic compounds (anthocyanins and other flavonoids) and carotenoids are abundantly present in fruits, vegetables, herbs and roots [51]. These compounds are known to have antioxidant properties, which are important for protecting cellular components from free radicals, which reduces the oxidative stress, ROS, and oxidative damage to the body's cells [52]. Due to these properties, compounds from natural matrices have great potential in becoming valuable ingredients or supplements utilized by the food, cosmetic and pharmaceutical industries [53].

However, it is important to point out that other factors can have an impact on the consumption of Amazonian fruits and, consequently, on the promotion of innovation strategies involving these species [54]. This is the case with extractive activities, such as the deforestation of the Amazon rainforest, which has hit a record high in the last three decades. One reflection of this is the number of native trees lost, which between 2020 and 2022 amounted to more than 1 billion units, corresponding to an economic loss of up to 17 billion US dollars [47]. The study by Hall et al. [55] showed that deforestation in Tanzania has led to a reduction in fruit and vegetable consumption, resulting in a loss in the quality of the population's diet. Thus, we cannot fail to point out that the innovation scenario involving açaí, tucumã, bacaba, pequi, bacupari, and rambuta may change in the coming years due to these factors, even if it is in the long term.

As shown in Fig. 2, in terms of application areas, the patent documents found in this study are distributed in three main areas: cosmetics (28.02 %), pharmaceuticals (25.38 %) and food (20.08 %). In this way, it is possible to observe that the biodiversity of molecules enables the generation of different bioproducts, which in turn, present a high added value and a varied potential of application in the production of drugs, cosmetics, and dermo cosmetics, as well as in the food and beverage industry [56]. The new generation of bioproducts not only attributes sustainability to production processes, but also competes in many sectors with conventional products, in terms of technological and functional properties [57].

Globally, the cosmetic industry is growing exponentially due to the sustainability and clean beauty movement. Cosmetic products containing naturally derived ingredients, fully organic cosmetic products and cruelty free have become a trend [58]. Brazil has emerged as a prominent player in the global cosmetic industry, renowned for its diverse and innovative beauty products. With an abundant array of natural resources like exotic Amazonian botanicals and acai berries, Brazil capitalizes on its rich biodiversity to craft

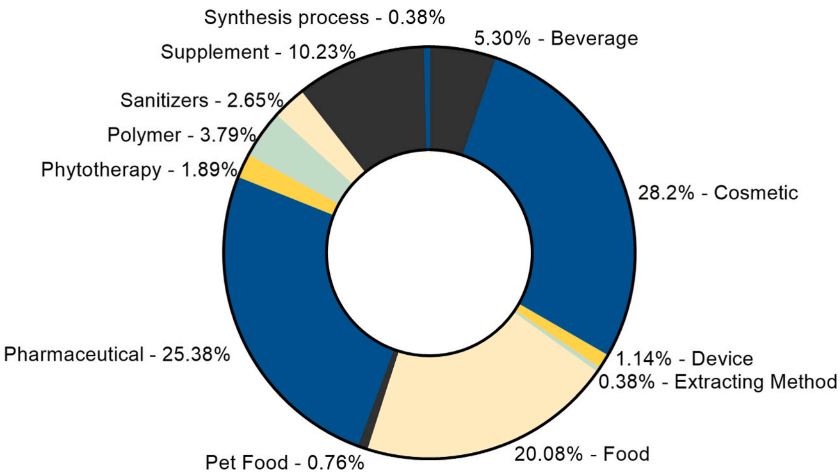

Fig. 2. Distribution of the studied patents in application areas.

unique and eco-friendly beauty formulations [59]. The country's expertise extends to haircare, skincare, and fragrance lines, showcasing a deep-rooted cultural appreciation for beauty and self-care [60]. Most of the technologies developed in the patents focused on cosmetics with bioactive activities. The growing interest in cosmetics made with ingredients derived from natural matrices reflects current societal concerns in reducing negative impacts on the environment, promoting sustainable development of products and packaging, as well as reducing exposure to components potentially harmful to health, such as parabens, dyes and petrolatum [61]. In response to these consumer interests, companies are introducing products organically made with natural extracts, oils, and others polyphenols compounds that promise a healthier alternative. The patent KR2016059263A relates to a waterless foam-type shampoo composition that can be used by people who cannot groom their scalp for prolonged periods of time, such as pre- or post-operation patients, the elderly, the disabled, or people engaged in outdoor activities. One of the suggested formulations contains *Euterpe oleracea* fruit oil. It is worth noting that the market for natural cosmetics with ingredients derived from natural resources from the Amazon is growing worldwide [62]. The oil produced from the fruit pulp can be used in several cosmetic products, such as after-sun products,

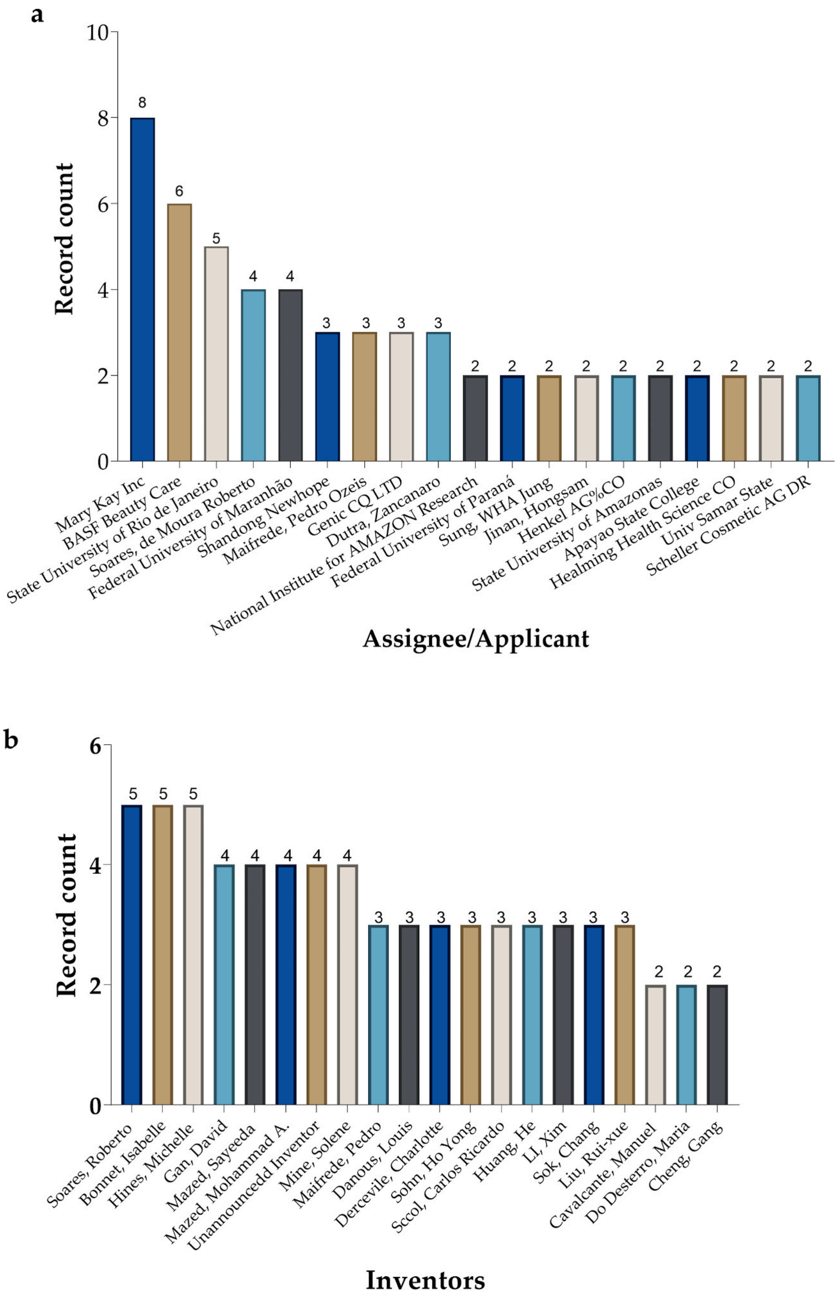

Fig. 3. Analysis of the main (**a**) applicants and (**b**) inventors of the prospected technologies.

creams, lotions, shampoos, face masks, among others. It is considered to have skin regenerative and anti-aging properties due to constituents such as essential fatty acids, phytosterols and vitamins [63].

Throughout human history, civilizations have made use of natural matrices as important sources of bioactive compounds. Many countries around the world possess a rich body of empirical knowledge that demonstrates the use of medicinal plants and their derivatives for the treatment of different diseases [64]. Nearly 85 % of the preparation of traditional medicine entails the use of natural bioactive compounds extracted from plants [65]. The interest in plants and fruits with potential pharmaceutical application is due to some important characteristics, such as safety for human consumption, reduction of waste generation, acceptability by the population, biological activity, and the ability to produce formulations that allow the delivery of non-toxic concentrations without losing biological activity [66].

The patent CN104431957A, of 2015, refers to a spicy black bean sauce containing rambutan [67]. Rambutan (*Nephelium lappaceum* L.) is one of the most important tropical commercial fruits widely cultivated in Southeast Asia, Australia, South America, and African countries. Its acceptance by the consumer market and its industrial application is increasing every day [63]. For example, rambutan seed has a high concentration of geraniin (ranging from 444 to 1011 mg/fruit), which can be used as an antihyperglycemic agent [68]. In addition, the extract obtained from the rambutan seed shows cytotoxic activity against tumor cell lines, but non-toxic against normal cells, and a satisfactory antimicrobial action against clinically relevant strains, such as *Staphylococcus epidermidis* [69,70]. Within this context, it is important to highlight the differentiated profile of Amazonian fruits when it comes to bioactive compounds, causing them to be strongly explored, among other functions, for the control of metabolic disorders [71].

Today, consumers are increasingly aware of the benefits of natural ingredients in their diet, an awareness that continues to strengthen over time. The growing emphasis on health and well-being has led people to question the foods they consume, seeking more natural and less processed options [72]. Trust in natural ingredients as a safer and healthier choice, coupled with benefits proven by scientific research, such as antioxidant and anti-inflammatory activity, has been driving this trend. As a result, the preference for natural ingredients is increasingly shaping consumers' food choices, reflecting a significant shift in consumer perceptions and habits [73]. The patent CN111685189A, filed in 2020, focuses on the preparation of vegetable fat powder using *Nephelium lappaceum* kernel oil to enhance the mouthfeel of milk tea [74]. Another notable patent showcasing the use of biomolecules from fruits to enhance food functionality is BR102018017202A2, also filed in 2020. This patent involves a mixture that combines milk with a soluble extract derived from *Euterpe oleracea* mart [75].

The main patent applicants found were Mary Kay and BASF Beauty Care (Fig. 3a), both in the cosmetics industry. According to Burlando and Cornara [76], Amazonian species have great potential when it comes to the development of skin care products, products that are within the scope of Mary Kay and BASF Beauty Care. These results reinforce the potential application of Amazonian fruits in the development of products for the cosmetic sector presented in Fig. 2, which has been standing out worldwide due to factors such as exotic fragrance perfume, high potency moisturizing cream for the skin, among others [62]. We can also notice that Roberto Soares de Moura appears both among the main applicators (Fig. 3a) and inventors (Fig. 3b). It can be seen that such an inventor/applicant has carried out important studies with Amazonian plants, exploring the potential of their pharmaceutical properties [77–81].

Another point worth highlighting is the legal status of the patents found, in which half are dead (50 %), approximately 27.5 % are undetermined and about 22.5 % are active (Fig. 4a). Mary Kay is the organization with the most patents filed (n = 8), however, it is noted that 62.5 % (n = 5) are dead. Within this context, among the top 10 applicants, only 5 have active patents, these being BASF Beauty Care, Federal University of Maranhão, Genic CO, Pedro Maifrede and Sung Jung (Fig. 4b). The majority presence of patents with dead status among the group of documents evaluated in this study may indicate the current difficulty about the lack of investments to support the elucidation of the properties of Amazonian fruits, in addition to the difficulty of companies to explore the properties of these fruits in a sustainable way, since their use is restricted to local communities [82]. The use of açaí, tucumã, bacaba, pequi, bacupari and rambutan as a source of antioxidant products, for example, still lacks investments in research and development to elucidate their effects, both in vitro and in vivo models, which can have negative impacts on the generation of technological innovations [83].

With regard to the main countries of origin of the patent applicants found in this research, one can see the prominence of the Asian

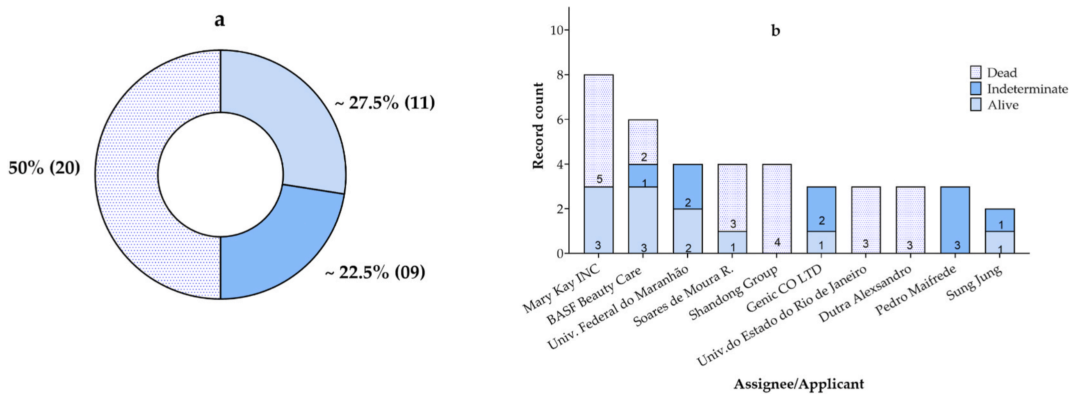

Fig. 4. Analysis of number of patent documents: (**a**) general legal status of the publications found; (**b**) number of publications per applicant.

continent, with China being responsible for 89 documents, followed by the Republic of Korea, with 31 patents (Fig. 5). In second place is Brazil (48 documents), home to most of the Amazon rainforest (Fig. 5). An important issue is that, in recent years, the exploitation of the flora of the Amazon rainforest has been targeted by different foreign countries, which may be one of the reasons why countries that are not contemplated by the rainforest show prominent indices when it comes to innovation [84,85]. Especially, Asian countries have been considered important producers and consumers of exotic fruits, including açaí, and this behavior is associated with the possible functional, biological, and physiological actions that these fruits exhibit [86]. An example of this is rambutan, a fruit that has been widely consumed in Southeast Asia, especially in Indonesia [87]. The availability of these products can directly support the conduct of research and development of new products, reflected in innovation indexes, such as patents. In addition, even though it has a prominent position in patent applications, this indicator cannot be used to suggest that the natural resources of the Brazilian forest are being exploited in an innovative and sustainable way [88]. This is in view of the need for initiatives aimed at developing products from components of these fruits so that they can be widely used in a sustainable and responsible way in future generations [89].

Table 1 shows some documents found in this prospection. Patent CN113876873A involves the development of a fermented food with *Euterpe oleracea* fruit from a pool of microorganisms, with claims of enzyme activity inhibition, weight reduction, and muscle gain. Patent CN113876873A involves the development of fermented food by a pool of microorganisms, with claims of enzyme activity inhibition, weight reduction, and muscle gain. Several studies mention the various bioactive properties of the fruit which are associated with its chemical matrix composition, including bioactive compounds capable of interacting positively with cellular oxidative metabolism [64–66]. The field of cosmetics, which represents the largest percentage in this prospection, is shown in Fig. 2. Patent CN114931534A involves a composition useful for the preparation of lotions and cosmetics for the repair of sensitive skin containing, among other plants, rambutan (*Nephelium Lappaceum*). This fruit is a promising raw material for the personal care industry [90].

In terms of scientific publications, several studies have addressed the content of bioactive compounds and their therapeutic potential, including both complementary approaches as well as conventional treatments. For example, a nanoemulsion of Pequi (*Caryocar brasilense Cambess*) oil has shown promising in vitro results as a complementary therapeutic approach to be employed along with conventional breast cancer treatment [101] (Table 2). *In vitro* analysis also demonstrated the potential of ethanolic extract of pequi to promote oxidative protection in human coronary artery endothelial cells [102]. Bacupari (*Garcinia gardneriana*) extracts also demonstrated activity on neoplastic cell lines tested, possibly due to the large content of carotenoids in the fruits and leaves [103]. Its use has also been commonly associated with the treatment of gastritis and hepatitis in Brazil due to its high concentrations of 7-epi-clusianone, guttiferone-A and fukugetin [104]. Another very important approach is the investigation of bioactive compound contents in industry co-products for applications and new product developments. For example, in the case of rambutan, there is a great nutritional and functional potential of the seeds, making it a potential fruit for applications in the food, pharmaceutical, and cosmetic industries [90]. The study by Alves et al. [105] demonstrated that the co-products from the açaí pulp can be an important source of

Fig. 5. Geographical distribution of the analysis of the main countries/regions of the depositors of the prospected technologies with their number of patent document. EPO—European Patent Office and WIPO—World Intellectual Property Organization.

Table 1
Examples of recent documents found in the technological prospection carried out.

Title	Application Number	Assignee or inventor	Aplication	Country	Related to	Publication Date
Azayier fruit leavening for increasing muscle and reducing fat and delaying aging	CN113876873A	Baiyuete Biotechnology (Shanghai) Co. Ltd.	Food	China	Use of *Euterpe oleracea* fruit leavening for preparing the weight-reducing composition. Prepared by fermenting multiple strains, including *Saccharomyces*, lactic acid bacteria and acetic acid bacteria [91].	04/01/2022
Skin sensitive repair composition and application thereof	CN114931534A	Shanghai New Cogi Cosmetic Co. Ltd.	Cosmetic	China	Skin sensitive repair composition for skin and application thereof, relating to the technical field of cosmetic, the sensitive skin composition. Composition comprises *Fucus vesiculosus* extract, *Nephelium lappaceu*m peel extract, *Mirabilis jalapa* extract, and *Centella asiatica* leaf extract [92].	08/23/2022
Euterpe oleracea based emulsion mart.com larvicidal activity	BR102020013253A2	Federal University of Pernambuco, Federal University of Vale do São Francisco, Foundation University of Amazonas	Pharmaceutical	Brasil	The emulsion comprises *Euterpe oleracea* oil as an active pharmaceutical ingredient. The emulsion is an alternative for use in vector control programs for *A. aegypti* and to provide a larvicidal effect on *Aedes aegypti* [93].	01/11/2022
Selenium liquor for protecting liver and preventing liver disease	CN114099620A	Sichuan Zhongchang Kanglv Industry Development Co. Ltd.	Pharmaceutical	China	Selenium liquor for protecting liver and preventing liver disease, comprising the following components: wine base, selenium-enriched shepherd ' s-purse plant crushing powder, new food raw material, medicinal plant, medicinal animal and medicinal animal product [94].	03/01/2022
Agent for preventing or improving oxidative stress, inflammation, and aging of skin caused by violet light, blue light, and ultraviolet rays, and external skin formulation	JP2022065588A	KOEI KOGYO KK	Cosmetic	Japão	Preventive/ameliorating agent for skin oxidative stress, inflammation and aging caused by violet light, blue light and UV rays contains extracts or fermented products chosen from fermented products [95].	04/27/2022
A water eyebrow pencil and preparation method thereof	CN113974300A	Jiaoshi Daily Chemical (Hangzhou) Co. Ltd.	Cosmetic	China	Water eyebrow pencil and method of preparation, which uses Amazon fruit as a skin conditioning agent [96].	01/28/2022

(*continued on next page*)

Table 1 (*continued*)

Title	Application Number	Assignee or inventor	Aplication	Country	Related to	Publication Date
A vegetable fat powder for improving mouthfeel of milk tea and preparation method thereof	CN111685189A	ZHANG Zi-qi, Huanggang, Hubei	Food	China	Preparing vegetable fat powder comprises e.g. stirring and mixing maltodextrin, sugar, sodium caseinate, dipotassium phosphate, emulsifier and water, mixing with *Nephelium lappaceum* kernel oil, homogenizing and spray drying [97].	09/22/2020
Antimicrobial Can Extract Obtained From The Leaves Of Euterpe Oleracea (Açai) | Fitoterápico Antimicrobiano Obtido A Partir Do Extrato Das Folhas De Euterpe Oleracea (Açai)	BR102017013494A2	Federal University of Maranhão	Phytotherapy	Brazil	Antimicrobial agent comprises *Euterpe oleracea* leaves extract, and formulated in form of capsule, solution, syrup, tablets, gel, aerosols, antiseptic, cream, powder, paste, ointments, pellets and soap [98].	01/15/2019
Nephelium lappaceum and chayote compound beverage and preparation method thereof	CN110495538A	Jiangsu Zhineng Biotechnology Co. Ltd.	Beverage	China	Fruit juice beverage based on the fruits of *Euterpe oleracea*, comprises: Euterpe oleracea juice (8–12 %); apple juice (7–10 %); pear juice (3–5%); lime juice (2.5–5%); passion fruit juice (1.5–4%); acerola (6–10 %); and orange juice (3–5%) [99].	11/26/2019
Process For Preserving the Husk and Use of Rambutan (*Nephelium Lappaceum*) in Food Products	WO2022006367A2	Rambuhealth Corp.	Supplement	United States	A formulation for delivering one or more health benefits to a human post-consumption and a method to create the formulation are described. The formulation comprises a shell extract of *Nephelium lappaceum* in a form of a powder or a liquid and at least one material [100].	01/06/2022
Cosmetics with fair complexion producing and antiinflammatory effects contain water-soluble solvent extract of fruit peels of Garcinia mangostana or Nephelium lappaceum	JP4244004A	Nonogawa Shoji Kk	Cosmetic	Japan	Cosmetic having excellent whitening activity. anti-inflammatory activity and storage stability, improving the spots, dark colors and freckles of skin. Containing the water-soluble solvent extract of fruit peels of Garcinia mangostana or Nephelium lappaceum	09/01/1992
Composition useful as antibacterial agent, includes combined volume ratio of ethanol extracts from powdered Durio zibethinus (durian) and powdered Nephelium lappaceum (rambutan)	PH22019050217U1	Philippine Science High School	Pharmaceutical	Philippines	Antibacterial agent against E. coli and S. aureus which comprises a combined ratio by volume of ethanol extracts from a powdered Durio zibethinus (durian) and a powdered Nephelium lappaceum (rambutan).	10/02/2020

Table 2
Articles that focus on the application of Amazonian fruits.

Title	Main Findings and/or Conclusions	Reference
Nutraceutical potential of Amazonian oilseeds in modulating the immune system against COVID-19 – A narrative review	The study compiled the available evidence regarding the biochemical properties of some Amazonian fruits, especially Brazil nut, acai berry, bacaba, peach palm, sapucaya and Tucuma fruits, on human health and immune system. These effects were discussed from an etiological and pathophysiological perspective, emphasizing their potential role as a co-adjuvant strategy against COVID-19.	[10]
Açaí (*Euterpe oleracea Mart*) seed extract protects against maternal vascular dysfunction, hypertension, and fetal growth restriction in experimental preeclampsia	The article investigated whether *Euterpe oleracea Mar*t. (acai) seed extract prevents maternal cardiovascular changes and intrauterine growth restriction (IUGR) in experimental preeclampsia (PE). As a conclusion they found that the extract protected against maternal cardiovascular changes and IUGR in L-NAME-induced PE. The protective effect of ASE may be partially explained by its antioxidant property.	[81]
Peels of tucumã (*Astrocaryum vulgare*) and peach palm (*Bactris gasipaes*) are by-products classified as very high carotenoid sources	In this study, for the first time, the carotenoid profile in the peel of tucuma and peach fruits was studied. The carotenoid content of the peel of both fruits was higher than those found in the pulp. Thus, the fruit peels of tucuma and peach were classified as very high sources of carotenoids to be used by any potentially interested industry.	[107]
Bacaba powder produced in spouted bed: an alternative source of bioactive compounds and energy food product Bacaba	This study evaluated the Bacaba powder produced in a beak bed as a source of bioactive compounds and high energy value. The results of total phenolics (376.43 mg GAE 100 g^{-1}), high solubility (92 %), flowability (14 %), and energy of Bacaba powder suggest the potential for many applications, such as the development of dietary supplements, high-energy beverages, milk-based and instant products, and bakery products.	[108]
Pequi oil (*Caryocar brasilense Cambess*.) nanoemulsion alters cell proliferation and damages key organelles in triple-negative breast cancer cells in vitro	The study was investigated the effects of pequi oil-based nanoemulsion (PeNE) on triple-negative breast cancer cells (4T1), in vitro. PeNE showed a dose- and time-dependent cytotoxic effect with IC50 lower than free pequi oil after 48 h of exposure ($p < 0.001$). These promising results highlight the use of PeNE as a potential complementary therapeutic approach to be employed alongside conventional breast cancer treatments in the future	[101]
Antiproliferative Activity and Antioxidant Potential of Extracts of *Garcinia gardneriana*	The study evaluated the antiproliferative activity, antioxidant potential, and the chemical profile obtained from the whole fruit and leaves of Garcinia gardneriana. The content of carotenoids in the fruit and leaves were expressive. The ethyl extract and the hexane and chloroform fractions of the fruit were active in all the neoplastic lines tested. The leaves showed cytotoxic activity in the hexane fraction in the mammary carcinoma line. This demonstrates its therapeutic potential as a fruit.	[103]
Functional and nutritional properties of rambutan (*Nephelium lappaceum* L.) seed and its industrial application: A review	Rambutan seed is a major co-product of the industry that is rich in fat, protein, carbohydrates, fiber, antioxidants, and phenolics and can be used in various segments of the food, pharmaceutical, and cosmetic industries. Research should also continue to determine if rambutan seed fat can be fractionated, chemical and enzymatic interesterified, and blended with other fats to make cocoa butter alternatives.	[90]
Antiproliferative Activity and Antioxidant Potential of Extracts of *Garcinia gardnerina*	The study evaluated the e antiproliferative activity, the antioxidant potential, and the chemical profile obtained from the whole fruit and from leaves of *Garcinia gardneriana.* The findings demonstrated *Garcinia* as a potential source of bioactive compounds with a significant antiproliferative effect in breast neoplastic lines (MCF).	[103]
Açaí (*Euterpe oleracea Mart.*) Modulates Oxidative Stress Resistance in Caenorhabditis elegans by Direct and Indirect Mechanisms	In this study, the *Caenorhabditis* elegans model to evaluate the in vivo antioxidant properties of açaí on an organismal level and to examine its mechanism of action. Supplementation with açaí aqueous extract (AAE) increased both oxidative and osmotic stress resistance independently of any effect on reproduction and development. The researchers conclude that, AAE increased polyglutamine protein aggregation and decreased proteasome activity under certain conditions by direct and indirect mechanisms.	[20]
Antidiabetic effect of *Euterpe oleracea Mart*. (açaí) extract and exercise training on high-fat diet and streptozotocin-induced diabetic rats: A positive interaction	The article assess the effect of the ac¸ai' seed extract (ASE) associated with exercise training on diabetic complications induced by high-fat (HF) diet plus streptozotocin (STZ) in rats. In type 2 diabetic rats, the treatment with ASE reduced blood glucose, insulin resistance, leptin and IL-6 levels, lipid profile, and vascular dysfunction. The group conclued that, ASE treatment has an antidiabetic effect in type 2 diabetic rats by activating the insulin-signaling pathway in muscle and adipose tissue, increasing GLP-1 levels, and an anti-inflammatory action.	[79]

fiber and antioxidant compounds. In addition, Santos et al. [106] pointed out that the bacaba powder obtained through a freeze-drying technique has a wide concentration of antioxidant components with bioactive properties, which allows its application in different industrial sectors.

Thus, the data presented in this study demonstrates the important biological properties contained by the evaluated fruits, especially in reference to the presence of antioxidant components. It is these properties which provide important opportunities for development in the pharmaceutical and food industries.

4. Conclusions

The Amazon is a biome known worldwide for having among its flora exotic fruits, such as pequi, açaí, and rambutan, which has attracted interest due to its differentiated composition regarding the presence of bioactive components and other nutritionally relevant compounds. However, the results found in this study revealed that there is still an important gap between the in natura consumption of these fruits and the development of innovative products, leading to the generation of patents. One of the main findings of this study was the dominance of Asian countries as depositors of the documents found, which indicates the weaknesses of innovation among the countries that are part of the Amazon. In addition, the patent documents found in this search showed that the cosmetic, pharmaceutical and food areas have explored the potential of these fruits more than other sectors, especially in regards to their composition and potential application in the development of new, anti-aging, antioxidant and nutraceutical products. However, increased investment in translational research is necessary to harness the potential of these fruits and expand their utilization from local communities to industrial innovation. Finally, it is important to emphasize that the innovation scenario involving exotic fruits with a focus on the Amazon may be impacted in the coming years due to increasingly common extractive activities in this region, which may hinder the development of new technologies. The findings contained in this work could support not only the market and scientific trends involving the fruits evaluated, but also the elucidation of a scenario exposed to anthropological activities.

Funding

This research received no external funding.

Institutional review Board statement

Not applicable.

Data availability statement

All the results found during this study are available in this manuscript.

CRediT authorship contribution statement

Leticia de Alencar Pereira Rodrigues: Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Danielle Devequi Gomes Nunes:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Katharine Valéria Saraiva Hodel:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Josiane Dantas Viana:** Writing – review & editing, Validation, Methodology, Formal analysis. **Edson Pablo Silva:** Writing – review & editing, Validation, Methodology, Formal analysis. **Milena Botelho Pereira Soares:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors thank the SENAI CIMATEC University Center for their support in the development of this research and Nicole Marie Hitchcock for her support in revising the article.

References

[1] F.F. de Sousa, C. Vieira-da-Silva, F.B. Barros, The (in)visible market of miriti (Mauritia flexuosa L.f.) fruits, the "winter acai", in Amazonian riverine communities of Abaetetuba, Northern Brazil, Glob. Ecol. Conserv. 14 (2018), e00393 https://doi.org/10.1016/j.gecco.2018.e00393.

[2] T.M. Uekane, L. Nicolotti, A. Griglione, H.R. Bizzo, P. Rubiolo, C. Bicchi, M.H.M. Rocha-Leão, C.M. Rezende, Studies on the volatile fraction composition of three native Amazonian-Brazilian fruits: murici (Byrsonima crassifolia L., Malpighiaceae), bacuri (Platonia insignis M., Clusiaceae), and sapodilla (Manilkara sapota L., Sapotaceae), Food Chem. 219 (2017) 13–22, https://doi.org/10.1016/J.FOODCHEM.2016.09.098.

[3] L.C. Neves, J.M. Tosin, R.M. Benedette, L. Cisneros-Zevallos, Post-harvest nutraceutical behaviour during ripening and senescence of 8 highly perishable fruit species from the Northern Brazilian Amazon region, Food Chem. 174 (2015) 188–196, https://doi.org/10.1016/J.FOODCHEM.2014.10.111.

[4] M. do S.M. Rufino, R.E. Alves, E.S. de Brito, J. Pérez-Jiménez, F. Saura-Calixto, J. Mancini-Filho, Bioactive compounds and antioxidant capacities of 18 non-traditional tropical fruits from Brazil, Food Chem. 121 (2010) 996–1002, https://doi.org/10.1016/J.FOODCHEM.2010.01.037.

[5] J.V. Faria, I.H. Valido, W.H.P. Paz, F.M.A. da Silva, A.D.L. de Souza, L.R.D. Acho, E.S. Lima, A.P.A. Boleti, J.V.N. Marinho, M.J. Salvador, E.L. dos Santos, P. K. Soares, M. López-Mesas, J.M.F. Maia, H.H.F. Koolen, G.A. Bataglion, Comparative evaluation of chemical composition and biological activities of tropical fruits consumed in Manaus, central Amazonia, Brazil, Food Res. Int. 139 (2021), 109836, https://doi.org/10.1016/J.FOODRES.2020.109836.
[6] D. Pallet, Perspectives de valorisation des fruits amazoniens issus de l'extractivisme, 2002, pp. 1–8.
[7] A. Berto, A.F. da Silva, J.V. Visentainer, M. Matsushita, N.E. de Souza, Proximate compositions, mineral contents and fatty acid compositions of native Amazonian fruits, Food Res. Int. 77 (2015) 441–449, https://doi.org/10.1016/J.FOODRES.2015.08.018.
[8] C. Clement, M. De Cristo-Araújo, G. Coppens D'Eeckenbrugge, A. Alves Pereira, D. Picanço-Rodrigues, Origin and domestication of native amazonian crops, Diversity 2 (2010) 72–106, https://doi.org/10.3390/d2010072.
[9] M.R.M.R. Pinto, D. de A. Paula, A.I. Alves, M.Z. Rodrigues, É.N.R. Vieira, E.A.F. Fontes, A.M. Ramos, Encapsulation of carotenoid extracts from pequi (Caryocar brasiliense Camb) by emulsification (O/W) and foam-mat drying, Powder Technol. 339 (2018) 939–946, https://doi.org/10.1016/J.POWTEC.2018.08.076.
[10] O.V. dos Santos, A.C. da, C. Pinaffi Langley, A.J. Mota de Lima, V.S. Vale Moraes, S. Dias Soares, B.E. Teixeira-Costa, Nutraceutical potential of Amazonian oilseeds in modulating the immune system against COVID-19 – a narrative review, J. Funct.Foods 94 (2022), https://doi.org/10.1016/j.jff.2022.105123.
[11] F. Dias, B. Abadio, I. Galv, R. Botelho, Physicochemical characteristics and antioxidant activity of three native fruits from brazilian savannah (cerrado), Aliment. e Nutr. 23 (2012) 1–6. https://www.researchgate.net/publication/281253670. (Accessed 28 December 2022).
[12] M.H. Ferrari Felisberto, M. Souza Costa, F. Villas Boas, C. Lopes Leivas, C. Maria Landi Franco, S. Michielon de Souza, M.T. Pedrosa Silva Clerici, L. Mach Côrtes Cordeiro, Characterization and technological properties of peach palm (Bactris gasipaes var. gasipaes) fruit starch, Food Res. Int. 136 (2020), 109569, https://doi.org/10.1016/J.FOODRES.2020.109569.
[13] C. Giombelli, I.J. Iwassa, C. da Silva, B.C. Bolanho Barros, Valorization of peach palm by-product through subcritical water extraction of soluble sugars and phenolic compounds, J. Supercrit. Fluids 165 (2020), 104985, https://doi.org/10.1016/J.SUPFLU.2020.104985.
[14] S. Torgbo, P. Rugthaworn, U. Sukatta, P. Sukyai, Biological characterization and quantification of rambutan (Nephelium lappaceum L.) peel extract as a potential source of valuable minerals and ellagitannins for industrial applications, ACS Omega 7 (2022) 34647–34656, https://doi.org/10.1021/acsomega.2c04646.
[15] H.S. Cheng, S.H. Ton, K. Abdul Kadir, Ellagitannin geraniin: a review of the natural sources, biosynthesis, pharmacokinetics and biological effects, 2016, Phytochem. Rev. 161 (16) (2016) 159–193, https://doi.org/10.1007/S11101-016-9464-2.
[16] S. Klongdee, U. Klinkesorn, Optimization of accelerated aqueous ethanol extraction to obtain a polyphenol-rich crude extract from rambutan (Nephelium lappaceum L.) peel as natural antioxidant, Sci. Rep. 12 (2022), 21153, https://doi.org/10.1038/s41598-022-25818-7.
[17] A.M. de Melo, B.P. Costa, M. Ikeda, R.H. Ribani, Identification of bioactive compounds, morphology, and nutritional composition of bacupari (Garcinia brasiliensis (Mart)) pulp powder in two stages of maturation – a short communication, Food Chem. 391 (2022), https://doi.org/10.1016/J.FOODCHEM.2022.133279.
[18] R. Lopes, R.N.V. Da Cunha, M. dos S. Tavares, M.D.M. Raizer, C.A. Dos Santos, E.J.D. Da Silva, M.T.G. Lopes, Seasonality of fruit production of Euterpe oleracea and E. precatoria açaí palm trees cultivated in the metropolitan region of Manaus (AM), Rev. AGRO@MBIENTE ON-LINE. 16 (2022) 1–14, https://doi.org/10.18227/1982-8470ragro.v16i0.7282.
[19] A.G.V. Costa, D.F. Garcia-Diaz, P. Jimenez, P.I. Silva, Bioactive compounds and health benefits of exotic tropical red–black berries, J. Funct.Foods 5 (2013) 539–549, https://doi.org/10.1016/J.JFF.2013.01.029.
[20] L. de Freitas Bonomo, D. Nunes Silva, P. Ferreira Boasquivis, F. Aparecida Paiva, J. Ferreira da Costa Guerra, T. Alves Faria Martins, lvaro Gustavo de Jesus Torres, I. Thadeu Borges Raposo de Paula, W. Luiz Caneschi, P. Jacolot, N. Grossin, F.J. Tessier, E. Boulanger, M. Eustá quio Silva, M. Lú cia Pedrosa, R. de Paula Oliveira, Açaí (Euterpe oleracea mart.) modulates oxidative stress resistance in Caenorhabditis elegans by direct and indirect mechanisms, PLoS One 9 (2014), 89933, https://doi.org/10.1371/journal.pone.0089933.
[21] A. Ibiapina, L. da S. Gualberto, B.B. Dias, B.C.B. Freitas, G.A. de S. Martins, A.A. Melo Filho, Essential and fixed oils from Amazonian fruits: proprieties and applications, Crit. Rev. Food Sci. Nutr. 62 (2022) 8842–8854, https://doi.org/10.1080/10408398.2021.1935702.
[22] J.A.M. Pereira, C. V Berenguer, C.F.P. Andrade, J.S. Câmara, Unveiling the bioactive potential of fresh fruit and vegetable waste in human health from a consumer perspective, Appl. Sci. 12 (2022) 2747, https://doi.org/10.3390/app12052747.
[23] D. Martins, L.R. Garcia, D.A.R. Queiroz, T. Lazzarin, C.R. Tonon, P. da S. Balin, B.F. Polegato, S.A.R. de Paiva, P.S. Azevedo, M.F. Minicucci, L. Zornoff, Oxidative stress as a therapeutic target of cardiac remodeling, Antioxidants 11 (2022) 2371, https://doi.org/10.3390/antiox11122371.
[24] C. Iacobini, M. Vitale, J. Haxhi, C. Pesce, G. Pugliese, S. Menini, Mutual regulation between redox and hypoxia-inducible factors in cardiovascular and renal complications of diabetes, Antioxidants 11 (2022) 2183, https://doi.org/10.3390/antiox11112183.
[25] A.M. Soldo, I. Soldo, A. Karačić, M. Konjevod, M.N. Perkovic, T.M. Glavan, M. Luksic, N. Žarković, M. Jaganjac, Lipid peroxidation in obesity: can bariatric surgery help? Antioxidants 11 (2022) 1537, https://doi.org/10.3390/antiox11081537.
[26] S.A. Bukhari, K. Zafar, M.I. Rajoka, Z. Ibrahim, S. Javed, R. Sadiq, Oxidative stress-induced DNA damage and homocysteine accumulation may be involved in ovarian cancer progression in both young and old patients, Turk. J. Med. Sci. 46 (2016) 583–589, https://doi.org/10.3906/sag-1406-17.
[27] N. Cook, Flavonoids—chemistry, metabolism, cardioprotective effects, and dietary sources, J. Nutr. Biochem. 7 (1996) 66–76, https://doi.org/10.1016/S0955-2863(95)00168-9.
[28] M.F. Manica-Cattani, A.L. Hoefel, V.F. Azzolin, M.A.E. Montano, I.E. da Cruz Jung, E.E. Ribeiro, V.F. Azzolin, I.B.M. da Cruz, Amazonian fruits with potential effects on COVID-19 by inflammaging modulation: a narrative review, J. Food Biochem. 46 (2022), e14472, https://doi.org/10.1111/jfbc.14472.
[29] K.R. Paudel, V. Patel, S. Vishwas, S. Gupta, S. Sharma, Y. Chan, N.K. Jha, J. Shrestha, M. Imran, N. Panth, S.D. Shukla, S.K. Jha, H.P. Devkota, M.E. Warkiani, S. K. Singh, M.K. Ali, G. Gupta, D.K. Chellappan, P.M. Hansbro, K. Dua, Nutraceuticals and COVID-19: a mechanistic approach toward attenuating the disease complications, J. Food Biochem. 46 (2022), e14445, https://doi.org/10.1111/jfbc.14445.
[30] S.C. da C. Marques, J.R.C. Mauad, C.H. de F. Domingues, J.A.R. Borges, J.R. da Silva, The importance of local food products attributes in Brazil consumer's preferences, Futur, Foods 5 (2022), 100125, https://doi.org/10.1016/j.fufo.2022.100125.
[31] F. Cortezzi, Açaí in the globalization model of amazon plants: an ancient product, new forms of spatial production and reproduction, Geosaberes 11 (2020) 493, https://doi.org/10.26895/geosaberes.v11i0.975.
[32] L.B. Virgolin, F.R.F. Seixas, N.S. Janzantti, Composition, content of bioactive compounds, and antioxidant activity of fruit pulps from the Brazilian Amazon biome, Pesqui. Agropecuária Bras. 52 (2017) 933–941, https://doi.org/10.1590/S0100-204X2017001000013.
[33] N.L. Barboza, J.M. dos, A. Cruz, R.F. Corrêa, C.V. Lamarão, A.R. Lima, N.M. Inada, E.A. Sanches, J. de A. Bezerra, P.H. Campelo, Buriti (Mauritia flexuosa L. f.): an Amazonian fruit with potential health benefits, Food Res. Int. 159 (2022), https://doi.org/10.1016/J.FOODRES.2022.111654.
[34] C.M. Bemfeito, J. de D.S. Carneiro, E.E.N. Carvalho, P.C. Coli, R.C. Pereira, E.V. de B. Vilas Boas, Nutritional and functional potential of pumpkin (Cucurbita moschata) pulp and pequi (Caryocar brasiliense Camb.) peel flours, J. Food Sci. Technol. 57 (2020) 3920–3925, https://doi.org/10.1007/S13197-020-04590-4/TABLES/2.
[35] M. Mascaraque, Top 5 Trends Shaping Health and Wellness, 2019. https://blog.euromonitor.com/top–5-trends-shaping-health-and-wellness/.
[36] Federação das Indústrias do Estado de São Paulo, Brazil Food Trends 2020, 2020. http://www.brasilfoodtrends.com.br/publicacao.html.
[37] R.F. Neves, M.D. Chiarello, L.A. Lima, G.F. Ghesti, Forecasting study of food-related patents protected by the University of Brasilia, Brazil: case study, Heliyon 9 (2023), https://doi.org/10.1016/j.heliyon.2023.e17111, 1-12.
[38] M.J.A. Ferreira, M.F.S. Mota, R.G.B. Mariano, S.P. Freitas, Current scenario and recent advancements from tucumã pulp oil and kernel fat processing, Eur. J. Lipid Sci. Technol. 124 (2022) 1–11, https://doi.org/10.1002/ejlt.202100231.
[39] M, The Arshad, Bioethanol: a sustainable and environment friendly solution for Pakistan, Sci. Vis. 15 (2011) 16.
[40] M. Arshad, Clean and Sustainable Energy Technologies, Elsevier Inc., 2017, https://doi.org/10.1016/B978-0-12-805423-9.00003-X.
[41] S.K.R. Lima, A.G. Coêlho, M. Lucarini, A. Durazzo, D.D.R. Arcanjo, The platonia insignis mart. As the promising Brazilian 'amazon gold': the state-of-the-art and prospects, Agric. For. 12 (2022) 1–18, https://doi.org/10.3390/agriculture12111827.

[42] C.V. dos Santos, F.M.e. Silva, L.I.L. de Faria, The Brazilian Atlantic Forest genetic resources in patents and the challenges to control the economic use of biodiversity, World Pat. Inf. 74 (2023), https://doi.org/10.1016/j.wpi.2023.102218.
[43] World Intellectual Property Organization - WIPO, What Is Intellectual Property?, 2020. https://www.wipo.int/publications/en/details.jsp?id=4528.
[44] W.I.P.O.- WIPO, Understanding Industrial Property, 2016. https://www.wipo.int/publications/en/details.jsp?id=4080.
[45] A.M.M. Guedes, R. Antoniassi, A.F. de Faria-Machado, Pequi: a Brazilian fruit with potential uses for the fat industry, OCL 24 (2017) D507, https://doi.org/10.1051/ocl/2017040.
[46] D.S.C. Soares, M.N. da, S. Florêncio, P.M. de Souza, T.P. Nunes, A.M. de Oliveira Júnior, Research and development on jabuticaba (Myrciaria Cauliflora): overview on academic research and patents, Food Sci. Technol. 39 (2019) 1005–1010, https://doi.org/10.1590/fst.13418.
[47] D.O. Brandão, L.E.S. Barata, C.A. Nobre, The effects of environmental changes on plant species and forest dependent communities in the amazon region, Forests 13 (2022) 466, https://doi.org/10.3390/f13030466.
[48] L.P. Martins, E. da C. Araujo Junior, A.R.P. Martins, M. Duarte, G.G. Azevedo, Species diversity and community structure of fruit-feeding butterflies (Lepidoptera: nymphalidae) in an eastern amazonian forest, Pap, Avulsos Zool 57 (2017) 481–489, https://doi.org/10.11606/0031-1049.2017.57.38.
[49] L. de A.P. Rodrigues, I.L. Leal, K.V.S. Hodel, G.B.T. Góes, Mapeamento tecnológico de Bebidas fermentadas funcionais com cacau, Cad. Prospecção. 15 (2022) 865–880, https://doi.org/10.9771/cp.v15i3.47803.
[50] M.M. Papamichael, G. Moschonis, C. Mavrogianni, S. Liatis, Konstantinos Makrilakis, F. Greet Cardon, J. De Vylder, Kivelä, Fathers' daily intake of fruit and vegetables is positively associated with children's fruit and vegetable consumption patterns in Europe, The Feel4Diabetes Study 2 (2021) 12, https://doi.org/10.1111/jhn.12945.
[51] M. Li, Y. Fan, X. Zhang, W. Hou, Z. Tang, Fruit and vegetable intake and risk of type 2 diabetes mellitus: meta-analysis of prospective cohort studies, BMJ Open 4 (2014), e005497, https://doi.org/10.1136/BMJOPEN-2014-005497.
[52] N.R. Desam, A.J. Al-Rajab, The importance of natural products in cosmetics, Adv. Struct. Mater. 140 (2021) 643–685, https://doi.org/10.1007/978-3-030-54027-2_19/COVER.
[53] L.M. Aguiar, J.L. Bicas, E. Fuentes, M. Alarcón, I.P. Gonzalez, G.M. Pastore, M.R. Maróstica, C.B.B. Cazarin, Non-nutrients and nutrients from Latin American fruits for the prevention of cardiovascular diseases, Food Res. Int. 139 (2021), 109844, https://doi.org/10.1016/J.FOODRES.2020.109844.
[54] M. Peña-Claros, C. Nobre, A regional approach to save the Amazon, Science 381 (80) (2023), https://doi.org/10.1126/science.adk8794, 1261–1261.
[55] C.M. Hall, L.V. Rasmussen, B. Powell, C. Dyngeland, S. Jung, R.S. Olesen, Deforestation reduces fruit and vegetable consumption in rural Tanzania, Proc. Natl. Acad. Sci. 119 (2022), https://doi.org/10.1073/pnas.2112063119.
[56] A. Guaadaoui, S. Benaicha, N. Elmajdoub, M. Bellaoui, A. Hamal, What is a bioactive compound? A combined definition for a preliminary consensus, Int. J. Nutr. Food Sci. 3 (2014) 174, https://doi.org/10.11648/j.ijnfs.20140303.16.
[57] F.C. de Paula, C.B.C. de Paula, J. Contiero, F.C. de Paula, C.B.C. de Paula, J. Contiero, Prospective biodegradable plastics from biomass conversion processes, Biofuels - State Dev. (2018), https://doi.org/10.5772/INTECHOPEN.75111.
[58] R. Rocca, F. Acerbi, L. Fumagalli, M. Taisch, Sustainability paradigm in the cosmetics industry: state of the art, Clean. Waste Syst. 3 (2022), https://doi.org/10.1016/j.clwas.2022.100057.
[59] J.S. Santos, T.N. Barradas, G.D. Tavares, Advances in nanotechnology-based hair care products applied to hair shaft and hair scalp disorders, Int. J. Cosmet. Sci. 44 (2022) 320–332.
[60] M.L. Mitterer-Daltoé, V.B. Martins, C.R.B. Parabocz, M.A.A. da Cunha, Use of cosmetic creams and perception of natural and eco-friendly products by women: the role of sociodemographic factors, Cosmetics 10 (2023), https://doi.org/10.3390/cosmetics10030078.
[61] J.S. Câmara, M. Locatelli, J.A.M. Pereira, H. Oliveira, M. Arlorio, I. Fernandes, R. Perestrelo, V. Freitas, M. Bordiga, Behind the Scenes of Anthocyanins—From the Health Benefits to Potential Applications in Food, Pharmaceutical and Cosmetic Fields, 2022.
[62] M. Funasaki, H. Dos, S. Barroso, V. Lia, A. Fernandes, I.S. Menezes, Amazon rainforest cosmetics: chemical approach for quality control, Quim. Nova 39 (2016) 194–209, https://doi.org/10.5935/0100-4042.20160008.
[63] B. Burlando, L. Verotta, L. Cornara, E. Bottini-Massa, Herbal principles in cosmetics: properties and mechanisms of action, Herb. Princ. Cosmet. Prop. Mech. Action (2010) 1–381, https://doi.org/10.1201/EBK1439812136.
[64] F. Ahmad, S.T. Khan, Potential industrial use of compounds from by-products of fruits and vegetables, Heal. Saf. Asp. Food Process. Technol. (2019) 273–307, https://doi.org/10.1007/978-3-030-24903-8_10.
[65] D.A. Dias, S. Urban, U. Roessner, A Historical overview of natural products in drug discovery, Metabolites 2 (2012) 303–336, https://doi.org/10.3390/metabo2020303.
[66] L. Pachuau, Laldinchhana, P.K. Roy, J.H. Zothantluanga, S. Ray, S. Das, Bioactive Natural Products for Pharmaceutical Applications, 2021.
[67] Y. Xu, An Eel Spicy Black Bean Sauce and Preparation Method Thereof, 2015. CN104431957A.
[68] U.D. Palanisamy, L.T. Ling, T. Manaharan, D. Appleton, Rapid isolation of geraniin from Nephelium lappaceum rind waste and its anti-hyperglycemic activity, Food Chem. 127 (2011) 21–27, https://doi.org/10.1016/j.foodchem.2010.12.070.
[69] N. Thitilertdecha, A. Teerawutgulrag, N. Rakariyatham, Antioxidant and antibacterial activities of Nephelium lappaceum L. extracts, LWT–Food Sci. Technol. 41 (2008) 2029–2035, https://doi.org/10.1016/j.lwt.2008.01.017.
[70] N. Thitilertdecha, N. Rakariyatham, Phenolic content and free radical scavenging activities in rambutan during fruit maturation, Sci. Hortic. (Amsterdam) 129 (2011) 247–252, https://doi.org/10.1016/j.scienta.2011.03.041.
[71] M.C. de Andrade Júnior, J.S. Andrade, Amazonian fruits: an overview of nutrients, calories and use in metabolic disorders, Food Nutr. Sci. 5 (2014) 1692–1703, https://doi.org/10.4236/fns.2014.517182.
[72] N. Mehta, P. Kumar, A.K. Verma, P. Umaraw, Y. Kumar, O.P. Malav, A.Q. Sazili, R. Domínguez, J.M. Lorenzo, Microencapsulation as a noble technique for the application of bioactive compounds in the food industry: a comprehensive review, Appl. Sci. 12 (2022) 1–34, https://doi.org/10.3390/app12031424.
[73] S.C. Lourenço, M. Moldão-Martins, V.D. Alves, Antioxidants of natural plant origins: from sources to food industry applications, Molecules 24 (2019) 14–16, https://doi.org/10.3390/molecules24224132.
[74] Zi-qi Zhang, Non-dairy Creamer for Increasing Mouth Feel of Milk Tea, and Preparation Method of Non-dairy Creamer, 2020. CN111685189A.
[75] P.O. MAIFREDE, MISTURA PARA O PREPARO DE CAPPUCCINO COM SORO DE LEITE E EXTRATO SOLÚVEL DO CAROÇO DE AÇAÍ (EUTERPE OLERACEA MART), E SEU PROCESSO DE OBTENÇÃO, BR102018017202A2, 2023, https://doi.org/10.31857/s0044460x21010145.
[76] B. Burlando, L. Cornara, Revisiting amazonian plants for skin care and disease, Cosmetics 4 (2017) 25, https://doi.org/10.3390/cosmetics4030025.
[77] R.S. de Moura, Â.C. Resende, Cardiovascular and metabolic effects of açaí, an amazon plant, J. Cardiovasc. Pharmacol. 68 (2016) 19–26, https://doi.org/10.1097/FJC.0000000000000347.
[78] D.E. Machado, K.C. Rodrigues-Baptista, J. Alessandra-Perini, R.S. De Moura, T.A. Dos Santos, K.G. Pereira, Y.M. Da Silva, P.J.C. Souza, L.E. Nasciutti, J. A. Perini, Euterpe oleracea extract (açaí) is a promising novel pharmacological therapeutic treatment for experimental endometriosis, PLoS One 11 (2016), e0166059, https://doi.org/10.1371/JOURNAL.PONE.0166059.
[79] G.F. de Bem, C.A. Costa, I.B. Santos, V. da S. Cristino Cordeiro, L.C.R.M. de Carvalho, M.A.V. de Souza, R. de A. Soares, P.J. da C. Sousa, D.T. Ognibene, A. C. Resende, R.S. de Moura, Antidiabetic effect of Euterpe oleracea Mart. (açaí) extract and exercise training on high-fat diet and streptozotocin-induced diabetic rats: a positive interaction, PLoS One 13 (2018), e0199207, https://doi.org/10.1371/journal.pone.0199207.
[80] C.E. da S. Monteiro, H.B. da C. Filho, F.G.O. Silva, M. de F.F. de Souza, J.A.O. Sousa, Á.X. Franco, Â.C. Resende, R.S. de Moura, M.H.L. de Souza, P.M.G. Soares, A.L. dos R. Barbosa, Euterpe oleracea Mart. (Açaí) attenuates experimental colitis in rats: involvement of TLR4/COX-2/NF-κB, Inflammopharmacology 29 (2021) 193–204, https://doi.org/10.1007/s10787-020-00763-x.
[81] A. de S. da Silva, D.V.Q. Nunes, L.C. dos, R.M. de Carvalho, I.B. Santos, M.P. de Menezes, G.F. de Bem, C.A. da Costa, R.S. de Moura, A.C. Resende, D. T. Ognibene, Açaí (Euterpe oleracea Mart) seed extract protects against maternal vascular dysfunction, hypertension, and fetal growth restriction in experimental preeclampsia, Hypertens. Pregnancy 39 (2020) 211–219, https://doi.org/10.1080/10641955.2020.1754850.

[82] F.B. Barros, F.F. de Sousa, J.P. de Andrade, F.M. Ramos, C. Vieira-da-Silva, Ethnoecology of miriti (Mauritia flexuosa, L.f.) fruit extraction in the Brazilian Amazon: knowledge and practices of riverine peoples contribute to the biodiversity conservation, J. Ethnobiol. Ethnomed. 17 (2021) 3, https://doi.org/10.1186/s13002-020-00430-z.
[83] Estruch Lapuente, Casas Shahbaz, Relation of fruits and vegetables with major cardiometabolic risk factors, markers of oxidation, and inflammation, Nutrients 11 (2019) 2381, https://doi.org/10.3390/nu11102381.
[84] J. Stropp, B. Umbelino, R.A. Correia, J.V. Campos-Silva, R.J. Ladle, A.C.M. Malhado, The ghosts of forests past and future: deforestation and botanical sampling in the Brazilian Amazon, Ecography 43 (2020) 979–989, https://doi.org/10.1111/ecog.05026.
[85] A.C. Roosevelt, The Amazon and the Anthropocene: 13,000 years of human influence in a tropical rainforest, Anthropocene 4 (2013) 69–87, https://doi.org/10.1016/j.ancene.2014.05.001.
[86] L. Cornara, J. Xiao, A. Smeriglio, D. Trombetta, B. Burlando, Emerging exotic fruits: new functional foods in the European market, EFood 1 (2020) 126–139, https://doi.org/10.2991/efood.k.200406.001.
[87] A.C. Kumoro, M. Alhanif, D.H. Wardhani, A critical review on tropical fruits seeds as prospective sources of nutritional and bioactive compounds for functional foods development: a case of Indonesian exotic fruits, Int. J. Food Sci. 2020 (2020) 1–15, https://doi.org/10.1155/2020/4051475.
[88] R.D. Garrett, F. Cammelli, J. Ferreira, S.A. Levy, J. Valentim, I. Vieira, Forests and sustainable development in the Brazilian amazon: history, trends, and future prospects, Annu. Rev. Environ. Resour. 46 (2021) 625–652, https://doi.org/10.1146/annurev-environ-012220-010228.
[89] G. Medina, C. Pereira, J. Ferreira, E. Berenguer, J. Barlow, Searching for novel sustainability initiatives in amazonia, Sustainability 14 (2022), 10299, https://doi.org/10.3390/su141610299.
[90] M. Jahurul, F. Azzatul, M. Sharifudin, M. Norliza, M. Hasmadi, J. Lee, M. Patricia, S. Jinap, M. Ramlah George, M. Firoz Khan, I. Zaidul, Functional and Nutritional Properties of Rambutan (Nephelium Lappaceum L.) Seed and its Industrial Application: A Review, 2020, https://doi.org/10.1016/j.tifs.2020.03.016.
[91] Lin Yongxiang, Peiyi Wu, Azayier Fruit Leavening for Increasing Muscle and Reducing Fat and Delaying Aging, 2022. CN113876873A.
[92] S.Z. Yang, X.Z. Bo, Skin Barrier Repair Cream and Preparation Method Thereof, 2022. CN108619018B.
[93] P.J.R.N. Silva, L.A. Rolim, R.M.F. Da Silva, I.A. De Souza, K.E.R. De Holanda, S.F. De Oliveira, R.C.D. Da Cruz, R.J.O. Costa, N.F. De França, M.S. Da Silva, E. M. Da Silva, Emulsão à Base de Euterpe Oleracea Mart, com atividade larvicida, 2022. BR102020013253-9 A2.
[94] J, , et al.L.J. Luo, L. Yi-rui, T. Man, Selenium Liquor for Protecting Liver and Preventing Liver Disease, 2022. CN114099620A.
[95] N. Tomohiro, K. Nanae, M. Shigeki, S. Takuya, Agent for Preventing or Improving Oxidative Stress, Inflammation, and Aging of Skin Caused by Violet Light, Blue Light, and Ultraviolet Rays, and External Skin Formulation, 2022. JP2022065588A.
[96] I. Nardolillo, T.R. Tabakman, A Water Eyebrow Pencil and Preparation Method Thereof, 2022. EP1048285A2.
[97] Z. Zhang, A Vegetable Fat Powder for Improving Mouthfeel of Milk Tea and Preparation Method Thereof, 2022. CN111685189A.
[98] F.U. of Maranhão, Fitoterápico Antimicrobiano Obtido A Partir Do Extrato Das Folhas De Euterpe Oleracea, Açai), 2017. BR102017013494A2.
[99] Jiangsu Zhineng Biotechnology Co Ltd, Nephelium Lappaceum and Chayote Compound Beverage and Preparation Method Thereof, 2019, CN110495538A.
[100] H. Rojas, Process for Preserving the Husk and Use of Rambutan (Nephelium Lappaceum) in Food Products, WO2022006367A2, 2022.
[101] A.S. Ombredane, L.R.A. Silva, V.H.S. Araujo, P.L. Costa, L.C. Silva, M.C. Sampaio, M.C.F. Lima, V.F. Veiga Junior, I.J.C. Vieira, R.B. Azevedo, G.A. Joanitti, Pequi oil (Caryocar brasilense Cambess.) nanoemulsion alters cell proliferation and damages key organelles in triple-negative breast cancer cells in vitro, Biomed. Pharmacother. 153 (2022), 113348, https://doi.org/10.1016/J.BIOPHA.2022.113348.
[102] K.M.S. Braga, E.G. Araujo, F.W. Sellke, M.R. Abid, Pequi Fruit Extract Increases Antioxidant Enzymes and Reduces Oxidants in Human Coronary Artery Endothelial Cells, Antioxidants 11 (2022) 474, https://doi.org/10.3390/antiox11030474.
[103] S. da Cunha Demenciano, M.C.B. Lima e Silva, C.A. Farias Alexandrino, W.H. Kato, P. de Oliveira Figueiredo, W.S. Garcez, R.P. Campos, R. de Cássia Avellaneda Guimarães, U.C. Sarmento, D. Bogo, Antiproliferative activity and antioxidant potential of extracts of Garcinia gardneriana, 2020, Mol 25 (2020) 3201, https://doi.org/10.3390/MOLECULES25143201, 3201. 25.
[104] D.A. Rodrigues, B.L. de Sousa, J.G. da Silva, G.A.M. Pereira, G.M. Bousada, A.A. da Silva, A.J. Demuner, É.D.M. Costa, E.J. Pilau, E. Silva, M.H. dos Santos, Phytotoxic property of metabolites isolated from Garcinia gardneriana, Comput. Biol. Chem. 92 (2021), 107460, https://doi.org/10.1016/j.compbiolchem.2021.107460.
[105] V.M. Alves, E.R. Asquieri, E. da S. Araújo, G.A. de S. Martins, A.A.M. de Melo, B.C.B. de Freitas, C. Damiani, Provenient residues from industrial processing of açaí berries (Euterpe precatoria Mart): nutritional and antinutritional contents, phenolic profile, and pigments, Food Sci. Technol. 42 (2022), https://doi.org/10.1590/fst.77521.
[106] O.V. dos Santos, A.A. Viana, S.D. Soares, E.L.S. Vieira, M.G. Martins, F. das C.A. do Nascimento, B.E. Teixeira-Costa, Industrial potential of Bacaba (Oenocarpus bacaba) in powder: antioxidant activity, spectroscopic and morphological behavior, Food Sci. Technol. 42 (2022), https://doi.org/10.1590/fst.62820.
[107] K.A. Noronha Matos, D. Praia Lima, A.P. Pereira Barbosa, A. Zerlotti Mercadante, R. Campos Chisté, Peels of tucumã (Astrocaryum vulgare) and peach palm (Bactris gasipaes) are by-products classified as very high carotenoid sources, Food Chem. 272 (2019) 216–221, https://doi.org/10.1016/J.FOODCHEM.2018.08.053.
[108] R.A. Do Nascimento, E.L. Andrade, E.B. Santana, N.F. Da Paixão Ribeiro, C.M.L. Costa, L.J.G. De Faria, Bacaba powder produced in spouted bed: an alternative source of bioactive compounds and energy food product, Braz. J. Food Technol. 22 (2019), https://doi.org/10.1590/1981-6723.22918.