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Sustainable production of bioactive compounds from jabuticaba (Myrciaria cauliflora): A bibliometric analysis of scientific research over the last 21 years

Rafael Gabriel da Rosa [a], William Gustavo Sganzerla [a,*], Tiago L.C.T. Barroso [a], Luz S. Buller [a], Mauro D. Berni [b], Tânia Forster-Carneiro [a]

[a] *School of Food Engineering (FEA), University of Campinas (UNICAMP), Campinas, São Paulo, Brazil*
[b] *Center for Energy Planning, University of Campinas (UNICAMP), Campinas, São Paulo, Brazil*

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ABSTRACT

The demand for pharmaceutical products based on bioactive compounds obtained from by-products and manufactured by sustainable technological routes is a worldwide demand to the circular economy transition. In this review, a bibliometric analysis on jabuticaba (*Myrciaria cauliflora*) research over the last 21 years was conducted to identify prospects for the sustainable production of bioactive compounds from its by-products. The Web of Science© database was used and the dataset was analyzed on VosViewer© bibliometric software's to perform maps based on the main keywords. In total, 255 articles and 5 reviews were published related to research on jabuticaba. The bibliometric analysis elucidated that *Food Science Technology* was the main research area, and the most frequent keywords on the field were associated with anthocyanins, demonstrating that there is a trend in determine the optimum extraction method of this bioactive compound from jabuticaba. Furthermore, this review provides direction for the production of bioactive compounds (gallic acid, cyanidin, malvidin, peonidine, petunidine, pelargonidine, and many others) in different sustainable technological routes (ultrasound-assisted extraction, supercritical carbon dioxide extraction, and pressurized liquid extraction) using jabuticaba's by-products as feedstock.

1. Introduction

Fruit consumption is encouraged and essential due to the richness of nutrients and bioactive compounds, which are vital in preventing chronic diseases and beneficial to human health (Schmidt et al., 2020). Brazil has in its territory the most significant flora diversity globally, with more than thirty thousand different species of angiosperms endorsed with flowers and fruits (Dutra et al., 2015). Among the diversity in Brazilian territory, the Myrtaceae family has ecological and economic prominence as the eighth largest family of flowering plants (Donado-Pestana et al., 2018; Schmidt et al., 2020). Its specimens are found in Australia, southeast Asia, and South America, with about 130–150 genera and more than 5800 species (Frauches and Amaral, 2016; Schmidt et al., 2020). The Myrtaceae family includes guava (*Psidium* spp.), clove (*Syzygium aromaticum*), allspice (*Pimenta dioica*), cambuci (*Campomanesia phaea* Berg.), camu-camu (*Myrciaria dubia* McVaugh), jabuticaba (*Myrciaria cauliflora*), and many other fruits with high agro-industrial potential (Donado-Pestana et al., 2018).

* Corresponding author.
E-mail address: sganzerla.william@gmail.com (W.G. Sganzerla).

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Fig. 1 shows the jabuticaba tree and the fruit in their development stages. Jabuticaba, belonging to the Myrtaceae family, is a very perishable fruit due to the high amount of sugar and water, with a low shelf life for *in natura* consumption (Martins et al., 2021). Therefore, this fruit is commonly used in derivatives processed products (e.g., juices, jellies, ice cream, tea, liqueurs, and others) to achieve a more integral use of the fruit and avoid waste (Tarone et al., 2021). Brazil has an annual production of 5000 tons of jabuticaba only within formal trade, not including the amount related to domestic or informal consumption (Massa, 2020).

Jabuticaba presents a high amount of bioactive compounds, especially polyphenols (anthocyanins, flavonoids, and tannins), which have antioxidant activity (Plaza et al., 2016), as well as amino acids (tryptophan and lysine), vitamins (Wu et al., 2013), ascorbic acid (Rufino et al., 2011), magnesium, and copper (Alezandro et al., 2013). The consumption of jabuticaba can reduce serum triglycerides, improve insulin sensitivity, and anti-inflammatory action, promoting its consumption as beneficial to human health (Inada et al., 2020b; Lamas et al., 2018).

In the jabuticaba's industrial processing, the pulp is responsible for the highest market share, while peels and seeds are by-products (Fidelis et al., 2021). Approximately 50% of the weight of the jabuticaba fruit consists of peels and seeds, which are discarded without any recovery or utilization (Morales et al., 2016). When those organic by-products are dumped into the environment without treatment or disposal control, they release many macronutrients, such as phosphorus and nitrogen, which have been associated with water eutrophication, greenhouse gas (GHG) emissions, among other environmental side-effects (Peltzer et al., 2008).

Currently, landfilling is the leading destination of organic waste despite to risk of environmental pollution (Zhang et al., 2018). Other disposal routes to reduce this practice focusing on energy recovery should be employed (Chen and Jiang, 2017), as well as green technologies to recover value-added compounds (Benvenutti et al., 2021; Oldfield et al., 2016; Peltzer et al., 2008). The compounds extracted from solid and food waste are proteins, fibers, vitamins, minerals, lipids, phenolic compounds, antioxidants, and phytomoniums (Coelho et al., 2001). The recovery, recycling, and reuse of organic waste are widely highlighted in the literature, especially to produce compounds of immediate biological interest, such as anthocyanins, which are abundant in jabuticaba peels (Ferreira et al., 2020).

Several technological routes for generating new value-added products from solid waste are possible (Ortiz et al., 2020). From identifying the industrial most economically attractive opportunities (Dantas et al., 2013), process and cost optimization can be designed (Hannan et al., 2020). It is necessary to evaluate the waste characterization to study the possibilities of applying the various technologies and knowledge of their industrial and commercial flows to manage them, preferably punctually and locally (Pimentel et al., 2020). Biotechnological advances, driven by environmental and economic benefits, provide notoriety to lignocellulosic wastes (Bilal et al., 2017). The possible technologies of valuing waste from the food industry are essential to support action plans and decision-making to avoid the loss of their biological potential and produce bio-based products, a clean and desirable strategy to improve industry sustainability.

Notwithstanding, the use of bibliometric analysis has been a tool widely used to disseminate the prospects in diverse research fields. For instance, in the areas of bio-waste (Obileke et al., 2020), energy recovery from macaúba husk (Ampese et al., 2021), valorization of orange industrial waste (Jiménez-Castro et al., 2020), biorefinery for the circular economy transition of the beer industry (Sganzerla et al., 2021), anaerobic digestion (Ampese et al., 2022), biodiesel production (Rajeswari et al., 1993), and enzyme immobilization (Almeida et al., 2021), bibliometrics identified the knowledge gaps and elucidated the establishment of future studies to better understand the state of the art in the research field. However, a bibliometric analysis to guide future directions on the research of jabuticaba was not reported in the literature.

Fig. 1. Illustration of (a) jabuticaba tree, (b) fruits, and (c) different stages of fruit ripening of jabuticaba.

Based on the mentioned above, this study accomplished a bibliometric review on jabuticaba (*Myrciaria cauliflora*) research over the last 21 years, aiming to identify prospects for the sustainable production of bioactive compounds. It also intends to identify green technological routes to generate new bio-products from jabuticaba's by-products. This study will identify the most attractive opportunities for the industrial production of bioactive compounds from jabuticaba by-products, identifying the possible knowledge gaps and research opportunities for the jabuticaba production chain.

2. Methodology for literature search and bibliometric analysis

The systematic literature search was carried out by selecting documents to demonstrate how the research has been developed and changed over the years. Based on the number of publications, it is possible to hypothesize the trends and technical decisions on the field. This study retrieve the publications related to practical applications of jabuticaba and its by-products. Hence, based on the documents selected in the literature search, new technological routes can be proposed for the sustainable extraction of bioactive compounds.

For the literature search and bibliometric study, the data collection was based on scientific publications indexed in the Science

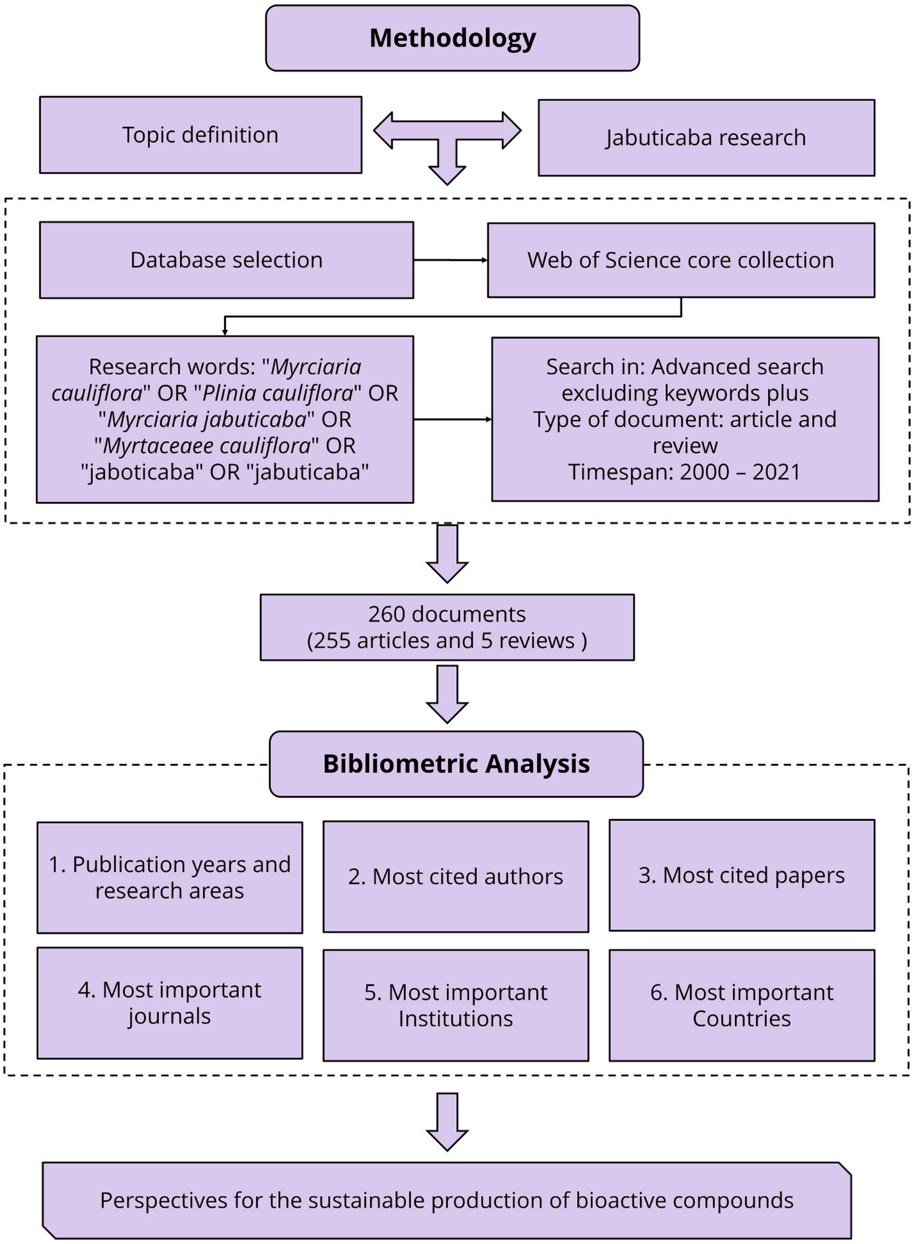

Fig. 2. Methodological steps for the bibliometric analysis.

Citation Index Expanded (SCI-E) – Clarivate Analytics' ISI – Web of Science© (WoS) database. The research in WoS core collection was conducted in the section "advanced search", to obtain reliable and accurate data in the field. The WoS search was performed applying the following logic operation: TS=("*Myrciaria cauliflora*" OR "*Plinia cauliflora*" OR "*Myrciaria jabuticaba*" OR "*Myrtaceaee cauliflora*" OR "jaboticaba" OR "jabuticaba") NOT KP=("*Myrciaria cauliflora*" OR "*Plinia cauliflora*" OR "*Myrciaria jabuticaba*" OR "*Myrtaceae cauliflora*" OR "jaboticaba" OR "jabuticaba"). Through this search query, it was possible to filter the publications based on selected words included in the title, abstract, author's keywords, and not in the keywords-plus of each document, avoiding mismatches with words that only appeared on references and are not the subject of the studies. The research was done for the period from 2000 to 2021, to cover the last 21 years of publication. Fig. 2 presents the methodological steps for the literature search and bibliometric study.

Furthermore, a filter based on the document type was used, where "article" and "review" were selected. The dataset obtained was exported and analyzed on VOsViewer bibliometric software's. Maps based on the main keywords and connections between them were performed in the VOsViewer software (van Eck and Waltman, 2010). Lastly, the overlay visualization was chosen to identify the documents that have received more attention from the scientific community and visualize the most important articles published.

3. Research trends on jabuticaba

3.1. Publication evolution and research areas

The evolution of the research related to jabuticaba over the last 20 years can be observed in Fig. 3. From the literature search, two hundred sixty (260) documents (255 articles and 5 reviews) were recorded in the WoS database. According to the overall development trend, the relevant research progress can be divided into three stages. From 2000 until 2010, the number of publications was lower than 32. Afterward, from 2010 to 2017, an average of 14.5 documents was published per year. Finally, an exponential trend can be observed from 2018, reaching 38 documents published in 2020. In 2021, the number of publications recorded in WoS database decreased to 29. Articles involving jabuticaba research were ranked in the 10 top publication areas, affiliations, countries, and journals (Table 1). Food Science Technology (43.01%), Chemistry (22.30%), and Agriculture (21.15%) were the most predominant research field. Therefore, the documents published during the last several years demonstrate the speed and progress of research in Food Science Technology, reflecting the relevant studies fields.

3.2. Study of main keywords in the field

The literature suggests that the study of keywords is one of the most important aspects of a bibliometric study (Ampese et al., 2022; Sganzerla et al., 2021). This analysis plays a crucial and facilitating role in information and co-word examination, acting as a filter in file searches (Melo, 2021; Rodríguez-Rojas et al., 2019). Therefore, Fig. 4 presents the 44 most frequent authors' keywords in the field, associated with a minimum number of occurrences of 3 keywords.

The map-based on different clusters indicates that the size of the circles is directly proportional to the keyword total link strength. In contrast, the distance between two of the terms suggests if they are closely related to each other or not. From the bibliometric coupling, 711 keywords were obtained from the search. Table 2 shows the top 20 keywords on the field. The most frequent keywords were "jaboticaba" (33 occurrences), "anthocyanins" (30 occurrences), "jabuticaba" (29 occurrences), and "phenolic compounds" (26 occurrences), indicating that these words are central and co-occurs with numerous others, as noted in the number of links (lines) in Fig. 4a. Moreover, there are some variations in the terminology "jabuticaba" and "jaboticaba" to express the name of the fruit, and this fact also occurs in the scientific name of the species (*Myrciaria cauliflora*, *Myrciaria jabuticaba, Plinia cauliflora,* and *Plinia trunciflora*).

Table 3 shows the clusters based on the keyword's analysis. It is possible to identify three clusters coupled with the most important keywords associated with the biological properties of bioactive compounds from jabuticaba. Also, the most critical keywords revealed that *in vivo* studies dealt with the effectiveness of jabuticaba for human health. Therefore, the keywords "antioxidants", "ellagic acid",

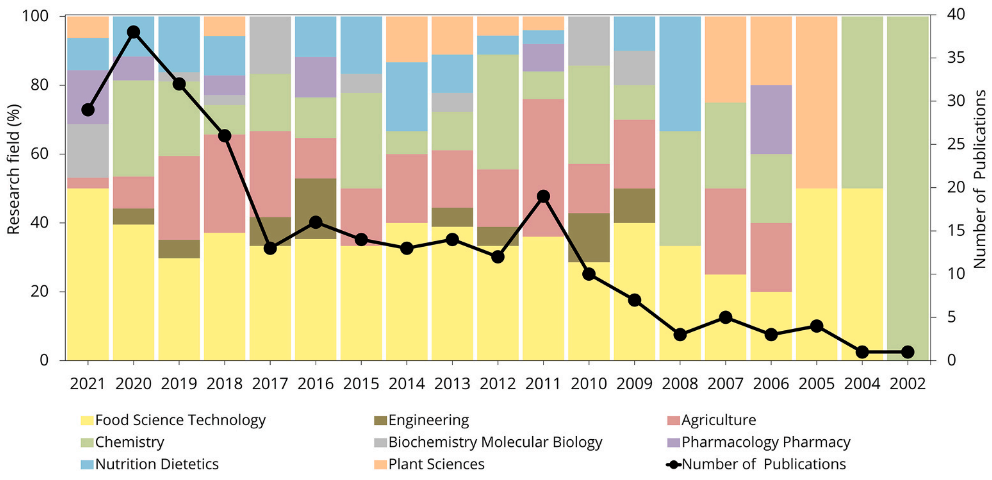

Fig. 3. Evolution of the publications and research fields on the use of jabuticaba.

Table 1
Ranking of the 10 top publication areas, affiliations, countries, and journals.

Ranking	Research areas	Number	%[a]
1st	Food Science Technology	112	43.07
2nd	Chemistry	58	22.30
3rd	Agriculture	55	21.15
4th	Nutrition Dietetics	34	13.07
5th	Pharmacology Pharmacy	19	7.30
6th	Plant Sciences	18	6.92
7th	Biochemistry Molecular Biology	16	6.15
8th	Engineering	12	4.61
9th	Science Technology (other topics)	8	3.07
10th	Materials Science	7	2.69
Ranking	Affiliations (Country)	Number	%[a]
1st	University of São Paulo, USP (Brazil)	42	16.15
2nd	University of Campinas, UNICAMP (Brazil)	40	15.38
3rd	Federal University of Goias, UFG (Brazil)	22	8.42
4th	Federal Technological University of Parana, UTFPR (Brazil)	18	6.92
5th	Federal University of Lavras, UFLA (Brazil)	17	6.53
6th	Brazilian Agricultural Research Corporation, EMBRAPA (Brazil)	16	6.15
7th	São Paulo State University, UNESP (Brazil)	14	5.38
8th	Federal University of Viçosa, UFV (Brazil)	13	5.01
9th	Federal University of Santa Catarina, UFSC (Brazil)	11	4.23
10th	Federal University of Santa Maria, UFSM (Brazil)	11	4.23
Ranking	Countries	Number	%[a]
1st	Brazil	236	90.76
2nd	United Stated of America	15	5.76
3rd	Portugal	7	2.69
4th	Spain	7	2.69
5th	China	6	2.30
6th	Canada	5	1.92
7th	Taiwan	4	1.53
8th	Colombia	3	1.15
9th	Finland	3	1.15
10th	France	3	1.15
Ranking	Journals	Number	%[a]
1st	Food Research International	16	6.15
2nd	*Revista Brasileira de Fruticultura**	16	6.15
3rd	Food Chemistry	12	4.61
4th	Journal of Functional Foods	7	2.69
5th	Molecules	7	2.69
6th	Food Science and Technology	6	2.30
7th	Journal of Agricultural and Food Chemistry	6	2.30
8th	LWT – Food Science and Technology	6	2.30
9th	Acta Scientiarum Agronomy	5	1.92
10th	Journal of Food Engineering	5	1.92

[a] Percentage of 260 documents (automatically calculated in WoS). Data reatrived on WoS at February 02nd, 2022. *In Portuguese.

"ellagitannins", "flavonoids", "antimicrobial", "insulin resistance", "lipid profile", "obesity", and "oxidative stress" demonstrate that jabuticaba can be a promising feedstock to extract bioactive compounds for technological applications (Inada et al., 2020b; Quatrin et al., 2020). The keywords analysis revealed that the phytotherapeutic properties of jabuticaba are relevant for its potential use in the food industry since most keywords are associated with antioxidant, antimicrobial, and anti-inflammatory activity (Inada et al., 2020a, 2020b). These properties are represented by chemical groups such as phenols, flavonoids, and others, which generally benefit human health (do Nascimento et al., 2020; Fidelis et al., 2021; Massa, 2020).

Notwithstanding, Fig. 4b demonstrates the term average year map, a tool to observe the publication evolution based on the keyword analysis. From Fig. 4b, the hottest topics in the field are associated with the isolation of bioactive molecules (i.e., anthocyanins and ellagic acid) to determine antioxidant and antimicrobial activity. The jabuticaba properties have been extensively studied since 2010 and have been quoted mainly since 2015. The results showed that it was possible to identify the highest priority topic for the study of jabuticaba, which is the extraction of bioactive compounds with eco-friendly technologies for human health purposes.

3.3. *The most cited publications*

Table 4 presents the most cited articles related to research using jabuticaba. The article "*Blue sensitizers for solar cells: Natural dyes from Calafate and Jabuticaba*" was the most cited (146 citations), published at *Solar Energy Materials and Solar Cells*. In this study, the authors used anthocyanin extracts obtained from jabuticaba. The results indicated a high conversion of visible light into electricity or a broadband semiconductor in solar cells sensitized with anthocyanins (Polo and Iha, 2006).

The 2nd most cited article studied the extraction of anthocyanins using methanol as a solvent of twelve (12) different fruits,

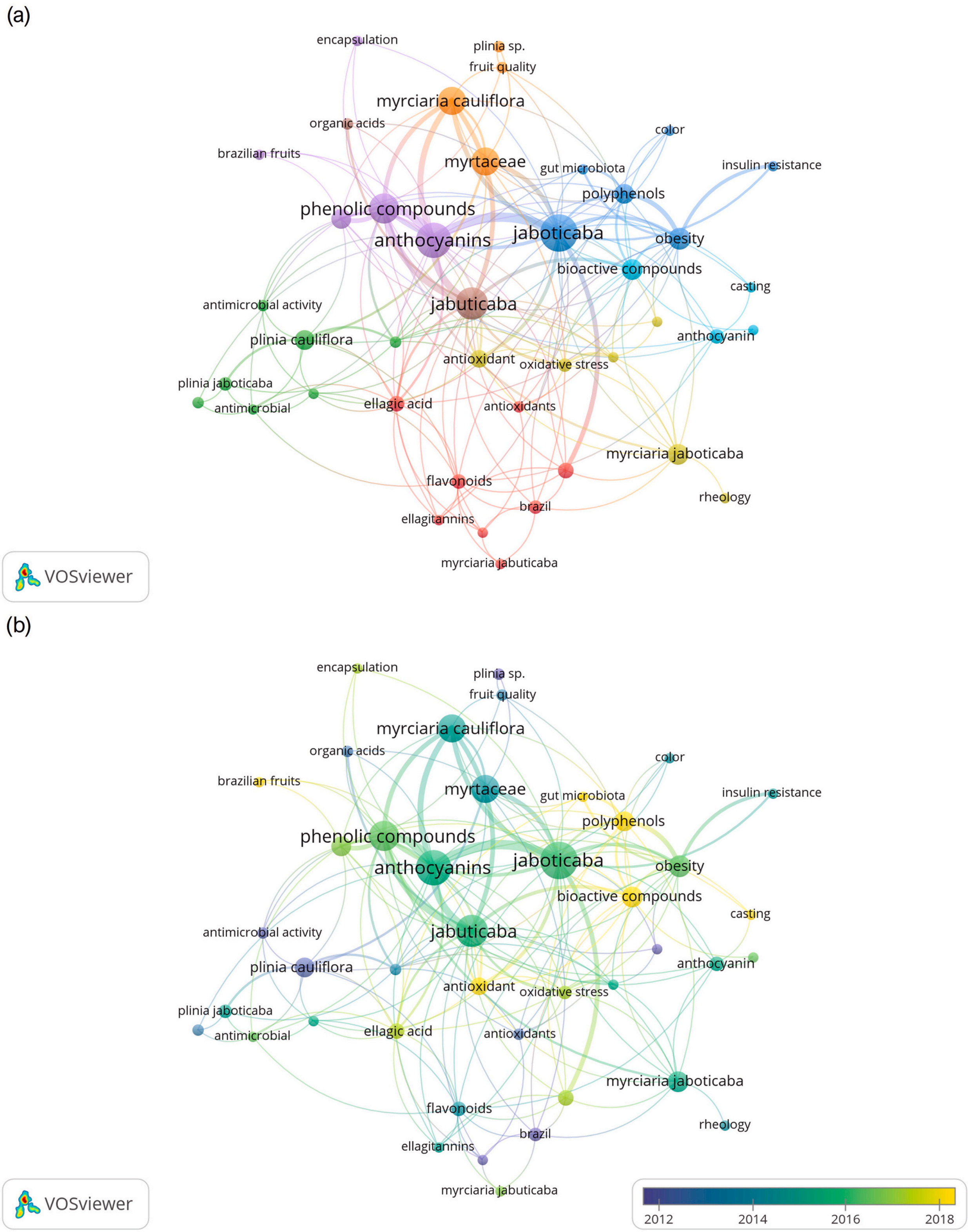

Fig. 4. The most employed authors' keywords. (a) Term map based on different clusters; (b) Term average year map.

Table 2
The top 20 keywords on the field (rank based on total link strength).

Ranking	Keyword	Occurrences	Total link strength
1	Jaboticaba	33	49
2	Anthocyanins	30	46
3	Jabuticaba	26	39
4	Phenolic compounds	23	37
5	*Myrciaria cauliflora*	20	23
6	Obesity	12	23
7	Bioactive compounds	11	18
8	Polyphenols	10	18
9	Antioxidant activity	10	17
10	Ellagic acid	7	15
11	*Myrciaria jabuticaba*	11	13
12	Myrtaceae	20	13
13	*Plinia cauliflora*	10	13
14	Antioxidant	8	12
15	Flavonoids	6	12
16	Oxidative stress	5	12
17	Antioxidant capacity	7	11
18	*Plinia trunciflora*	4	11
19	Anthocyanin	6	8
20	Antimicrobial	3	8

Table 3
Identification of the clusters based on the keywords analysis.

Clusters[a]	Number of items	Keywords
1	8	Antioxidant capacity, antioxidants, Brazil, ellagic acid, ellagitannins, flavonoids, fruits, and *Myrciaria jabuticaba*
2	7	Antimicrobial, antimicrobial activity, cytotoxicity, HPLC, *Plinia cauliflora*, *Plinia jaboticaba,* and *Plinia trunciflora*
3	6	Color, gut microbiota, insulin resistance, jaboticaba, obesity, and polyphenols
4	6	Antioxidant, lipid profile, *Myrciaria jaboticaba*, *Myrciaria jaboticaba* (vell.) berg, oxidative stress, and rheology.
5	5	Anthocyanins, antioxidante activity, brazilian fruits, encapsulation, and phenolic compounds
6	4	Fruit quality, bioactive compounds, casting, and postharvest
7	2	Jabuticaba and organic acids

[a] Cluster represented in Fig. 4a.

including jabuticaba, finding a radical DPPH scavenging assay value of 6.2 ± 0.7 μg mL^{-1} (IC_{50}) and identified the presence of cyanidine-3-glucode in the semi-purified fractions. This study is entitled "*Anthocyanin antioxidants from edible fruits*", presents 133 citations and was published at *Food Chemistry* (Einbond et al., 2004). In this same research area, the article "*Optimization and economic evaluation of pressurized liquid extraction of phenolic compounds from jabuticaba skins*", published at *Journal of Food Engineering*, presented 103 citations, the 6th most cited paper in the ranking. In this study, the authors concluded that the pressurized liquid extraction (PLE) allowed the obtention of anthocyanins (13.0 ± 0.9 mg cyanidin-3-glucose g^{-1} dry material) and phenolic compounds (7.8 ± 0.4 mg of GAE g^{-1} dry material) from the jabuticaba peels (Santos et al., 2012). Following, the 3rd most cited article was "*Parameter optimization for spray-drying microencapsulation of jabuticaba (Myrciaria jabuticaba) peel extracts using simultaneous analysis of responses*". The authors concluded that the use of maltodextrin and Arabic gum allowed the formation of more homogeneous particles, being cited 125 times and published at *Journal of Food Engineering* (Silva et al., 2013).

Following, a study quantified the anthocyanins content in jabuticaba peels and verified its *in vitro* antiproliferative activity (Leite-Legatti et al., 2012). This work was cited 109 times, occupying the 4th position in the ranking. The study concluded that lyophilized jabuticaba peels are rich in fiber and anthocyanins (delfinidine-3-glycoside and cyanid-3-glycoside), presenting high antioxidant activity. In the 5th position (106 citations), the article "*Dietary against obesity and inflammation*", published in *Nutrients*, described the beneficial effects of dietary anthocyanins on metabolic disorders caused by obesity and inflammation, citing various fruits that have a variety of anthocyanins, in addition to discussing the interaction between inflammation and obesity, and their subsequent regulation through the use of dietary anthocyanins (Lee et al., 2017).

Also, concerning bioactive compounds, the 7th work, published at *Journal of Functional Foods*, was cited 102 times, with the title "*Screening of the chemical composition and occurring antioxidants in jabuticaba (Myrciaria jabuticaba) and jussara (Euterpe edulis) fruits and their fractions*". The authors found eleven phenolic compounds, the most abundant anthocyanins, demonstrating a high commercial potential due to nutritional and functional properties (Inada et al., 2015). Beyond, the polar and non-polar extracts showed antiproliferative effects against leukemia and prostate cancer, respectively. Another study with a similar purpose was published at *Journal of Natural Products*, entitled "*Bioactive depsides and anthocyanins from jabuticaba (Myrciaria cauliflora)*", accounting for 101 citations, is the 8th most cited article. The authors showed that anthocyanins and jabuticaba depsides have good antiradical and cytotoxicity activity, inhibiting the production of IL-8 in epithelial cells of the small airways, treated and not treated with cigarette smoke extract (Reynertson et al., 2006). The 9th most cited article reported that jabuticaba is a bright fruit with good antioxidant capacity. However, during processing, the levels of some of the anthocyanins and other polyphenols significantly decrease, reducing the antioxidation

Table 4
Top 10 most cited documents in the field of jabuticaba research.

Ranking	Title	Journal	Publication Year	Total Citations[a]	Average Citation per Year	Reference
1st	Blue sensitizers for solar cells: Natural dyes from Calafate and Jabuticaba	Solar Energy Materials and Solar Cells	2006	146	10.82	Polo and Iha (2006)
2nd	Anthocyanin antioxidants from edible fruits	Food Chemistry	2004	133	9.05	Einbond et at. (2004)
3rd	Parameter optimization for spray-drying microencapsulation of jabuticaba (*Myrciaria jabuticaba*) peel extracts using simultaneous analysis of responses	Journal of Food Engineering	2013	125	14.8	Silva et al. (2013)
4th	Jabuticaba peel: Antioxidant compounds, antiproliferative and antimutagenic activities	Food Research International	2012	109	12.36	Leite-Legatti et al. (2012)
5th	Dietary anthocyanins against obesity and inflammation	Nutrients	2006	106	21.67	Lee et al. (2017)
6th	Optimization and economic evaluation of pressurized liquid extraction of phenolic compounds from jabuticaba skins	Journal of Food Engineering	2017	103	9.64	Santos et al. (2012)
7th	Screening of the chemical composition and occurring antioxidants in jabuticaba (*Myrciaria jabuticaba*) and jussara (*Euterpe edulis*) fruits and their fractions	Journal of Functional Foods	2012	102	13	Inada et al. (2015)
8th	Bioactive depsides and anthocyanins from jabuticaba (*Myrciaria cauliflora*)	Journal of Natural Products	2012	101	6.41	Reynertson et al. (2006)
9th	Metabolite profiling of jabuticaba (*Myrciaria cauliflora*) and other dark-colored fruit juices	Journal of Agricultural and Food Chemistry	2010	89	9.45	Wu et al. (2012)
10th	Characterization of different fruit wines made from cacao, cupuassu, gabiroba, jabuticaba and umbu	LWT – Food Science and Technology	2015	86	7.85	Duarte et al. (2010)

[a] Total citations recorded until 2021.

capacity of these products concerning fresh fruit, thus diminishing the benefits to human health (Wu et al., 2012).

In the 10th position, the study "*Characterization of different fruit wines made from cacao, cupuassu, gabiroba, jabuticaba and umbu*" published at *LWT – Food Science and Technology* presents 86 citations. This study evidenced that the use of tropical fruits for wine production is a viable alternative that allows harvest surplus and a nobler destination for underused fruits, resulting in the introduction of new products into the market (Duarte et al., 2010).

Finally, it is observed that all of the ten (10) most cited studies using jabuticaba focused on the bioactive compounds of the fruit in the areas of food, nutrition, and health. From the studies carried out, it is possible to indicate research gaps in the scientific literature, to define new alternatives for the valorization of jabuticaba, and to identify other possible technological routes or applications.

3.4. Bibliometric study of authors, journals, institutions, and countries

The bibliometric study of jabuticaba research covered the analysis of cited authors, journals, institutions (affiliations), and countries. The most productive and cited authors are Marostica MR (18 publications), Wagner A (11 publications), Citadin I (11 publications), Batista AG (9 publications), and Correa AD (8 publications). The most critical journals in the field were *Food Research International* (6.15%), *Revista Brasileira de Fruticultura* (6.15%), *Food Chemistry* (4.61%), and *Journal of Functional Foods* (2.69%), accounting for 51 documents in total. Otherwise, from the 260 documents, around 20% were published in the four mentioned journals, indicating that studies on jabuticaba have been published in a range of journals, highlighting the studies on Food Science Technology. Moreover, the ten (10) most prestigious journals are related to the scope and research area of bioactive compounds, phytochemicals, biological activity, and food processing, indicating that most of the publications with jabuticaba are associated with these research field.

Several publications were used to evaluate the countries and institutions involved in the study of jabuticaba. The leading country is Brazil (236 publications), followed by the United States of America (15 publications), Portugal (7 publications), and Spain (7 publications). A network between the countries was observed, revealing that the scientific community is joining efforts to propose solutions to extract bioactive compounds from jabuticaba. The most productive institutions were universities from Brazil: the University of São Paulo (USP) (42 publications) and the University of Campinas (UNICAMP) (40 publications), affiliations with the highest number of publications.

4. Industrial processing of jabuticaba

After the harvest of jabuticaba, the fruit presents rapid senescence due to the high sugar and water content (de Sá et al., 2014). The industrial processing of jabuticaba is an excellent option to increase the shelf life. For this, processing goes through a few steps, starting with fruits selection, washing and sanitizing, followed by heating application to extract pigments from the skin, and finally pulping in machines that separate the pulp from skin and seeds (Benvenutti et al., 2021). From the industrial processing juices, ice creams, liqueurs, wines, jams, syrups, yogurts, and powdered products can be obtained (Tarone et al., 2021). Fig. 5 illustrates the industrial processing of jabuticaba and the marketable product generated.

The industrial processing of jabuticaba generates large amounts of by-products (peel, seeds, and residual pulp) with a considerable amount of bioactive compounds, fibers, proteins, and vitamins than whole fruit (Albuquerque et al., 2020; Benvenutti et al., 2021; Gurak et al., 2014). Thus, it is crucial to identify and evaluate the new industrial process to recover value-added compounds presented in the by-product that would be discarded without any use, reducing the environmental impacts simultaneously as it aggregates value to the by-products.

Jabuticaba peels do not yet have an established commercial profile, although verified their potential of phytochemical compounds in their composition, is traditionally used for tea. The high concentration of phenolic compounds opens the perspective to the user as a dye (Dallabona et al., 2020), incorporation in foods (Oliveira et al., 2018) to claim functionality (Morales et al., 2016), and the strict isolation of these compounds for the use of the pharmacological and chemical sectors (Albuquerque et al., 2020). For example, cyanidin-3-O-glucoside and delphinidin-3-O-glucoside isolated with purity above 95% in Sigma-Aldrich® (10 mg packages) is sold by 162–613 USD.

Notwithstanding, studies on the practical applications of jabuticaba by-products are recent and involve technological innovation due to in-depth knowledge on its potential characteristics hitherto unknown (Soares et al., 2018). There are several patents involving the utilization of jabuticaba by-products. Most of them have been granted since innovative processes and technologies were developed. For instance, the patent "*Jabuticaba shell has undergoing dehydration processes has antioxidants, phenolic compounds, carotenoids and tannins*" consists in the fact that jabuticaba peel has bioactive compounds and allows the consumption of healthy food (Garcia et al., 2016). The jabuticaba peel should be subjected to osmotic dehydration and oven drying. The osmotic solution was used at concentrations of 40–70 °Brix. The resulting product can replace different kinds of sugars such as sucrose, glucose, fructose, dextrose, maltodextrin, maltose, sweeteners such as aspartame, sucralose, stevia, and sorbitol as individuals or as mixtures. Moreover, a patent reported the composition of *Myrciaria cauliflora*'s extract and its use for obesity-related metabolic abnormalities control, especially the inhibition of diseases caused by high-fat diets, including obesity, fatty liver, and chronic inflammation (Huang and Wang, 2016).

Regarding the development of technological processes for food production, another patent focused in bioactive compounds extraction system using supercritical carbon dioxide as solvent and water, ethanol, or isopropanol as co-solvents (Meireles et al., 2018). The final product comprised a probiotic microorganism containing a supercritical extract of jabuticaba peels with antioxidant effect. The preferred operational conditions reported are solvent and co-solvent ratio of 80:20 (w/w), at 50 °C under 10–30 MPa. This extract can be used for yogurt or cheese (petit suisse) formulation. Beyond, Oliveira and Steel (2019) produced cereal in co-rotating double screw extruder from jabuticaba peel flour. The extruded and expanded cereal contained 80% of wheat flour, 10% of jabuticaba peel flour, and 10% of corn flour. For this, the extrusion conditions were fixed as follows: feed moisture content of 16%, feed rate of 13 kg h^{-1}, roscade speed of 325 RPM, 75 °C in the first zone, and 100 °C in the second, third, and fourth zone. Therefore, jabuticaba by-products can be applied in different ways, however, the most appropriate technologies should be used to increase the profitability and to decrease environmental impacts. In the next section, innovative processes for the valorization of jabuticaba by-products was described to elucidade the production of bioactive compounds.

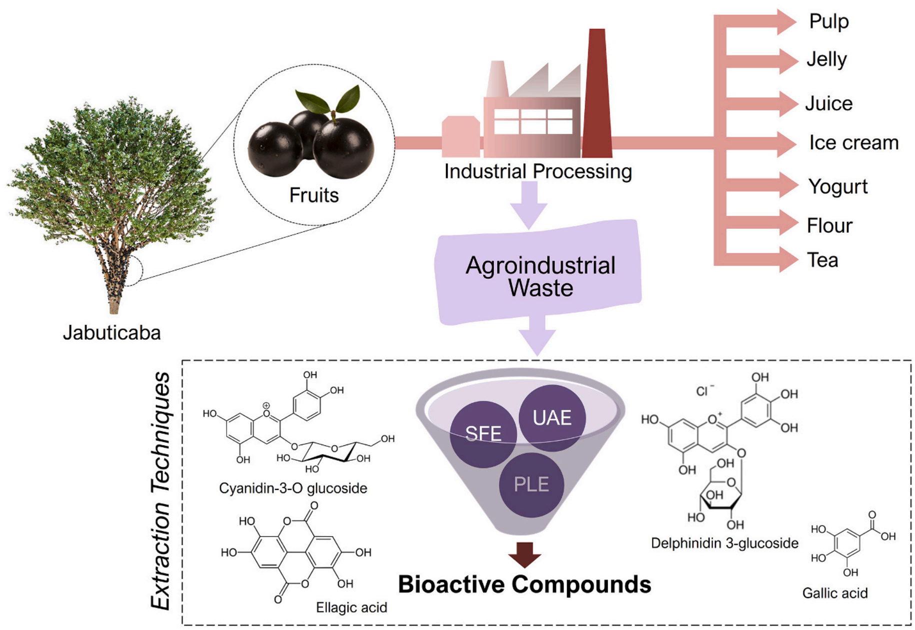

Fig. 5. Illustration of industrial processing of jabuticaba and value-added products generated.

5. Technological routes to the valorization of jabuticaba by-products

The production chain of jabuticaba does not take advantage of the peels and seeds, so these parts of the fruit are seen as waste, totaling 50% (w/w) of peels and seeds (Morales et al., 2016). Nevertheless, the scientific literature works to the great biological potential of these by-products. For instance, the peel of jabuticaba has high antioxidant activity (Albuquerque et al., 2020), as well as anti-inflammatory, antimutagenic, antimicrobial, antiproliferative action (Tarone et al., 2021). Other studies reported the potential applications as increased insulin resistance (Lenquiste et al., 2012), the oxidizing effect of blood plasma (Leite et al., 2011) without hepatotoxicity, and the absence of toxicity (Albuquerque et al., 2020).

The compounds found in jabuticaba are mostly phenolic, produced as secondary metabolites, and part of the defense mechanisms of plants against ultraviolet rays, attacks of insects or animals, and pathogens (Alara et al., 2021). Phenolic compounds have applications in different areas, such as food, aesthetics, and pharmaceutical products (Mikołajczak et al., 2021). In the food industry, its application has increased in products stability and nutritional and sensory properties (Heck et al., 2020; Martins et al., 2021). Due to its antioxidant action, it also has application in the human diet as a preventive action against diseases and deceleration of reactions related to oxidative stress (Alara et al., 2018).

Table 5 presents the compounds, quantity, and method of extraction of phytochemical compounds of jabuticaba (pulp, seed, and peels). Fig. 6 presents the chemical structure of bioactive compounds obtained from jabuticaba. From the peels, cyanidin-3-O-glucoside and delphinidin-3-O-glucoside have been widely extracted. Malvidin, peonidine, petunidine, and pelargonidine, complete the group of anthocyanin compounds relevant to the food industry (Santos-Buelga et al., 2019), either for their bioactive properties or as a dye (Pires et al., 2021). The greater extraction of phenolic compounds from a plant material depends on the sample type and

Table 5
Compounds, quantity, and method of extraction of phytochemical compounds of Jabuticaba (*Myrciaria cauliflora*).

Compunds	Part of the plant	Quantity (mg kg^{-1})	Method	Reference
3,4-dihydroxybenzoic acid	Pulp and peel	12.99	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
4-hydroxybenzoic acid	Pulp and seed	0.6–1.8	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
Caffeic acid	Pulp and peel	0.26	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Catechin	Pulp and seed	3.0–15.0	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
Chlorogenic acid	Pulp and peel	1.93	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Ellagic acid	Pulp and seed	39.6–198	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
	Pulp, peel and seed	5.05×10^4	Extraction with methanol, water, and acetic acid solution (70:30:0.5, v/v/v) and detection with HPLC-PDA	Alezandro et al. (2013)
Ferulic acid	Pulp and peel	1.99	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Gallic acid	Pulp and seed	4–12	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
	Pulp and peel	41.64	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Syringic acid	Pulp and peel	0.97	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
	Pulp and seed	3–15	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
p-coumaric acid	Pulp and peel	3.58	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
p-coumaric acid	Pulp and seed	0.18–0.54	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
Cyanidin-3-O-glucoside	Peel	19.45×10^3	Extraction with water and ethanol (80:20) (v/v) and detection by HPLC-PDA-ESI/MS	Albuquerque et al. (2020)
	Pulp, peel and seed	1.23×10^3	Extraction with methanol, water, and acetic acid solution (70:30:0.5, v/v/v) and detection with HPLC-PDA	Alezandro et al. (2013)
	Peel	2.58×10^4	Maceration with ethanol acidified with 1.5 mol L^{-1} HCl (85:15, v/v) and quantification by HPLC-PDA	Lima et al. (2011)
	Pulp	1.8×10^2	Maceration with ethanol acidified with 1.5 mol L^{-1} HCl (85:15, v/v) and quantification by HPLC-PDA	Lima et al. (2011)
Delphinidin-3-O-glucoside	Peel	5.09×10^3	Extraction with water and ethanol (80:20) (v/v) and detection by HPLC-PDA-ESI/MS	Albuquerque et al. (2020)
	Pulp, peel and seed	2.35×10^2	Extraction with methanol, water, and acetic acid solution (70:30:0.5, v/v/v) and detection with HPLC-PDA	Alezandro et al. (2013)
	Peel	3.09×10^3	Maceration with ethanol acidified with 1.5 mol L^{-1} HCl (85:15, v/v) and quantification by HPLC-PDA	Lima et al. (2011)
Isoquercitrin	Pulp and peel	8.64	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Isorhamnetin	Pulp and peel	0.79	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Kaempferol	Pulp and seed	3–15	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
	Pulp and peel	0.33	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Luteolin	Pulp and peel	0.05	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Myricetin	Pulp and seed	0.3–1.5	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
Naringenin	Pulp and seed	0.12–0.36	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Senes et al. (2021)
	Pulp and peel	0.37	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Pinobanksin	Pulp and peel	0.42	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)
Quercetin	Pulp and seed	0.3–1.5	Extraction with VA-MSPD and detection by UHPLC-MS/MS	Seraglio et al. (2018)
	Pulp and peel	52.11	Acid hydrolysis with HCl and detection by LC-ESI-MS/MS	Seraglio et al. (2018)

Label: VA-MSPD, vortex-assisted matrix solid-phase dispersion; UHPLC-MS/MS, ultra-high performance liquid chromatography-mass spectrometry; LC-ESI-MS/MS, liquid chromatography electrospray ionization tandem mass spectrometric; HPLC-PDA, high-performance liquid chromatography with photodiode array detection; HPLC-PDA-ESI/MS, high performance liquid chromatography with photodiode array detection and electrospray ionization tandem mass spectrometry.

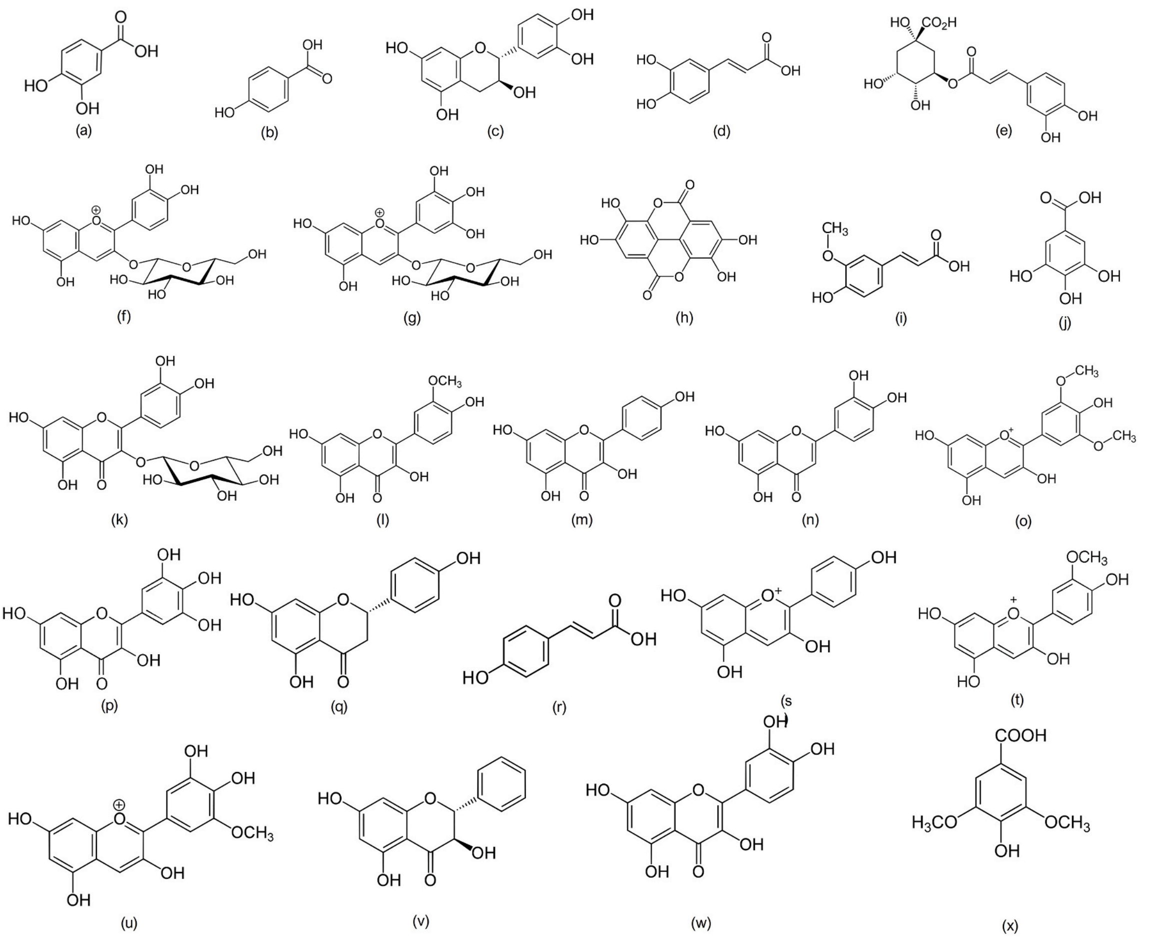

Fig. 6. Chemical structure of bioactive compounds obtained from jabuticaba. (a) 3,4-dihydroxybenzoic acid; (b) 4-hydroxybenzoic acid; (c) catechin; (d) caffeic acid; (e) chlorogenic acid; (f) cyanidin-3-O-glucoside; (g) delphinidin-3-O-glucoside; (h) ellagic acid; (i) ferulic acid; (j) gallic acid; (k) isoquercitrin; (l) isorhamnetin; (m) kaempferol; (n) luteolin; (o) malvidin; (p) myricetin; (q) naringenin; (r) *p*-coumaric acid; (s) pelargonidine; (t) peonidine; (u) petunidine; (v) pinobanksin; (w) quercetin; and (x) syringic acid.

phenolics content. The quantification and highest yield of phenolic compounds depend on the extraction technique (Alara et al., 2021). Still, crude extracts are traditionally obtained by solvent extraction methods, maceration, infusion, percolation, and decoction (Alara et al., 2018). Modern ultrasound-assisted extraction techniques, pressurized wate, supercritical fluids, solid-phase dispersion, and microwaves have shown high extraction efficiency (Fernandes et al., 2020; Selvamuthukumaran and Shi, 2017; Senes et al., 2021). Fig. 7 illustrates the most usual extraction techniques of bioactive compounds from jabuticaba. Briefly, new extraction procedures based on pressurized liquid extraction were reported in the literature. This process uses organic solvents at high pressure and a temperature above their boiling point to extract the analytes from the sample matrices. Higher pressure increases the contact between the extracting fluid and sample, while higher temperature is used to break the analyte-matrix bonds (Dias et al., 2021). Beyond, supercritical fluid extraction has been used with gas assolvent in its critical point (Singh et al., 2021). Carbon dioxide (CO_2) is usually used as solvent in this method because it can extract lipid-soluble compounds and it enables a high-level recovery.

Moreover, there are several benefits for the use of CO_2, such as its low cost, non-hazardous and non-flammable aspects, and safety (Lefebvre et al., 2021). In the case of ultrasound-assisted extraction, mass transfer increase is observed, and the diffusion of the solvent into the matrix is enhanced due to pores creation in the membranes, which allows higher access to the bioactive compounds extraction. The ultrasound technology has been demonstrated as a rapid and highly effective one for mass transfer due to cavitation phenomena, being more and more applied in food processing and natural products extraction (Khadhraoui et al., 2021).

Studies characterized jabuticaba concerning its phenolic compounds, antioxidant capacity, total monomeric anthocyanin, sugars, and minerals during ripening (Seraglio et al., 2018). The authors concluded that jabuticaba could be considered a source of natural bioactive and nutritional compounds is a promising raw material for the food industry. The jabuticaba has high antioxidant power, presenting excellent protection against lipid oxidation, potential to be used as an additive in the food industry, with possible benefits to consumer health (Lima et al., 2011).

Fig. 8 illustrates the several technological routes for the valorization of jabuticabas by-products to obtain bioactive compounds. The main technologies reported are extraction by maceration, solid-phase extraction, ultrasound-assisted, high-intensity ultrasound,

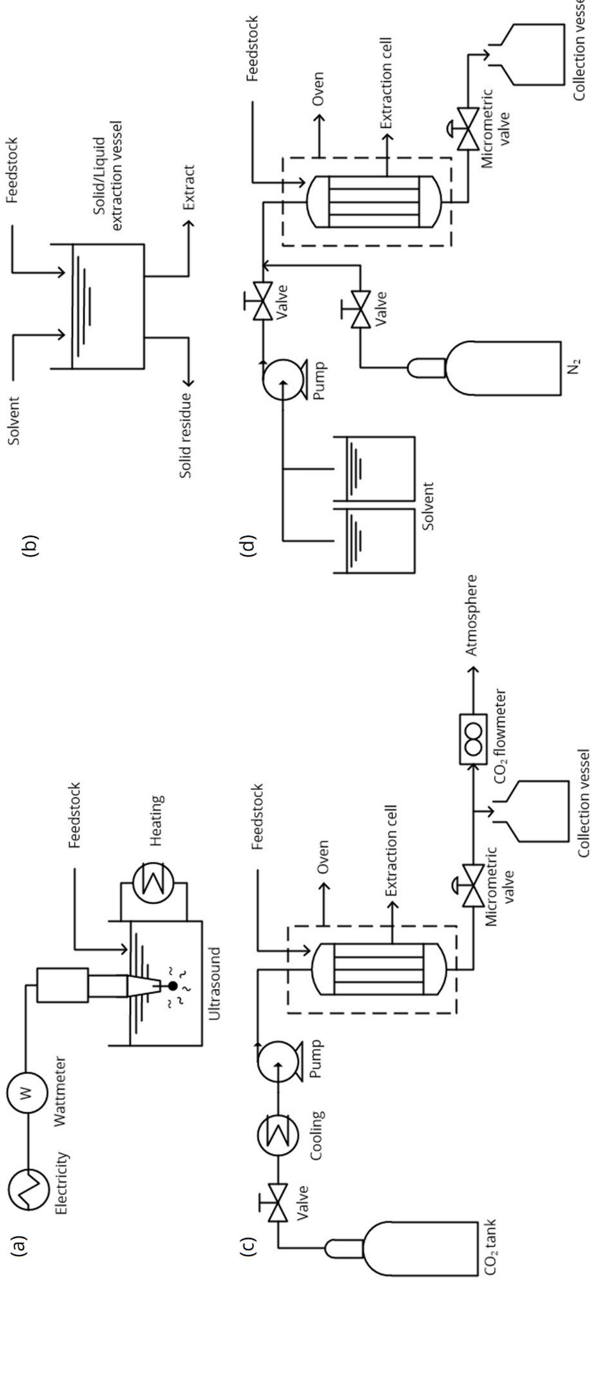

Fig. 7. Scheme of the most usual extraction techniques of bioactive compounds from jabuticaba. (a) ultrasound-assisted extraction; (b) solid-liquid extraction; (c) supercritical carbon dioxide extraction; and (d) pressurized liquid extraction.

pressurized hot water, and high-pressure carbon dioxide. All of them obtained bioactive compounds from jabuticaba peels varying yield, concentration, or isolation depending on the selected technology, as can be observed in Table 6.

The ultrasound-assisted extraction technique using ethanol as a solvent demonstrates promising results for dry jabuticaba peel, of 4.8 mg of anthocyanin g^{-1}, 92.8 mg of gallic acid g^{-1}, 4.9 mg of cyanidin-3-O-glucoside g^{-1}, and 7.8 mg ellagic acid g^{-1} (Rodrigues et al., 2015). With the same technique with water as the solvent, 8.9 mg gallic acid equivalent g^{-1}, 0.9 mg ellagic acid g^{-1}, and 7.9 mg cyanidin-3-O-glucoside g^{-1} can be obtained, with the highest yields of bioactive compounds at 25 kHz, 20 min of extraction, and pH 1.5 (Fernandes et al., 2020). Also, the ultrasound-assisted extraction technique showed the effect of the addition of formic, acetic, and phosphoric acids to the extraction process (Barros et al., 2019). The authors concluded that formic acid with pH 1.0 had the best recovery of anthocyanins obtaining 3.4 mg anthocyanin g^{-1} material and an antioxidant capacity of 841 μmol Trolox g^{-1} material.

Using the high-intensity ultrasound technology technique, at the intensity of 3.7 W cm^{-2} and 50 g water 100 g^{-1} ethanol, the best results of recovery of bioactive compounds were obtained: 3391 mg GAE L^{-1}; 287 mg anthocyanin L^{-1}; 667 mg flavonoids L^{-1}; and 11625 mg tannins L^{-1} (Tarone et al., 2021). Thus, phenolic compounds can be recovered with fast, relatively inexpensive, and simple technology that reduces environmental costs and impacts compared to conventional extraction processes.

Using an exhaustive extraction of dried jabuticaba peel with water, ethanol, and formic acid solution as a solvent in the ratio 85:15:0.5 (v/v), a polyphenolic profile of two varieties of jabuticaba (*M. trunciflora*) was evaluated (Quatrin et al., 2019). In the study, the authors obtained high levels of bioactive compounds with a total of 1813 mg anthocyanins 100 g^{-1}, 356.5 mg ellagic acid 100 g^{-1}, and 3315.4 total hydroxybenzoate 100 g^{-1}. Beyond using maceration with distilled water, the optimum extraction condition was at 88 °C with pH 1. The results obtained (9.7 mg anthocyanin g^{-1}, 230.48 mg GAE g^{-1}, and 7.18 mg cyanidin-3-glucoside g^{-1}) showed that the peels have a high content of total phenolics, antioxidant activity, and anthocyanins (Avila et al., 2020).

Another technological route is the extraction with methanol and water solution (70:30, v/v) for 30 min at 30 °C in an ultrasonic bath with a frequency of 37 kHz and 320 W (Senes et al., 2020). After this, the extracts were filtered before the cleaning step with diatomaceous earth, chitosan, and graphite carbon black as adsorbents. Eight compounds were found, the majority being ellagic acid (1643 mg kg^{-1}), cutting acid (252 mg kg^{-1}), and 4-hydroxybenzoic acid (154 mg kg^{-1}).

With pressurized fluid technology, high-pressure carbon dioxide-assisted extraction was used to optimize the process variables for the maximum recovery of anthocyanins and phenolic compounds of dried jabuticaba peels (Santos and Meireles, 2011). The best conditions were 117 bar, 80 °C, and 20% pressurized solid-liquid/CO_2 mixture, finding the total content of phenolic compounds of 2273 mg cyanidin-3-glucoside g^{-1} and 13 mg gallic acid equivalents g^{-1}. Beyond, using pressurized hot water extraction with water, ethanol, and formic acid (94:5:1, v/v) as a solvent, for the extraction of dried jabuticabas peels, the results show that the amount of cyanidin 3-glucoside (2866.2 ± 40.1 mg 100 g^{-1}) represents the total of 63% of the total phenolic compounds of the peels (Plaza et al., 2016).

Currently, jabuticaba peels are considered by-products and are generally discarded without any use. However, the previous research showed that it is possible to extract high-value bioactive compounds, allowing this by-product insertion into a production cycle. The bibliometric analysis presented shows that the scientific community addressed the recovery of bioactive compounds from jabuticaba peels. Moreover, the recycling of agro-industrial by-products is placed within the circular economy, a worldwide concept advocating the industrial process's circularity, closing raw material cycles to maximize resource use (Ghisellini et al., 2016). A new end-of-life concept to reduce, reuse, recycle, and recover resources supports sustainable development from energy, economic, social, and environmental perspectives (Kirchherr et al., 2017).

6. Conclusions and future perspectives

The demand for pharmaceutical products enriched with natural biocompounds to replace synthetic ones is worldwide. Active biocompounds, such as anthocyanins, contribute to human health. Jabuticaba and its by-products present high biological potential,

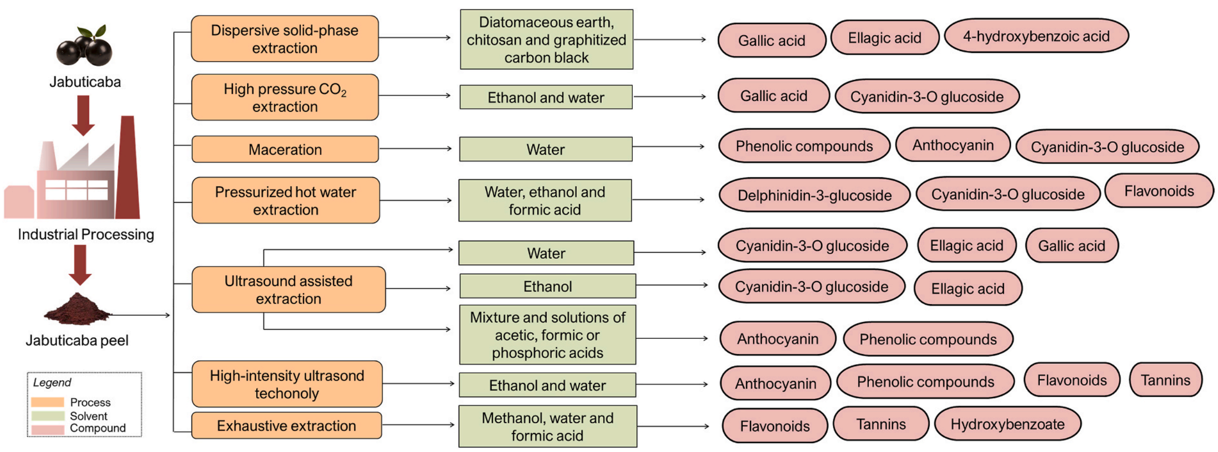

Fig. 8. Technological routes for the valorization of jabuticaba by-products to obtain value-added products.

Table 6
Synthesis of research on the extraction of bioactive compounds from jabuticaba peel.

Obtained compounds	Methodology	Yield	Additional information	References
Cyanidin-3-O-glucoside and ellagic acid.	Ultrasound assisted extraction using ethanol as solvent.	4.8 mg of anthocyanin g^{-1} dry peel; 92.8 mg of gallic acid g^{-1} dry peel; 4.9 mg of cyanidin-3-O-glucoside g^{-1} dry peel; 7.8 mg ellagic acid g^{-1} dry peel.	The results showed that with an adequate operating condition it was possible to reach good yields using a simple extraction process.	Rodrigues et al. (2015)
Anthocyanin and phenolic compounds.	Ultrasound assisted extraction using a hydroalcoholic mixture and solutions of acetic, formic or phosphoric acids to regulate pH.	3.4 mg anthocyanin g^{-1} raw material; 841 μmol Trolox g^{-1} raw material for antioxidant capacity.	The acid that presented the best recovery of anthocyanin and best antioxidant capacity was formic acid in pH 1.0.	Barros et al. (2019)
Anthocyanin, phenolic compounds and Cyanidin-3-O-glucoside	Maceration with distilled water and solutions of hydrochloric acid and sodium hydroxide to regulate pH.	9.7 mg anthocyanin g^{-1} raw material; 230.48 mg GAE g^{-1} raw material; 7.18 mg cyanidin-3-O-glucoside g^{-1} raw material.	The optimal conditions for extraction were 88 °C and pH 1.0.	Avila et al. (2020)
Cyanidin-3-O-glucoside, ellagic acid and gallic acid.	Ultrasound assisted extraction using water as solvent.	8.9 mg GAE g^{-1} dry peel; 0.9 mg ellagic acid g^{-1} dry peel; 7.9 mg cyanidin-3-O-glucoside g^{-1} dry peel.	The highest yield of bioactive compounds was attained at 25 kHz, 20 min of extraction and pH 1.5.	Fernandes et al. (2020)
Cyanidin-3-glucoside and gallic acid.	High pressure carbon dioxide assisted extraction.	2.2 mg cyanidin-3-glucoside g^{-1} dry peel; 13 mg GAE g^{-1} dry peel.	The best extraction conditions were achieved at 117 bar, 80 °C and 20% volume ratio of solid–liquid mixture/pressurized CO_2.	Santos and Meireles (2011)
Polyphenol, anthocyanin, flavonoids and tannins.	High-intensity ultrasound technology with water and ethanol as solvents.	3391 mg GAE L^{-1}; 287 mg anthocyanin L^{-1}; 667 mg flavonoids L^{-1}; 11,265 mg tannins L^{-1}.	This tecnique promoted the best recovery of bioactive compounds at an ultrasound intensity of 3.7 W cm^{-2} and 50 g water 100 g^{-1} ethanol.	Gadioli Tarone et al. (2021)
Ellagic acid, gallic acid and 4-hydroxybenzoic acid.	Extraction with methanol/H_2O solution (70:30 v/v) for 30 min at 30 °C in an ultrasonic bath with a frequency of 37 kW and 320 W,	1643 mg ellagic acid kg^{-1}; 252 mg gallic acid kg^{-1}; 154 mg 4-hydroxybenzoic acid kg^{-1}.	The use of diatomaceous earth with graphitized carbon black in a ratio of 100:10 (w/w) was the best clean-up step condition.	Senes et al. (2020)
Cyanidin 3-glucoside, delphinidin 3-glucoside, ellagitannins, gallotannins, ellagic acid and derivatives, and flavonols.	Pressurized hot water extraction using water, ethanol and formic acid as solvents.	2866.2 mg cyanidin 3-glucoside 100 g^{-1} dry peel, representing around 63% of the total phenolic compounds.	Even though cyanidin 3-glucoside is in the highest concentration, it represents only 25% of the total antioxidant capacity.	Plaza et al. (2016)
Anthocyanins, flavonols and ellagic acid derivates and hydroxybenzoate derivatives or tannins.	Exhaustive extraction with solutions of methanol, water and formic acid as solvents.	1813 mg total anthocyanins 100 g^{-1} dry peel; 356.5 mg ellagic acid derivates 100 g^{-1} dry peel; 3315.4 total hydroxybenzoate 100 g^{-1} dry peel.	There were analyzed two different species of jabuticaba: *Myrciaria jabuticaba* and *M. trunciflora*. The second one presented the highest levels of bioactive compounds in general.	Quatrin et al. (2019)

like antioxidant, antimicrobial, anti-inflammatory, antidiabetic, among other functional properties. Despite this, this potential remains scarcely used. Currently, by-products materials constitute a niche market, especially because of environmental, economic, and social implications in the circular economy concept. The jabuticaba peels can be recycled to produce bioproducts with health benefits employing green technologies in a circular economy. Besides reducing industrial waste, the use of emerging green technologies to process jabuticaba by-products allows the recovery of high-quality bioactive compounds. Furthermore, using jabuticaba by-products can support the efficient utilization of a natural resource, this little-explored Brazilian fruit. However, further investigation is necessary to properly address the adoption of biotechnologies to achieve economically viable bioproducts using jabuticaba by-products, redesigning and extending the uses and applications of the potential present in its by-products.

In this study, a systematic review of jabuticaba industrial by-products to obtain valuable active compounds revealed new trends and technologies for the recovery of bioactive compounds. The bibliometric analysis of jabuticaba research indicated that 255 articles and 5 reviews were published over the last 21 years. The most predominant research fields were Food Science Technology, Chemistry, and Agriculture. In addition, from the keywords analysis, it was possible to identify that most of the research is associated with the biological properties of bioactive compounds extracted from jabuticaba. This feedstock and its by-products have been submitted to bioactive compounds extraction in different sustainable technological routes, such as ultrasound-assisted extraction, supercritical carbon dioxide extraction, and pressurized liquid extraction.

CRediT authorship contribution statement

Rafael Gabriel da Rosa: Conceptualization, Methodology, Formal analysis, Writing – original draft. **William Gustavo Sganzerla:**

Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Tiago L.C.T. Barroso:** Writing – original draft. **Luz S. Buller:** Writing – review & editing. **Mauro D. Berni:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Tânia Forster-Carneiro:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

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.

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