EXTRACTION OF SUPERCRITICAL BURITI OIL (Mauritia flexuosa) AND PHYSICOCHEMICAL CHARACTERIZATION AIMING AT ITS APPLICATION FOR THE FORMULATION OF GOURMET OLIVE OIL

EXTRAÇÃO DO ÓLEO SUPERCRÍTICO DE BURITI (Mauritia flexuosa) E CARACTERIZAÇÃO FÍSICO-QUÍMICA VISANDO SUA APLICAÇÃO PARA FORMULAÇÃO DE AZEITE GOURMET

EXTRACCIÓN DE ACEITE SUPERCRÍTICO DE BURITI (Mauritia flexuosa) Y CARACTERIZACIÓN FISICOQUÍMICA CON VISTAS A SU APLICACIÓN PARA LA FORMULACIÓN DE ACEITE GOURMET

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ABSTRACT
The present study aimed to extract buriti oil (Mauritia flexuosa) using supercritical carbon dioxide and characterize it physicochemically with a view to its application as gourmet olive oil. The fruit pulp was collected in Abaetetuba (PA), freeze-dried and subjected to supercritical extraction at 40ºC and 400 bar for 120 minutes. The acidity index, peroxides, degree of unsaturation, density, viscosity, oleic acid content and total carotenoids were analyzed. The results demonstrated that the supercritical buriti oil has a low acidity index (1.12 mg KOH/g) and peroxides (10.04 meq/kg), being within the acceptable standards for vegetable oils, although above the acidity limit for classification as extra virgin. The degree of unsaturation was 55.3%, lower than that recommended for olive oils, possibly due to storage factors. The oleic acid content (54.08%) was close to the minimum required for extra virgin olive oil (55%), a parameter used to identify the quality of vegetable oils, and the carotenoid content (228.75 mg/100 g) was significantly higher than that of traditional olive oils, providing high antioxidant potential. It is concluded that supercritical buriti oil presents desirable physicochemical and functional properties, especially due to its high concentration of carotenoids, which makes it promising as a functional ingredient and in the formulation of gourmet olive oils with an Amazonian identity. The application of supercritical extraction proved to be efficient, reinforcing its potential as a clean and sustainable technology for adding value to regional resources.

Keywords: Buriti Oil. Supercritical Extraction. Gourmet Olive Oil. Carotenoids. Oleic Acid.

RESUMO
O presente estudo teve como objetivo extrair óleo de buriti (Mauritia flexuosa) utilizando dióxido de carbono supercrítico e caracterizá-lo físico-quimicamente visando sua aplicação como azeite gourmet. A polpa dos frutos foi coletada em Abaetetuba (PA), liofilizada e submetida à extração supercrítica nas condições de 40ºC e 400 bar por 120 minutos. Foram

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analisados o índice de acidez, peróxidos, grau de insaturação, densidade, viscosidade, teor de ácido oléico e carotenoides totais. Os resultados demonstraram que o óleo supercrítico de buriti possui baixo índice de acidez (1,12mg KOH/g) e peróxidos (10,04 meq/kg), estando dentro dos padrões aceitáveis para óleos vegetais, embora acima do limite de acidez para classificação como extravirgem. O grau de insaturação foi de 55,3%, inferior ao recomendado para azeites de oliva, possivelmente, devido a fatores de armazenamento. O teor de ácido oléico (54,08%) foi próximo ao mínimo exigido para o azeite extravirgem de oliva (55%), parâmetro utilizado para identificar qualidade de óleos vegetais, e o conteúdo de carotenoides (228,75 mg/100g) foi significativamente superior ao de azeites tradicionais, conferindo elevado potencial antioxidante. Conclui-se que o óleo supercrítico de buriti apresenta propriedades físico-químicas e funcionais desejáveis, especialmente, pela alta concentração de carotenoides, o que o torna promissor como ingrediente funcional e na formulação de azeites gourmet com identidade amazônica. A aplicação da extração supercrítica demonstrou ser eficiente, reforçando seu potencial como tecnologia limpa e sustentável para agregação de valor a recursos regionais.

Palavras-chave: Óleo de Buriti. Extração Supercrítica. Azeite Gourmet. Carotenoides. Ácido Oléico.

RESUMEN

Este estudio tuvo como objetivo extraer aceite de buriti (Mauritia flexuosa) utilizando dióxido de carbono supercrítico y caracterizarlo fisicoquímicamente para su uso como aceite de oliva gourmet. La pulpa de la fruta se recolectó en Abaetetuba, Pará, Brasil, se liofilizó y se sometió a extracción supercrítica a 40 °C y 400 bar durante 120 minutos. Se analizaron el índice de acidez, los peróxidos, el grado de insaturación, la densidad, la viscosidad, el contenido de ácido oleico y los carotenoides totales. Los resultados demostraron que el aceite de buriti supercrítico tiene un bajo índice de acidez (1,12 mg KOH/g) y peróxidos (10,04 meq/kg), dentro de los estándares aceptables para aceites vegetales, aunque por encima del límite de acidez para la clasificación como virgen extra. El grado de insaturación fue del 55,3 %, inferior al recomendado para aceites de oliva, posiblemente debido a factores de almacenamiento. El contenido de ácido oleico (54,08%) se acercó al mínimo requerido para el aceite de oliva virgen extra (55%), parámetro utilizado para identificar la calidad de los aceites vegetales. El contenido de carotenoides (228,75 mg/100 g) fue significativamente superior al de los aceites de oliva tradicionales, lo que le confiere un alto potencial antioxidante. Se concluye que el aceite de burití supercrítico presenta propiedades fisicoquímicas y funcionales deseables, en particular debido a su alta concentración de carotenoides, lo que lo hace prometedor como ingrediente funcional y en la formulación de aceites de oliva gourmet con identidad amazónica. La aplicación de la extracción supercrítica demostró ser eficiente, reforzando su potencial como tecnología limpia y sostenible para la valorización de los recursos regionales.

Palabras clave: Aceite de Burití. Extracción Supercrítica. Aceite de Oliva Gourmet. Carotenoides. Ácido Oleico.

1 INTRODUCTION

The Brazilian production of oils in 2023 was 209,632 tons per day, according to ABIOVE (Brazilian Association of Vegetable Oil Industries), with the South and Midwest regions being the largest responsible for this production. The lowest share is from the North region of Brazil, where a large part of the production of oilseed vegetable matrices predominates, however, this region has also been presenting offers of new oils with different extraction methods.

Sustainability combined with product diversification has allowed the management of fruits and seeds from the Amazon rainforest, to present to the consumer market exotic oils obtained from vegetable matrices of great nutritional potential.

Brazil is a country rich in biodiversity due to its location in the so-called "heart of the Amazon" with a biome that has renewable raw materials, and one of the most diversified. The area occupied by the Amazon biome comprises several states, including Pará, in the North region. In this part of the territory there are numerous plant species, among which are producers of seeds and oleaginous fruits, from which vegetable oils of chemical composition and various physicochemical properties are extracted, as already demonstrated by Pesce (2009) through his research, contributing invaluable to the knowledge of the Amazonian flora. Works of this nature constitute for the chemical industry a source of knowledge of raw material for various purposes and, at the same time, can serve as alternative information for the sustainable development of the region.

The food industry is growing more and more due to the increase in demand for products characterized as functional, that is, that contain, in addition to nutrients, bioactive compounds that bring specific health benefits (Verruck, Dantas & Prudencio, 2019; Demirci *et al.,* 2020). As an example of these bioactive compounds, we can mention carotenoids, which are the compounds found in greater quantities in oilseed fruits from the Amazon, with buriti being the fruit with the highest concentration of β-carotenes ever known among the various Brazilian foods already studied, according to Rodriguez-Amaya *et al*. (2008), a fact that is corroborated in other studies (Schiassi, *et al.*, 2018). In addition, the buriti (*Mauritia flexuosa*) is a promising fruit for commercial use and management, as it has good genetic variability, demonstrating great economic importance, having practically all its parts used (FAPEAM, 2010; Sampaio & Carrazza, 2012; Resende, Franca & Oliveira, 2019**).**

Carotenoids, bioactive compounds, are also called antioxidant pigments due to their coloring properties, and are often used in the food, pharmaceutical, cosmetic, and animal feed industries. In addition to their wide use as natural coloring agents, they are also used in food fortification due to their activity as provitamin A and their health-beneficial biological functions, such as strengthening the immune system, reducing the development of degenerative diseases (Barboza *et al*., 2022; Foods Ingredients, 2019), antioxidant properties and anti-obesity and lipid-lowering activities (Aquino *et al.,* 2023).

Buriti oil, in addition to being an excellent source of carotenoids, is also rich in nutrients from the plant matrix (Pereira-Freire *et al*., 2022; Castro, 2018), such as calcium, sodium, phosphorus, potassium and magnesium, as well as some phenolic compounds, however, its nutritional potential is highlighted due to the content of fatty acids, especially oleic acid, also called omega-9.

Quintero-Angel, Martínez-Girón, and Orjuela-Salazar (2023) in their study compared the lipid levels of buriti oil in relation to olive oil and sunflower oil, among others, widely used in the diet of the population that seeks to achieve a balanced and preventive diet, regarding the development of diseases. In this research, the author states that buriti oil presented higher levels of oleic acid when compared to all the oils analyzed. Pereira *et al.* (2018) and Borges *et al.* (2017) state that this high content of oleic acid provides high stability to oxidation in addition to being an excellent source of carotenoids, a compound found at low levels in olive oil, used as a quality parameter for evaluating vegetable oils.

Studies related to the physicochemical analysis of buriti oil are presented as a new source of oil to be explored by the food industry, since it presents similarities in terms of its nutritional properties with other oils considered to be of high nutritional and market value, especially extra virgin olive oil (AEVO) (*Olea europaea L.)*element. However, little is known about the physical, chemical and sensory parameters of this new oleic source, extracted from innovative methods, such as supercritical extraction, which contribute to the maintenance of its quality and which makes technological projects for the insertion of this product in the food market unfeasible. For this reason, the knowledge of its chemical and physical properties is useful not only for the characterization of its identity and maintenance of its quality, but also to assist the industry in its production and application in the elaboration of products more accessible to the population.

The industrial bioproduction of oils is well established and has been expanding commercially, in an increasing and accelerated way. However, the extraction and recovery operations of products and direct extraction of plant sources are still under development in the literature. In addition, according to Mezzomo and Ferreira (2016), some extraction processes contribute to increase production costs, presenting other negative factors, which emphasize the need for detailed research in this area.

In this sense, it is advisable to immerse yourself in studies that can present alternatives capable of offering sustainable solutions for a harmonious relationship between the environment and the economy, such as the so-called "green technologies". Supercritical fluid extraction (SCEF) is one of such technologies, since it is used in industrial processes that have its use progressively increased, mainly due to the environmental issue, since it does not degrade the environment, nor the raw materials used and the possibility of managing the operational parameters, which reflects on the quality of the process. It is a toxic residues-free procedure, does not require post-processing of the extracts for solvent removal and does not cause degradation of the thermal extracts, allows use at low temperatures, and avoids oxidation reactions, due to the absence of light and oxygen in the extraction column. In addition, it is a flexible process due to the possibility of continuous adjustment of the solvent's solvation power and selectivity (Picot-Allain *et al.,* 2021; Poveda *et al.,* 2018).

The need to evaluate the oilseed potential of buriti is reinforced by the current research reports of several agencies, which list buriti as a promising and natural source of bioactive compounds, including the high concentration of polyunsaturated fatty acids beneficial to human health. However, despite having proven health benefits, there are still few exploratory studies on obtaining buriti oil through supercritical carbon dioxide technology, and no existing study on the extraction of the oil aiming at its application as a quality gourmet olive oil, configuring a possible natural substitute for AEVO. Therefore, the objective of this work was to apply the technology with supercritical carbon dioxide to obtain buriti oil for the formulation of gourmet olive oil, to analyze the degree of acidity, peroxide and iodine index, density and viscosity, oleic acid content and total carotenoids using AEVO as a quality parameter for the purpose of comparative analysis.

2 LITERATURE REVIEW OR THEORETICAL FOUNDATION

2.1 AMAZON, ITS OILSEEDS AND THE ECONOMIC IMPORTANCE OF BURITI (*MAURITIA FLEXUOSA*)

The Amazon is the largest Brazilian biome, occupying, according to data from the IBGE (Institute of Geography and Statistics, 2022), 49.29% of the total Brazilian territory. This concept of biome is related to the existing biological set (plant and animal) that survives in similar geoclimatic conditions and results in its own biological diversity, that is, characteristic of this region, specifically. The Amazon biome occupies the totality of five units of the Brazilian federation (Acre, Amapá, Amazonas, Pará and Roraima), and comprises a part of Rondônia, Mato Grosso, Maranhão and Tocantins. Therefore, Pará is considered one of the richest Brazilian states in biodiversity, when compared to the others.

The Amazonian flora is extremely rich and diversified in oilseed plants, making it incomparable and unique. Climate, soil, and rainfall characteristics are favorable factors for the proliferation of the palm family (Kikuchi & Callado, 2021; Santos Junior *et al.*, 2014)element. Açaí (*Euterpe oleraceae*), ucuuba (*Virola surinamensis*), patauá (*Oenocarpusbataua*), murumuru (*Astrocaryummurumurú*) and buriti (*Mauritia flexuosa*) are oilseeds widely used by riverside communities and can also be good sources of raw materials of industrial interest.

From the point of view of the local, national and even global market, the products from these various Amazonian palm trees are linked to economic expansion, due to the possibility of their full use, say Silva, Sevalho and Miranda (2021) in their study. The oils extracted from its fruits represent sources of numerous bioactive compounds, which have, in addition to other benefits, the potential antioxidant capacity, a characteristic directly related to the stability and quality of vegetable oils in general (Kumar *et al*., 2017).

Pará, a state located in the northern region of Brazil, has a territorial extension of 1,247,950.003km², representing the second largest federative unit in the country. According to the population count carried out in 2022, by the IBGE, the population of Pará totals 8,116,132 inhabitants. Its economy, based on animal, vegetable and mineral extractivism, accordingto FAPESPA (2015) in its statistical yearbook, in the period from 2008 to 2012, generated approximately R$1,450,000.00 for the State from the extraction of about 1,270 tons of buriti for commercial purposes.

2.2 CHARACTERIZATION OF BURITI AND ITS INDUSTRIAL USE

Buriti (*Mauritia flexuosa*) (Fig. 1), from the *Arecaceae* family, is a fruit native to South America, and more than 473 tons were extracted in Brazil, according to IBGE data, in 2021. Its flowering peaks in the period between the rainy and dry seasons, usually at the end of the floods, while fruiting occurs during the rainy season, however, only 20% of the females bear fruit annually. Silva, Cavalcante, and Silva (2023) state that fruit production is influenced by the size of plant leaves, soil moisture, temperature, and precipitation and 'vice versa'. The fruit is climacteric and the optimal harvest point occurs 210 days after anthesis, the final stage of flowering, with the highest carotenoid levels observed 8 days after fruit fall.

It is a small, plum-sized oval drupe protected by a scaly pericarp that is red, dark red, or reddish-brown. The mesocarp is edible, with a thin layer of yellow pulp, while the endocarp has a spongy structure. The drupe described can be consumed in the processed forms of sweets, ice cream, juices, jellies, and wine (Neri-Numa *et al*., 2018; Resende, Franca and Oliveira, 2019; Sampaio & Carrazza, 2012).

The fruit pulp has significant levels of phenolic compounds and total carotenoids, thus having a high antioxidant capacity (Candido, Silva & Agostini-Costa, 2015; Araújo *et al*., 2017). The types and contents of fatty acids and beta-carotene in the oil extracted from the pulp are considered relevant for applications in the pharmaceutical, cosmetic and food industries (Garcia-Quiroz *et al*., 2003; Sampaio Neto, Batista & Meirelles, 2020).

Figure 1

Buriti (Mauritia flexuosa)

Source: Prepared by the authors (2025).

This fruit has been widely used by the industry for medicinal, cosmetic, nutritional purposes, among others. Studies carried out with experimental models have proven the effectiveness of the use of buriti oil in Wistar rats, demonstrating the reduction of bacterial activity and wound healing performed in these animals (Batista *et al*., 2012). Another study carried out with Fisher rats proved the antioxidant capacity of buriti flour, a source of the same nutrients present in the oil, offered in the diet of animals with induced diabetes, promoting a reduction in oxidative stress biomarkers (Lage *et al*., 2018). In the area of the cosmetic industry, a study conducted by Koga *et al*. (2017) attested that the use of buriti oil in biocosmetics, more specifically, in conditioners, resulted in hair fibers with improved elastic modulus, decreased breaking tension and tenacity when compared to fibers treated with base formulation and only dyed, that is, it contributed to the modification of the fiber and increased hair health.

Scientifically based data prove the various nutritional properties of buriti, demonstrating its high content of carotenoids, more specifically, beta-carotenes that are called provitamin A (retinol), since they are the precursors of vitamin A, which promotes the protection of the skin against the harmful effects of ultraviolet radiation, in addition to being responsible for maintaining vision health. The high content of carotenoids present in buriti pulp, combined with its pro-vitamin A activity, allows incentives for its use as a measure to prevent hypovitaminosis and the development of severe pathologies such as cancer (Arrudas *et al*., 2014; Stahl & Sies, 2012; Sousa *et al.,* 2021).

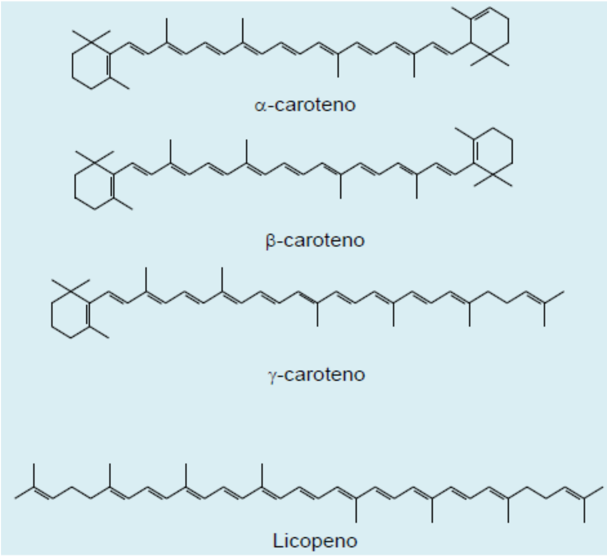
2.3 CAROTENOIDS: CHARACTERIZATION, BENEFITS AND DEFICIENCIES

Carotenoids are tetraterpene lipophilic pigments (C40) found in nature that range in color from colorless to yellow, orange, and red. They are synthesized by bacteria, algae, and plants and found in some animals due to their accumulation through food (Mulders *et al*., 2014; Nisar *et al*., 2015).

The classes of carotenoids found in nature are called carotenes, substances that have a hydrocarbon chain (Figure 2) and xanthophylls, substances that comprise the oxygenated derivatives of carotenes (Figure 3).

Figure 2

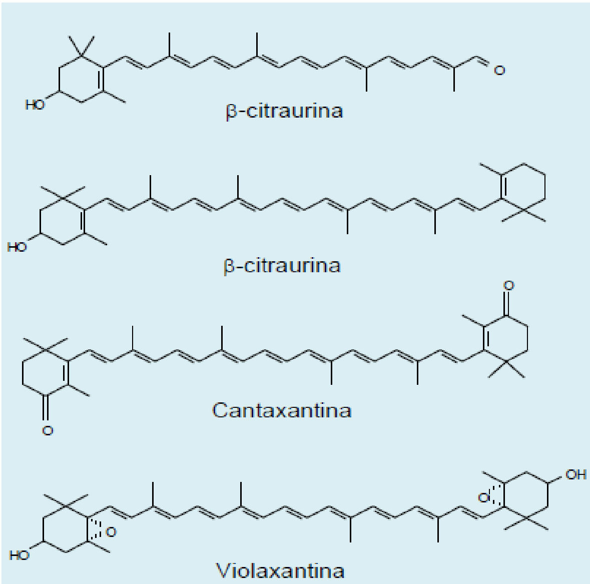
Chemical structure of carotenes



Source: Mesquita, Teixeira & Servulo (2017).

Figure 3

Chemical structure of xanthophylls

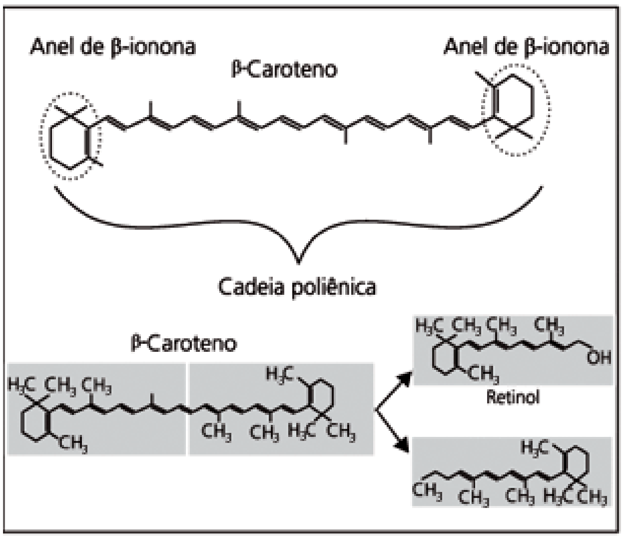


Source: Mesquita, Teixeira & Servulo (2017).

There are more than 600 types of carotenoids, however, only about 10% of these are considered precursors of vitamin A. The main carotenoids that exhibit provitamin A activity are: alpha-carotene, beta-carotene, gamma-carotene, alpha-cryptoxanthin, and betacryptoxanthin. Other carotenoids also have pro-vitamin A activity, however, beta-carotene has greater bioconvertibility in the body, as it is more active and generates two retinol molecules when ingested (Figure 4) (Ambrósio, Campos & Faro, 2006; Lewinski, 2009; Mesquita, Teixeira & Servulo, 2017).

Figure 4

Chemical structure and cleavage of beta-carotene



Source: Ambrósio, Campos & Faro (2006).

Carotenoid deficiency leads to organic changes, mainly related to the epithelial structures of different organs, including changes in the morphology of the eye. Xerophthalmia is the name given to the various ocular signs and symptoms of vitamin A deficiency (VAD). The earliest clinical form of xerophthalmia is night blindness, where the individual does not achieve good visual adaptation in poorly lit environments. In the more advanced stages, the cornea is also affected, constituting corneal xerosis, characterized by loss of brightness, assuming a granular aspect, and corneal ulceration; progressive ulceration can lead to necrosis and destruction of the eyeball, causing irreversible blindness, called keratomalacia (Schmitz, 2007; Loskutova *et al*., 2013; Faustino *et al*., 2016).

The WHO (World Health Organization, 2020) points out that each year 1.9 million people die from oxidative diseases, such as cancers and cardiovascular diseases (CVDs). Agarwal *et al.* (2012) and Fiedor & Burda (2014) state that dietary support of carotenoids reduces the morbidity of adult smokers susceptible to the development of lung cancer and CVDs, such as atherosclerosis, indicating that it may also be caused by VAD.

In addition, carotenoids represent a very important factor in innate and acquired immunity and in the inflammatory response, thus standing out as fundamental nutrients for strengthening the immune system and fighting infections of various nature (Ni *et al*., 2016; Rubin *et al*., 2017.)

Faustino *et al*. (2016) state that clinical presentations associated with VAD persist in poor regions around the world with the same clinical findings described centuries ago. The Ministry of Health (BRASIL, 2023) and Pedraza (2020) point to VAD as a serious public health problem, affecting worldwide, approximately 19 million pregnant women and 190 million pre-school children.

"The National Study of Child Food and Nutrition (Enani) showed that it (the DVA) is higher in the Midwest (9.5%), followed by the South (8.9%), North (8.3%), Northeast (5.2%) and Southeast (4.3%), especially among children in the first fifth of the National Economic Indicator (9%), that is, among children with the worst conditions of economic distribution in households. When looking at the age group from 6 to 23 months, the prevalence of vitamin A deficiency is 6.4%, being higher in the Midwest region (11.5%) and lower in the Southeast (5%)." (BRAZIL, 2023).

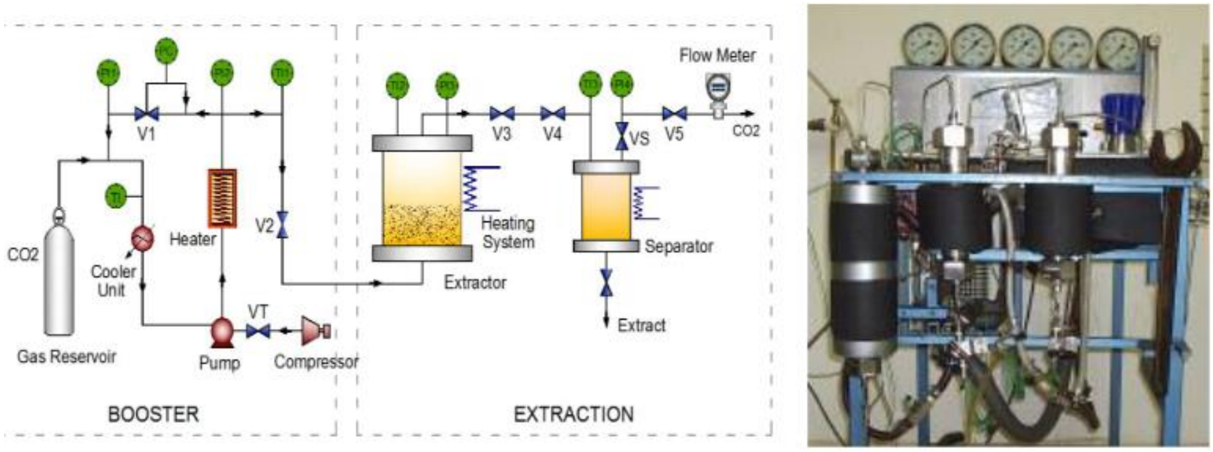
2.4 SUPERCRITICAL FLUID

The use of supercritical fluids in the extraction of natural products has been shown to be a potential technology in recent decades. Coelho (1994) defines supercritical fluid as that which is at a temperature above the critical temperature and at a pressure above the critical pressure, thus presenting intermediate physicochemical properties between the liquid and the gaseous state. The critical temperature, according to Tena *et al*. (1997) is the highest temperature at which a gas can be converted into a liquid by increasing pressure. Following this reasoning, the critical pressure is the highest pressure at which the liquid can be converted by a gas by increasing temperature.

Supercritical fluid has numerous advantages, as it does not induce toxicity or contaminate extracts, such as common solvents, for example (Salazar *et al.,* 2018). Because the solvent used is gaseous under normal pressure and room temperature, it can be more easily eliminated, another advantage would be the absence of chemical changes of the substances by the solvent, by impurities contained in them or caused by other factors, for example, the occurrence of hydrolysis, caramelization, esterification, oxidation, or thermal changes of the extracts used (Maul, Wasicky & Bacchi, 1996).

Figure 5

Supercritical extraction unit (ESC)



Source: Souza *et al.* (2017).

2.4.1 Supercritical oil

Supercritical fluid extraction (EFSC) is a promising process used to extract natural compounds from plant raw materials, avoiding thermal degradation and the presence of solvent residues in the extracts (García-Risco et al., 2011). It has several advantages over conventional extraction techniques. The operating temperature at the EFSC is reasonably low, allowing thermally stable compounds to be separated. Unlike what occurs in traditional techniques, in this process the extraction occurs almost instantaneously, with extracts being separated from the solvents only by reducing the system pressure or adjusting the temperature (Bhattacharjee et al., 2007), which contributes to the preservation of the physicochemical characteristics of the raw material, thus maintaining its sensory characteristics.

2.5 GOURMET OLIVE OIL AND OLIVE OIL

The term "Gourmet" has been rapidly becoming popular with the emphasis on Gastronomy worldwide, especially in Brazil. The entry in question is usually associated with an extremely well-prepared preparation or product, prepared with ingredients that are little used or known to the eyes of consumers, thus adding greater value to the product. Barreto (2020) states that criteria such as odor and appearance are crucial to classify a product as "gourmet", in addition to being prepared in a specific way that contributes to maintaining its quality.

Oliveira, Silva and Mesquita (2018) carried out a research based on the extraction of avocado oil for consumption entitled as *gourmet*, and justifying the use of the term "because the product has a specific characteristic: the drop in quality is only after reaching a temperature of 240°C, which confers good property to be used in fried foods in cooking." AEVO, considered the gold standard for comparative analysis of oil quality, in turn, reaches the point of degradation at 140°C. The result of this study indicated that avocado oil is proven to be more efficient in culinary preparations at high temperatures, and can therefore receive the denomination of "gourmet" due to its peculiarities.

In recent years, these "special or gourmet oils" have become widely disseminated due to consumer preference and their concern for health. These are oils obtained from vegetable and fruit seeds, oleaginous or not, and obtained from processing that preserves the sensory characteristics of these raw materials (such as cold pressing, for example), leaving aside traditional forms of processing such as conventional refining, bleaching and deodorization, which are routinely used to remove flavors and impurities, and also, in order to extend the shelf life of these oils. The use of ESC has the same benefits as cold pressing, as an extraction method, however, it is still little used by the industry to obtain oils.

When compared to refined oils that are colorless, these virgin oils retain their original color, and can have much more intense colors (as in palm oil: red; corn germ oil: orange; walnut and sunflower oil: different shades of yellow). In addition to their peculiar taste, which make them gourmet ingredients, specialty oils contain large amounts of nutritional and functional components (such as essential fatty acids, antioxidants, phenolic compounds, phospholipids, phytosterols, etc.) responsible for their health benefits and nutraceutical properties, which make them popular in the health-promoting food market.

AEVO has been studied as the gold standard of cold-pressed virgin oils, and for this reason it is used as a reference for the physicochemical characterization of gourmet oils and olive oils. The International Olive Council, IOC (2022) and the Codex Alimentarius Commission (2013) establish quality and identity criteria for the characterization of AEVO. The current Brazilian legislation is stipulated by Normative Instruction No. 1, of January 30, 2012, which provides subsidies for the application of legal requirements (BRASIL, 2012).

According to EU Regulation 1308/2013, "**virgin olive oils"** are obtained from the fruit of the olive tree solely by mechanical or other physical processes, under conditions that do not alter the product, and which have not undergone any treatment other than washing, decanting, centrifugation or filtration, with the exception of oils obtained from solvents, with adjuvants of chemical or biochemical action or by re-esterification processes, as well as any mixture with oils of another nature.

The applicability of new products with physicochemical profiles similar to AEVO is intrinsically related to several factors, such as health benefits and tradition, since this type of product has been used since ancient times, having a prominent place in the Mediterranean diet, for example. Its chemical composition and sensory characteristics place it in a privileged position among edible oils and fats, representing potential importance in the area of Gastronomy and high added value, since it is a product increasingly sought after by the consumer, and finally, consequently, with an impact on the economy of our country.

3 METHODOLOGY

3.1 COLLECTION AND PRE-TREATMENT OF RAW MATERIAL

Buriti fruits were collected in the municipality of Abaetetuba, Pará, Brazil (01º43'05''S and 48º52'57''W). The collection was done systematically in order to select ripe fruits. After collection, the fruits were manually pulped, totaling 10kg, and vacuum-packed in polyethylene plastic bags and transported in containers thermally insulated from light and heat to prevent oxidative reactions. At the Extraction Laboratory of the Federal University of Pará (LABEX/UFPA) the pulp was dehydrated through the cold drying technique by freeze-drying, in a semi-industrial freeze dryer (model LJI 015, Manufacturer JJ Científica, São Paulo).

Carlos, Brazil), finally, the lyophilized pulp was vacuum-packed in polyethylene bags until the moment of supercritical extraction.

Figure 6

Freeze-dried buriti (Mauritia flexuosa) polpa

Source: Prepared by the authors themselves (2025).

3.2 SUPERCRITICAL CARBON DIOXIDE EXTRACTION

The supercritical fluid extraction unit (Spe-ed SFE, model 7071, Allentown, USA) contains a fixed-bed extractor vessel, whose volume corresponds to a fixed height of 0.325 m and a bed diameter of 0.014 m. The experimental procedure was described by Silva et al. (2019). The global yield isotherms were determined in the supercritical fluid extraction unit using 0.003 kg of dry buriti pulp, which provides the apparent density of the bed (ρ_a) of 408 kg/m3 and bed height of 0.0478 m. The tests were carried out using supercritical carbon dioxide at 40°C and 400 bar. Under these conditions, several studies have already mentioned the greater solubility in the gas phase in the extraction of oils from vegetable matrices using supercritical technology (Melo, Ferreira & Carvalho Júnior, 2023; Souza, Carvalho Júnior & Chisté, 2023; Aires et al., 2025). 99.0% pure carbon dioxide was used at the rate of 5.31 g/min. The extraction time was 120 minutes. The overall extraction yield (X0) was calculated as a function of the feed mass (F) and the extracted oil mass (m_ext), as summarized in the following equation:

$$X_0(\%) = \frac{m_{ext}}{F} x100 \qquad (01)$$

3.3 PHYSICOCHEMICAL ANALYSIS

3.3.1 Acid value, peroxides, degree of unsaturation (iodine value), density and viscosity

To determine the general quality indices of supercritical buriti oil (OSB), physicochemical analyses of acidity, peroxides and degree of unsaturation were carried out according to the methodology described in Official Methods Analysis of AOAC International (1997). Density, kinematic viscosity and dynamic viscosity were measured at 25ºC by means of an automatic viscometer (Anton-Paar, model SVM 2001).

3.3.2 Oleic acid content

The sample was prepared at 0.010 g using 1 mL of the solvent 2-propanol. The analyses were performed in an Ultra Performance Convergence Chromatograph (Waters, Milford, MA, USA), consisting of a convergence manager (CC), a binary solvent pump (BSM), a sample manager (SM), a column manager (CM), an isocratic solvent manager (ISM) and a mass detector (QDa). The CC operated with ABPR at 1500 psi. As a mobile phase, CO_2 (A) and Methanol with 0.1 % formic acid (B) were used, whose BSM gradients were: Initial time with A (95%) and B (5%), 9 min A (75%) and B (25%), 10 min A (60%) and B (40%), 14 min A (60%) and B (40%), 15 min A (95%) and B (5%), with a flow rate of 0.5 mL/min. The temperature of the SM was 15ºC with an injection volume of 1 µL. In the CM, the column adopted was HSS C18 SB (1.8 µm, 2.1 mm X 150 mm) at a temperature of 50ºC. The ISM used as solvent methanol with 0.1% ammonium hydroxide, with a flow rate of 0.2 mL/min. QDa operated in negative ionization mode, cone voltage at 30 V and capillary voltage at 0.8 kV (Merck, Germany) (Isaac et al., 2013).

3.3.3 Total Carotenoid Analysis

The concentration of total carotenoids was determined for OSB, according to the methodology proposed by Rodriguez-Amaya & Kimura (2004). Petroleum ether was the solvent used and the readings were performed in a spectrophotometer (Evolution 60 model, Thermo Scientific, USA) at 450 nm.

4 RESULTS AND DISCUSSIONS

4.1 SUPERCRITICAL EXTRACTION

4.1.1 Influence of particle diameter on extraction yield

The average particle diameter of the lyophilized buriti pulp was 5.6x10-4 m, the actual particle density (ρ_t) was 1360 kg/m3, and the bed porosity (ε) was 0.70. The results showed that the diameter of the particles influences the overall yield of the extraction. The extraction yield increased with the increase in the surface area of the particles, whose extraction yield values were 13.71%, 17.77% and 21.28% for meshes 48, 20 and 14, respectively. The reason is that the reduction in particle diameter caused a significant increase in the surface area of the particles. Consequently, the yield increased due to the increase in the specific mass transfer area. Thus, considering the higher extraction yield, the buriti oil extracted from the dry pulp collected in mesh 14 was used and subjected to subsequent chemical analyses.

4.2 Physicochemical Analyses

4.2.1. Acid value, peroxides, degree of unsaturation (iodine value), density and viscosity

The physicochemical analyses are shown in Table 1. The acidity index of OSB (1.12 ± 0.009 mg KOH/g) was discrepant from the result obtained by Mesquita et al. (2020), which showed acidity between 12.27 ± 0.18 and 13.77 ± 0.48 mg KOH/g in oils stored for 70 days. In another study, Soares et al. (2021), obtained acidity values between 2.64 and 3.16 mg KOH/g in oils obtained from fruits collected in different regions of Brazil. According to the Codex alimentarius (2024), the acceptable limit for unrefined oils is a maximum of 4 mg KOH/g. Buriti oil, considered unrefined, showed a low acidity value, indicating its good quality. However, the value of 1.12% exceeds the maximum limit of 0.8% established by the legislation for classification of AEVO. Although the acidity value prevents the classification of the product as "extra virgin", the oil can still be considered of acceptable quality for culinary use or in gourmet formulations, since it meets the other physical-chemical and sensory parameters.

The peroxide content is a measure of primary rancidity, which indicates whether there has been deterioration of the oil due to the action of oxygen. In this study, the value found was 10.04 ± 0.01 meq/kg, in the research by Soares et al. (2021) the values ranged between 1.68 and 2.37 meq/kg, while Freitas et al. (2017) found a value equal to 14.2 meq/kg. According to current legislation (Codex Alimentarius, 2024) the value of peroxides must not exceed the maximum limit of 15 meq/kg. In this research, it was observed that the value of peroxides meets the parameters designated for vegetable oils, and in addition, this value is within the recommendation for comparative purposes to AEVO, which according to the Legislation should be a maximum of 20 meq/kg (Brasil, 2012), reinforcing the high quality of the oil obtained. However, the unsaturation values in this work were 55.30 ± 0.20%, lower than that found by Freitas et al. (2017) of 76%, according to the Codex alimentarius (2024) the unsaturation index should vary between 75 and 94%. The low unsaturation values found in this study may be related to inadequate storage of the oil, which may have been subjected to high temperatures and/or exposure to oxygen and UV radiation, factors that can provide the breakdown of molecule unsaturations, since Ramos-Escudero et al. (2022) identified that OSB It has a high content of monounsaturated fatty acids (74.56 to 81.20%) compared to the content of saturated fatty acids (17.06 to 22.58%). The density of the oil was 0.910 mg/cm3, a result similar to that found by Parente et al. (2022), with a value of 0.947mg/cm3 and by Mesquita et al. (2020) with densities ranging from 0.905 to 0.910 mg/cm3. The viscosity of the oil was 69.06 ± 0.04 mPa.S, while in the study by Freitas et al. (2017), the result was 66.01 mPa.S. In another study (Mesquita et al., 2020) the viscosity of buriti oil ranged from 53.33 to 65mPa.S, similar values found in this research, indicating the stability and quality of the oils, since this parameter is related to the presence of unsaturated fatty acids in the sample and represents the level of degraded compounds responsible for altering the physicochemical characteristics of the oils.

Table 1

Physicochemical characterization, oleic acid content and carotenoids of supercritical buriti oil

Analysis	Average	Legislation*
Acid value (KOH/g)	1.12 ± 0.009	0,8
Peroxide Index (meq/kg)	10.4 ± 0.01	20
Degree of unsaturation (%)	55.30 ± 0.26	75-94
Density (g/cm3)	0.910 ± 0.00	0,910-0,916
Dynamic Viscosity (mPa.S)	69.06 ± 0.04	-
Oleic (%C18:1)	54,08	55-83
Carotenoids (mg/100g)	228.75	-

*Brazilian legislation and Codex Alimentarius regarding extra virgin olive oil

4.2.2 Oleic acid content

The studies carried out by Soares et al. (2021) and Silva et al. (2009), showed oleic acid values equal to 77.82 and 74.06 %, respectively. A similar result was found in the research carried out by Mesquita et al. (2020), which indicated a composition of 78.06% of oleic acid. The oleic acid content equal to 54.08% was slightly lower than the minimum limit established by the current legislation for AEVO, which ranges from 55 to 83% (Codex alimentarius, 2024). However, despite not reaching the minimum limit established for AEVO, the oleic acid content observed is still expressive, giving the oil desirable characteristics from a nutritional point of view and oxidative stability, favoring its application as an alternative gourmet olive oil.

4.2.3 Total Carotenoid Analysis

OSB showed an expressive carotenoid content of 228.75 mg/100g, highlighting its high antioxidant capacity and its functional and nutritional potential. In the study conducted by Soares et al. (2021), these values ranged from 206.47 to 324.63 mg/100 g and are higher than the findings by Pelosi et al. (2020) of 37 to 30 mg/100 g. In addition, oils obtained in different Brazilian regions may have a carotenoid concentration ranging between 54.08 and 99.96 mg/100g (Soares et al., 2021), other studies also corroborate this information (Santos et al., 2015; Oliveira et al., 2020). According to Rodriguez-Amaya, Kimura and Amaya-Farfan (2008), to be considered a source of carotenoids, the product must contain at least 2 mg/100g of the bioactive, in this case, OSB is a rich source of this constituent. In addition, the value found in this study is substantially higher than the values found in AEVO, which, according to the literature, have levels ranging from 1.81 to 11.81 (Oliveira et al., 2019; Gonçalves et al., 2022).

This high value gives OSB an advantage over AEVO, especially in terms of functional value and appeal to products with a "gourmet" positioning or aimed at health and well-being. The high content of carotenoids can contribute to a greater oxidative stability of the oil, favoring its application in foods that require resistance to oxidative rancidity and long shelf life.

5 FINAL CONSIDERATIONS

Although the acidity index exceeds the value established for AEVOor OSB It has typical characteristics of the species and has potential for application in differentiated food products. It is important to consider that adjustments in post-harvest handling, processing and storage can contribute to the reduction of acidity in future productions. A similar analysis can be performed in relation to the oleic acid value, slightly below the standards established for AEVOs. Or OSB It has an oleic acid content compatible with products of high nutritional quality, being promising for use as a "gourmet" olive oil, especially when considering the set of its physicochemical properties and bioactive compounds.

The high carotenoid content of OSB positions it as an ingredient with great nutritional, functional and sensory potential, and can complement or even surpass the AEVO in certain applications, especially in the formulation of special oils or considered "gourmet" with antioxidant appeal and of Amazonian origin.

It is therefore concluded that the use of OSB as an alternative to AEVO, can be strategically interesting in tropical regions, especially in the Amazon, where buriti is native and widely available. This can favor the use of local resources, adding value to regional production chains and promoting sustainable development.

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