OCL 2026, 33, 2
© N. Callejas Campioni *et al.*, Published by EDP Sciences, 2026
https://doi.org/10.1051/ocl/2025040

OCL Oilseeds & fats Crops and Lipids

Available online at:
www.ocl-journal.org

RESEARCH ARTICLE OPEN ACCESS

Lipid profile and thermal behavior of oils extracted from Butiá's seeds☆

Nicolás Callejas Campioni, María Emilia Arias Gulpio and Nadia Segura Herrera*

Fats and Oils Area, Department of Food Science and Technology, Facultad de Química, Universidad de la Republica (UDELAR), Av. Gral. Flores 2124, 11800 Montevideo, Uruguay

Received 28 April 2025 – Accepted 24 November 2025

Abstract – This study investigates the potential of *Butiá odorata* seeds, a native palm species from southern South America, as a novel and sustainable source of vegetable oil. Two types of oil, denominated Butiá almond oil (BAO) and Butiá seed oil (BSO), were mechanically extracted and characterized in terms of lipid content, fatty acid profile, triglyceride composition, and thermal behavior. Both oils exhibited high content of short and medium chain saturated fatty acids, particularly lauric and capric acids, as well a notable presence of oleic acid. Triglyceride analysis revealed a predominance of tri-saturated and di-saturated mono-unsaturated species, with low ECN values. Thermal analysis from DSC confirmed low melting points indicating typical liquid oil behavior. The properties studied suggest that Butiá oils may be suitable for food applications where rapid melting and enhanced sensory attributes are desired, and potentially for use in cosmetics, pharmaceuticals, and biofuels. Given the limited previous research, this work provides valuable data on *Butiá odorata* and supports its valorization within the scope of the circular economy. Further studies are recommended to optimize processing and fully explore industrial applications of these underutilized native resources.

Keywords: Butiá oils / mechanical extraction of oils / thermal analysis / triglyceride analysis

Résumé – Profil lipidique et comportement thermique des huiles extraites des graines de butiá. Cette étude examine le potentiel des graines de *Butiá odorata*, une espèce de palmier originaire du sud de l'Amérique du Sud, en tant que source nouvelle et durable d'huile végétale. Deux types d'huiles, appelées huile d'amande de butiá (BAO) et huile de graine de butiá (BSO), ont été extraites mécaniquement et caractérisées en termes de teneur lipidique, de profil en acides gras, de composition en triglycérides et de comportement thermique. Les deux huiles ont présenté une teneur élevée en acides gras saturés à chaîne courte et moyenne, en particulier l'acide laurique et l'acide caprique, ainsi qu'une présence notable d'acide oléique. L'analyse des triglycérides a révélé une prédominance d'espèces tri-saturées et d'espèces di-saturées mono-insaturées, avec de faibles valeurs de Nombre Équivalent de Carbone (ECN). L'analyse thermique par Analyse calorimétrique différentielle (DSC) a confirmé la faiblesse des points de fusion, indiquant un comportement typique des huiles liquides. Les propriétés étudiées suggèrent que les huiles de butiá pourraient être adaptées à des applications alimentaires où une fusion rapide et des attributs sensoriels améliorés sont recherchés, ainsi que potentiellement pour une utilisation en cosmétique, en pharmacie et dans les biocarburants. Étant donné le peu de recherches antérieures, ce travail fournit des données précieuses sur *Butiá odorata* et soutient sa valorisation dans le cadre de l'économie circulaire. Des études complémentaires sont recommandées afin d'optimiser les procédés et d'explorer pleinement les applications industrielles de ces ressources natives sous-utilisées.

Mots-clés : huiles de Butiá / extraction mécanique des huiles / analyse thermique / analyse des triglycérides

☆ Contribution to the Topical Issue: "Minor oils from atypical plant sources / Huiles mineures de sources végétales atypiques".

*Corresponding author: nsegura@fq.edu.uy

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Highlights

- Two oils from *Butiá odorata* seeds were characterized, showing high levels of short and medium chain saturated fatty acids, particularly lauric and capric acid. The oils showed favorable thermal properties and low ECN values in the triglyceride profiles, making them suitable for food, cosmetic, and bioenergy applications.

1 Introduction

South America has a great diversity of native fruit species that are consumed regionally and are beginning to gain popularity due to their pleasing sensory characteristics, such as taste, flavor and color, as well as their nutritional and bioactive potential. There has been considerable interest in the exploration of these alternative species (Hoffmann *et al.*, 2014).

The genus Butiá in particular, native to southern South America, predominantly in areas in southern Brazil, eastern Paraguay, northeastern Argentina, and northwestern and southeastern Uruguay (Lorenzi *et al.*, 2010) has great potential for expansion. The peak of fruiting occurs between December and April. Currently, the species in Brazil and Uruguay are considered of great vulnerability since the adult plants are centenary and suffer with the increase in the area for livestock and intensive agriculture. Human action in the native areas causes a great impact on the regeneration cycle of the trees (Morais *et al.*, 2022).

In Uruguay, the Butiá Fruits are consumed fresh or processed as pulp, liquor, jams, juices, sweets, ice creams and chocolates (INIA, 2014).

Global production and consumption of the main vegetable oils have increased significantly over the last 10 yr and are expected to increase further (Teixeira *et al.*, 2022). Therefore, the search for new sources of oils and sustainable processing practices, including the use of by-products, has been a challenging in recent decades.

Butiá palm trees, for example, may have a high potential for exploitation. Firstly, it is a little explored fruit with scarce information on its properties, which results in a gap in the literature to evaluate potential applications; and secondly, the seeds of the fruits of this palm have great potential for industrial applications, including food, cosmetic products, and biodiesel production (Teixeira *et al.*, 2022). Morais *et al.*, (2022) concluded that *Butiá odorata* have a rich nutritional and bioactive compounds composition and need more attention, considering the limited studies that have been reported in the literature.

According to a study done in 2014, it's estimated that about 15 tonnes of butiá fruit are used to make products like jam, liqueur, jelly, sauce, sweets, chocolates, and baked goods. This number is based on data provided by the three main entrepreneurs, to which is added an estimate of the volume used by other entrepreneurs and their own harvest (INIA, 2014).

No new studies related to this aspect have been found in Uruguay. However, it is known that there has been strong growth in small entrepreneurs dedicated to butiá processing in the last years, so it is to be expected that the current values are higher than those reported in the study mentioned above.

Food industry generates a large amount of waste that is obtained after processing and transformation, due to pre- and post-harvest losses, transport and storage, marketing, as well as mishandling by end consumers (Granados, 2020). Waste is defined as the by-products generated during production and processing and can be of animal and plant origin (Obi *et al.*, 2016). The transition to the circular economy model has been proposed as a good alternative. With proper management, study and action, waste can be processed into new raw materials that can be converted into bioenergy, fertilizers, biomaterials and new ingredients for the development of functional or nutraceutical foods, giving them greater added value (Preciado-Saldaña *et al.*, 2022). Particularly, Butiá seed is considered a by-product derived from human consumption and fruit processing agroindustries (Hoffmann *et al.*, 2014).

Studies on the extraction and characterization of oils from Butiá seeds are scarce because they are small, hard, and challenging to handle. However, represent a great potential for the sustainable exploitation of products with high added value, especially may become an alternative raw material for oil production (Mumbach *et al.*, 2022; Vieira *et al.*, 2016).

The aim of this present work was the extraction of lipids present in the Butiá seeds, to characterize their fatty acid profile, triglyceride composition and analyze the thermal properties in order to define potential uses.

2 Materials and methods

2.1 Materials

The Butiá fruits (*Butiá odorata*) were obtained from palm groves located at km 270 of route 9 (Rocha, Uruguay) and harvested in 2024. Mature fruits were submitted to a manual pulp removal process. Then, the seeds were separated and dried at 50 °C. Two different oils were mechanical extracted from the seeds using an electric powered (1200 W) screw press, denominated Butiá almond oil (BAO) and Butiá seed oil (BSO). BAO was extracted from the seeds previously broken and removed manually the almond. Then the almond was crushed in a domestic blender. BSO was extracted from the whole seeds previously crushed in a hammer mill to obtained a seeds powder.

The total lipid content present in Butiá almonds and seeds were determined gravimetry after extraction with a solvent mixture (hexane: isopropanol 3:2 v/v) using the method reported by Hara & Radin, (1978).

2.2 Fatty acid profile

The oils were treated with KOH/MeOH, 2 N (potassium hydroxide solution in methanol) according to the AOCS method Ce 2-66 (AOCS, 2017) to convert the triacylglycerols to the corresponding methyl esters. The methyl esters were analyzed by GC, using an equipment Shimadzu GC-2010, equipped with FID and a capillary column Supelco SP2560

(100m × 0.25mm × 0.20 um). The temperature program started at 175 °C, followed by a heating step (5 °C/min) to 220 °C, and remained at 220 °C for 60 min. Nitrogen at 150 kPa at column head was used as the carrier gas, with a split ratio 1:80.

Fatty acid composition was determined in duplicate, and average results reported. The fatty acids methyl esters identification of the samples was done by comparison with the retention time of a standard mixture of fatty acid methyl esters (37 FAME Mix 47885, Supelco) under identical conditions. The results were expressed as a percentage of the area of each peak over the total area of all fatty acids in the chromatogram.

2.3 Triglyceride (TAG) composition

The oils were dissolved in a mixture of solvents acetone: acetonitrile: chloroform 47.5/47.5/5 v/v/v (15–30 mg/mL) and the TAG composition directly analyzed by HPLC using Shimadzu model 20A equipped with two in-series columns, Supelcosil TM C-18 (25 cm × 4.6 mm × 5 um), and a Shimadzu RID model 10A detector (refractive index).

The analysis started from a mixture of acetone: acetonitrile: chloroform 47.5/47.5/5 v/v/v, which was kept constant through the analysis time (45 min) at a flow rate of 1 mL/min. Peaks were identified using pure TAG standards and considering the order of elution according to the equivalent carbon number (ECN). TAG elute from a reverse phase column in which those with higher ECN values are retained and elute later. Elution of TAG from these columns is in increasing order of ECN (AOCS method Ce 5b-89). Two replicate analyses were performed, and the average values were reported.

2.4 Thermal behavior

Crystallization and melting thermograms were determined by differential scanning calorimetry (DSC), using a calorimeter Shimadzu model 60A plus, equipped with a refrigerated cooling system Thermo scientific EK90/SH. The temperature was programmed according to the AOCS method Cj 1–94 with some modifications, which involves initial heating to 60 °C to ensure the complete melting of the sample, followed by cooling at 10 °C/min to −50 °C, a tempering at −50 °C for 30 min, and a final heating step at 5 °C/min until complete melting. Data processing was performed using TA Universal Analysis 2000 software (version 3.9A). Two replicate analyses were performed, and the average values reported.

2.5 Free acidity

Was measured according to technique COI/T.20/DOC. N°34. Titration was performed on 1.5 g of sample with 0.01 N sodium hydroxide solution using phenolphthalein as an indicator. Determinations were performed in triplicate.

2.6 Statistical analysis

The values were expressed in means and data were submitted to analysis of variance (ANOVA). Tukey's test was applied to compare means with a statistical significance level of $p \leq 0.05$.

3 Results and discussion

3.1 Extraction yield and extractability

The lipid extraction yield obtained using solvents from almond and seed Butiá was 47.2 % and 10.9 %, respectively. In relation to the almond, numerous bibliographic sources mention it is high potential for obtaining oil, showing high extraction yields. *Butiá odorata* almond oil extraction has been reported a variation from 29 % to 56 % (Hoffmann *et al.*, 2014). Moreover, it shows an extraction yield ranging from 32 % to 54 % (Faria *et al.*, 2008; Barbosa *et al.*, 2021). Other study indicated an amount of oil extracted around 41.7 % (Kobelnik *et al.*, 2016). As expected, the results obtained in this study agree with those ranges reported in the literature.

The solvent extraction yield can be considered as the maximum oil extraction obtained. Based on the above, it is possible calculate the extractability parameter (Ex), which is defined as the ratio between the yield obtained by applying mechanical extraction and the yield obtained by applying solvent extraction. Based on this, the Ex of the almond and seed Butiá was 0.39 and 0.17, respectively. It is clear from the results of the calculations that the oil yields obtained by mechanical extraction were very low (Saini *et al.*, 2021).

However, the choice of mechanical extraction over solvent extraction offers a number of advantages. The first and most important advantage is that a virgin oil is obtained, which retains all its natural components as well as its typical aroma and flavors. These are currently the most demanded types of oil (Jahirul *et al.*, 2013).

Solvent extraction, although a more reproducible process with high yields, is more expensive, despite the possibility of reducing these costs by recovering and reusing the solvents used (Jahirul *et al.*, 2013). However, solvents are potential contaminants of the oil if they are not properly eliminated. Therefore, the oil has to be refined, which would have a negative impact on the attributes mentioned before. In addition, safety and environmental aspects in relation to the use of solvents must be taken into consideration (Jahirul *et al.*, 2013).

The acidity of the oils was determined, obtaining a value of 0.31% for BAO and 0.36% for BSO, both in accordance with the national regulations for virgin oils (a maximum value of 2 %). It would be noted that the free acidity value obtained in these oils is below the maximum allowed for extra virgin olive oil (0.8%). It is important to mention that oil deterioration depends on the storage conditions of the seeds, as well as the extraction conditions.

The visual characteristics of both oils at room temperature are their liquid physical state with a sweet and almond-like smell. In addition, there are clear differences in their color, as can be seen in Figure 1. BSO has a strong yellow-orange color, while BAO has a slightly yellow color.

3.2 Fatty acid composition

Table 1 shows the fatty acid composition of both butiá oils obtained (BSO and BAO). Lauric acid is the major fatty acid in both oils (approx. 36 %) followed by oleic acid (approx. 20 %) and capric acid (approx. 15 %). This composition agrees with the previously reported by Faria *et al.*, (2008). In relation with

Fig. 1. Physical appearance of the oils obtained from mechanical extraction of Butiá seeds and almonds (left – BSO, right – BAO).

the others fatty acids, it can be seen a high content of short fatty acids, composed by caprylic and capric (8:0 and 10:0) representing almost 25 % of the total composition. This aspect is of great importance, as these fatty acids are related to the aromatic attributes of the oil and it is rapid assimilation in the process of lipid digestion (Sáyago-Ayerdi et al., 2008). The content of medium and long saturated fatty acid is relatively low (myristic, palmitic and stearic acid), with values of 6, 4 and 3 %, respectively. On the other aspect, the content of w-6 and w-3 fatty acids (particularly linoleic and linolenic acid) found was low, with 4 and 0.01 %, respectively. Faria *et al.*, (2008) also has reported 4 % of linoleic acid. In addition, minor saturated fatty acids with values below 0.1 % were identified. The composition of both oils was practically identical, being 10:0 the only fatty acid that showed a significant difference.

Therefore, the lipid profile of BSO and BAO are predominantly composed by saturated fatty acids, representing almost 75 % of it is total composition. The results obtained are similar to those reported by Jansen Alves *et al.*, (2023), being that the short chain fatty acids such as caprylic acid (C8:0) and medium chain fatty acid as lauric acid (C12:0) the most representative. Lauric acid has been studied to have antimicrobial action, and when applied in packaging, it maintained it is action against pathogenic and food degrading bacteria (Pereira *et al.*, 2022). Respect with unsaturated fatty acids, there was a high concentration of oleic acid. In addition, the presence of oleic acid (w-9) and linoleic acid (w-6) is important due to their nutritional benefits (Hoffmann *et al.*, 2014). These types of fatty acids are commonly found in palm fruit oils (Pereira *et al.*, 2022). These compositions differ markedly from that reported by Morais *et al.* (2022), who mention a high linoleic, oleic and palmitic acid content. This difference is due to the fact that these authors analyzed the lipids presented in pulp.

It is important to take into consideration that the fatty acid composition could show some variations due to the geographical conditions where the palm trees are located as well as variety of the raw material, the cultivation method, storage, and the technologies applicated to lipid extraction (Hoffmann *et al.*, 2014).

The fatty acid composition of oils extracted with solvents is included. As shown in Table 1, minimal differences were observed in the composition of oils extracted by both extraction methods, with no changes in the overall profile. This demonstrates that, although there were high oil losses in mechanical extraction, this did not cause the oil to be fractionated.

3.3 Triglyceride composition

Data on the TAG composition of butiá species are still scarce in the literature. Teixeira *et al.*, (2022) shows that 43% of the 25 Arecaceae palm fruits analyzed had their TAG profile reported. Figure 2 shows the TAG composition of BSO and BAO based in the ECN. The ECN may also be referred to as partition number.

In both oils, the TAG composition showed groups with low ECN between 30–36, representing almost 50% of the total composition. The main ECN was 32. According to Nájera *et al.* (1998), it is possible to group TAG according to their ECN values: short-chain TAG (ECN < 34), intermediate-chain TAG (ECN = 36–40) and long-chain TAG (ECN > 40). Based on these results, BSO and BAO present mostly higher content of short-chain TAG. These results agree with the fatty acid composition mentioned before.

The ECN characterize the molecular structure of TAG. It is therefore possible to identify which fatty acids contribute to TAG as the ECN discriminates by chain length and degree of unsaturation. Based on the range of values of the majority ECNs determined, their definition and the fatty acid composition it is possible to find the main TAGs. For ECN = 30 the major TAG found would be 8:0/10:0/12:0. For ECN = 32, ECN = 34 and ECN = 36, the following major TAGs found would be: 8:0/12:0/12:0 and 8:0/8:0/18:1; 10:0/12:0/12:0 and 8:0/12:0/18:1; 12:0/12:0/12:0 and 8:0/12:0/18:1, respectively. Therefore, if we group the TAGs in the BSO and BAO, the most important ones would be the tri-saturated (SSS) and di-saturated mono-unsaturated (SSU). An interesting aspect to consider among the oils is that in most of the ECNs the percentage was lower in BAO compared to BSO (only ECN 28, 30 and 50 did not show significant differences). In ECN 26 an increase was observed. These results may be due to the fact that the Butiá seed husk contains oil with different composition (which comes from the pulp and is incorporated by absorption into the husk). According to Morais *et al.*, (2022) the fatty acid composition of the lipids present in the pulp is mainly palmitic, oleic and linoleic. For this reason, it is more probably that the highest proportion of triglycerides have higher ECNs.

As the ECN increases, the chances of the triglyceride positions being occupied by long-chain fatty acids increase. Therefore, the presence of monounsaturated triglycerides should also increase. This explains why the maximum TAG composition is between PN 30–36 (with values above 10 %), where the highest values correspond to ECN = 32. Although the method used for ECN identification and TAG separation is efficient, it is not able to discriminate between TAG isomers. Thus, the regiodistribution of the fatty acids cannot be determined by this method. Therefore, despite the availability of this valuable and innovative information on the physicochemical characterization of the oil, it is important to continue to explore more aspects of it. In relation to the above, the TAG composition of these oils plays a fundamental role when considering their industrial application, especially if used in food processing.

3.4 Thermal behavior

Generally, the thermal behavior of fats and oils is commonly described by melting and crystallization. DSC is

Table 1. Fatty acid composition of Butiá seed oil (BSO) and Butiá almond oil (BAO) obtained by solvent extraction (SE) and mechanical extraction (ME).

	BSO (%)		BAO (%)	
	SE	ME	SE	ME
C 6:0 (Caproic)	0,64 ^{b}	0,23 ^{a}	0,70 ^{b}	0,40 ^{a}
C 8:0 (Caprylic)	11,9 ^{b}	9,8 ^{a}	12,9 ^{b}	10,5 ^{a}
C 10:0 (Capric)	14,1 ^{a}	15,4 ^{b}	14,2 ^{a}	14,4 ^{a,b}
C 12:0 (Lauric)	33,3 ^{a}	35,8 ^{a}	33,5 ^{a}	35,6 ^{a}
C 14:0 (Myristic)	6,7 ^{a,b}	6,3 ^{a}	6,7 ^{a,b}	6,8 ^{b}
C 16:0 (Palmitic)	5,5 ^{b}	4,5 ^{a}	5,2 ^{b}	4,9 ^{a,b}
C 18:0 (Stearic)	2,2 ^{a}	2,8 ^{a}	2,4 ^{a}	2,7 ^{a}
C 18:1 w-9 (Oleic)	20,4 ^{a}	19,5 ^{a}	19,2 ^{a}	19,8 ^{a}
C 18:2 w-6 (Linoleic)	5,3 ^{a}	4,4 ^{a}	4,9 ^{a}	4,8 ^{a}
C 20:0 (Arachidic)	*nd*	0,06 ^{a,b}	0,04 ^{a}	0,07 ^{b}
C 18:3 w-3 (Linolenic)	*nd*	0,01 ^{a}	0,02 ^{a}	0,02 ^{a}
C 20:1 w-9 (Gadoleic)	0,04 ^{a}	0,05 ^{a}	0,04 ^{a}	0,06 ^{a}
C 22:0 (Behenic)	*nd*	0,01 ^{a}	0,01 ^{a}	0,01 ^{a}
C 24:0 (Lignoceric)	*nd*	0,02 ^{a}	0,01 ^{a}	0,02 ^{a}
SFA	74,4 ^{a}	74,9 ^{a}	75,7 ^{a}	75,4 ^{a}
UFA	25,7 ^{a}	24,0 ^{a}	24,2 ^{a}	24,7 ^{a}

In each row, the difference between mean values is statistically significant (p <0.05) if have different letters. *nd*: not detected.

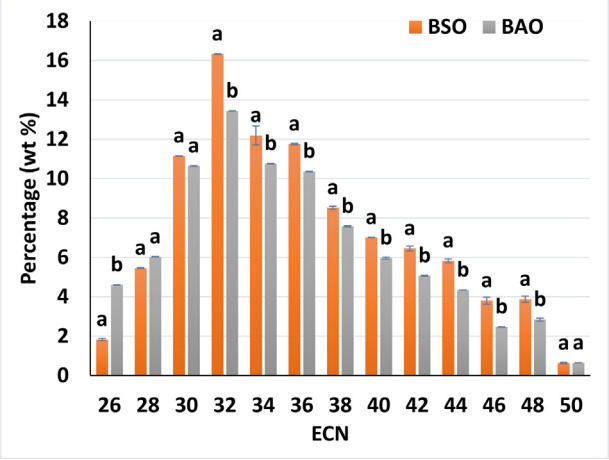

Fig. 2. Triglyceride composition (%) in terms of the equivalent carbon number (ECN) of butiá seed oil (BSO) and butiá almond oil (BAO) obtained by applying mechanical extraction. In each ECN, the difference between mean values is statistically significant (p <0.05) if have different letters.

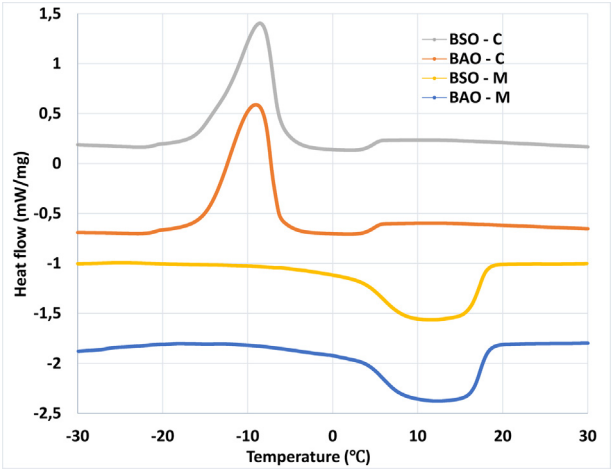

Fig. 3. Melting (M) and crystallization (C) thermograms of Butiá seed oil (BSO) and Butiá almond oil (BAO) obtained by applying mechanical extraction.

a useful technique to study melting and crystallization by obtaining and analyzing the respective thermograms. Melting and crystallization thermograms of BSO and BAO are presented in Figure 3. Some parameters of interest determined from thermograms are shown in Table 2. Both melting thermograms showed only one endothermic peak. Endothermic peak temperature ($T_{p\text{-}m}$) refers to the temperature at which the biggest proportion of TAG species melted with maximum thermal effect. For BSO and BAO, the maximum value was at 11.6 and 12.3 °C, respectively. Despite presenting a single endothermic peak, it is broad. This behavior is due to melting of the different tri-saturated and di-saturated mono-unsaturated TAGs present in the oils. The presence of a single peak indicates that although TAGs have different melting points, they are close to each other and solubilize well, making the melting process gradual and continuous.

Another value of interest obtained from the thermogram is the end-set temperature (T_{end}). This value indicates the end of the melting of the oil and can be considered as an approximate value of the melting temperature. The values obtained for BSO and BAO were 18.1 and 18.2 °C, respectively.

Both peak and end-set temperature values were high with respect to the typical oils but low with respect to fats like a beef tallow. This is directly related to the TAG composition composed mostly of short chain fatty acids (8:0 and 10:0) and

Table 2. Melting and crystallization peak temperature (T_p), on-set temperature (T_{on}) and end-set temperature (T_{end}) of Butiá seed oil (BSO) and Butiá almond oil (BAO) obtained by applying mechanical extraction, determined from the thermograms obtained by DSC analysis (Fig. 3).

	Crystallization			Melting		
	T_p (°C)	T_{on}(°C)	△H (cal/g)	T_p (°C)	T_{end} (°C)	△H (cal/g)
BSO	−8,6 [a]	−5,7 [a]	21,6 [a]	11,6 [a]	18,1 [a]	−22,4 [a]
BAO	−9,0 [a]	−6,2 [a]	21,5 [a]	12,3 [b]	18,2 [a]	−22,7 [a]

In each column, the difference between mean values is statistically significant (p <0.05) if have different letters.

medium chain fatty acids (12:0) which have a lower melting temperature range compared to TAG containing long chain fatty acids (14:0, 16:0 and 18:0). Jansen Alves *et al.*, (2023) studied the BSO melting thermogram and the values determined are similar to those shown in this study where BAO presented an endothermic event that ending at 16.5 °C. Based on the values of temperatures obtained, both oils have liquid physical properties at room temperature, agree with the physical appearance showed in Figure 1.

Related to crystallization thermogram, both oils, as well as the melting, showed a single exothermic peak, indicating that different types of TAGs were crystallized at similar temperatures. For BSO and BAO, the crystallization peak temperature ($T_{p\text{-}c}$) was at −8.6 and −9.0 °C, respectively. In crystallization, the most relevant temperature to analyze is the on-set temperature (T_{on}). This value indicates the approximate temperature at which the oil begins to crystallize, so the first crystals are formed. The values obtained for BSO and BAO were −5.7 and −6.2 °C, respectively. The low values obtained in the crystallization thermograms could again be explained by the fatty acid and TAG composition determined.

When the melting thermograms show only endothermic peaks over the whole temperature range studied, it is possible to determine the fraction of material that has not yet melted, thus determining the amount of solids remaining (% solids). This is determined through a partial integration of the thermogram obtained (Márquez *et al.*, 2012). It is important to explain that the determination of the solids fat content (SFC) must be carried out by pulsed nuclear magnetic resonance (p-NMR), which is the official method established for this purpose (AOCS Method Cd 16b-93). However, this method requires individual measurements at each required temperature, which limits the information that can be obtained. DSC has been proposed as an alternative method for the determination of SFC, as it has the advantage of including the whole temperature range from a single measurement. Despite the above, it is possible to obtain an approximation of this parameter through DSC as they are essentially different methods (Márquez *et al.*, 2012). The curves of the % solids as a function of temperature for BSO and BAO are presented in Figure 4. The % solids of both oils did not show a sharp decrease with increasing temperature. From these curves, some values of interest can be obtained at certain temperatures. The % solids are a parameter of great interest as it is closely related to physical characteristics such as appearance, plasticity, spreadability and sensory properties. The % solids below 10 °C was approximately above 50 %. This indicates a product of high structure when kept refrigerated (solid appearance). The largest variation in % solids occurred between 5 and 15 °C, from about 80 % to about

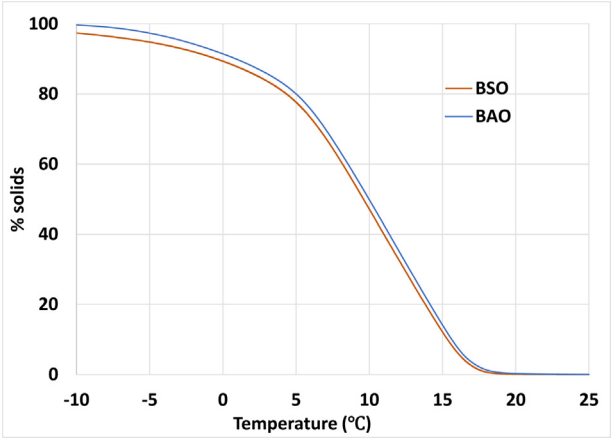

Fig. 4. Variation of the amount of solids (% solids) with temperature of Butiá seed oil (BSO) and Butiá almond oil (BAO) obtained by applying mechanical extraction, determined from the integration of the melting thermograms.

10 %. The desirable spreadability of shortenings occurs within a range of 15–35 % SFC, the so-called plastic range of fats (Shi *et al.*, 2015). Remarkably, the changes in % solids that characterize the plastic fats are between 15 and 25 °C (Ribeiro *et al.*, 2009). Both BAO and BSO showed low % solids along the whole temperature range mentioned before, confirming low plasticity. In the majority of cases, the explanation is usually given by their low percentage of saturated fatty acids. In these oils, the explanation does not depend on their content, but on the type of saturated fatty acids they contain, characterized by short and medium fatty acids chains, which have considerably lower melting points. After 20 °C the oils present a % solids below 0.01 %. In conclusion, both oils not offer structure at ambient temperature, but offering good melting characteristics at body temperature, as they do not provide any solids.

From the Figure 4 it can be shown that the % solids over the whole temperature range are higher in BAO than in BSO. This difference observed may be due to the slight changes in TAG composition analyzed between the oils. In addition, the thermal behavior of both oils is similar.

3.5 Possible applications

The physicochemical characteristics of BSO and BAO showed a typical behavior of vegetable oil as a liquid oil at room temperature. The food industry needs to replace

hydrogenated and naturally saturated fats due to their adverse health effects. Vegetable oils that can be used in the manufacture of structured oil include canola, corn, soybean, sunflower, olive, palm, walnut oil, among several others (Jansen Alves *et al.*, 2023).

Therefore, BSO and BAO can be used as feedstock for food processing in cases where an oil is required directly or mixed with another material containing attributes that give it structure and plasticity, or even used as a starting material for modification to obtain a new oil with other properties of interest. Butiá seeds oils has been used as an ingredient for sweets, bread, cakes, pies, and cookies. The results showed that it could enhance the texture, flavor and nutritional properties of these foodstuffs (Faria *et al.*, 2008).

In addition to the above, the oils can be used as ingredients in the cosmetic, pharmaceutical and biofuel industries. However, it is noted that more studies are needed to better understand their behavior and to explore this type of native species, which are so outstanding in the region of Uruguay.

4 Conclusions

The Butiá seeds indicates a great opportunity for their sustainable exploitation. The recovery of lipids and other components that come from their fruits has been a growing trend in the last two decades, indicating an increasing interest in valorizing such raw materials with point of view in circular economy. This type of native fruits is important to Uruguay for different aspect and found possible applications in order to use all the components of the fruits gives it greater diversification. This preliminary study in the oil obtained from Butiá seed and almond show a typical composition of palm trees, with high content of short and medium chain fatty acids and a TAG composition mostly composed by tri-saturated and di-saturated mono-unsaturated. The thermal behavior is in accordance with the TAG composition showing a typical liquid oil behavior at room temperature (quite comparable to most vegetable oils). The results suggest that these oils have physicochemical properties that can be used for different food applications. However, more studies on the physicochemical properties and other aspects are also needed.

Acknowledgments

The authors thank to CSIC (Comisión Sectorial de Investigación Científica, Universidad de la Republica) for the financial support.

Author contribution statement

N Callejas: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, review & editing. M Arias: Formal analysis & Investigation. N Segura: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, review & editing.

References

American Oil Chemists' Society (AOCS). 2017. Official methods and recommended practices of the American Oil Chemists' Society, 7th ed. In: Firestone D, ed. Champaign, IL: American Oil Chemists' Society.

Barbosa MCA, Rosa QS, Cardoso LM, *et al.* 2021. Composition proximate, bioactive compounds and antioxidant capacity of *Butiá capitata*. *Food Sci Technol* 2061: 1–6.

Faria JP, Arellano DB, Grimaldi R, *et al.* 2008. Caracterização química da Amêndoa de Coquinho-Azedo (*Butiá capitata var capitata*). *Rev Bras Frutic* 30: 549–552.

Granados SF. 2020. Pasando de pérdidas a soluciones en América Latina y el Caribe. Disponible en línea: https://parlatino.org/wp-content/uploads/2017/09/perdida-soluciones.pdf

Hara A, Radin NS. 1978. Lipid extraction of tissues with a low-toxicity solvent. *Anal Biochem* 90: 420–426.

Hoffmann JF, Barbieri RL, Rombaldi CV, Chaves FC. 2014. *Butiá spp*. (*Arecaceae*): an overview. *Scientia Horticulturae* 179: 122–131. https://doi.org/10.1016/j.scienta.2014.08.011.

Instituto Nacional de Investigación Agropecuaria (INIA). 2014. Valorización de frutos nativos como forma de promover el desarrollo local: Aprovechamiento agroalimentario del butiá en Rocha. Proyecto FPTA-178, ISSN: 1688-924X.

Jahirul MI, Brown JR, Senadeera W, *et al.* 2013. Optimisation of Bio-Oil Extraction Process from Beauty Leaf (*Calophyllum Inophyllum*) Oil Seed as a Second Generation Biodiesel Source. *Procedia Eng* 56: 619–624. https://doi.org/10.1016/j.proeng.2013.03.168

Jansen Alves C, Pacheco Da Cruz E, Silva Santos R, *et al.* 2023. Oleogels based on Butiá seed oil and beeswax: an alternative to replacing hydrogenated fat in cookies. *SSRN*. https://doi.org/10.2139/ssrn.4538403

Kobelnik M, Guadagnucci Fontanari G, Rodrigues Marques M, Augusto Ribeiro C, Spirandeli Crespi M. 2016. Thermal behavior and chromatographic characterization of oil extracted from the nut of the Butiá (*Butiá capitata*). *J Therm Anal Calorim* 123: 2517–2522. https://doi.org/10.1007/s10973-016-5239-7

Lorenzi H, Noblick L, Kahn F, Ferreira E. 2010. Flora Brasileira: Arecaceae (Palmeiras). *Nova Odessa: Instituto Plantarum*, pp. 367.

Márquez AL, Pérez MP, Wagner JR. 2012. Solid fat content estimation by differential scanning calorimetry: prior treatment and proposed correction. *J Am Oil Chem Soc* 90 (4): 467–473. http://doi.org/10.1007/s11746-012-2190-z

Morais RA, Teixeira GL, Ferreira SRS, Cifuentes A, Block JM. 2022. Nutritional composition and bioactive compounds of native Brazilian fruits of the Arecaceae family and its potential applications for health promotion. *Nutrients* 14: 4009. https://doi.org/10.3390/nu14194009

Mumbach GD, Alves JLF, da Silva JCG, *et al.* 2022. Investigation on prospective bioenergy from pyrolysis of butiá seed waste using TGA-FTIR: Assessment of kinetic triplet, thermodynamic parameters and evolved volatiles. *Renew Energy* 191: 238–250. https://doi.org/10.1016/j.renene.2022.03.159

Nájera AI, Barcina Y, De Renobales M, Barron LJR. 1998. Determination of triacylglycerol composition of idiazabal cheese. *Chromatographia* 47 (9-10): 579–586.

Obi FO, Ugwuishiwu BO, Nwakaire JN. 2016. Agricultural waste concept, generation, utilization and management. *Niger J Technol* 35 (4): 957–964. https://doi.org/10.4314/njt.v35i4.34

Pereira NRL, Lopes B, Fagundes IV, *et al.* 2022. Bio-packaging based on cellulose acetate from banana pseudostem and containing *Butiá catarinensis* extracts. *Int J Biol Macromol* 194: 32–41. https://doi.org/10.1016/j.ijbiomac.2021.11.179

Preciado-Saldaña AM, Ruiz-Canizales J, Villegas-Ochoa MA, Domínguez-Avila JA, González-Aguilar GA. 2022. Aprovechamiento de subproductos de la industria agroalimentaria. Un acercamiento a la economía circular. *Revista Iberoamericana de Tecnología Postcosecha* 23 (2): 92.

Ribeiro AP, Grimaldi R, Gioielli LA, Gonçalves L. 2009. Zero trans fats from soybean oil and fully hydrogenated soybean oil: physico-chemical properties and food applications. *Food Res Int* 42 (3): 401–410. https://doi.org/10.1016/j.foodres.2009.01.012

Saini RK, Prasad P, Shang X, Keum YS. 2021. Advances in lipid extraction methods—a review. *Int J Mol Sci* 22: 13643. https://doi.org/10.3390/ijms222413643

Sáyago-Ayerdi SG, Vaquero MP, Schultz-Moreira A, Bastida S, Sánchez-Muniz FJ. 2008. Utilidad y controversias del consumo de ácidos grasos de cadena media sobre el metabolismo lipoproteico y obesidad. *Nutrición Hospitalaria* 23 (3): 191–202.

Shi C, Chang M, Liu R, Jin Q, Wang X. 2015. Trans-free shortenings through the interesterification of rice bran stearin, fully hydrogenated soybean oil and coconut oil. *Int J Food Eng* 11 (4): 467–477. https://doi.org/10.1515/ijfe-2014-0279

Teixeira GL, Ibañez E, Block JM. 2022. Emerging lipids from Arecaceae palm fruits in Brazil. *Molecules* 27: 4188. https://doi.org/10.3390/molecules27134188

Vieira BM, Elicker C, Nunes CFP, *et al.* 2016. The synthesis and characterization of *Butiá capitata* seed oil as a FAME feedstock. *Fuel* 184: 533–535. https://doi.org/10.1016/j.fuel.2016.07.052

Cite this article as: Callejas Campioni N, Arias Gulpio ME, Segura Herrera N. 2026. Lipid profile and thermal behavior of oils extracted from Butiás seeds. *OCL* 33: 2. https://doi.org/10.1051/ocl/2025040