Diversitas Journal
ISSN 2525-5215
Volume 9, Issue 2 (apr./jun. 2024) p. 1037 - 1051
https://diversitasjournal.com.br/diversitas_journal

Components of the mastic tree to enhance the quality of the soap from the residual frying oil

LOPES, Gabriel de Freitas[(1)]; FERNANDES, Nathália Alcantara Rocha[(2)]; DIAS, Mauro Cesar[(3)]

[(1)] 0009-0002-6640-9792; Bachelor in Industrial Chemistry from the Federal Institute of Education, Science and Technology of Espírito Santo (*Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo*), Vila Velha, Espírito Santo (ES), Brazil. Email: gabrielflopes16@gmail.com

[(2)] 0009-0004-9983-9478; Bachelor's degree in Industrial Chemistry from the Federal Institute of Education, Science and Technology of Espírito Santo (*Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo*). Vila Velha, Espírito Santo (ES), Brazil. Email: nathaliafernandes2201@gmail.com

[(3)] 0000-0002-1355-2950; PhD in Chemistry from the Federal University of Minas Gerais (*Universidade Federal de Minas Gerais*) and Teacher at the Federal Institute of Education, Science and Technology of Espírito Santo (*Instituto Federal de Educação, Ciência e Tecnologia do Espírito Santo*). Vila Velha, Espírito Santo (ES), Brazil. Email: maurocesar@ifes.edu.br

ABSTRACT

The growing concern with the linear model of production, leading to the search for more sustainable alternatives. The circular economy emerges as an answer, aiming to transform the way we produce and consume. One of the challenges is the improper disposal of residual frying oil (RFO), which is potentially polluting and capable of contaminating large volumes of water. The objective of this article is to treat RFO with sodium hypochlorite (NaClO) as well as to incorporate the components of the mastic tree (stem, leaves and fruits) in the formulation of the soap in order to enhance the quality of the product, exploiting the rich local biodiversity. The incorporation of the extracts, composed of tannins from the plant in the formulation of the soap, resulted in safer products for the skin, keeping the pH in the range of 2 and 11.5 and the alkalinity below 1%, according to the legislation, aligning with the harmony between the circular economy and green chemistry. Concomitantly, it was proposed to treat the RFO with sodium hypochlorite, together with extracts and essential oil of mastic tree, in order to ensure the quality of the soap produced. The results indicated an influence on parameters such as moisture (reduction from 0.78 to 0.17%), saponification index (reduction from 200 to 198 mg KOH/g) and acidity index (reduction from 1.00 to 0.40 mg KOH/g), evidencing the importance of these processes for the quality of the product's raw material. The production of soap was carried out without heating, chemical, physical, and sensory analyses were carried out, converging to the conclusion that sustainable solutions for the recycling of RFO demonstrate the effective integration between the circular economy, practicing green chemistry and the production of safe products, meeting environmental demands and consumer preferences.

ARTICLE INFORMATION

Article Process:
Submetido: 04/29/2024
Aprovado: 06/28/2024
Publicação: 06/29/2024

Keywords*:*
Residual frying oil, mastic, sodium hypochlorite, soap.

RESUMO

A crescente preocupação com o modelo linear de produção, levando à busca por alternativas mais sustentáveis. A economia circular surge como resposta, visando transformar a forma como produzimos e consumimos. Um dos desafios é o descarte inadequado do óleo residual de fritura (ORF), potencialmente poluente e capaz de contaminar grandes volumes de água. O objetivo do presente artigo é realizar o tratamento do ORF com hipoclorito de sódio (NaClO) assim como incorporar os componentes da aroeira (caule, folhas e frutos) na formulação do sabão a fim de potencializar a qualidade do produto, explorando a rica biodiversidade local. A incorporação dos extratos, compostos por taninos da planta na formulação do sabão, resultou em produtos mais seguros para a pele, mantendo o pH na faixa de 2 e 11,5 e a alcalinidade abaixo de 1%, de acordo com a legislação, alinhando-se à harmonia entre a economia circular e a química verde. Em concomitância propôs-se o tratamento do ORF com hipoclorito de sódio, juntamente com extratos e óleo essencial de aroeira, visando garantir a qualidade do sabão produzido. Os resultados indicaram influência nos parâmetros como umidade (reduzindo de 0,78 para 0,17%), índice de saponificação (reduzindo de 200 para 198 mg KOH/g) e índice de acidez (reduzindo de 1,00 para 0,40 mg KOH/g), evidenciando a importância desses processos para a qualidade da matéria-prima do produto. A produção de sabão foi realizada sem aquecimento, realizaram-se análises químicas, físicas e sensoriais, convergindo para a conclusão de que soluções sustentáveis para a reciclagem do ORF demonstram a integração eficaz entre a economia circular, praticando a química verde e a produção de produtos seguros, atendendo às demandas ambientais e às preferências dos consumidores.

***Palavras-Chave*:**
Óleo residual de fritura, aroeira, hipoclorito de sódio, sabão.

DOI: 10.48017/dj.v9i2.3023

Introduction

The increasing production of waste exerts significant environmental impacts (Moreno, 2023). In this context, it is evident that the reuse of waste as sources of energy, inputs or raw materials for other production cycles is a viable perspective. However, a notable example is vegetable oil, which is often used in cooking, but after being used in frying, it turns into a by-product that requires proper disposal, preventing it from reaching the environment (Ministério da Saúde, 2020).

Residual frying oil (RFO) originating from households, commercial establishments and industrial sectors, is classified as municipal solid waste and can represent a substantial polluting agent when disposed of improperly. Improper disposal should be avoided, as a single liter of this waste has the potential to contaminate up to 25,000 liters of water (SABESP, 2019).

The RFO is usually discharged into the municipal sewer system, causing pollution of the rainwater and sanitary networks. If this material penetrates the soil, the groundwater will be contaminated, making the water also unfit for consumption (Rodrigues *et al.*, 2022).

The traditional linear method of production has been questioned for its environmental unsustainability and social and economic impacts. On the other hand, the circular economy has emerged, which proposes a new model focused on sustainable consumption and waste reduction, promoting the efficient use of resources by closing the life cycles of products (Korhonen *et al.*, 2017).

“Green” cosmetics are produced with active ingredients derived from plants or minerals, minimizing or eliminating synthetic components. Its production chain must be eco-friendly and sustainable to meet the growing demand, driven by consumers environmental concern and distrust of synthetic products. Associated benefits include the reduction of skin irritations and allergies (Santos *et al.*, 2023).

Verde Vida Institute (*Instituto Verde Vida* - IVV) is an NGO located in the Aribiri neighborhood, in the municipality of Vila Velha (ES), which promotes the selective collection of urban solid waste and RFO. The IVV acquired environmental licensing from the Municipal Department of the Environment (*Secretaria Municipal do Meio Ambiente* - SEMMA), with Municipal Regularization License (*Licença Municipal de Regularização* - LMAR) No. 108/2014, Class I. Thus, it has authorization to manufacture soap from the collected RFO (Gouveia *et al.*, 2016).

A sustainable alternative would be the production of ecological soap incorporating RFO with stabilizing properties of natural species such as *Schinus terebinthifolia*, known as mastic-beach-tree or mastic.

The Anacardiaceae family has about 81 genera and 800 species, adapted to dry and humid environments in tropical and subtropical regions. *Schinus terebinthifolia*, native to

Brazil, occurs in the *Caatinga*, *Cerrado*, Atlantic Forest and *Pampa*, especially along the South and Southeast coasts. Espírito Santo is the main Brazilian state in the extraction of mastic trees, widely used in the pharmaceutical, food and cosmetics industries (Mesquita, 2023).

One of the best-selling cosmetic products in Brazil is bar soap, used in personal hygiene. The creation of green formulations of this type of product that incorporate regional products of the flora can be of great value for the development of the economy of biodiversity-rich regions (Furman *et al.*, 2022). The production of mastic trees in the state of Espírito Santo is basically destined for export for the manufacture of cosmetics and spices in the sophisticated cuisine of the whole world (Péla, 2014).

Among the main biological activities attributed to *Schinus terebinthifolia*, the antioxidant, antifungal (Oliveira *et al.*, 2018) and antibacterial potential can be highlighted (Salem *et al.*, 2018).

Tannins can be defined as complex polyphenolic compounds (Souza, 2021), identified in plant bark, leaves, fruits, and branches (Castejon, 2011), and have the potential to influence pH levels in solutions, since plant extracts have an acidic character (Costa *et al.*, 2008).

The article proposes to improve the quality and stability of soap through the addition of natural components and treatment of the raw material. It focuses on innovative research that incorporates extracts from the leaf and essential oil of the mastic fruit in bar soaps formulated with RFO, highlighting the role of tannins as neutralizing and pH stabilizing agents. It also addresses a method of washing the oil with an aqueous solution of NaCIO (Justino *et al.*, 2011) aiming at the removal of impurities from the raw material by the affinity of NaCIO with the water that agglomerates the impurities present in the RFO, in addition to evaluating the application of this method in *Instituto Verde Vida*.

Methodology

Collection and preparation of mastic components

Leaves, fruits and stems of the mastic tree were collected at Praça Benedito Rodrigues da Cruz, in the Mata da Praia neighborhood, in Vitória. This area, close to Camburi Beach and with sandy soil, is conducive to the exploitation of the raw material, as shown in Figure 1.

Samples were collected carefully to preserve the trees, selecting healthy and mature plants to ensure the quality of the extracts. This not only supports research but also promotes the conservation and sustainable use of natural resources.

Figure 1.
Collection region for mastic tree components.
A) Collection region; B) Mastic; C) Leaves and fruits; D) Stem.

Source: *Own authorship, 2023.*

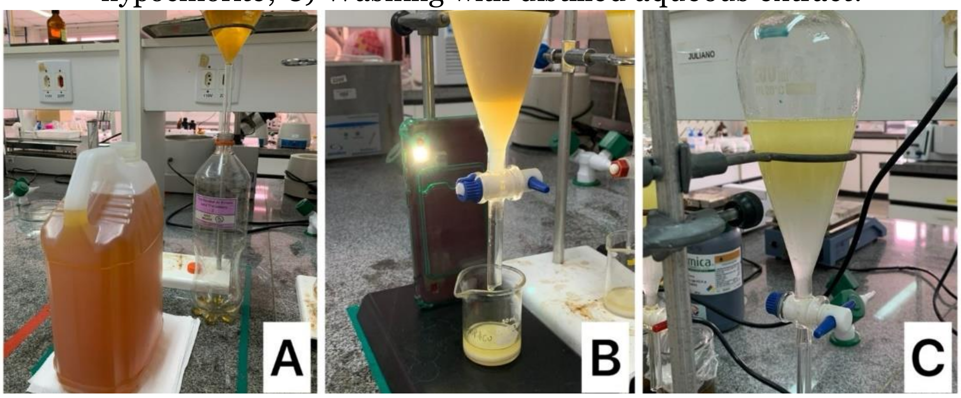
The samples collected were taken to the Green Chemistry Laboratory (*Laboratório de Química Verde* - LabQV) at Ifes Campus Vila Velha. According to the methodology used in the final work of Nishimoto and Souza (2016), these collected components were sanitized with a 2% NaCIO solution, washed and dried in an oven at 60°C for 2 hours. The leaves and fruits were crushed in an industrial blender and the stem was crushed in a knife mill.

Preparation of residual frying oil and treatment with sodium hypochlorite

The RFO sample used for the development of the research was obtained from households in the city of Vitória (ES). The oil was filtered to remove impurities and dirt (Figure 2A) and separated for further handling, corresponding to Oil 1.

The previously filtered RFO was submitted to treatment following the methodology of Justino *et al.* (2011). The sample was washed with an aqueous solution of NaCIO, thus obtaining the sample identified as Oil 2 (Figure 2B). Oil 3 (Figure 2C) consisted of subsequent washing with the distilled aqueous extract of mastic leaves.

Figure 2.
Treatment and identification of RFO samples: A) RFO filtering; B) Treatment with sodium hypochlorite; C) Washing with distilled aqueous extract.



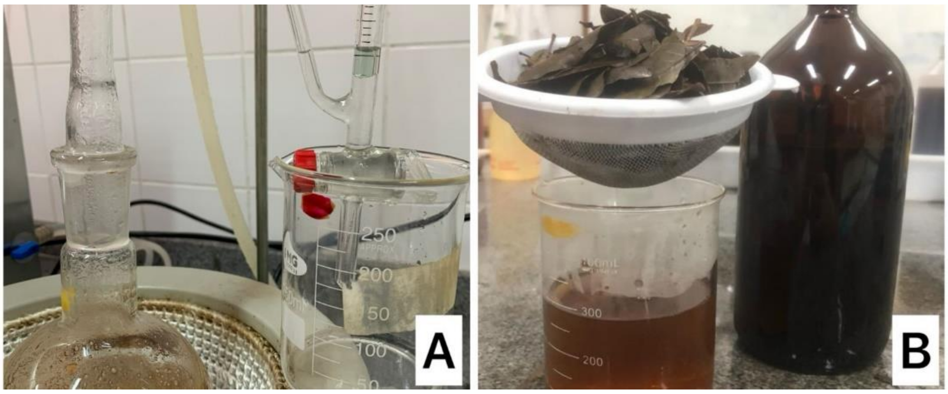
Source: *Own authorship, 2023.*

Obtaining extracts of the components of the mastic tree

Following the methodology employed by Santos *et al.* (2020), it was possible to obtain the essential oil of pink pepper fruits and the aqueous extract distilled from the aqueous phase of distillation (Figure 3A). Following the methodology used in the Herbal Medicine Form of the Brazilian Pharmacopoeia (Anvisa, 2021), it was possible to obtain the crude extract of mastic leaves (Figure 3B). The distilled extract was used to wash the RFO treated with sodium hypochlorite. On the other hand, the crude extract and the essential oil of pink pepper were used in the formulation of the soap.

Figure 3.

Distillation processes. A) Essential oil; B) Crude extract.



Source: *Own authorship, 2023.*

After obtaining the RFO samples according to each proposed treatment, tests were performed to evaluate the parameters, such as moisture (Moretto & Fett, 1998), saponification index (Farmacopeia, 2019), acidity index (Instituto Adolfo Lutz, 2008), refractive index (Moretto & Fett, 1998), density (Borges, 2011) and viscosity (Cortez, 2002).

Soap formulations

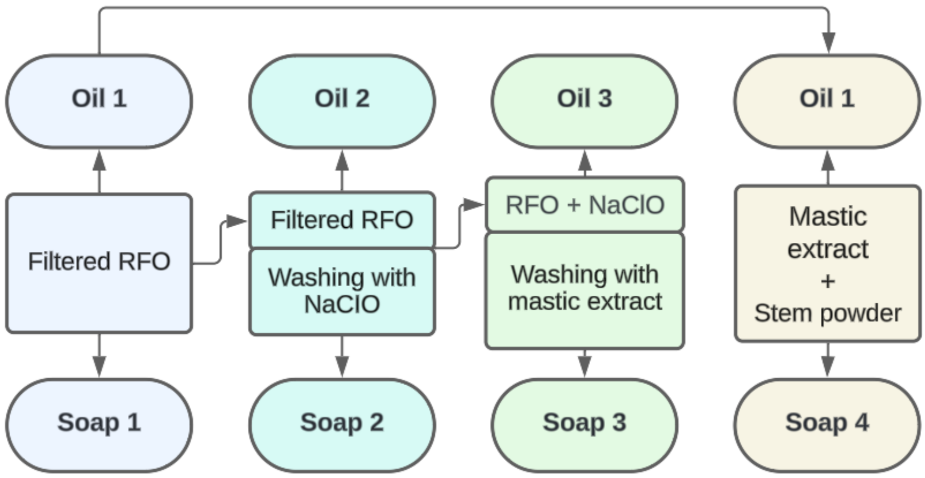
For each RFO sample obtained with the treatments described above (Oil 1, 2, 3), soap was made by adjusting the formulation according to the SI (Saponification Index) (mg KOH/g) of the samples. Thus, soap samples 1, 2, and 3 were generated, according to the flowchart in Figure 4.

The soap samples were properly cut and thus subjected to the accelerated stability test at room temperature and tests such as mass loss (Anvisa, 2004), humidity, pH and alkalinity (Herranz, 2013), as well as the observation of color, odor and appearance (Anvisa, 2004).

As another soap formulation proposal in order to use the properties of the ground stem and the crude extract of the mastic tree, soap 4 was formulated with 700 g of filtered RFO, 189.35 g of NaOH, 315 g of water, 25 g of crude extract and 21 g of ground stem. The ground mastic stem was added to the RFO and after the addition of the NaOH solution, the crude extract was then incorporated into the mixture. The soap was placed in a recyclable form of UHT milk packaging, providing an eco-friendly aspect to the process.

Figure 4.

Results of waste oil characterization tests.



Source: *Own authorship, 2023.*

Results and Discussion

From the procedures described, it was possible to obtain the results listed in Table 1, referring to the quality parameters evaluated in the RFO before (Oil 1) and after the treatments with NaClO (Oil 2) and with the incorporation of the aqueous extract of mastic tree in the oil wash (Oil 3).

Table 1.

Results of waste oil characterization tests.

Analysis/Sample	Oil 1	Oil 2	Oil 3
Humidity (%)	0.11 ± 0.040	0.78 ± 0.050	0.17 ± 0.010
Saponification Index (mg KOH/g)	200.11 ± 2.380	198.07 ± 1.230	198.55 ± 1.640
Acid Index (mg KOH/g)	1.00 ± 0.00	0.40 ± 0.00	2.12 ± 0.06
Refractive Index	1.473 ± 0.000	1.473 ± 0.000	1.473 ± 0.000
Density (g/mL)	0.92 ± 0.020	0.92 ± 0.000	0.92 ± 0.010
Viscosity (mPa.s)	91.68 ± 3.660	92.71 ± 0.480	74.37 ± 0.160

*Reference Value (RV) for %H_2O = < 0.80%; RV for SI = 189 to 195 mg KOH/g; RV for AI = 0.3 mg KOH.g^{-1}; RV for RI = 1.466 to 1.470; VR for density = 0.914 to 0.922 g/mL (MAPA, 2006); RV for viscosity = 59.0 mPas.s (BROOCK *et al.*, 2008).

Source: *Own authorship, 2023.*

In terms of oil moisture, even though it is within the acceptable range for virgin soybean oil (< 0.80%) according to MAPA, the increase in moisture in Oil 2 due to the presence of excess reagent is notorious. Oil 3, which was subjected to a mild heating, showed a small increase in moisture due to the incorporation of the distilled aqueous extract (which presented a yield of 77.33% v/v).

Regarding the saponification index (SI), they were outside the considerable limit for virgin soybean oil (189 to 195 mg KOH/g), however, a reduction in this parameter can be observed when comparing the result obtained for the RFO in relation to the treated samples, which may confer a lower amount of reagent for soap formulation.

The acidity index (AI) of the samples showed a reduction in this parameter when comparing the RFO with Oil 2 and an increase in Oil 3, due to the mild heating to remove moisture, causing new oxidation reactions.

According to the results presented by Gonçalves *et al.* (2021), who evaluated the change in the acidity index of RFO samples with time variation, the increase in AI with temperature variation was notorious. The rate of formation of free fatty acids (FFA) is influenced by several factors, including temperature and the number of heating cycles. The degradation of triacylglycerols is accelerated with heat, which consequently releases FFA (Instituto Adolfo Lutz, 2008).

In times of refractive index (RI) and density of the treated samples, it is possible to observe that there is no considerable variation of these parameters, since there is no significant incorporation of matter in the RFO, capable of increasing its molecular mass to increase the density of the oil, as well as the treatments, it is not able to remove properties in terms of molecular mass.

The viscosity determined by the Ford Cup (*Copo Ford*) method is inconclusive, due to the small flow diameter, the difficulty of passing the fluid was noted, causing it to present points of stagnation during the efflux time, compromising the reliability of the flow time, thus, the extrapolation of the experimental viscosity compared to the theoretical viscosity was notorious, considering the data obtained by Broock and collaborators (2008), corresponding to 59.0 mPas.s for soybean oil using a viscometer.

Compared to the results presented by Lopes and Rosa (2024), the treatment of the oil with aqueous mastic extract increases moisture due to the addition of a liquid phase. This phase can be removed with activated carbon to reduce the moisture content in the sample, without compromising the increase in acidity index due to heating that induces new oxidation reactions.

According to the data obtained, the treatment can be carried out on a large scale at the *Instituto Verde Vida* taking into account some observations. The upper drum, where the RFO is stored for decanting the water from the frying process, can be replaced by a drum with transparent material as illustrated in Figure 5, to be able to visualize the phases present inside the container to perform the oil treatment, using the same gravity mechanism already used in the institute.

Figure 5.

Proposal for application of the treatment at the *Instituto Verde Vida*. A) IVV settling system; B) Transparent canister.

Source: *Own authorship, 2023.*

In terms of the process variables already observed in the laboratory, in order to ensure better quality to the final product, it is necessary to perform complete removal of excess NaCIO present in the RFO to ensure better quality of the product of interest. And even if the viscosity results are inconclusive in terms of literary comparison, it would not compromise the functioning of the system, as it does not present an increase in viscosity that would hinder the flow of the oil.

The results in Table 2 refer to the analysis of the soap samples formulated from the treated oils exposed to room temperature in the laboratory and the pH and alkalinity results of the soap formulated with the crude extract and the ground stem (Soap 4).

Table 2.

Stability test results in soap formulation.

Analysis/Sample	**Soap 1**	**Soap 2**	**Soap 3**	**Soap 4**
%PDM	14.6 ± 0.00	13.4 ± 0.10	18.2 ± 0.50	-
%H_2O	5,44 ± 0.38	5.91 ± 0.46	7.57 ± 0.90	-
pH	10.13 ± 0.02	10.09 ± 0.02	10.16 ± 0.01	8.07 ± 0.01
%Na_2O	0.046 ± 0.021	0.091 ± 0.000	0.059 ± 0.002	ND
Aspect	N	IM	N	-
Color	N	IM	N	-
Smell	N	N	N	-

*Reference Value (RV) for pH = Between 2 and 11.5; RV for %PDM = Variation less than 20% in relation to T0; RV for %Na_2O = below 1% (Anvisa, 2004); N, LM, IM, ND: Normal condition, slightly modified, intensely modified, nothing detected (Anvisa, 2004).

Source: *Own authorship, 2023.*

Through the analysis of mass loss, a value lower than 20% was observed when compared to the initial time, being within the limit established by Anvisa.

In terms of soap moisture, the increase in humidity in Soap 3 is notorious, as it is a gravimetric analysis, the essential oil present in soap increases this parameter because it is not volatile. The commercial essential oil was used due to the low yield in the extraction process (0.61% w/w).

Regarding the parameters of pH and alkalinity of the soap, the results remained within the pH range established by Anvisa (remaining in the range of 2 and 11.5) classified as risk I and the alkalinity remained below 1%.

The influence of tannins in the soap formulation was evidenced, resulting in a decrease in pH compared to soaps produced without this additive (from 10.1 to 8.07), as expected by the addition of the mastic stem in Soap 4, making it safer for the skin. The inclusion of the stem powder favored the neutralization of the alkalinity of the soap, contributing to the safety for the skin.

Comparing with experimental results already existing in the literature, Fernandes *et al.* (2023) using RFO as a component in the formulation of soaps, obtained the product with a pH that ranged from 11.21 to 11.28.

Pereira *et al.* (2018) produced bar soaps formulated from RFO and freeze-dried olive pomace, obtaining pH ranging from 11.70 to 11.93.

In the work of Queiroz *et al.* (2022) in evaluating the influence of avocado pulp in the formulation of bar soap, a pH of 10 was obtained for the formulation containing avocado pulp, coconut oil, and glycerin bar soap, reducing the pH to 7 by adding sodium laurylsulphosuccinate, coconut starch, propylbetaine fatty acid diethanolamide, polyglycoside lauryl, corn starch, talc and white clay.

According to Uchimura (2021), for skin cleansing, the ideal pH of soaps is between 6.5 and 8.5, approaching neutrality. As for washing clothes, a pH of around 10.0 is recommended.

Taking these values into account, the soaps formulated in this study with extracts from the mastic leaf and pink pepper essential oil (Soap 3) are classified as laundry detergents. On the other hand, the soap produced with the stem of the mastic tree (Soap 4) can be classified as a soap for cleaning the skin.

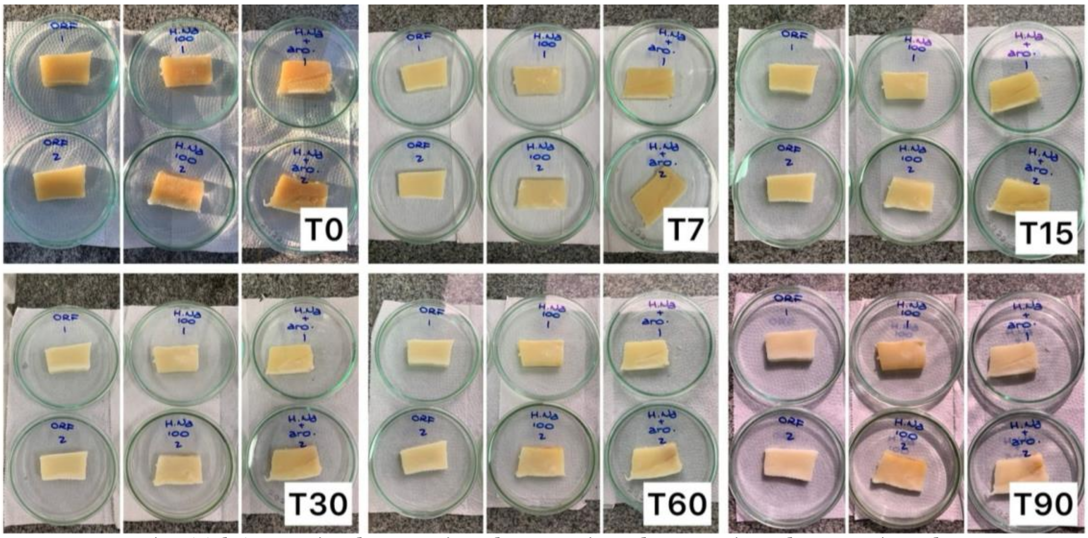
Also comparing the results with the existing literature, the use of mastic component favors the reduction of the pH of the product, reducing the risks to the consumer, with the lower use of reagents in the formulation of the soap.

The odor of the soap did not vary, even though the soap is devoid of essence, it did not present an unpleasant smell over the time of exposure, as well as the aroma of the essential oil of pink pepper (Soap 3) remained after this time of analysis.

The appearance and color results obtained through the stability test of Soap 1, 2 and 3 can be seen in Figure 6.

Figure 6.

Appearance and color results during 90 days of analysis.



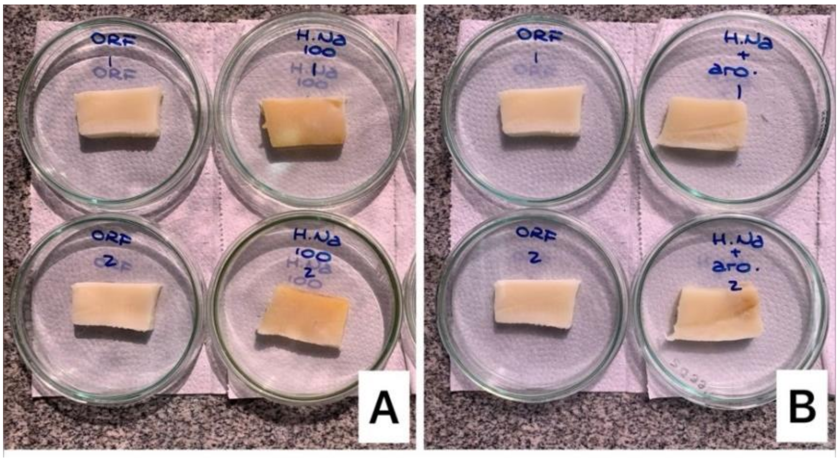
**T0) Initial time; T7) 7 days; T15) 15 days; T30) 30 days; T60) 60 days; T90) 90 days.*

Source: *Own authorship, 2023.*

Figure 7 shows the comparison between the soap formulated from Oil 1 and the soap samples formulated from Oil 2, as well as the comparison only between the soaps formulated with Oil 1 and 3.

Figure 7.

Comparison of appearance and color results after 90 days of analysis. A) Comparison of Soap 1 and 2; B) Comparison of Soap 1 and 3.



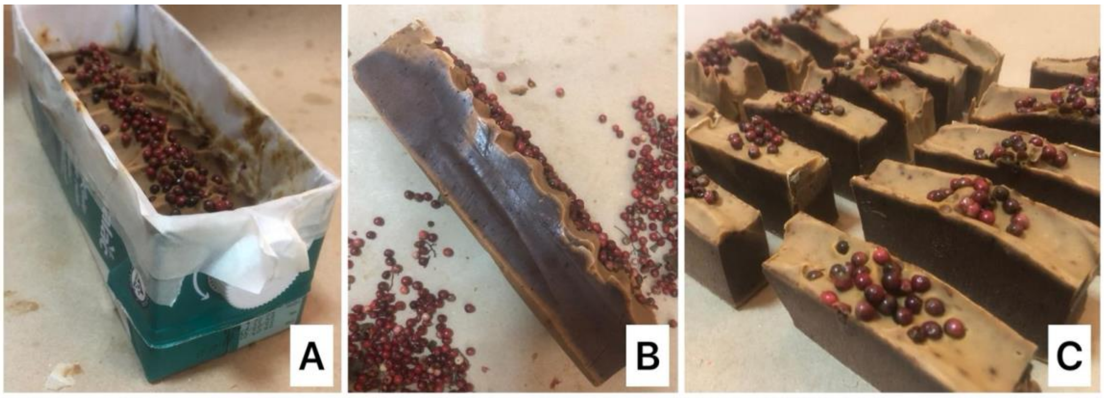
Source: *Own authorship, 2023.*

In terms of color and appearance, it is possible to identify in Soap 2, after 90 days, the change in color, presenting a yellowish appearance due to the excess of NaCIO present in Oil 2. On the other hand, for the soap formulated from Oil 3, it showed a better stability in relation to the other soaps after the 90 days of stability analysis, where it was possible to notice the minimal change in the color of the sample, due to the stability resulting from the antioxidant, antifungal and antibacterial characteristics of the essential oil of pink pepper.

The formulation of soap with the incorporation of the stem of the mastic tree (Soap 4) showed remarkable results, successfully capturing the characteristic aroma of the plant. In addition, it obtained an internal and external coloration in shades of brown, giving the soap a natural aesthetic, without the need to resort to artificial dyes, as can be seen in Figure 8.

Figure 8.

Saponification in recyclable packaging and cutting of soap bars. A) Soap in the milk carton; B) Internal appearance of the product; C) Cut soap.



Source: *Own authorship, 2023.*

The achievement of this color provides a distinct visual aspect, in line with the proposal to incorporate natural elements. In addition, the solid and consistent texture of the soap has proven to be ideal for the production of bar soaps, reinforcing the quality of the final product. These aspects not only enrich the user's sensory experience but also reflect the sustainable and innovative approach.

The adoption of cold processes and the selection of recyclable packaging are evidence of a holistic attention to sustainability throughout the production cycle. In doing so, the research not only develops bar soaps, but serves as a paradigm that illustrates how the intersection of circular economy and green chemistry can result in more eco-conscious products, meeting both environmental demands and consumer preferences for natural, lower-impact products.

Conclusions

The paper presents an innovative experimental development in the circular economy, emphasizing green chemistry. This initiative not only addresses the issue of waste recycling, but also the incorporation of natural elements that have properties capable of contributing positively to the effectiveness and safety of the product. Residual frying oil was used as raw material, incorporating elements of mastic and using UHT milk packaging.

The purification of residual frying oil with sodium hypochlorite shows a commitment to sustainability by reusing waste and using affordable reagents.

The inclusion of pink pepper essential oil gives stability to the soap due to its antioxidant and antimicrobial properties and the mastic stem powder contributes to stabilizing the pH and alkalinity of the product, improving its quality.

The treatment of residual frying oil with sodium hypochlorite is feasible and economical, easily adapting to the structures of *Instituto Verde Vida* and other institutions, reinforcing the applicability of the initiative.

REFERENCES

Anvisa. (2004). Guia de Estabilidade de Produto Cosméticos. https://bvsms.saude.gov.br/bvs/publicacoes/cosmeticos.pdf

Anvisa. (2021). Formulário de Fitoterápicos da Farmacopeia Brasileira. (2ª ed.). https://www.gov.br/anvisa/pt-br/assuntos/farmacopeia/formulario-fitoterapico/2024-fffb2-1-er-3-atual-final-versao-com-capa-em-word-2-jan-2024.pdf

Anvisa. (2021). Informe Técnico nº 11, de 5 de outubro de 2004: utilização e descarte de óleos e gorduras utilizados para fritura. (Atualizado em 27/08/2021). https://www.gov.br/anvisa/pt-br/assuntos/alimentos/informes/copy_of_11de2004.

Borges, K. (2011). Efeito das variáveis operacionais na transesterificação metílica e etílica do óleo de soja. [Dissertação de Mestrado em Química Instituto de Química, Universidade Federal de Uberlândia. Uberlândia - MG] p. 91.

Broock, J., Nogueira, M. R., Zakrzevski, C., Corazza, F. C., Corazza, M. L., & Oliveira, J. V. (2008). Determinação experimental da viscosidade e condutibilidade térmica de óleos vegetais. Ciência e Tecnologia de Alimentos, 28(3), p. 564-570. https://doi.org/10.1590/S0101-20612008000300010

Castejon, F. (2011). Taninos e Saponinas. [Seminários Aplicados do Programa de Pós-graduação em Ciência Animal da Escola de Medicina Veterinária e Zootecnia, Universidade Federal de Goiás], Centro de Recursos Computacionais. https://files.cercomp.ufg.br/weby/up/67/o/semi2011_Fernanda_Castejon_1c.pdf

Cortez, G. (2002). Determinação do coeficiente de viscosidade em líquidos – Método de Stokes. Apresentação de aula prática. https://sistemas.eel.usp.br/docentes/arquivos/5840841/LOQ4060/AULA%20%20PRATICA%2002.pdf.

Costa, C. T. C., Bevilaqua, C. M. L., Morais, S. M., & Vieira, L. S. (2008). Revista Brasileira de Plantas Medicinais, 10(4), p. 108-116.

https://ainfo.cnptia.embrapa.br/digital/bitstream/item/27754/1/API-Taninos-e-sua-utilizacao-em-pequenos-ruminantes.pdf

Fernades, L. D. F., Nunes, H. P., Galvão, E. L. (2023). Aproveitamento do óleo residual de fritura do restaurante universitário para produção de sabão em barra. [Trabalho e Conclusão de Curso do Departamento de Ciências Exatas e Tecnologia da Informação, Universidade Federal Rural do Semi-Árido em Campus Angicos]. https://repositorio.ufersa.edu.br/items/0706c3ab-7cee-485e-9693-10c307456456

Furman, A. C., Veit, M. T., Palácio, S. M., Gonçalves, G. C., Barbieri, J. C. Z. (2022). Sustentabilidade no processo produtivo da indústria cosmética: uma revisão da literatura. Research, Society And Development, 11(13), p. 1-23. https://doi.org/10.33448/rsd-v11i13.35852

Gonçalves, R. P., Zanetti, V. C., Feltes, M. M. C., & Gonzalez, S. L. (2021) Comportamento do óleo de soja durante estresse térmico / Soybean oil behavior during thermal stress. Brazilian Journal of Development, 7(4). doi:10.34117/bjdv7n4-377

Gouveia, T. G., Oliveira. G. V. D., Palomé, L., Carvalho, R. M., Alonso, M. K., Santos, M. G. L., Soares, A. B., Carmo, A. P. D., Endringer, D. C., Oliveira, R. D. V., & Dias, M. C. (2016). Monitoramento da coleta seletiva de resíduos e produção de sabão no Instituto Verde Vida, Região do Rio Aribiri - Vila Velha - ES. Revista Guará, 5(16), p. 69. https://doi.org/10.30712/guara.v1i5.14614

Herranz, A. P. (2013). Qualidade física, química e antimicrobiana de sabões líquidos elaborados com óleo residual de fritura e diferentes agentes saponificantes. [Dissertação de Mestrado em Ciência e Tecnologia de Alimentos, Universidade Federal de Goiás, Goiânia] https://files.cercomp.ufg.br/weby/up/71/o/DISSERTA%C3%87%C3%83O_FINAL__ANDRESSA_2013.pdf

Instituto Adolfo Lutz. (2008). Métodos físico-químicos para análise de alimentos. (4ª ed.). São Paulo: Instituto Adolfo Lutz.

Justino, A. L., Lage, M. M. R., Pereira, T. G. G., Rodrigues, M. F., Silva, M. C. M. A., Orlandi, D., Maia, G., Sales A., Queiroz, B., Cézar. J., & Epifanio. Y. (2011). A Engenharia De Produzir Sabonetes Com Óleo Vegetal: Uma Produção Sustentável. E-xacta, Belo Horizonte, 4(2) – Edição Especial Interdisciplinaridade. p. 19-28. http://dx.doi.org/10.18674/exacta.v4i2.310

Korhonen, J., Nuur. C., Feldmann. A., & Birkie. S. E. (2017). Circular economy as an essentially contested concept. Journal of Cleaner Production, 175. https://doi.org/10.1016/j.jclepro.2017.12.111

Lopes, G. F., Rosa, J. G. (2024). Comparação da eficiência do tratamento de óleo residual de fritura com hipoclorito de sódio e carvão ativado. Research Society and Development, 13(4), e1613445462. https://doi.org/10.33448/rsd-v13i4.45462

Mesquita, A. (2023, outubro 25). Aroeira: tradição e geração de renda em comunidade de Aracruz. Prefeitura de Aracruz. https://www.aracruz.es.gov.br/noticias/aroeira-tradicao-e-geracao-de-renda-em-comunidade-de-aracruz-13085

Moreno, S. (2023, 3 de abril). Brasil gera cerca de 80 milhões de toneladas de resíduos por ano. Radioagência. https://agenciabrasil.ebc.com.br/radioagencia-nacional/meio-ambiente/audio/2023-04/brasil-gera-cerca-de-80-milhoes-de-toneladas-de-residuos-por-ano.

Moretto, E., & Fett, R. (1998). Tecnologia de óleos e gorduras vegetais na indústria de alimentos. Varela Editora e Livraria Ltda.

Nishmoto, K., & Souza, M. (2016). Extração do óleo essencial da *Schinus terebenthifolius* Raddi e avaliação da eficiência bactericida do sabonete desenvolvido. [Trabalho e Conclusão de Curso do Departamento de Engenharia Química, Universidade do Vale do Paraíba em São José dos Campos]. Biblioteca Univap. https://biblioteca.univap.br/dados/00002c/00002c96.pdf

Oliveira, M. S. D., Gontijo, S. M., Teixeira, M. S., Teixeira, K. I. R., Takahashi, J. A., Millan, R. D. S., & Segura, M. E. C. (2018). Chemical composition and antifungal and anticancer activities of extracts and essential oils of *Schinus terebinthifolius* Raddi fruit. Revista Fitos, 12(2), p. 135-146. https://www.arca.fiocruz.br/bitstream/handle/icict/27868/mariana_de_oliveira_et_all.pdf?sequence=2&isAllowed=y

Pereira M. S., Dias, C. S., Janner, N. N., Crexi, V. T. (2018, 6 a 8 de Novembro). Reaproveitamento de resíduos: formulação de sabão em barras. [Trabalho Completo]. 10º Salão Internacional de Ensino, Pesquisa e Extensão (SIEPE). Universidade Federal do Pampa, Santana do Livramento. https://guri.unipampa.edu.br/uploads/evt/arq_trabalhos/18215/seer_18215.pdf

Péla, J. J. (2014). Caracterização agronômica da aroeira (*schinus terebinthifolius raddi*) no município de São Mateus, no estado do Espírito Santo. Universidade Estadual do Norte Fluminense Darcy Ribeiro. https://uenf.br/posgraduacao/producao-vegetal/wp-content/uploads/sites/10/2014/09/Tese-Jadir-Vers%C3%A3o-final.pdf

Queiroz M. L. P., Alves, J. S., Terçariol, C. A. S. (2022). Avaliação da influência de excipientes na formulação de sabonete em barra contendo polpa de abacate (*Persea americana*). [Trabalho Completo]. XV Encontro de Iniciação Científica do Centro Universitário Barão de Mauá. https://api3.baraodemaua.br/media/23818/maria-laura-peron-queiroz.pdf

Rodrigues, G. O., Modro, N. R., Dalmolin, L. C., & Ribeiro, N. (2022). Impacto do descarte correto do óleo de cozinha: uso da dinâmica de sistemas para avaliação. Revista Prociências, 5(1). https://periodicos.ufpel.edu.br/index.php/prociencias/article/view/25962/19133

Sabesp. (s.d.). *Programa de Reciclagem de Óleo*. http://site.sabesp.com.br/site/fale-conosco/faq.aspx?secaoId=134&cid=28.

Salem, M. Z. M., El-Hefny, M., Ali, H. M., Elansary, H. O., Nasser, R. A., El-Settawy, A. A. A., El-Shanhorey, N., & Salem, A. Z. M. (2018). Antibacterial activity of extracted bioactive molecules of *Schinus terebinthifolius* ripened fruits against some pathogenic bacteria. Microbial Pathogenesis, (120), p. 119-127. https://doi.org/10.1016/j.micpath.2018.04.040

Santos, Í., Farias. J. C. D., Lima, T. L. S., & Queiroga, I. M. B. M. (2020). Essential oil extraction pink pepper (*Schinus terebinthifolius* Raddi) and determination of cytotoxicity and inhibitory count minimum. Research, Society and Development, 9(8). https://doi.org/10.33448/rsd-v9i8.6674.

Santos, C. C. L., Damasceno, M. R., Gonçalves, E. K. M., Dias, T. T. L., Silva, T. F. (2023). Desenvolvimento de sabonete em barra com manteigasde murumuru (*Astrocaryummurumuru*) e cupuaçu (*Theobromagrandiflorum*). Brazilian Journal of Development, *9*(6), p. 19646–19661. https://doi.org/10.34117/bjdv9n6-062

Souza, L. T. D. (2021). Quantificação dos taninos das diferentes partes da *Cenostigma nordestinum*. Repositório Institucional UFRN. https://repositorio.ufrn.br/handle/123456789/37321

Uchimura, M. S. (2021). Dossiê Técnico. Serviço Brasileiro de Respostas Técnicas – SBRT. http://www.sbrt.ibict.br/dossie-tecnico/downloadsDT/Nzk=.