

Formulation of a Sustainable Liquid Soap from *Capra aegagrus hircus* Fat and *Stenocereus griseus* Fruit: Physicochemical Analysis and Antioxidant Capacity

Diego F. Cifuentes-Galindres

Universidad de America

Diana M. Galindres-Jiménez

Universidad de America

Santiago Useche

Universidad de America

Paula Piñeros

Universidad de America

Miguel A. Estesó

Universidad Católica de Ávila: Universidad Católica de Ávila

Gerson-Dirceu López

gerson.dirceu@correounivalle.edu.co

Universidad del Valle <https://orcid.org/0000-0001-5621-8410>

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Abstract

In recent years, there has been a growing interest in the consumption of natural products, driven by concerns over the potential health risks associated with synthetic compounds. Furthermore, in response to environmental pollution, research on cosmetic products incorporating a circular economy approach has been undertaken. In this study, we formulated a liquid soap using goat fat (*Capra aegagrus hircus*) as a fatty acid source, combined with the antioxidant properties of iguaraya fruit (*Stenocereus griseus*). Physicochemical characterization of goat fat, including pH, free acidity, saponification, iodine and peroxide indices, moisture content, volatile matter, and other critical quality parameters, confirmed that this raw material met the required standards. Gas chromatography-mass spectrometry (GC-MS) analysis revealed that the major fatty acids were palmitic (C16), stearic (C18), and oleic (C18:1) acids. Additionally, the iguaraya extract contributed to the antioxidant capacity of the liquid soap formulation, according to the DPPH analysis results. These findings suggest that the raw materials used are appropriate for cosmetic formulations and provide additional benefits in terms of quality and functional properties. Thus, we successfully formulated and developed a cosmetic product from natural raw materials, which allowed for the utilization of by-products generated from *Capra egagrus hircus*, promoting biomass conversion and the use of renewable resources, which are key principles of the circular economy and sustainable development goals (SDGs).

1 Introduction

Currently, aesthetic products significantly influence human needs. Appearance and personal care play an important role in modern lifestyles, attracting an increasing number of consumers to products used to clean, enhance, or alter the appearance of the skin, hair, or nails [1, 2]. This growing interest in personal care has energized the cosmetic market, with new products launched at a rapid pace. The global market in this industry is forecasted to reach \$463.5 billion by 2027 [3, 4], reflecting how demand intensifies due to increasing concerns about aesthetics and personal well-being.

According to the United States Food and Drug Administration (FDA), the law defines cosmetics as "articles intended to be rubbed, poured, sprinkled, sprayed on, introduced into, or otherwise applied to the human body for cleansing, beautifying, promoting attractiveness, or altering the appearance". Among the most popular products for body cleansing are toilet soaps [5], which are presented in liquid form or as solid bars (the former is widely distributed in many public bathrooms). These soaps are obtained through a process called saponification, in which the soap base is produced from a transesterification reaction between a fat or oil (triglycerides) and a NaOH solution (for solid soaps) or KOH (for liquid soaps) [6, 7]. This base is the main component of a typical toilet soap formulation, and its techno-functional properties, such as detergent action, emollience, foaming capacity, antibacterial action, and biodegradability, among others, are derived from it [8–10].

Due to a better understanding of the adverse effects of artificial or synthetic ingredients on human health and the environment, there has been considerable interest in using safer ingredients derived from natural and renewable sources. Throughout history, plant extracts, oils, and bioactive compounds have been used in cosmetic formulations, and today, the most globally recognized brands utilize them to enhance the efficacy of their products [11, 12]. Although the use of vegetable ingredients predominates in the cosmetic industry because of their sustainability [6], the use of animal fats in the manufacture of cosmetic products is a traditional practice that remains relevant today. These ingredients are valued for their ability to replicate human skin lipids,

providing deeper and longer-lasting hydration than vegetable alternatives, a feature that favors the restoration of the skin barrier. This ability makes them especially useful in products aimed at treating dry skin [13, 14].

The ancestral territory of the Wayuu indigenous people is located on the Guajira Peninsula, covering both the north of the Colombian department of La Guajira and northeast of Venezuela. These people have a solid cultural identity and consider livestock a fundamental pillar, not only to face food insecurity but also as a source of income. In this region, 79.4% of Colombia's goat population is raised, and many of these animals are slaughtered mainly for their meat [15, 16]. However, the resulting fat has few uses and thus becomes an underutilized waste, generating environmental impacts. Another natural resource highly valued by this community is the "Yosú" (*Stenocereus griseus*), a desert cactus that offers them a varied range of options, from the collection of fruits (Iguaraya) for consumption, the accumulation of young stems for goat grazing, as material for building houses and traditional medical applications [17]. The Iguaraya fruit (pitaya in other regions of Latin America) has a round-oval shape, and the color of its pulp is red due to the presence of polyphenols (betalains), water-soluble natural pigments, which exhibit a wide range of desirable biological activities, including antioxidant, anti-inflammatory, hepatoprotective, and anticarcinogenic properties [18–20].

Currently, no studies have been conducted on the development of cosmetic or pharmaceutical products from these raw materials. Therefore, in this study, the development of toilet soap is proposed as an alternative for the use of fatty residues from goat, combined with the extract of the Iguaraya fruit. This study aligns with sustainability trends and the use of local resources, promoting a more efficient and environmentally friendly production cycle.

2 Materials and methods

2.1 Reagents, standards and solvents

The various solvents used for the extraction of analytes of interest, as well as the reagents or catalysts used in the development of the formulations and the standards used for their quantification, were of analytical grade from Sigma-Aldrich Inc., Merck, and PanReac AppliChem:

Table 1. Reagents, standards and Solvents Employed: Source and Purity

Table 1
Reagents, standards and solvents employed: source and purity

Chemical Name	Source	Purity
Hydrochloric acid	Merck	37%
Petroleum ether	PanReac	99.5%
Ethyl alcohol	Merck	96%
Cyclohexane	PanReac	99.5%
Glycerol standard	Sigma-Aldrich Inc	> 99.99%
Wijs reagent	PanReac	Not report
Sodium hydroxide	Merck	99%
Sodium thiosulfate	Merck	96%
Sulfuric acid	Sigma-Aldrich	98%
Potassium iodide	Merck	100%
Phenolphthalein	Sigma-Aldrich	98%
Acetic acid	Merck	100%
Hexane	Merck	95%

2.2 Raw Materials, Ingredients, and Additives

The raw materials used in the soap making were goat fat (*Capra aegagrus hircus*) and iguaraya fruit extract (*Stenocereus griseus*) obtained from the Department of La Guajira, potassium hydroxide, propylene glycol, and cocoamide from Merck.

2.2.1 Goat Fat (*Capra aegagrus hircus*)

The fat used was supplied by the Jirrawaikat community located at Km 17, Valledupar Road, Colombia (10°27'37" N 73°15'35" O), who performed the slaughtering and butchering of *Capra aegagrus hircus* following traditional Amerindian techniques [21]. During this process, they extracted subcutaneous and visceral fat, which was subsequently melted and filtered to remove impurities. Afterwards, the processed fat was kept under controlled refrigeration at 4°C.

2.2.2 Iguaraya Fruit Extract (IGFE)

The fruit was obtained from a local distributor in Riohacha (11°32'40" N 72°54.433' O), selected according to ripeness criteria such as medium firmness, intense red color, average dimensions of 6 cm in length by 8 cm in diameter, and an approximate weight of 80 g. It was kept under controlled refrigeration conditions at 4°C until transported to the laboratory in Bogotá D.C. Fruits were initially washed with a 200 ppm sodium hypochlorite solution. Subsequently, they were processed by homogenization in water in a Black & Decker BLBD210GSS blender (Middleton, USA), the mixture was left to rest for 24 hours to facilitate the diffusion of the compounds into the water, and finally filtered [22]. Two extracts were formed by changing the ratio of the amount of water to

fruit: a medium level for a ratio of 35 g fruit and 65 g water, and a high level for a ratio of 65 g fruit and 35 g water.

2.3 Characterization of *Capra aegagrus hircus* Fat

2.3.1 Physicochemical Analysis

2.3.1.1 Saponification index

The saponification index was determined according to the AOAC 920.160 standard [23], using 5 g of sample that reacted with 25 mL of 30% potassium hydroxide heated on a water bath for 30 minutes. After cooling for a few minutes, the resulting solution was titrated with 0.5 M HCl, using phenolphthalein as an indicator. In addition, a blank titration was performed without the sample. The saponification value was calculated using Eq. 1 [24].

$$\text{Saponification index} = 28.5 (y - x)/m \quad (1)$$

In this case, the symbol m represents the mass of the sample used in the evaluation, expressed in grams (g). The symbols x and y indicate the volumes in milliliters (mL) of HCl consumed, by the sample and the blank, respectively.

2.3.1.2 Iodine index

The iodine index was measured according to the AOAC 993.20 standard [25], by dissolving the sample in cyclohexane, adding iodine trichloride, and titrating the excess iodine with sodium thiosulfate after adding potassium iodide and water, followed by starch indicator until the color change [26]. The volume of thiosulfate consumed with the sample (x) and without it (y) was recorded, using Eq. 2 of the study to calculate the iodine index.

$$\text{Iodine index} = 1.269 (y - x)/m \quad (2)$$

where the symbol m indicates the mass of the sample used in the evaluation, expressed in grams (g).

2.3.1.3 Peroxide index

The peroxide index, according to the AOAC 965.33 standard [27] used acetic acid, potassium iodide, and final titration with 0.01 M sodium thiosulfate until the disappearance of the yellow color. A 5% (w/v) starch solution was used as an indicator [28]. The titration of the sample consumed a volume x (mL) while the blank consumed y (mL), where the peroxide value was calculated with Eq. 3.

$$\text{Peroxide index} = 10 (x - y)/m \quad (3)$$

here, m indicates the mass of the sample in grams (g).

2.3.1.4 Free fatty acids

The amount of free fatty acids was determined using the AOAC 940.28 standard [29] by dissolving the sample in neutralized ethyl alcohol and 0.1M sodium hydroxide [28].

2.3.1.5 Acidity value

Acidity was evaluated following the ISO 660:2020 standard [30], using hot ethanol with phenolphthalein and neutralizing with 0.1M sodium hydroxide at 70°C [28].

$$\text{Acidity value} = 5.61 \, n/m \quad (3)$$

Here, n represents the volume in milliliters (mL) of 0.1 M NaOH. In the meantime, m represents the mass in grams (g) of the sample.

2.3.1.6 Unsaponifiable matter

To determine unsaponifiable matter ISO 18609 [31] was used, which includes saponification, extraction in hexane, evaporation of the solvent, and determination of the residue [32].

2.3.1.7 Moisture and volatile matter

Moisture and volatile matter were measured using Method B of the NTC 287, drying the sample for 1 hour until a constant weight was reached.

2.3.2 Analysis of Fatty Acid Methyl Esters by GC-MS

Initially, the fatty acids from the sample were transformed into their methyl ester form using the AOAC 920.160 method [23]. For the analysis and identification of fatty acids, the instrumental conditions previously reported were used [33], employing a gas chromatograph-mass spectrometry (GC-MS) Shimadzu QP2010 Ultra, using an electronic ionization (EI) source. The separation of the fatty acid methyl esters (FAMES) was performed on a fused silica capillary column Rtx-5MS (30 m × 0.25 mm internal diameter × 0.25 µm film thickness) from Restek (Bellefont, PA, USA). The analysis was performed using He as the carrier gas at a flow rate of 1.2 mL/min. The injection volume was 1 µL in split mode with a split ratio of 1:10, with a split flow of 11.5 mL/min and a temperature of 250°C at the injector. In the MS, ion signals were acquired in full scan mode over an m/z range of 40–400 Da. The samples were analyzed in triplicate.

2.4 Formulation of Liquid Toilet Soap

The soap formulation was carried out using the methodology reported previously [34] with some modifications. In the first phase, the fat was heated until completely melted and maintained at a temperature of 60°C, simultaneously a 30% potassium hydroxide (KOH) solution was prepared and heated to 60°C. Subsequently, the hot KOH solution was added to the fat, maintaining constant stirring at 600 rpm and controlling the temperature of the process at 60°C until a viscous white mass was obtained (soap base). In the second phase, the obtained soap base was combined with the ingredients listed in Table 2, the mixture was homogenized for 3 hours maintaining the temperature at 60°C. In the third phase, the IGFE was integrated, resulting in three formulations of liquid toilet soap.

Table 2
Formulations of liquid toilet soap with different levels of IGFE

	Formulation of Toilet Soap			
	Ingredients	LTS-C	LTS-M	LTS-H
Phase 1	Goat Fat (<i>Capra aegagrus hircus</i>) (g)	75	75	75
	30% KOH solution (g)	52,74	52,74	52,74
Phase 2	Glycerin (g)	10,25	10,25	10,25
	Polyethylene glycol (g)	22,75	22,75	22,75
	Cocoamide (g)	15	15	15
	Water (g)	148,25	148,25	148,25
Phase 3	IGFE (g)	100 ^C	100 ^M	100 ^H
^C corresponds to the control where the IGFE is composed of 100% water				
^M corresponds to the medium level where the IGFE is composed of 35% fruit and 65% water				
^H corresponds to the high level where the IGFE is composed of 65% fruit and 35% water				

2.5 Analysis of the Physicochemical Properties of Liquid Toilet Soap Formulations with IGFE

The content of free alkali, water and alcohol insoluble matter, as well as the determination of moisture and volatile matter, were performed according to NTC 5604 [35], in order to assess the compliance of the product with international quality standards. The free alkali content was determined by heating the sample in a water bath, filtering it, and adding 1% phenolphthalein, with subsequent titration using NaOH 0.1 N or HCl 0.1 N, depending on the alkalinity of the sample. The insoluble matter was determined by subjecting the sample to digestion with hot ethanol (78°C), filtering, washing with hot neutral ethanol, drying, and weighing the residue. Moisture and volatile matter were measured by drying the sample in a Binder FD 23 oven (Tuttlingen, Germany) at 105°C ± 2°C until constant weight. Additionally, the pH was measured using a Hanna HI-5521 potentiometer (Woonsocket, USA) according to the [36] standard, and the foaming capacity was evaluated by mixing 49 mL of distilled water with 1 mL of soap in a graduated cylinder, shaking it vigorously 10 times, and measuring the volume of foam generated and its stability over time [34]. Figure 1 present the process of liquid toilet soap formulation and its physicochemical analysis.

2.6 Determination of Antioxidant Activity using DPPH

The antioxidant activity of the liquid soap was assessed using the DPPH method [37]. A stock soap solution was prepared at 0.1 mg/mL. For the assay, 1000 µL of the soap stock solution was mixed with 0.5 mL of a DPPH solution (0.2 mg/mL in methanol), completing the volume to 5 mL with methanol. The mixture was incubated in the dark at room temperature for 20 minutes. Methanol was used as a control instead of the soap solution, maintaining the same volume of DPPH. The inhibition percentage was determined using a calibration curve ($R^2 = 0.993$) with ascorbic acid at 0.1 mg/mL as the standard, taking aliquots of 10, 50, 75, 100, and 200 µL and

treated in the same manner as the soap samples. Absorbances were measured at 517 nm in a UV-VIS spectrophotometer. The percentage of DPPH free radical inhibition was calculated using the formula:

$$Inhibition \% = \left(\frac{Ac - Am}{Ac} \right) \times 100 \quad EC.1$$

Where:

- Ac is the absorbance of the negative control,
- Am is the absorbance of the soap sample or ascorbic acid.

2.7 Statistical Analysis

The data obtained from the fat characterization were analyzed by calculating the mean (n = 3) and standard deviation. For the physicochemical characterization of the soap formulations, a one-way analysis of variance (ANOVA) was applied. Statistically significant differences between means ($P < 0.05$) were determined using the Fisher (LSD) method, employing the software Statgraphics Centurion XIX [38].

3. Results and Discussion

3.1. Physicochemical and Chromatographic Analysis of *Capra aegagrus hircus* Fat

Table 3 Fatty acids identified as FAMES in *Capra Aegagrus Hircus* Fat Extracts

Table 3
Fatty acids identified as FAMES in *Capra Aegagrus Hircus* fat extracts

Peak No.	Retention time (min)	Fatty acid (Methyl-)	Free fatty acid formulas	Molecular mass (m/z)	Main fragments (m/z)	Matching factor	Relative Concentration (mg/g)
1	7.988	Decanoic acid	C ₁₀ H ₂₀ O ₂	186	155,143, 101, 87, 74.	97	1.27 ± 0.06
2	10.008	Dodecanoic acid	C ₁₂ H ₂₄ O ₂	214	183,171, 143, 87, 74.	97	1.11 ± 0.03
3	11.835	Tetradecanoic acid	C ₁₄ H ₂₈ O ₂	242	211, 199, 143, 87, 74.	99	28.83 ± 0.55
4	12.403	Pentadecanoic acid-Isomer 1	C ₁₅ H ₃₀ O ₂	256	213, 143, 87, 74.	96	2.30 ± 0.03
5	12.561	Tetradecanoic acid, 12-methyl	C ₁₅ H ₃₀ O ₂	256	213, 199, 143, 87, 74.	98	2.19 ± 0.04
6	12.898	Pentadecanoic acid- Isomer 2	C ₁₅ H ₃₀ O ₂	256	213, 143, 87, 74.	98	5.91 ± 0.11
7	13.536	Pentadecanoic acid, 14-methyl	C ₁₆ H ₃₂ O ₂	270	227, 143,87,74.	97	1.94 ± 0.03
8	14.173	Hexadecanoic acid	C ₁₆ H ₃₂ O ₂	270	227, 143,87,74.	99	217.19 ± 4.31
9	14.457	7-Hexadecenoic acid	C ₁₆ H ₃₀ O ₂	268	236, 194, 69, 55, 44.	97	4.06 ± 0.77
10	14.568	9-Hexadecenoic acid	C ₁₆ H ₃₀ O ₂	268	236, 194, 69, 55, 44.	99	7.02 ± 0.53
11	14.858	Hexadecanoic acid, 14-methyl	C ₁₇ H ₃₄ O ₂	284	255, 241, 143, 87, 74.	98	3.99 ± 0.10
12	15.073	Hexadecanoic acid, 15-methyl	C ₁₇ H ₃₄ O ₂	284	255, 241, 143, 87, 74.	96	5.08 ± 0.15
13	15.508	Heptadecanoic acid	C ₁₇ H ₃₄ O ₂	284	253, 241, 143, 87, 74.	99	16.35 ± 0.33
14	15.931	9-Octadecenoic acid (Z)	C ₁₈ H ₃₄ O ₂	296	250, 208, 69, 55, 44.	93	3.50 ± 0.07
15	17.206	Octadecanoic acid	C ₁₈ H ₃₆ O ₂	298	267, 255, 143, 87, 74.	98	302.08 ± 6.13
16	17.524	7-Octadecenoic acid	C ₁₈ H ₃₄ O ₂	296	222, 180, 69, 55, 44.	99	251.52 ± 3.97

Peak No.	Retention time (min)	Fatty acid (Methyl-)	Free fatty acid formulas	Molecular mass (m/z)	Main fragments (m/z)	Matching factor	Relative Concentration (mg/g)
17	17.692	8-Octadecenoic acid	C ₁₈ H ₃₄ O ₂	296	264, 222, 74, 55, 41.	99	3.38 ± 0.64
18	18.036	11-Octadecenoic acid	C ₁₈ H ₃₄ O ₂	296	264, 222, 74, 55, 41.	91	5.36 ± 0.10
19	18.399	11,14-Octadecadienoic acid	C ₁₈ H ₃₂ O ₂	294	263, 95, 81, 67, 55, 41.	99	11.63 ± 0.38
20	19.661	9,12,15-Octadecatrienoic acid	C ₁₈ H ₃₀ O ₂	292	261, 95, 79, 67, 55, 41.	96	3.71 ± 0.06
Subtotal		Saturated fatty acids (SFA)					588.21 ± 2.02
Subtotal		Monounsaturated fatty acids (MUFA)					257.59 ± 1.48
Subtotal		Polyunsaturated fatty acids (PUFA)					15.34 ± 0.23
Total							859.88 ± 15.00

Table 4 Physicochemical quality indicators of *Capra aegagrus hircus* fat

Table 4
Physicochemical quality indicators of *Capra aegagrus hircus* fat

Quality Indicator	Value
Saponification index (mg KOH/g fat)	211.41 ± 3.67
Iodine index (g I/g fat)	31.75 ± 0.97
Peroxide index (meq O ₂ /kg)	4.03 ± 0.07
Free fatty acids (%)	4.07 ± 0.10
Acidity index (mg KOH/g fat)	0.37 ± 0.02
Unsaponifiable matter (%)	1.91 ± 0.37
Moisture and volatile matter (%)	0.08 ± 0.04
Results are presented as mean ± standard deviation (n = 3)	

3.1.1 Analysis of FAMES in *Capra aegagrus hircus* Fat by GC/MS

Fatty acids were identified as FAMES considering retention times in chromatograms (Fig. 2) and comparing mass spectra of compounds with the database of the National Institute of Standards and Technology (NIST library, Gaithersburg, MD, USA). Additionally, as a criterion for fatty acid identification, a matching factor above 80% was considered between the mass spectra obtained from the sample and the NIST library (values between

91–99%, see Table 3). The mass spectra analysis of saturated fatty acids is characterized by mass-to-charge ratios m/z 74, m/z 87, m/z [M-31]⁺ (peaks 1, 2, 3, 4, 6, 8, 13, and 15 see Table 3), corresponding to McLafferty rearrangement (normally appears as base peak in the spectra of saturated fatty acids) and the loss of the methoxide (OMe) group respectively [39]. Meanwhile branched saturated fatty acids such as iso-FA (Pentadecanoic acid, 14-methyl and Hexadecanoic acid, 15-methyl) exhibit high intensity peaks at both m/z 74 and m/z 87, in addition to a characteristic peak at m/z [M-43]⁺ (Table 3). Conversely, antiiso-fatty acids (Tetradecanoic acid, 12-methyl and Hexadecanoic acid, 14-methyl) also characterize by peaks at m/z 74 as well as at m/z 87, besides a relatively high intensity at m/z [M-57]⁺ corresponding to the terminal loss of the isobutyl group in the fatty acid and another less intense signal at m/z [M-29]⁺ due to the loss of the ethyl group (Table 3). In the sample, monounsaturated MUFA and polyunsaturated PUFA fatty acids were also identified, characterized by signals m/z 55, m/z 41, and m/z [M-32]⁺ (Table 3), associated with the same fragmentation pattern but with two mass units less, due to the unsaturation's of the carbon chains [39].

The results of the fatty acid profile of *Capra aegagrus hircus* showed similarities in the type of fatty acid and differences in the percentage concentration reported in samples of *Slavonska slanina* (pork bacon) [40]. Among the unsaturated fatty acids present in *Slavonska slanina* samples, oleic acid (C18:1) is the main MUFA, found at a percentage concentration of about 47%, while palmitic acid (C16) is the main SFA with concentrations close to 24%, followed by linoleic acid (10%) as the main PUFA. The MUFA content observed in goat fat is comparable to that reported in salmon [41], where oleic acid accounts for 54%. Meanwhile, linolenic and linoleic acids represent 6% and 15% of the PUFAs in this fish, respectively. In another study, the fatty acid profile in seeds of *C. sinensis* by GC-MS was determined [42], showing linoleic acid (36%) and oleic acid (27%) as the main lipid components, correlating them with the highlighted results of antioxidant activity.

3.1.2. Physicochemical Quality Indicators in *Capra aegagrus hircus* Fat

The quality indicators of the fat are fundamental parameters that can affect the behavior of the soap during and after the manufacturing process. The quality of the fat directly influences the saponification process and the final properties of the soap, such as its stability, cleaning ability, and effects on the skin [43, 44]. In Table 4, the values obtained for the physicochemical indicators evaluated in *Capra aegagrus hircus* fat are presented, in order to establish a physicochemical characterization of this raw material, and its potential as an ingredient in the formulation of cosmetic products.

The saponification index is a measure of a fat or oil's ability to hydrolyze in the presence of a strong base, such as potassium hydroxide or sodium hydroxide, producing soap [45]. The saponification index for *Capra aegagrus hircus* fat obtained in this study (211.41 mg KOH/g fat) falls within the typical ranges expected for fats and oils used in the manufacture of soaps or cosmetic products. For example, the saponification index of palm oil is 195 to 211 mg KOH/g fat [46, 47], pig fat is 192 to 201 mg KOH/g [48, 49], in sheep fat 189 mg KOH/g [48] and in beef fat between 193 mg KOH/g [50]. On the other hand, unsaponifiable matter, depending on the origin of the raw material, consists of a mixture of apolar compounds that do not turn into soap during the saponification process. This mixture includes vitamins, sterols, carotenoids, volatile compounds, and other bioactive compounds [51, 52]. The unsaponifiable matter content in *Capra aegagrus hircus* fat in this study was 1.91%, comparable with those found in reports for other types of fats (0.5–2% of the lipid portion) [53].

During storage and processing, fats and oils are prone to oxidation, especially in the presence of high temperatures, light, oxygen, and metal ions. This decomposition process leads to the formation of compounds that cause rancidity, altering the smell and affecting the quality of the raw material [54, 55]. Such deterioration can be estimated with the peroxide index, which is a widely used indicator to assess the degree of rancidity [44]. The peroxide index for *Capra aegagrus hircus* fat obtained in this study (4.03 meq O₂/kg) is low compared to the maximum recommended limit of 30 meq O₂/kg, considered safe for this type of raw materials [56, 57]. This value is comparable with those reported for other animal fats, such as beef or vegetable oils like palm, where peroxide index values can vary between 0.5 and 10 meq O₂/kg, in which studies suggest that these fats have not undergone advanced oxidative deterioration [46, 58, 59].

The iodine index determines the degree of unsaturation of the oil or fat, where a high iodine index indicates a greater number of unsaturated double bonds present in the raw material [60] an important parameter related to the physical and chemical characteristics of fat, as well as its stability [61]. In this study, an iodine index value of 31.75 g I/100 g for *Capra aegagrus hircus* fat was obtained, indicating a moderate proportion of unsaturated fatty acids and is consistent with the semiquantitative analysis conducted by GC-MS, which confirmed the predominant presence of saturated fatty acids (68%), highlighting the presence of palmitic and stearic acids. This value is lower than observed in vegetable oils like sunflower or olive oil, whose iodine indexes can exceed 100 g I/100 g [62, 63] However, it is comparable to values reported for other animal fats, which generally have iodine indexes close to 35 g I/100 g depending on the feeding and conditions of the animals [64, 65].

Free fatty acids (FFA) and the acidity index are two fundamental parameters to assess the quality of a fat, as they are closely related to its stability and degradation. The release of FFA is the result of the hydrolysis of triglycerides, a process that occurs during storage and processing, and directly contributes to the acidity of the fat [66, 67]. In this study, the FFA content in *Capra aegagrus hircus* fat was 4.07%, a value comparable to those reported for other animal fats such as beef (around 4%) and vegetable oils like palm (3.5%) [47, 68, 69]. The acidity index, which measures the amount of potassium hydroxide (KOH) necessary to neutralize the FFA present, was 0.37 mg KOH/g fat in the *Capra aegagrus hircus* sample, confirming the low FFA content.

The Codex Alimentarius recommends a maximum content limit of moisture and volatile matter for olive oil of 0.2% and in palm oil mentions maximum values of 0.25%, in both cases suggesting that under these conditions the risk of hydrolysis and microbial growth, factors that could compromise the quality of the fat, is minimized [70–72]. For this study, a value of 0.08% for this indicator was found. This result is in line with other indicators, such as the peroxide index, and the acidity index, which reflected a low level of degradation or decomposition.

The physicochemical characterization of *Capra aegagrus hircus* fat highlights the quality of this raw material, showing adequate values for the studied indicators. The results found demonstrate its potential as an ingredient in cosmetic and industrial applications, where stability and low susceptibility to degradation are essential. These properties suggest that the fat could be integrated into formulations positively contributing to the functionality and quality of the final products.

3.2. Physicochemical Evaluation of Liquid Toilet Soap Formulations with IGFE

Figure 1 illustrates the visual appearance of the liquid toilet soap formulations developed with different concentrations of iguaraya extract (IGFE). The liquid soap variants (LTS-C, LTS-M, and LTS-H) presented visible

differences in color, attributable to the concentration of IGFE included. The LTS-C formulation, without iguaraya extract, showed a whitish coloration, while the LTS-M and LTS-H formulations, with medium and high concentrations of IGFE respectively, exhibited pinkish hues that increased in intensity proportionally to the extract content and the presence of bioactive compounds and natural pigments, primarily betalains.

During use, the formulations were characterized by a soft and creamy texture on contact with the skin. Rubbing the soap between the hands resulted in the formation of moderate foam with a homogeneous texture. A feeling of cleanliness was perceived after rinsing, without leaving greasy residues or causing a sensation of dryness on the skin.

Table 5 Physicochemical quality indicators of liquid toilet soap formulations with IGFE

Table 5 Physicochemical quality indicators of liquid toilet soap formulations with IGFE			
Formulation of Toilet Soap			
Quality indicator	LTS-C	LTS-M	LTS-H
Amount of foam (mL)	159.3 ^a ± 3.1	161.0 ^a ± 1.0	158.7 ^a ± 3,1
Moisture and volatile matter (%)	65.372 ^a ± 0.149	65.830 ^b ± 0.690	66.72 ^c ± 0.189
Free fat (%)	8.135 ^a ± 0.002	8.136 ^a ± 0.001	8.136 ^a ± 0.002
pH	10.032 ^a ± 0.004	9.983 ^b ± 0.002	9.892 ^c ± 0.003
Free alkali (%)	0.009 ± 0.001	n.d.	n.d.
Free acidity (%)	n.d.	0.146 ^a ± 0.010	0.169 ^b ± 0.006
Insoluble matter in alcohol (%)	0.370 ^a ± 0.076	0.896 ^b ± 0.117	0.930 ^b ± 0.103
Antioxidant capacity (%)	16,944 ^a ± 0,761	25,516 ^b ± 1,506	33,007 ^c ± 1,377
Results are presented as mean ± standard deviation (<i>n</i> = 3), different letters in the			
same row indicate significant differences (<i>P</i> ≤ 0.05). n.d.: not determined.			

Soap formulations must comply with certain physicochemical parameters that guarantee their quality, stability, and efficient functionality. The study of physicochemical variables allows for establishing the behavior of the formulations under different conditions, thereby identifying possible variations in the formulation that may compromise the process efficiency, quality, and acceptance by the end consumer [73, 74]. *Stenocereus griseus*, like other fruits, is known for its high-water content and bioactive compounds [75], and these properties are expected to be preserved in the IGFE and thus transmitted to each of the soap formulations. In Table 5, the results obtained for the quality indicators measured in the liquid toilet soap formulations with IGFE are presented, which allowed for a comparative analysis of the effects of adding the fruit extract on the stability and functionality of the soap. In the analysis of the liquid soap formulations with IGFE, significant differences were observed in the physicochemical parameters except for the amount of foam and free fat. These results can be

explained by the dilutive effects of the functional components of the soap due to the amount of extract added or by the contribution of bioactive compounds present in the *Stenocereus griseus* fruit and transmitted to the IGFE.

The moisture and volatile matter content increased significantly ($P < 0.05$) in each of the formulations as the amount of IGFE increased, with the LTS-H formulation, having the highest concentration of extract, showing the highest value. This can be attributed to the high-water content (about 80%) and the presence of volatile compounds such as esters and essential oils in the fruit [76, 77]. Similarly, the amount of IGFE caused significant increases ($P < 0.05$) in the values obtained for insoluble matter in alcohol and antioxidant capacity in the formulations. The insoluble matter in alcohol reflects the presence of alcohol-insoluble compounds originating from the saponification process or from the ingredients used in the formula such as mineral salts, oxides, clays, etc. [74]. In the LTS-M and LTS-H formulations, this increase can be explained by the incorporation of insoluble compounds from the IGFE: such as mineral salts and organic nature compounds (carbohydrates, fiber, pigments, among others).

On the other hand, Thevamirtha et al. [37] found a higher antioxidant capacity in the production of liquid soaps formulated with extract of palmyrah fruit pulp. In this study, a similar pattern was observed with the LTS-M and LTS-H formulations, which showed a higher antioxidant capacity compared to the control. The addition of IGFE introduced phenolic compounds, such as betalains, known for their antioxidant properties [18, 78], contributing to this increase. It is relevant to mention that the control formulation also exhibited antioxidant capacity, which could be related to the content of MUFAs and PUFAs with 29.9% and 1.70% of total lipids respectively. These unsaturated fatty acids play a crucial role in protecting against oxidative stress in living organisms, performing a natural antioxidant function [79], which could explain what was observed in the LTS-C formulation in terms of antioxidant capacity.

The formulation of the soap base was carried out with precise control of the addition of potassium hydroxide, following the saponification index and ensuring that the resulting base maintained a controlled excess of unsaponified fat. This, along with the addition of IGFE, directly influenced the pH, acidity, and free alkali values in the different formulations. The formulations showed a significant increase ($P < 0.05$) in acidity as the amount of IGFE increased, this due to the presence of organic acids in IGFE, generating a decrease in pH, the contribution of these acid nature substances in the LTS-M and LTS-H formulations neutralized any trace of residual alkali derived from the saponification process, which explains the presence of this indicator only in the LTS-C formulation. The free fat and the amount of foam did not show significant differences ($P \geq 0.05$) among the formulations, indicating that the addition of IGFE did not affect these parameters. Free fat refers to the amount of unsaponified and unsaponifiable fat [80]. The fact that no changes were observed in the values obtained for this indicator is consistent with the use of the same soap base ratio in all formulations and the fact that the extract is not a significant source of fatty acids. On the other hand, the foam obtained from soap corresponds to a colloiddally stabilized dispersion where gas bubbles are suspended in a liquid matrix [81, 82]. The values obtained for this indicator are consistent with the fact that key foaming components, such as the soap base and the surfactants used (cocoamide), remain constant across all formulations. Although certain compounds in IGFE (divalent cations or acidic species) were expected to interfere with foam stability, the quantities present were not sufficient to alter this parameter.

4. Conclusions

The physicochemical characterization of the liquid toilet soap formulations with IGFE reflected results consistent with cosmetic products. The results for pH, free acidity, saponification, iodine and peroxide indexes, moisture, volatile matter, and other critical indicators remained within the allowed ranges, ensuring both the safety and functionality of the soap. Fat from *Capra aegagrus hircus* used in the soap base provided stability to the saponification process, allowing for a controlled level of fat in the final product to leverage its emollient properties. Additionally, the antioxidant capacity of the *Stenocereus griseus* extract provides protective ability against radicals in the liquid soap according to the results obtained. Thus, in line with new trends in personal care and sustainability, the formulation and development of a cosmetic product from natural raw materials was achieved. These materials offer benefits in terms of quality and techno-functional properties, focusing on biomass conversion, waste reduction, and the use of renewable resources, which allows for the utilization of by-products generated by *Capra aegagrus hircus*, concepts aligned with key principles of the circular economy and sustainable development goals.

Declarations

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Author contributions

D. F.C.-G., D.M. G.-J., S. U., and P. P. contributed to the study design. All the authors realized acquisition, analysis, or interpretation of data. D. F.C.-G. and G.-D. L. wrote the original manuscript. D.M. G.-J., M. A. E., and G.-D. L. revised the manuscript and checked grammar. G.-D. L. handled typesetting and submission. All authors approved the final manuscript.

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Data availability

The datasets used and analyzed during the current study are available within the article.

Conflict of interest

The authors declare no competing interests.

References

1. Nadeeshani, D., Gamage, D.G., Dharmadasa, R.M., Chandana Abeysinghe, D., Wijesekara, S., Prathapasinghe, R.G., Someya, G.A.: T.: Global Perspective of Plant-Based Cosmetic Industry and Possible Contribution of Sri Lanka to the Development of Herbal Cosmetics. *Evidence-Based Complementary and Alternative Medicine*. 1–26 (2022). (2022). <https://doi.org/10.1155/2022/9940548>
2. Mascarenhas-Melo, F., Mathur, A., Murugappan, S., Sharma, A., Tanwar, K., Dua, K., Singh, S.K., Mazzola, P.G., Yadav, D.N., Rengan, A.K., Veiga, F., Paiva-Santos, A.C.: Inorganic nanoparticles in dermatopharmaceutical and cosmetic products: Properties, formulation development, toxicity, and regulatory issues. *Eur. J. Pharm. Biopharm.* **192**, 25–40 (2023). <https://doi.org/10.1016/j.ejpb.2023.09.011>
3. Fonseca, S., Amaral, M.N., Reis, C.P., Custódio, L.: Marine Natural Products as Innovative Cosmetic Ingredients. *Mar. Drugs*. **21**, 170 (2023). <https://doi.org/10.3390/md21030170>
4. Mohd-Setapar, S., John, C., Mohd-Nasir, H., Azim, M., Ahmad, A., Alshammari, M.: Application of Nanotechnology Incorporated with Natural Ingredients in Natural Cosmetics. *Cosmetics*. **9**, 110 (2022). <https://doi.org/10.3390/cosmetics9060110>
5. Dreher, F., Jungman, E., Sakamoto, K., Maibach, H.I.: *Handbook of Cosmetic Science and Technology*. CRC, Boca Raton (2022)
6. Atolani, O., Olabiyi, E.T., Issa, A.A., Azeez, H.T., Onoja, E.G., Ibrahim, S.O., Zubair, M.F., Oguntoye, O.S., Olatunji, G.A.: Green synthesis and characterisation of natural antiseptic soaps from the oils of underutilised tropical seed. *Sustain. Chem. Pharm.* **4**, 32–39 (2016). <https://doi.org/10.1016/j.scp.2016.07.006>
7. Mijaljica, D., Spada, F., Harrison, I.P.: Skin Cleansing without or with Compromise: Soaps and Syndets. *Molecules*. **27**, 2010 (2022). <https://doi.org/10.3390/molecules27062010>
8. Perifanova-Nemska, M., Delinska, N., Dimitrova, E.: Chemical characteristics of soap with using plum kernel oil (*Prunus domestica* L.). In: 2022 8th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE). pp. 1–5. IEEE (2022)
9. Klimaszewska, E., Wieczorek, D., Lewicki, S., Stelmasiak, M., Ogorzałek, M., Szymański, Ł., Tomasiuk, R., Markuszewski, L.: Effect of New Surfactants on Biological Properties of Liquid Soaps. *Molecules*. **27**, 5425 (2022). <https://doi.org/10.3390/molecules27175425>
10. Azme, S.N.K., Yusoff, N.S.I.M., Chin, L.Y., Mohd, Y., Hamid, R.D., Jalil, M.N., Zaki, H.M., Saleh, S.H., Ahmat, N., Manan, M.A.F.A., Yury, N., Hum, N.N.F., Latif, F.A., Zain, Z.M.: Recycling waste cooking oil into soap: Knowledge transfer through community service learning. *Clean. Waste Syst.* **4**, 100084 (2023). <https://doi.org/10.1016/j.clwas.2023.100084>
11. Mohd-Setapar, S., John, C., Mohd-Nasir, H., Azim, M., Ahmad, A., Alshammari, M.: Application of Nanotechnology Incorporated with Natural Ingredients in Natural Cosmetics. *Cosmetics*. **9**, 110 (2022). <https://doi.org/10.3390/cosmetics9060110>
12. Shafie, M.H., Kamal, M.L., Zulkiflee, F.F., Hasan, S., Uyup, N.H., Abdullah, S., Hussin, M., Tan, N.A., Zafarina, Y.C.: Application of Carrageenan extract from red seaweed (Rhodophyta) in cosmetic products: A review. *J. Indian Chem. Soc.* **99**, 100613 (2022). <https://doi.org/10.1016/j.jics.2022.100613>
13. Russell, M.F., Sandhu, M., Vail, M., Haran, C., Batool, U., Leo, J.: Tallow, Rendered Animal Fat, and Its Biocompatibility With Skin: A Scoping Review. *Cureus*. (2024). <https://doi.org/10.7759/cureus.60981>
14. Cheng, D., Liu, Y., Ngo, H.H., Guo, W., Chang, S.W., Nguyen, D.D., Zhang, S., Luo, G., Bui, X.T.: Sustainable enzymatic technologies in waste animal fat and protein management. *J. Environ. Manage.* **284**, 112040 (2021). <https://doi.org/10.1016/j.jenvman.2021.112040>

15. Forero, O.A., Rúa Bustamante, C., Ortiz, Z.: Beyond Animal Husbandry: The Role of Herders Among the Wayuu of Colombia. *Hum. Ecol.* **51**, 627–640 (2023). <https://doi.org/10.1007/s10745-023-00416-x>
16. Rojas, M.Y., Alonso, L.A., Sarmiento, V.A., Eljach, L.Y., Usaquén, W.: Structure analysis of the La Guajira-Colombia population: A genetic, demographic and genealogical overview. *Ann. Hum. Biol.* **40**, 119–131 (2013). <https://doi.org/10.3109/03014460.2012.748093>
17. Villalobos Soraya, V., Orlando, M., Sandra: Usage, Managment and Conservation of yosú, *Stenocereus griseus* (Cactaceae), in the Upper Guajira, Colombia. *Acta Biolo Colomb.* **12**, 99–112 (2007)
18. García-Lucas, K.A., Méndez-Lagunas, L.L., Rodríguez-Ramírez, J., Campanella, O.H., Patel, B.K., Barriada-Bernal, L.G.: Physical properties of spray dried *Stenocereus griseus* pitaya juice powder. *J. Food Process. Eng.* **40** (2017). <https://doi.org/10.1111/jfpe.12470>
19. Daher, C.C., Barreto, S.M.A.G., de Brito Damasceno, G.A., de Santana Oliveira, A., Leite, P.I.P., Reginaldo, F.P.S., Escudeiro, C.C., Ostrosky, E.A., Giordani, R.B., Ferrari, M.: Use of sisal industrial waste (*Agave sisalana* Perrine) in sustainable and multifunctional cosmetic products. *Int. J. Cosmet. Sci.* **45**, 815–833 (2023). <https://doi.org/10.1111/ics.12890>
20. García-Cruz Leticia, S.-M., Yolanda, V.-G., Salvador: Betalains, phenolic compounds and antioxidant activity in pitaya de mayo (*Stenocereus griseus* H.). *Revista fitotecnica mexicana.* **35**, 01–05 (2012)
21. Guerra, W.: Alimentación y cocina en la península de La Guajira una aproximación histórica. *Salud bucal / Confederación Odontológica de la República Argentina. LIV.* **98**, 59–70 (2020)
22. Fleck, J.D., Betti, A.H., Da Silva, F.P., Troian, E.A., Olivaro, C., Ferreira, F., Verza, S.G.: Saponins from Quillaja saponaria and Quillaja brasiliensis: Particular Chemical Characteristics and Biological Activities. *Molecules.* **24**, 171 (2019). <https://doi.org/10.3390/molecules24010171>
23. Association of Official Analytical Chemists (AOAC): Official method 920.160: Saponification value of fats and oils. Presented at the: (1920)
24. Krishnamoorthy, R., Hai, A., Banat, F.: Subcritical Water Extraction of Mango Seed Kernels and Its Application for Cow Ghee Preservation. *Processes.* **11**, 1379 (2023). <https://doi.org/10.3390/pr11051379>
25. Association of Official Analytical Chemists (AOAC): Official method 993.20: Iodine value of fats and oils. Presented at the: (1993)
26. Dzarma, G.W., Agu, C.M., Nwosu-Obieogu, K., Onyedikachi, L.N., Kalu, O.A., Ekezie, E.O., Adiele, M.C., Chukwulebile, A.S.: Parametric study of oil extraction from African Star Apple (*Chrysophyllum albidum*) seeds. *Clean. Chem. Eng.* **2**, 100018 (2022). <https://doi.org/10.1016/j.clce.2022.100018>
27. (AOAC), of O.A, A., .C.: Official method 965.33: Peroxide value of oils and fats. Presented at the: (1969)
28. Paulk, C.B., Stark, C.R., Dunmire, K.M.: Feed Processing Technology and Quality of Feed. In: Sustainable Swine Nutrition, pp. 429–444. Wiley (2022)
29. (AOAC), of O.A, A., .C.: Official method 940.28: Fatty acids (free) in crude and refined oils. Presented at the: (1940)
30. International Organization for Standardization (ISO): ISO 660:2020: Animal and vegetable fats and oils – Determination of acid value and acidity. Presented at the (2020)
31. (ISO), I.O. for S.: ISO 18609:2000: Animal and vegetable fats and oils – Determination of unsaponifiable matter – Method using hexane extraction. Presented at the: (2000)

32. Niyukuri, J., Raiti, J., Ntakarutimana, V., Hafidi, A.: Lipid composition and antioxidant activities of some underused wild plants seeds from Burundi. *Food Sci. Nutr.* **9**, 111–122 (2021).
<https://doi.org/10.1002/fsn3.1969>
33. Cruz Reina, L.J., López, G.-D., Durán-Aranguren, D.D., Quiroga, I., Carazzone, C., Sierra, R.: Compressed fluids and Soxhlet extraction for the valorization of compounds from Colombian cashew (*Anacardium occidentale*) nut shells aimed at a cosmetic application. *J. Supercrit Fluids.* **192**, 105808 (2023).
<https://doi.org/10.1016/j.supflu.2022.105808>
34. Widyasanti, A., Ayuningtyas, B., Rosalinda, S.: Characterization of liquid soap from castor oil (*Ricinus communis*) with the addition of white tea extracts. *IOP Conf. Ser. Earth Environ. Sci.* **443**, 012061 (2020).
<https://doi.org/10.1088/1755-1315/443/1/012061>
35. INCOTEC: NTC NTC 5604: Soaps and detergents. Tests methods for the physicochemical analysis. Part 2. Soap and soap products. Presented at the: (2024)
36. International, A.S.T.M.: ASTM D1172-14: Standard guide for pH measurement of soaps and detergents. Presented at the (2014)
37. Thevamirtha, C., Balasubramaniam, A., Srithayalan, S., Selvakumar, P.M.: An Insight into the antioxidant activity of the facial cream, solid soap and liquid soap made using the carotenoid extract of palmyrah (*Borassus flabellifer*) fruit pulp. *Ind. Crops Prod.* **195**, 116413 (2023).
<https://doi.org/10.1016/j.indcrop.2023.116413>
38. Cifuentes-Galindres, D.F., Fuenmayor, C.A., López-Vargas, J.H.: Restructured beef steaks with inclusion of digestion-resistant maltodextrin: Techno-functional characteristics, nutritional value, sensory quality, and storage stability. *Bioactive Carbohydr. Diet. Fibre.* **31**, 100391 (2024).
<https://doi.org/10.1016/j.bcdf.2023.100391>
39. Hvidsten, I., Mjøs, S.A., Bødtker, G., Barth, T.: Fatty acids in bacterium *Dietzia* sp. grown on simple and complex hydrocarbons determined as FAME by GC–MS. *Chem. Phys. Lipids.* **190**, 15–26 (2015).
<https://doi.org/10.1016/j.chemphyslip.2015.06.002>
40. Latin, K., Mastanjević, K., Raguž, N., Bulaić, M., Lužaić, R., Heffer, M., Lukić, B.: Differences in Fatty Acid Profile and Physical-Chemical Composition of Slavonska slanina—Dry Cured Smoked Bacon Produced from Black Slavonian Pig and Modern Pigs. *Animals.* **12**, 924 (2022). <https://doi.org/10.3390/ani12070924>
41. Inguglia, L., Chiaramonte, M., Di Stefano, V., Schillaci, D., Cammilleri, G., Pantano, L., Mauro, M., Vazzana, M., Ferrantelli, V., Nicolosi, R., Arizza, V.: *Salmo salar* fish waste oil: Fatty acids composition and antibacterial activity. *PeerJ.* **8**, e9299 (2020). <https://doi.org/10.7717/peerj.9299>
42. Atolani, O., Adamu, N., Oguntoye, O.S., Zubair, M.F., Fabiyi, O.A., Oyegoke, R.A., Adeyemi, O.S., Areh, E.T., Tarigha, D.E., Kambizi, L., Olatunji, G.A.: Chemical characterization, antioxidant, cytotoxicity, Anti-Toxoplasma gondii and antimicrobial potentials of the Citrus sinensis seed oil for sustainable cosmeceutical production. *Heliyon.* **6**, e03399 (2020). <https://doi.org/10.1016/j.heliyon.2020.e03399>
43. Dastidar, S.G., Yarovoy, Y., Leopoldino, S.R., Agarwal, P., Ghosh, C., Bangal, A., Perala, S.R.K., Chakrapani, H.G., Joseph, M.T., Vincent, C., Rodseth, C., Katz, M., Singh, V., Hegishte, S., King, H., Ghatlia, N., Sanzgiri, V., Raut, J.S.: Revisiting the role of total fatty matter in soap bars. *J. Surfactants Deterg.* **26**, 797–806 (2023).
<https://doi.org/10.1002/jsde.12699>
44. Giriprasad, R., Goswami, H.S.: Animal fat-Processing and Its Quality Control. *J. Food Process. Technol.* **04** (2013). <https://doi.org/10.4172/2157-7110.1000252>

45. Méndez-Cid, F.J., Lorenzo, J.M., Martínez, S., Carballo, J.: Oxidation of edible animal fats. Comparison of the performance of different quantification methods and of a proposed new semi-objective colour scale-based method. *Food Chem.* **217**, 743–749 (2017). <https://doi.org/10.1016/j.foodchem.2016.09.009>
46. MacArthur, R., Teye, E., Darkwa, S.: Quality and safety evaluation of important parameters in palm oil from major cities in Ghana. *Sci. Afr.* **13**, e00860 (2021). <https://doi.org/10.1016/j.sciaf.2021.e00860>
47. Edo, G.I., Makinde, M.G., Nwosu, L.C., Ozgor, E., Akhayere, E.: Physicochemical and Pharmacological Properties of Palm Oil: an Approach for Quality, Safety, and Nutrition Evaluation of Palm Oil. *Food Anal. Methods.* **15**, 2290–2305 (2022). <https://doi.org/10.1007/s12161-022-02293-4>
48. Xu, F., Zhang, L., Cao, Y., Yang, L., Zhang, H., Li, Y., Zhao, H., Li, Y.: Chemical and Physical Characterization of Donkey Abdominal Fat in Comparison with Cow, Pig and Sheep Fats. *J. Am. Oil Chem. Soc.* **90**, 1371–1376 (2013). <https://doi.org/10.1007/s11746-013-2287-z>
49. Adepoju, T.F.: Optimization processes of biodiesel production from pig and neem (*Azadirachta indica* a.Juss) seeds blend oil using alternative catalysts from waste biomass. *Ind. Crops Prod.* **149**, 112334 (2020). <https://doi.org/10.1016/j.indcrop.2020.112334>
50. Teixeira, L.S.G., Assis, J.C.R., Mendonça, D.R., Santos, I.T.V., Guimarães, P.R.B., Pontes, L.A.M., Teixeira, J.S.R.: Comparison between conventional and ultrasonic preparation of beef tallow biodiesel. *Fuel Processing Technology.* **90**, 1164–1166 (2009). <https://doi.org/10.1016/j.fuproc.2009.05.008>
51. Seo, D., Kim, N., Jeon, A., Kwon, J., Baek, I., Shin, E.-C., Lee, J., Kim, Y.: Hypoglycemic and hypolipidemic effects of unsaponifiable matter from okra seed in diabetic rats. *Nutr. Res. Pract.* **18**, 345 (2024). <https://doi.org/10.4162/nrp.2024.18.3.345>
52. Veljković, V.B., Banković-Ilić, I.B., Stamenković, O.S., Hung, Y.-T.: Waste Vegetable Oils, Fats, and Cooking Oils in Biodiesel Production. Presented at the (2021)
53. Gómez-Coca, R.B., Pérez-Camino, M.C., Moreda, W.: Neutral Lipids: Unsaponifiable. In: *Handbook of Food Analysis - Two Volume Set*, pp. 483–514. CRC (2015)
54. Arakawa, K., Sagai, M.: Species differences in lipid peroxide levels in lung tissue and investigation of their determining factors. *Lipids.* **21**, 769–775 (1986). <https://doi.org/10.1007/BF02535410>
55. Figueiredo, P.S., Candido, C.J., Jaques, J.A., Nunes, Â.A., Caires, A.R., Michels, F.S., Almeida, J.A., Filiú, W.F., Hiane, P.A., Nascimento, V.A., Franco, O.L., Guimarães, R.C.: Oxidative stability of sesame and flaxseed oils and their effects on morphometric and biochemical parameters in an animal model. *J. Sci. Food Agric.* **97**, 3359–3364 (2017). <https://doi.org/10.1002/jsfa.8186>
56. Zhang, N., Li, Y., Wen, S., Sun, Y., Chen, J., Gao, Y., Sagymbek, A., Yu, X.: Analytical methods for determining the peroxide value of edible oils: A mini-review. *Food Chem.* **358**, 129834 (2021). <https://doi.org/10.1016/j.foodchem.2021.129834>
57. Gotoh, N., Wada, S.: The importance of peroxide value in assessing food quality and food safety. *J. Am. Oil Chem. Soc.* **83**, 473–474 (2006). <https://doi.org/10.1007/s11746-006-1229-4>
58. Zeng, Z., Qin, X., Wang, H., Chen, Z., Huang, D., Xiang, D., Liu, X.: Effect of the chemical composition and structural properties of beef tallow from different adipose tissues on bread quality. *LWT.* **192**, 115736 (2024). <https://doi.org/10.1016/j.lwt.2024.115736>
59. Zhou, L., Zhang, T., Zheng, M., Wang, S., Li, B., Hu, Z., Nie, Q., He, D., Hu, C., Zheng, J., Lei, F., Zhang, Q.: Physicochemical properties and flavor substances analyses of refined beef tallow with dry fractionation treatment. *Food Chem.* **460**, 140736 (2024). <https://doi.org/10.1016/j.foodchem.2024.140736>

60. Phuah, E.-T., Yap, J.W.-L., Lau, C.-W., Lee, Y.-Y., Tang, T.-K.: Vegetable Oils and Animal Fats: Sources, Properties and Recovery. In: Recent Advances in Edible Fats and Oils Technology, pp. 1–26. Springer Singapore, Singapore (2022)
61. Athira, K.R., Sifana, P.I., Menon, S.: Science and Technology of Fats and Lipids. In: Handbook of Biomass, pp. 1371–1397. Springer Nature Singapore, Singapore (2024)
62. Konuskan, D.B., Arslan, M., Oksuz, A.: Physicochemical properties of cold pressed sunflower, peanut, rapeseed, mustard and olive oils grown in the Eastern Mediterranean region. *Saudi J. Biol. Sci.* **26**, 340–344 (2019). <https://doi.org/10.1016/j.sjbs.2018.04.005>
63. Pulassery, S., Abraham, B., Ajikumar, N., Munnilath, A., Yoosaf, K.: Rapid Iodine Value Estimation Using a Handheld Raman Spectrometer for On-Site, Reagent-Free Authentication of Edible Oils. *ACS Omega*. **7**, 9164–9171 (2022). <https://doi.org/10.1021/acsomega.1c05123>
64. Gunstone, F.D., Russell, W.C.: Animal fats. IX.—The relation between composition and iodine value. *J. Sci. Food Agric.* **8**, 290–297 (1957). <https://doi.org/10.1002/jsfa.2740080508>
65. Martins, A.A., Andrade, S., Correia, D., Matos, E., Caetano, N.S., Mata, T.M.: Valorization of Agro-Industrial Residues: Bioprocessing of Animal Fats to Reduce Their Acidity. *Sustainability*. **13**, 10837 (2021). <https://doi.org/10.3390/su131910837>
66. Medeiros Vicentini-Polette, C., Ramos, R., Bernardo, P., Gonçalves, C., De Oliveira, L.: Determination of free fatty acids in crude vegetable oil samples obtained by high-pressure processes. *Food Chem. X*. **12**, 100166 (2021). <https://doi.org/10.1016/j.fochx.2021.100166>
67. Ismail, B.P., Nielsen, S.S. (eds.): Nielsen's Food Analysis. Springer International Publishing, Cham (2024)
68. García-Morales, R., Zúñiga-Moreno, A., Verónico-Sánchez, F.J., Domenzain-González, J., Pérez-López, H.I., Bouchot, C., Elizalde-Solis, O.: Fatty acid methyl esters from waste beef tallow using supercritical methanol transesterification. *Fuel*. **313**, 122706 (2022). <https://doi.org/10.1016/j.fuel.2021.122706>
69. Tan, C.-H., Ariffin, A.A., Ghazali, H.M., Tan, C.-P., Kuntom, A., Choo, A.C.-Y.: Changes in oxidation indices and minor components of low free fatty acid and freshly extracted crude palm oils under two different storage conditions. *J. Food Sci. Technol.* **54**, 1757–1764 (2017). <https://doi.org/10.1007/s13197-017-2569-9>
70. Molitor, A., Yucel, U., Vipham, J., Jones, C., Trinetta, V.: Effects of moisture and temperature on Salmonella survivability in beef tallow, white grease, and chicken rendered fat. *Transl Anim. Sci.* **5** (2021). <https://doi.org/10.1093/tas/txab110>
71. Ragni, L., Iaccheri, E., Cevoli, C., Berardinelli, A., Bendini, A., Toschi, T.G.: A capacitive technique to assess water content in extra virgin olive oils. *J. Food Eng.* **116**, 246–252 (2013). <https://doi.org/10.1016/j.jfoodeng.2012.10.031>
72. Chew, C.L., Ng, C.Y., Hong, W.O., Wu, T.Y., Lee, Y.-Y., Low, L.E., Kong, P.S., Chan, E.S.: Improving Sustainability of Palm Oil Production by Increasing Oil Extraction Rate: a Review. *Food Bioproc Tech.* **14**, 573–586 (2021). <https://doi.org/10.1007/s11947-020-02555-1>
73. Nchimbi, H.Y.: Quantitative and qualitative assessment on the suitability of seed oil from water plant (*Trichilia emetica*) for soap making. *Saudi J. Biol. Sci.* **27**, 3161–3168 (2020). <https://doi.org/10.1016/j.sjbs.2020.07.019>
74. Stillman, R.C.: The analysis of soaps. *J. Am. Oil Chem. Soc.* **29**, 573–576 (1952). <https://doi.org/10.1007/BF02632654>

75. Ali, A., Riaz, S., Sameen, A., Naumovski, N., Iqbal, M.W., Rehman, A., Mehany, T., Zeng, X.-A., Manzoor, M.F.: The Disposition of Bioactive Compounds from Fruit Waste, Their Extraction, and Analysis Using Novel Technologies. *Rev. Processes.* **10**, 2014 (2022). <https://doi.org/10.3390/pr10102014>
76. Le Bellec, F., Vaillant, F., Pitahaya: (pitaya) (*Hylocereus* spp.). In: *Postharvest Biology and Technology of Tropical and Subtropical Fruits*. pp. 247–273e. Elsevier (2011)
77. Jiang, X., Lu, Y., Liu, S.Q.: Effects of Different Yeasts on Physicochemical and Oenological Properties of Red Dragon Fruit Wine Fermented with *Saccharomyces cerevisiae*, *Torulaspora delbrueckii* and *Lachancea thermotolerans*. *Microorganisms.* **8**, 315 (2020). <https://doi.org/10.3390/microorganisms8030315>
78. Cejudo-Bastante, M.J., Hurtado, N., Muñoz-Burguillos, P., Heredia, F.J.: *Stenocereus griseus* (Haw) pitaya as source of natural colourant: technological stability of colour and individual betalains. *Int. J. Food Sci. Technol.* **54**, 3024–3031 (2019). <https://doi.org/10.1111/ijfs.14215>
79. Rydlewski, A.A., de Moraes, D.R., Rotta, E.M., Claus, T., Vagula, J.M., da Silva, M.C., Junior, S., Visentainer, O.O.: J.V.: Bioactive Compounds, Antioxidant Capacity, and Fatty Acids in Different Parts of Four Unexplored Fruits. *J Food Qual.* 1–9 (2017). (2017). <https://doi.org/10.1155/2017/8401074>
80. Sahu, S., Ghosh, M., Bhattacharyya, D.K.: Isolation of the unsaponifiable matter (squalene, phytosterols, tocopherols, γ -oryzanol and fatty alcohols) from a fatty acid distillate of rice bran oil. *Grasas y Aceites.* **69**, 262 (2018). <https://doi.org/10.3989/gya.1112172>
81. Fameau, A.-L., Saint-Jalmes, A.: Non-aqueous foams: Current understanding on the formation and stability mechanisms. *Adv. Colloid Interface Sci.* **247**, 454–464 (2017). <https://doi.org/10.1016/j.cis.2017.02.007>
82. Schramm, L.L., Wassmuth, F.: *Foams: Basic Principles*. Presented Oct. **15** (1994)

Figures

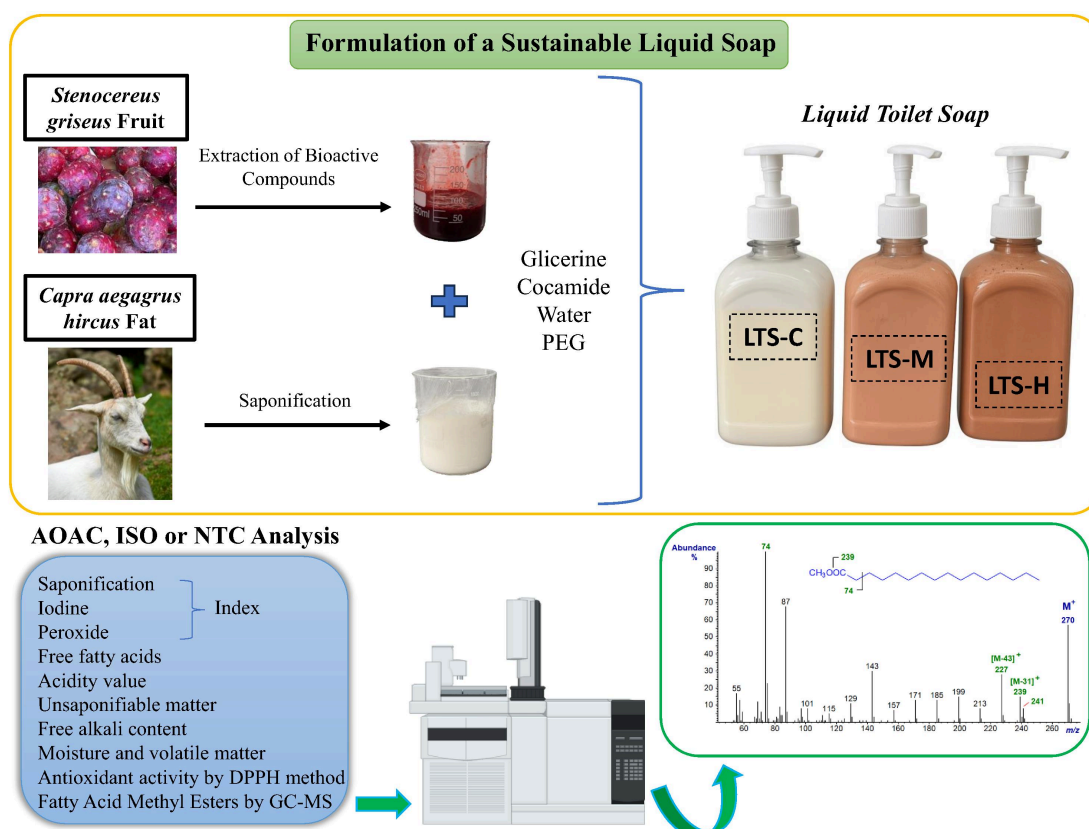


Figure 1

Process of liquid toilet soap formulation and its physicochemical analysis.

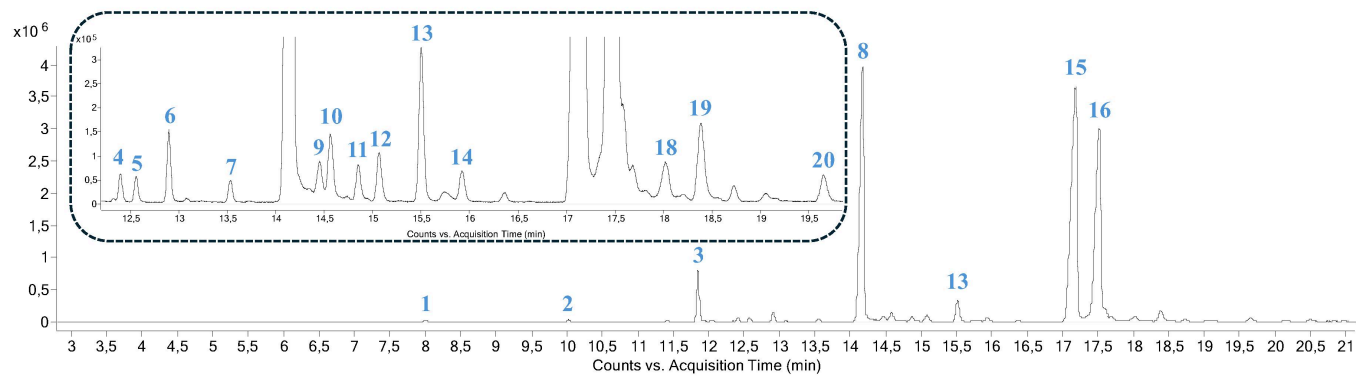


Figure 2

GC-MS chromatogram of FAMES in *Capra aegagrus hircus* Fat reported in Table 3.

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