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Original Article

Development and stability of intimate soap formulations using *Sapindus saponaria* L. extract as a natural surfactant

Desenvolvimento e estabilidade de formulações de sabonete íntimo usando como tensoativo natural o extrato de *Sapindus saponaria* L.

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Abstract

The use of synthetic surfactants reflects the high demand in the hygiene and cleaning sector for products with low-cost and good-effectiveness. These ingredients are the main components of intimate soap formulations. *Sapindus saponaria* L. is a plant rich in saponins, with the potential to be used as a natural surfactant due to its amphiphilic character and its foam-forming properties. Therefore, this study aimed to develop intimate soap formulations using *S. saponaria* extract as a natural surfactant and analyze its stability and surfactant characteristics. Preliminary and accelerated stability parameters, rheological characteristics, surface tension, foaming power, foam stability and emulsification potential were evaluated. The formulations were stable at a pH suitable for the intimate region (4.0 to 4.5), the presence of *S. saponaria* extract provided greater reduction of surface tension, better foaming and foam stability and greater emulsification power, desirable characteristics for an intimate liquid soap. These results demonstrate that the incorporation of *S. saponaria* extract into liquid soap formulations is an excellent option as a natural surfactant to reduce the use of synthetic anionic surfactants such as SLES.

Keywords: saponins, surfactant, cosmetics, lauryl-free.

Resumo

O uso de tensoativos sintéticos reflete a alta demanda do setor de higiene e limpeza por produtos de baixo custo e boa eficácia. Estes ingredientes, são os principais componentes das formulações de sabonete íntimo. A *Sapindus saponaria* L. é uma planta rica em saponinas, com potencial para ser utilizada como tensoativo natural devido a seu caráter anfifílico e suas propriedades espumógenas. Diante disso, este trabalho teve por objetivo o desenvolvimento de formulações de sabonete íntimo utilizando o extrato de *S. saponaria* como tensoativo natural e analisar sua estabilidade e características tensoativas. Foram avaliados parâmetros de estabilidade preliminar e acelerada, características reológicas, tensão superficial, poder e estabilidade de espuma e potencial de emulsionamento. As formulações se mostraram estáveis em pH adequado para a região íntima (4,0 a 4,5), a presença do extrato de *S. saponaria* proporcionou maior redução da tensão superficial, melhor poder e estabilidade de espuma e maior poder emulsificação, características estas desejáveis para um sabonete líquido íntimo. Esses resultados demonstram que a incorporação do extrato de *S. saponaria* em formulações de sabonete líquido é uma excelente opção como tensoativo natural para reduzir o uso de tensoativos aniônicos sintéticos como o LESNa.

Palavras-chave: saponinas, tensoativo, cosméticos, livre de lauril.

1. Introduction

The personal hygiene, perfumery, and cosmetics sector has been growing exponentially over the years (Almukainzi et al., 2022; Rocca et al., 2022) and soaps are among the most used items (Alquadeib et al., 2018). They have the function of removing dirt from the body helping to maintain skin health (Rai et al., 2021).

Soaps are used in various parts of the human body, however, to be used in the intimate region, the pH needs to be adjusted between 3.8 and 4.5, in order to contribute to the maintenance of vaginal flora and protection against diseases such as candidiasis and bacterial vaginosis (Bezerra et al., 2016). They are presented in solid or liquid forms, although the ease of pH adjustment is an advantage of liquid soaps.

Surfactants are the main ingredients of liquid soaps, organic substances of amphipathic character that

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have a hydrophilic portion and a hydrophobic portion (Felipe and Dias, 2016) and despite the different classes, anionic surfactants are the most used, due to their detergency and cleaning potential, while cationic, amphoteric, and non-ionic are used as secondary surfactants for foam stabilization and maintenance of skin hydration (Jurek et al., 2021).

The high demand of the sector for low-cost products associated with cleaning effectiveness makes synthetic surfactants derived from petrochemicals the most used (Wojtoń et al., 2021), however, the interest of the industry in replacing this type of ingredient is increasing due to toxicity to the environment and aquatic life (Johnson et al., 2021), in addition to often being associated with skin, eye, and scalp irritation (Jurek et al., 2021).

In this sense, the environmental concern arising from the use of products from non-renewable raw materials has mobilized studies for more ecological alternatives (Meshram et al., 2021), which can be obtained from natural sources and are less irritating to the skin and biodegradable (Chen et al., 2010; Johnson et al., 2021).

Saponin-rich plants are interesting because saponins are potential surfactants, since they have an amphiphilic character and the ability to produce foam (Bezerra et al., 2018; Tucker et al., 2020; Pradhan et al., 2022) and, although foam is not a guarantee of cleaning, it is an important aspect for the consumer (Daltin, 2011).

Sapindus saponaria L. is an angiosperm, belonging to the Sapindaceae family, found widely in the Brazilian territory (REFLORA - Herbário Virtual, 2023). Its fruits when rubbed under water, produce a soap-like foam (Wei et al., 2021) resulting from the presence of saponins in its metabolic structure (Tsuzuki et al., 2007; Damke et al., 2013; Gasca et al., 2019).

Because it is considered a natural surfactant, *S. saponaria* extract becomes of scientific and biotechnological interest to be used in the development of hygiene and cleaning products (Rai et al., 2021; Souza et al., 2019). Within this context, the objective of the study was to develop an intimate soap formulation using *S. saponaria* extract, as well as to evaluate the stability, and surfactant properties of the formulations.

2. Material and Methods

2.1. Plant material obtention

The *S. saponaria* fruits were collected at the Federal University of Mato Grosso (UFMT) campus of Sinop, municipality of Sinop/MT. Botanical identification was performed at the Centro-Norte-Mato-Grossense Herbarium (CNMT) at the Federal University of Mato Grosso, Campus of Sinop, where an exsiccata was stored under registration number 0759 and code AD2F8E4 at Sistema Nacional de Gestão do Patrimônio Genético e do Conhecimento Tradicional Associado (SisGen).

In the Quality Control laboratory (LaCQ), the fruits were dried in a forced convection drying oven at a temperature of 45 ± 2°C for a period of 48 h. After that, the fruits were ground and stored in a freezer at a temperature of -14 ± 2 ºC for later use.

2.2. Preparation of the extracts

The extracts were prepared by maceration in a 1:4 (w/v) ratio, using 70% ethanol (v/v), for a period of seven days in amber vials, with manual agitation every 24 h. Afterwards, they were filtered and the solvent evaporated in a rotary evaporator under reduced pressure providing an extract with semi-solid consistency which was then stored away from light and under refrigeration at 5 ± 2 ºC (Debiasi et al., 2023).

2.3. Reagents

Ethyl alcohol and propylene glycol were provided by "Synth", coconut fatty acid diethanolamide, Cocamidopropyl betaine, polyethylene glycol 6000 diesterate, hydroxyethyl cellulose and Nipaguard were purchased from "Engenharia das essências", disodium EDTA from "Sintética", citric acid from "Neon" and paraffin from "Vicpharma".

2.4. Formulations development

Three intimate soap formulations were developed, named F1 to F3 according to Table 1. The formulations were developed without the use of anionic surfactants and the ethanolic extract of *S. saponaria* was incorporated into two formulations.

Table 1. Developed formulations of intimate soap.

Phase	Raw material	F1 (%)	F2 (%)	F3 (%)
A	Cocamidopropyl betaine	25	25	15
A	Coconut fatty acid diethanolamide	5	5	10
A	Polyethylene glycol 6000 distearate	3	3	3
B	Propylene glycol	2	2	2
B	Nipaguard	0.2	0.2	0.2
C	*S. saponaria* Extract	0	10	10
C	Disodium EDTA*	0.05	0.05	0.05
C	Distilled water	64.75	54.75	59.75
D	Citric acid	q.s. pH 4-5	q.s. pH 4-5	q.s. pH 4-5

*EDTA- Ethylenediaminetetraacetic acid

The preparation was adapted from the methodology of Esprendor et al. (2019) where phases A, B, and C were heated separately. Phase B was poured over phase A and homogenized, then the volume was completed with phase C. After cooling, the pH was corrected with phase D.

2.5. Quality control and stability of formulations

The organoleptic characteristics and some physico-chemical parameters of the developed formulations were evaluated after 24 h of preparation. The same parameters were evaluated in the preliminary stability tests (alternating temperature cycles of 45 ± 2 ºC and 5 ± 2 ºC every 24 h for a period of 14 days) and accelerated stability, where new formulations were prepared and subjected to different storage temperatures (5, 25, and 45 ± 2 ºC) and exposure to light radiation for a period of 90 days. All tests were performed in triplicate.

2.5.1. Organoleptic characteristics

The formulations had their organoleptic characteristics visually evaluated by verifying homogeneity, color, and odor or changes such as the presence of precipitates, lumps, and dispersed particles (Brasil, 2004; Almukainzi et al., 2022).

2.5.2. Physico-chemical parameters

The parameters were evaluated according to (Cosmetics Europe, 2004; Brasil, 2004):

Centrifugation (Quimis®) was performed at 1000 g for 30 min to check for signs of instability and need for formulation adjustments.

The pH (Del Lab®) and conductivity (Tecnopon®) were evaluated by direct insertion of the electrode into the formulations.

The relative density was performed by the pycnometer method, through the ratio of the sample mass to the water mass at a given temperature, and then calculated the mass density (ρ).

The refractive index (Polax WYA-2S) was evaluated with the equipment previously calibrated with distilled water.

2.5.3. Rheological characterization

The rheological analysis was performed using a Modular Compact Rheometer – MCR 102 (Anton Paar®, Germany) coupled to the Rheoplus V3.61 Software, with permanent control of the measurement gap with a 0.099 mm TruGap™ support, a Toolmaster™ CP 50 measuring cell, and precise temperature control with the T-Ready™ feature. The assay was performed according to Ribeiro et al. (2020) using 600 µL of sample.

For the flow and viscosity curves, the shear stress (τ) was stablished to vary from 0 to 5 Pa for the upward curve and from 5 to 0 Pa for the downward curve. These measurements were performed under isothermal conditions at 25 ° C, comprising 75 readings per analysis.

2.5.4. Determination of Surface Tension (γ)

It was performed by the drop-counting method (Teixeira Neto et al., 2009) with solutions at concentrations of 0.1, 1.0, and 10% of formulations F1, F2, F3, and *S. saponaria* extract. The number of drops formed in a constant flow of 3 mL was correlated with the surface tension through the Equation 1 below:

$$\gamma sample = H_2O\ drop\ number \times \gamma H_2O / sample\ drop\ number \quad (1)$$

Where **γ**= surface tension and H_2O = water.

2.5.5. Determination of Foaming Power and Foam Stability

The foaming power and foam stability were determined by the stirring method (Chen et al., 2010; Gomes et al., 2022), where 20 mL of solutions at 0.5% and 1.0% (v/v) concentrations of formulations F1, F2, F3, and *S. saponaria* extract were manually stirred for 15 s and, after 30 s of rest, the volume (mL) of the formed foam was measured. After 5 min of rest, the foam stability (R5) was determined by the Equation 2:

$$R5 = (foam\ volume\ after\ 5\ min / foam\ volume\ after\ 30\ s) \times 100 \quad (2)$$

Where R5 = ratio of foam volume in 5 min to foam volume in 30 s

2.5.6. Determination of the Emulsification

The percentage of emulsification was measured using the methodology of Basu et al. (2015) where 2 mL of liquid paraffin and 2 mL of formulations F1, F2, F3, and of the *S. saponaria* extract were subjected to agitation in a Vortex mixer (Norte Científica, model NA 3600) for a period of 2 min and then allowed to rest for 24 h. The percentage of paraffin emulsification was determined using the Equation 3:

$$\% \text{ emulsification} = \text{emulsified area height / total solution height} \quad (3)$$

2.6. Analysis of the results

The results of the stability tests were subjected to analysis of variance (ANOVA) and the significant difference between the mean values were verified by Tukey's multiple comparisons test with 95% significance ($p<0.05$). Results were expressed as mean ± standard deviation using the Origin Pro software version 8.5.1 (OriginLab©).

3. Results and Discussion

Three formulations of liquid soap for the intimate area were prepared. They were liquid, homogeneous and translucent. The formulations in which the extract was incorporated had a brown color and a sweet smell, characteristic of the fruit.

The surfactants used were an extract obtained from *S. saponaria* and amphoteric and non-ionic auxiliary surfactants to contribute to foam stability and hydration. The most commonly used anionic surfactant, SLES, was not present in the formulations.

In the case of liquid soaps, formulating a product that replaces anionic surfactants such as Sodium Lauryl Ether Sulphate (SLES) is a challenge, as they are associated with factors such as foaming and cleaning (Jurek et al., 2021). The use of natural surfactants rich in saponins has been gaining prominence as they contribute to the detergency and emulsification process (Panotin et al., 2022).

The industry's interest in natural ingredients reflects consumer demand for less aggressive and more sustainable products, and the replacement of synthetic raw materials with natural ingredients offers better biocompatibility and less risk of allergens, as well as socio-environmental benefits with impact reduction (Rocca et al., 2022).

Table 2 shows the results for the organoleptic characteristics and physico-chemical parameters obtained during the preliminary stability test of formulations F1, F2, and F3, which remained stable at the end of the 14-day cycle.

The preliminary stability parameters (Table 2) showed the adequacy of the formulations, remaining stable throughout the entire period. New samples were prepared and subjected to accelerated stability (Table 3).

The formulations stored at a temperature of 25 ºC maintained all their organoleptic characteristics during the 90-day test period. The pH values were stable and within the established range of 4.0 to 4.5. Although there is no consensus, the literature suggests that the pH of intimate soaps should be in this range, as this prevents an imbalance of the intimate microbiota (Sousa et al., 2019; Gupta et al., 2019).

The incorporation of *S. saponaria* extract as a natural surfactant favored the acidic pH of the intimate liquid soap formulations because, due to the extract's pH of 4.29, the formulations had a pH of 3.8 to 4.8, being possible to adjust formulations to the desired range if necessary.

The electrical conductivity values of the formulations contributed to the evaluation of stability since the increase or decrease of these values are indicators of coalescence or aggregation of constituents in the formulation (Brasil, 2004).

The formulations submitted to a temperature of 5 ºC presented similar results to the formulations at 25 ºC. At a temperature of 45 ºC, all formulations presented one or more changes (color, pH, and electrical conductivity). Changes at high temperatures are expected, by the possibility of evaporation of water from the formulation, or by enzymatic oxidation of compounds present in the extract that are sensitive to temperature (Silva and Cavalcante, 2022).

When subjected to light radiation, the formulations remained stable, that is, they did not present any type of change, showing that transparent packaging can be used, which favors the acceptance of the product by the consumer (Pires et al., 2021; Silva and Cavalcante, 2022).

The mass density result of the formulations (Table 4) was between 1.0369 and 1.0562 g/mL. Although there are no established values for density, authors such as Hawa et al. (2022) and Pires et al. (2021) found values between 1.0077 and 1.066 g/mL with plant extracts. According to Rusdianto et al. (2021), values between 1.01 and 1.10 g/mL are acceptable for liquid soaps. This is an important parameter since it interferes with consumer experience with the product and the weight and volume of the final packaging (Brasil, 2004).

The rheology of the formulations showed that the behavior of the upward and downward flows occurs in a non-linear manner and that as the shear rate increases, a slight decrease in viscosity occurs (Figure 1 and Figure2), demonstrating that the samples behave as pseudoplastic type non-Newtonian fluids with a tendency to Newtonian, verified by the minimum hysteresis area.

Literature reports that pseudoplastic behavior is a desirable characteristic in liquid soaps because it is related to the consistency of the formulation (Kumar and Mali, 2010; Sharma et al., 2011; Alquadeib et al., 2018). Also, the incorporation of the extract into the formulations led to a reduction in viscosity from approximately 3.5 Pa·s to values less than 0.5 Pa·s, a behavior that provides less resistance to flow and improves characteristics such as spreadability (Cornwell, 2018).

The surface tension has great significance in the evaluation of liquid soap formulations since it is related to the detergency process. Figure 3 shows the surface tension data of formulations F1, F2, F3, and *S. saponaria* extract, which ranged from 48.22 to 31.72 m/Nm as the concentration of the samples increased.

All formulations showed good surface tension reduction and the addition of the extract in F2 and F3 potentiated this effect in all concentrations evaluated. This is an important parameter to be analyzed since surfactants, when in aqueous solutions, tend to interfere with factors such as wettability, wetting (Daltin, 2011), cleaning potential and particle dispersion (Teixeira Neto et al., 2009).

The extract of *S. saponaria* presented a minimum surface tension value of 48.22 m/Nm. Formulations and extracts analyzed by Kumar and Mali (2010), Wojton et al. (2021), and Yang et al. (2010), presented corroborating surface tension values and although there are no pre-established values of surface tension, these data indicate that *S. saponaria* extract offers the potential to be used for detergent purposes.

Table 2. Organoleptic characteristics and physico-chemical parameters of intimate soap formulations during the preliminary stability test.

Time	Formulation	Color, Odor and Appearance	pH	Electric Conductivity (mS/cm)	Refractive index
After 24 h	**F1**	N	4.03 ± 0.37	16.91 ± 0.20	1.3704 ± 0.01
	F2	N	4.14 ± 0.24	15.26 ± 0.12	1.3877 ± 0.02
	F3	N	4.16 ± 0.24	10.25 ± 0.19	1.3975 ± 0.01
After 14 days	**F1**	N	4.06 ± 0.14	16.85 ± 0.18	1.3755 ± 0.01
	F2	N	4.13 ± 0.36	15.22 ± 0.20	1.3946 ± 0.00
	F3	N	4.17 ± 0.36	10.07 ± 0.19	1.3875 ± 0.02

Appearance, color and odor: N – normal. Results expressed as mean values and relative standard deviation.

Table 3. Accelerated stability test of intimate soap formulations at different temperatures (5, 25, and 45 ± 2 ºC) and light radiation (UV).

Sample	T (ºC)	Days	Organoleptic Characteristics	pH	Electric Conductivity (mS/cm)	Refractive Index
F1	5 ± 2	0	N	4.23 ± 0.00	15.53 ± 0.00	1.3705 ± 0.00
		30	N	4.28 ± 0.13	15.85 ± 0.28	1.3711 ± 0.02
		60	N	4.30 ± 0.13	15.64 ± 0.09	1.3704 ± 0.02
		90	N	4.30 ± 0.35	15.72 ± 0.47	1.3710 ± 0.03
	25 ± 2	0	N	4.23 ± 0.00	15.53 ± 0.00	1.3705 ± 0.00
		30	N	4.24 ± 0.35	15.99 ± 0.25	1.3745 ± 0.02
		60	N	4.26 ± 0.23	15.81 ± 0.41	1.3744 ± 0.04
		90	N	4.26 ± 0.13	16.08 ± 0.12	1.3722 ± 0.02
	45 ± 2	0	N	4.23 ± 0.00	15.53 ± 0.00	1.3705 ± 0.00
		30	M	4.46 ± 0.48	16.26 ± 0.21	1.3744± 0.046
		60	M	4.50 ± 0.15	16.67 ± 0.19	1.3752 ± 0.06
		90	M	4.57 ± 0.15	16.49 ± 0.08	1.3728 ± 0.01
	UV	0	N	4.23 ± 0.00	15.53 ± 0.00	1.3705 ± 0.00
		30	N	4.27 ± 0.27	16.00 ± 0.40	1.3732 ± 0.03
		60	N	4.32 ± 0.13	16.52 ± 0.36	1.3732± 0.04
		90	N	4.29 ± 0.46	16.49 ± 0.12	1.3771 ± 0.04
F2	5 ± 2	0	N	4.25 ± 0.00	13.62 ± 0.00	1.3812 ± 0.00
		30	N	4.27 ± 0.35	13.70 ± 0.40	1.3850 ± 0.03
		60	N	4.28 ± 0.13	13.67 ± 0.37	1.3848 ± 0.06
		90	N	4.27 ± 0.46	13.70 ± 0.22	1.3824 ± 0.02
	25 ± 2	0	N	4.25 ± 0.00	13.62 ± 0.00	1.3812 ± 0.00
		30	N	4.24 ± 0.23	13.84 ± 0.15	1.3882 ± 0.05
		60	N	4.22 ± 0.23	13.88 ± 0.40	1.3878 ± 0.02
		90	N	4.23 ± 0.36	13.89 ± 0.21	1.3849 ± 0.04
	45 ± 2	0	N	4.25 ± 0.00	13.62 ± 0.00	1.3812 ± 0.00
		30	M	4.26 ± 0.16	13.65 ± 0.25	1.3840 ± 0.03
		60	M	4.27 ± 0.13	13.95 ± 0.25	1.3834 ± 0.05
		90	M	4.27 ± 0.13	14.02 ± 0.10	1.3848 ± 0.03
	UV	0	N	4.25 ± 0.00	13.62 ± 0.00	1.3812 ± 0.00
		30	N	4.24 ± 0.35	13.58 ± 0.25	1.3873 ± 0.03
		60	N	4.25 ± 0.13	13.87 ± 0.23	1.3879 ± 0.03
		90	N	4.24 ± 0.35	13.94 ± 0.21	1.3847 ± 0.01
F3	5 ± 2	0	N	4.28 ± 0.00	12.19 ± 0.00	1.3848 ± 0.06
		30	N	4.28 ± 0.13	12.67 ± 0.19	1.3865 ± 0.03
		60	N	4.30 ± 0.13	12.43 ± 0.42	1.3864 ± 0.04
		90	N	4.29 ± 0.13	12.55 ± 0.21	1.3860 ± 0.02
	25 ± 2	0	N	4.28 ± 0.00	12.19 ± 0.00	1.3859 ± 0.00
		30	N	4.24 ± 0.13	12.36 ± 0.28	1.3890 ± 0.03
		60	N	4.25 ± 0.13	12.16 ± 0.21	1.3909 ± 0.02
		90	N	4.30 ± 0.48	12.69 ± 0.23	1.3852 ± 0.05
	45 ± 2	0	N	4.28 ± 0.00	12.19 ± 0.00	1.3859 ± 0.00
		30	M	4.47 ± 0.31	11.04 ± 0.10	1.3822 ± 0.01
		60	M	4.50 ± 0.12	10.69 ± 0.33	1.3846 ± 0.04
		90	M	4.58 ± 0.21	10.30 ± 0.20	1.3833 ± 0.02
	UV	0	N	4.28 ± 0.00	12.19 ± 0.00	1.3859 ± 0.00
		30	N	4.28 ± 0.23	12.21 ± 0.12	1.3882 ± 0.04
		60	N	4.29 ± 0.13	12.67 ± 0.20	1.3907 ± 0.06
		90	N	4.29 ± 0.48	12.84 ± 0.20	1.3928 ± 0.04

Appearance, color and odor: N – normal, M – modified. Results expressed as mean values and relative standard deviation.

Foam, although not essential and does not contribute to the detergency process, is a relevant factor for the consumer when choosing a soap, due to the fact it is associated with greater cleaning power (Rai et al., 2021). Foam height values are in Table 5.

The formulation without extract, F1, presented foam volume values of 96 and 108 mL in 0.5 and 1.0% solutions. The incorporation of the extract in formulations F2 and F3 contributed in enhancing this power. These values corroborate those found in shampoos (formulation with characteristics similar to liquid soaps) with plant extracts by Sharma et al. (2011) and Panotin et al. (2022).

The foam potential of the extract in a solution at the same concentrations of the formulations demonstrated that the foam increase percentage of the formulations is equivalent to the foam percentage of the extract solution at the same concentration of the formulation solution. The legislation does not present pre-established values for this parameter, but the findings are in agreement with authors such as Rusdianto et al. (2021) and Meshram et al. (2021), who worked with plant extracts.

Table 4. Mass density of intimate soap formulations.

Sample	Density (g/mL)
F1	1.0369 ± 0.01
F2	1.0478 ± 0.00
F3	1.0562 ± 0.00

Results expressed as mean values and relative standard deviation.

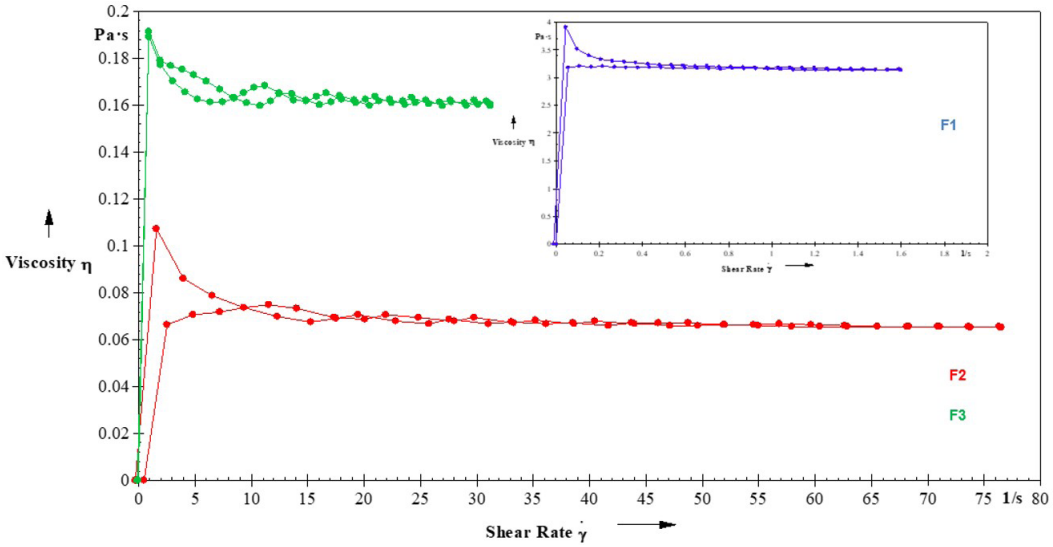

Figure 1. Viscosity curve by shear rate of formulations F1, F2 and F3.

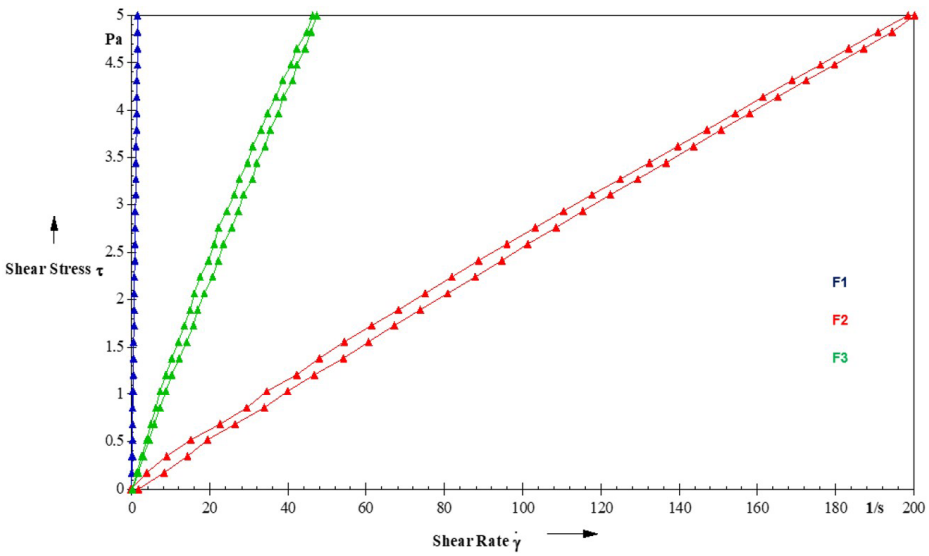

Figure 2. Shear stress by shear rate curve of formulations F1, F2 and F3.

Table 5. Foaming power and foam stability of F1, F2, F3, and *S. saponaria* extract in 0.5% and 1.0% solutions, measured after 30 s and after 5 min.

Sample	Foam (cm)					
	0.5% after 30 s	0.5% after 5 min	R5* (%)	1.0% after 30 s	1.0% after 5 min	R5* (%)
F1	96 ± 1.28	77 ± 1.48	80.20	108 ± 1.04	76 ± 1.44	70.37
F2	304 ± 0.36	280 ±0.34	92.10	332 ± 0.33	299 ± 0.32	90.06
F3	325 ± 0.34	294 ± 0.38	90.46	360 ± 0.31	327 ± 0.34	90.83
Ext	191 ± 1.55	166 ± 1.35	86.91	235 ± 0.82	197 ± 0.99	83.82

*R5 is the ratio of foam volume in 5 min to volume in 30 s. Results expressed as mean values and relative standard deviation.

Table 6. Percentage of paraffin emulsification for formulations F1, F2, F3, and *S. saponaria* extract.

Sample	% Emulsification
F1	18.47 ± 2.17
F2	88.75 ± 1.99
F3	89.90 ± 1.58
Ext 10%	62.90 ± 3.62

Results expressed as mean values and relative standard deviation.

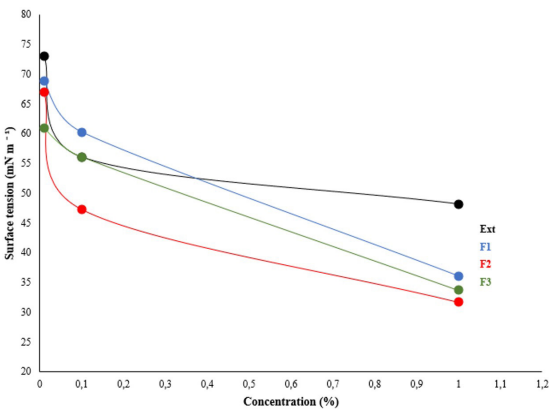

Figure 3. Surface tension of formulations F1, F2 and F3, and *S. saponaria* extract at concentrations of 0.01%, 0.1% and 1% through the drop-counting method.

The stability of the foam over time is an important aspect for the consumer because it means that the foam does not evaporate immediately when it comes into contact with the environment. All formulations showed good foam stability, and in F2 and F3, the presence of the extract enhanced stability, remaining greater than 90%. These results are in line with those found by Panotin et al. (2022) and Hawa et al. (2022) in formulations with plant extracts.

Regarding the foam stability of the *S. saponaria* extract at 0.5%, the value of 86.73% was found, results consistent with the findings of Chen et al. (2010), Yang et al. (2010), and Meshram et al. (2021). Foaming stability is associated with activity at the liquid-air interface, thus, it is a parameter that contributes to justify the potential of the extract as a surfactant (Wisetkomolmat et al., 2019).

The cleaning potential (Table 6) was calculated by the percentage of paraffin emulsification, and the values ranged between 18.47 and 89.90%.

F1, which does not have the extract in its composition, presented a value of 18.47%, and the addition of *S. saponaria* extract to F2 and F3, enhanced the emulsification, with results close to 90%. *S. saponaria* extract in a 10% solution showed 62.20% of emulsification, demonstrating excellent potential for incorporation into cleaning formulations. Natural surfactants need to have an emulsifying activity of 50 to 90% (Bezerra et al., 2018), a fact that is directly related to the surfactant potential of the product (Daltin, 2011). The values found corroborate the results of authors such as Saripalla et al. (2022) and Basu et al. (2015) in formulations and in plant extracts.

Emulsification is an important attribute because it is related to detergency through the removal of dirt from the body, such as oiliness (Daltin, 2011) and also brings the possibility of *S. saponaria* extract being used as an emulsifier in cosmetic formulations.

4. Conclusions

The incorporation of *S. saponaria* extract in an intimate soap formulation enabled the development of stable formulations at an appropriate pH for the intimate region and potentiated parameters such as emulsifying capability, foam, and reduction of surface tension.

Also, the replacement of synthetic surfactants such as SLES by a natural one contributes to sustainability due to its greater biodegradability, in addition to minimizing risks of skin irritations, which makes this formulation of intimate soap with *S. saponaria* extract an innovative option.

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