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Physical and sensory characteristics of soaps obtained using red hot pepper seeds oil (*Capsicum annuum* L.)

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Abstract. Sensory profile of cosmetic products, including soaps, is essential to consumer perception. Therefore, soap manufacturers, using new and alternative raw materials, strive to improve the appearance of soaps, their consistency, their ability to foam, the feeling of cleanliness, the feeling on the skin after use, etc. The aim of this research is to determine the quality and sensory characteristics of soaps obtained with hot pepper seeds oil (*Capsicum annuum* L.) – an alternative raw material from waste plant products. Four different soap variations were crafted, employing diverse combinations of palm oil, coconut oil, and hot pepper seed oil in their formulations. Certain quality attributes of the soaps were assessed, including hardness, stickiness, and surface tension. Also, the sensory evaluation was made. The conclusions drawn from the study align with the findings obtained through physicochemical and chemical analyses of the soap samples. The results affirm the potential of hot pepper seed oil for cold process soap production, albeit within a restricted range to 10 %.

1 Introduction

Modern consumer preferences are directed towards soaps with natural, new and non-traditional ingredients – glyceride oils, essential oils, extracts, herbs, spices, nuts, etc. That is why there is also interest from science and business in the so-called “handmade” or "homemade” soaps with natural ingredients and original design [1-4]. There is a trend towards ecological and natural products. This determines the need for the search for alternative raw materials for oils from renewable sources. Such raw materials are waste vegetable products, from which glyceride oils are obtained with a composition and qualities that allow their use, not only in food, but also in cosmetic products.

Sensory evaluation is important for assessing the quality and sensory characteristics of soaps. It helps in determining the hardness, stickiness, surface tension, cleansing, aroma, color of the soap.

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In the present study, glyceride oil from the seeds of hot pepper − *Capsicum annuum* L., variety Cayenne, was used for the production of cold process soap. Certain quality attributes of the soaps were assessed, including hardness, stickiness, and surface tension. Also, the sensory evaluation was made.

Soap hardness serves as a significant consumer indicator, influencing its durability, wear resistance, and usability comfort. Water content plays a crucial role in determining soap hardness; higher water content correlates with lower hardness, leading to decreased resistance during usage [5-6]. Additionally, the selection of fatty acids (FA) utilized in soap manufacturing contributes significantly to its hardness, influencing the soap's structure and texture [7-8].

To analyze the texture of the soaps, including surface characteristics, consistency, and resistance during use, the following parameters are assessed: hardness, modulus of deformation, work of deformation, force of adhesion, and work of adhesion. Such studies in the literature are scarce, or the hardness of soaps has mainly been studied using a similar methodology [7-10].

Another measure of soap quality, albeit less commonly employed, is the surface tension of soap solutions. Key determinants influencing the surface tension of soap solutions include the solubility of the soap, the length of the fatty acid hydrocarbon chain, and the concentration of the solution [11]. The cleaning action of soaps is related to surface tension as well as critical micellar concentration (CMC). The higher CMC and lower surface tension of aqueous solutions of soaps are associated with the formation of more micelles, therefore a more effective cleaning action [12].

According to the literature, for determining the consumers' acceptance or preference of soaps, the appearance, consistency, foaming, cleaning action, feeling on the skin after washing must be evaluated [2,6,13,14].

In the present study, glyceride oil from the seeds of hot pepper − *Capsicum annuum* L., variety Cayenne, was used for the production of cold process soap. Certain quality attributes of the soaps were assessed, including hardness, surface tension and stickiness. In view to create a competitive product on the market, the consumer preferences were analyzed, through a sensory evaluation of soaps.

2 Materials and methods

Four soap variants (designated as samples №1 to №4) containing varying proportions of palm oil (PO), coconut oil (CO), and hot pepper seeds oil (HPO) were formulated. The oil blend compositions for each of the four samples are detailed in Table I.

Table 1. Oil blends used for soap samples.

Oil components	**Oil blends №**			
	1	**2**	**3**	**4**
Hot pepper seeds oil (HPO)	-	5	10	20
Palm oil (PO)	80	75	70	60
Coconut oil (CO)	20	20	20	20

2.1 Sensory characteristics

The analysis of the soaps involves a researching the opinions of test subjects after application of the products. The indicators evaluated by them are appearance, color, resistance to erosion, foaming, hardness and overall perception after using the soap.

2.2 Surface tension. Maximum pressure method (Rebinder method)

The maximum pressure (*Pmax*) required to expel the air bubble from the tip of the capillary is determined. The capillary is submerged in the test solution, and the pressure is generated using a water manometer. Surface tension is according to equation (1).

$$\gamma = \frac{rg}{2}(\Delta H \rho_0 - r\rho) \quad (1)$$

where: γ – surface tension (mN/m), r – capillary radius (m), g – ground acceleration (m/s^2), ΔH – maximum difference at both ends of the manometer, ρ_0, ρ – relative water densities and test solution (kg/m^3).

2.3 Determination of relative density of soap solutions

First, a thoroughly dried empty pycnometer is weighed using an analytical balance. Subsequently, it is filled with the test solution and weighed once more. Finally, the pycnometer is filled with distilled water of a specific density and weighed again. This parameter is determined by equation (2):

$$\rho = \frac{m_1 - mg}{m_2 - m}\,\rho_0 \quad (2)$$

where: ρ – relative density of the test solution (kg/m^3), ρ_0 – density of water (kg/m^3), g – ground acceleration (m/s^2), m – mass of empty pycnometer (g), m_1 – mass of pycnometer with test solution (g), m_2 – mass of pycnometer with water (g).

2.4 Hardness and stickiness of the Texture Analyzer device

A Texture analyzer was used − Stable Micro systems TAXT2. To investigate the texture parameters, a penetration experiment ware performed by cylinder (Ø = 5 mm, speed of the deformation was 1 mm/s and maximum deformation was 5 mm). The hardness, deformation modulus, work of deformation, tensile strength and work of adhesion were derived from the curves. The curves characteristics define the rheological condition of the soaps, ranging from "soft-hard" or "elastic-hard" to highly visco-elasto-plastic fluid [15].

3 Results and discussion

Sensory analysis of the four samples of soap with HPO was performed with a panel of 20 evaluators. Every evaluator assigns a score ranging from 1 to 5 for each indicator, including surface appearance, color, erosion resistance, foaming ability, hardness, and overall perception post-usage. The data are presented in Table 2.

Regarding the initial criterion of surface condition assessment, factors such as the presence of stains, cracks and deformations are considered. Sample №1 received the highest rating (4.85), while a slightly lower level of surface integrity was observed for sample №4 (4.65).

The pattern repeats for the color assessment: sample № 1 exhibits the lightest hue. This observation aligns with visual expectations, as sample № 1 comprises solely coconut and palm oil, which are light colors. As the amount of hot pepper seed oil (HPO) increases sequentially in the samples, sample № 4 emerges as the darkest (with the most intense orange color).

Regarding the erosion resistance indicator, all samples received the highest rating (5) from the evaluators, indicating stability during usage and absence of disintegration. In terms of hardness, the ratings are consistent across all samples, with sample № 4 receiving the lowest score at 3.5.

Table 2. Consumer test.

Samples №		**Assessed indicators**					
		Appearance			Foaming	Hardness	Overall perception
		Surface	Color	Resistance to erosion			
№ 1	Average	4.85	4.15	5.00	3.70	4.05	4.05
	St. dev.	0.37	0.37	0.00	0.47	0.31	0.60
	St. error	0.08	0.08	0.00	0.11	0.07	0.14
№ 2	Average	4.70	2.95	5.00	3.75	4.05	3.80
	St. dev.	0.47	0.89	0.00	0.79	0.60	0.70
	St. error	0.11	0.20	0.00	0.18	0.14	0.16
№ 3	Average	4.70	2.90	5.00	3.15	3.75	4.30
	St. dev.	0.47	0.85	0.00	0.93	0.44	0.73
	St. error	0.11	0.19	0.00	0.21	0.10	0.16
№ 4	Average	4.65	1.90	5.00	2.85	3.50	4.30
	St. dev.	0.49	0.72	0.00	0.67	0.51	0.57
	St. error	0.11	0.16	0.00	0.15	0.11	0.13

The highest score for the foaming indicator was given for sample № 2 – 3.75; the estimate given for sample № 1 is also close – 3.70. Sample № 4 has the lowest score for this indicator – 2.85. These results match with the data obtained from the chemical analyses.

The conclusion of the sensory analysis shows that consumers give the highest overall perception rating to samples № 3 and № 4 – 4.3. The sensor profile is presented in Figure 1.

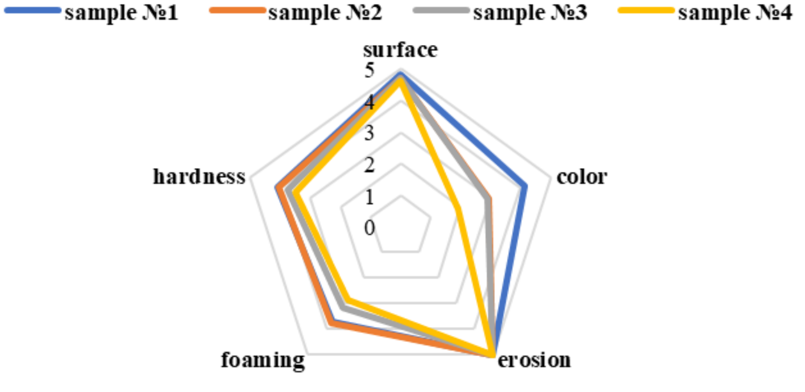


Fig. 1. Sensory analysis

The overall perception serves as a crucial factor influencing consumer preferences. It is gauged by the sensation experienced on the skin post-soap usage, encompassing aspects such as softness, moisture level, dryness, tautness, and so on, which significantly impact consumer satisfaction. Among the five samples, sample № 3 received the highest rating.

The relative density and surface tension values for the soap solutions of the four soap samples with HPO were determined. The data are presented in Table 3.

Table 3. Relative density and surface tension of soap solution of solid soaps with hot pepper seed oil.

№	**ρ (kg/m³)**	**γ (mN/m)**
1	0.818 ± 0.013[a]	37.062 ± 3.565
2	0.947 ± 0.017	61.268 ± 1.878
3	0.943 ± 0.014	55.504 ± 1.415
4	0.939 ± 0.009	49.692 ± 2.302

a. All data are presented as mean value ± standard deviation (n=3).

Solution № 1 exhibits the lowest values for both parameters, suggesting it will demonstrate the highest stability during prolonged testing. Higher surface tension correlates with reduced solution stability. Following this classification, solution № 4 ranks second in terms of stability.

Soap solutions of samples № 2, № 3 and № 4 have higher surface tension than that of the control sample, respectively – 61.268, 55.504 and 49.692 mN/m. The results show that the surface tension of the soap solutions significantly decreases with increasing percentage of HPO in the soap, but the values are not lower than those of the control sample № 1.

The surface tension measurements obtained in the current study align closely with those reported in the literature [12,16].

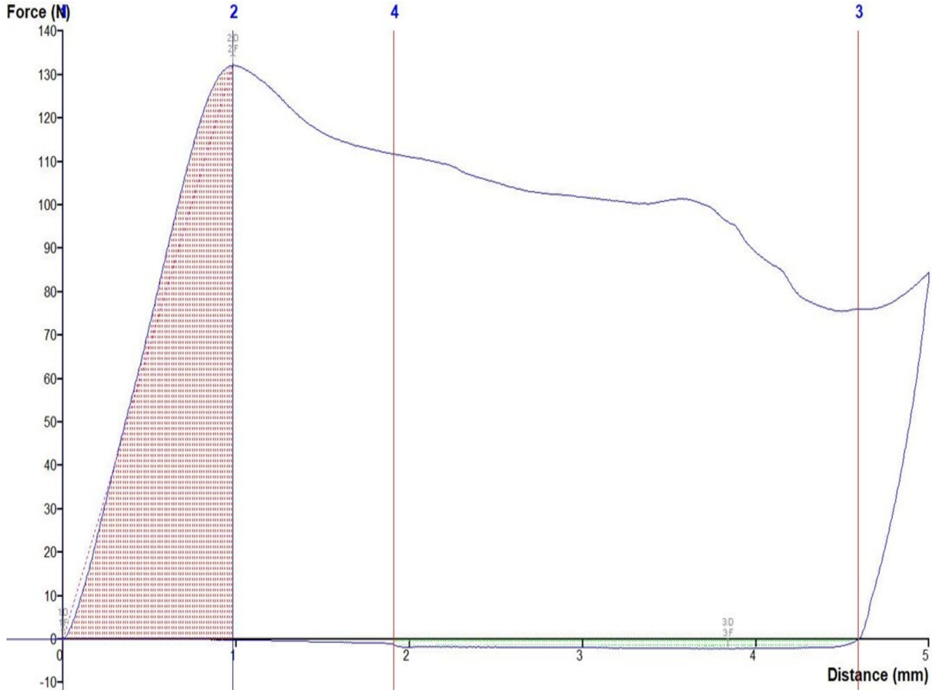
The parameters − hardness, modulus of deformation, deformation work, adhesion force and stickiness were also examined for the soap samples, with the respective outcomes presented in Table 4. Soap samples labelled from № 1 to № 4 correspond to designations sN_1 to sN_4 in Table 4. and the accompanying diagrams in Figure 2 and Figure 3.

Table 4. Hardness of soaps

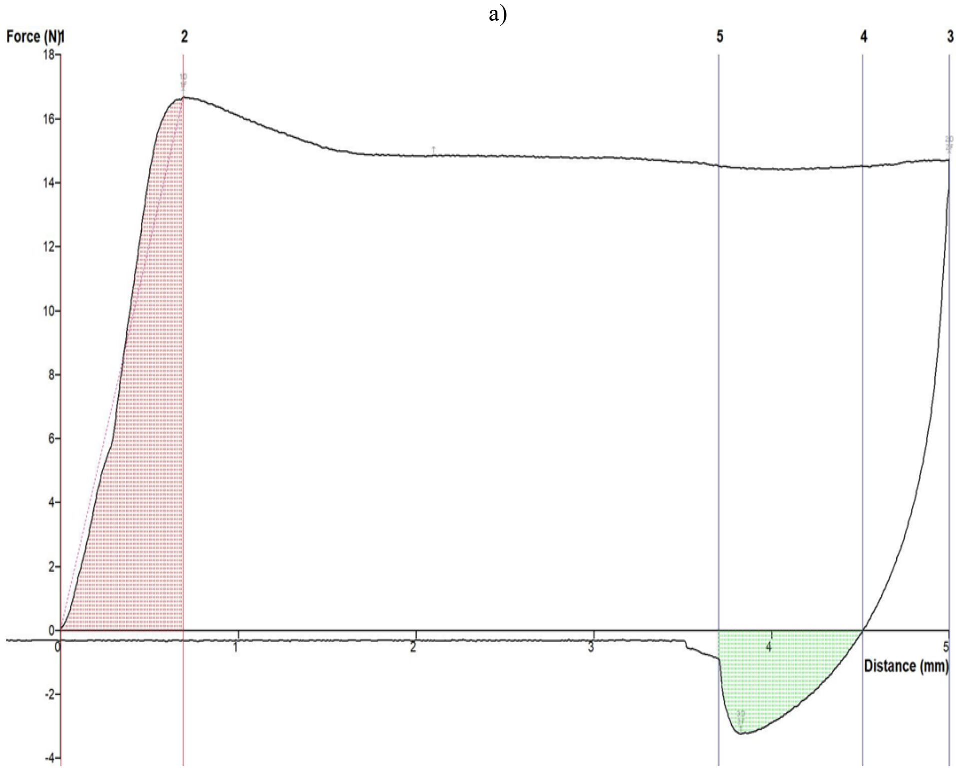
	Hardness (N)	**Modulus of deformation (N/mm)**	**Deformation work (N.mm)**	**Adhesion force (N)**	**Stickiness (N.mm)**	**Hardness2 (N)**
	avg±std	avg±std	avg±std	avg±std	avg±std	avg±std
sN_1	134.187 ± 1.908d	132.153 ± 15.482d	70.756 ± 4.717de	4.167 ± 0.610bc	-5.228 ± 0.117c	Is not available
sN_2	15.714 ± 1.499c	10.640 ± 1.490a	10.718 ± 1.435b	-3.556 ± 0.455b	-1.401 ± 0.194b	Is not available
sN_3	13.103 ± 0.932b	16.087 ± 2.619b	4.273 ± 0.763a	-1.986 ± 0.296a	-0.394 ± 0.045a	Is not available
sN_4	9.370 ± 0.574a	11.614 ± 1.020a	3.675 ± 0.441a	-3.259 ± 0.539b	-1.871 ± 0.250c	9.972 ± 0.687a

When the lowercase characters or letters are identical, this indicates one group according to statistics (i.e., there is no significant difference). When the symbols or letters are different, this indicates that the groups are also different according to statistics. When there are double letters (such as "ab"), this means there are differences on the border between the groups.

From the results, it can be seen that sample sN_1, in which there is no HPO, is the hardest. The hardness value of the control sample (134.187 N) was significantly higher than that of the soaps containing the oil (15.714; 13.103 and 9.370 N) for sample sN_2, sN_3 and sN_4, respectively. This shows that the inclusion of this oil in the soap formulation (even in small amounts) greatly affects its hardness. The resistance to deformation in use of the soaps is similar for samples sN_2, sN_3 and sN_4 (10.640; 16.087 and 11.614 N/mm) and much lower than that of the control sample (132.153 N/mm). The adhesion force has the highest value in the control sample, respectively -4.167 N. In sample sN_4, a second hardness (9.972 N) is also found, which determines an inhomogeneous texture and unequal evaporation of water from the soap.

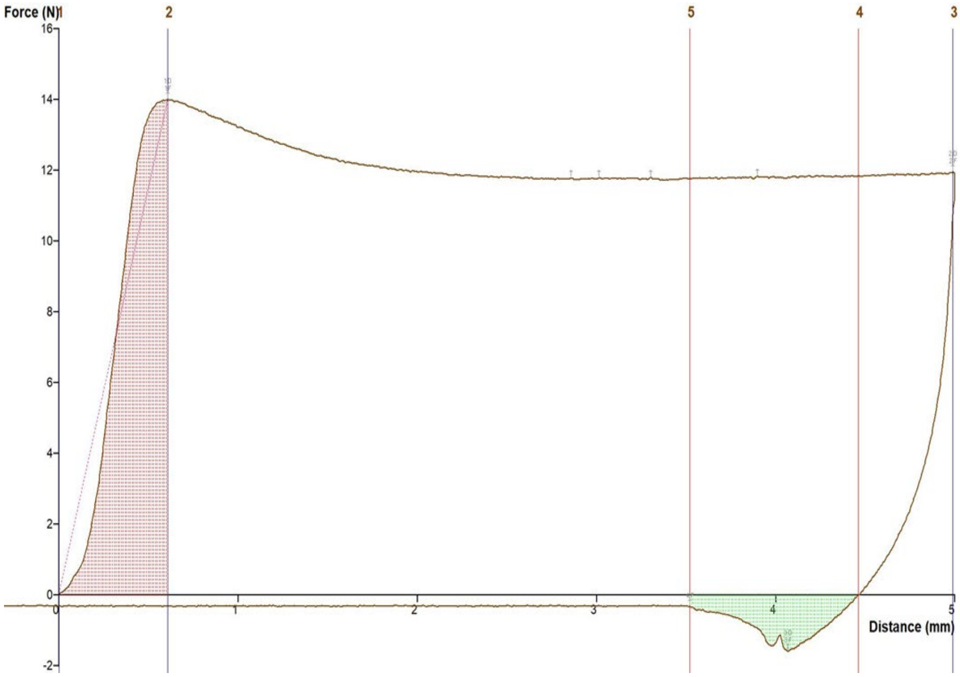


a)

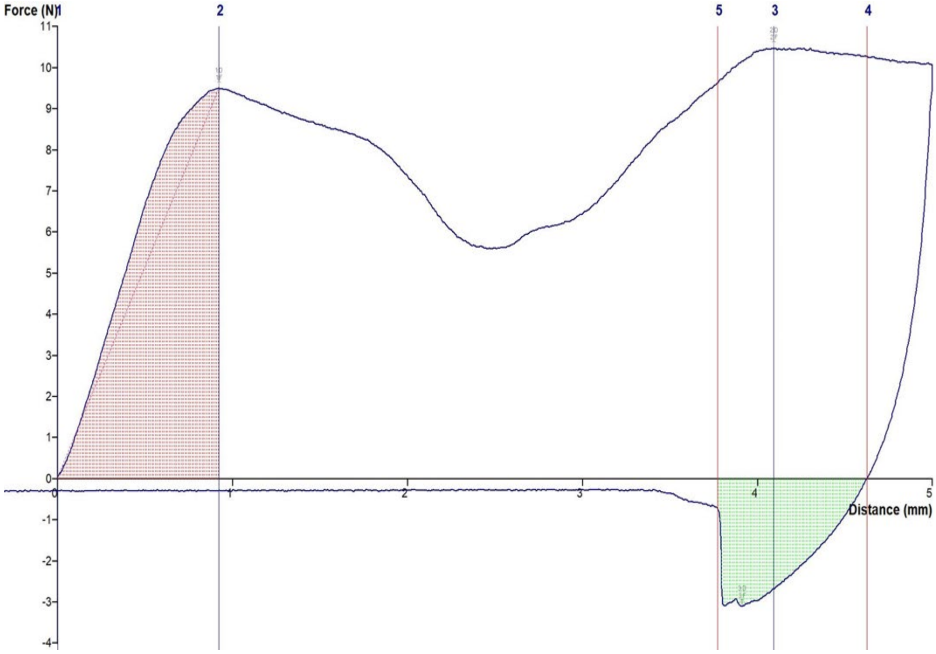


b)

Fig. 2. Hardness diagrams of soap samples: a) sN_1: Hardest soap, plastic-elastic body, medium but relatively low stickiness; b) sN_2: Hard soap, plastic, with high stickiness.



a)



b)

Fig. 3. Hardness diagrams of soap samples: a) sN_3: Medium hard soap, plastic, with relatively low stickiness; b) sN_4: Softest soap, plastic-elastic body, with great stickiness.

From the mean diagrams of the soap samples presented in Figure 2 and Figure 3 it is clearly seen that samples sN_2, sN_3 and sN_4 are much softer and more plastic than the control sample sN_1.

4 Conclusion

The results of the sensory evaluation conducted after application of the product show that the appearance of soaps with HPO meets the requirements for this category of cosmetic products – their surface is smooth, there are no irregularities and deformations. The soap with included HPO cleans without irritating and drying the skin. After using it, the feeling on it is most acceptable, thanks to the participation of HPO.
Adding more than 10 % of HPO to the oil mixture has a negative impact on the quality characteristics of the soap – hardness and resistance to use. The conclusions drawn from the study align with the findings obtained through physicochemical and chemical analyses of the soap samples. The results affirm the potential of hot pepper seed oil for cold process soap production, albeit within a restricted range to 10 %.

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