Influence of plum seed oil on emulgel sensorial and textural properties

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The applicative characteristics of topical preparations can be assessed using sensory analysis as a subjective method and texture analysis as an objective method. In this study, the sensory and textural properties of an emulgel containing 6% (w/w) plum seed oil, as the natural oil obtained from renewable resources, were compared to a placebo emulgel, in which the plum seed oil was replaced by caprylic/capric triglycerides, commonly used in cosmetic formulations. Both emulgels were semi-solid in consistency, slightly shiny, easy to spread, and demonstrated rapid absorption, low stickiness, and low oiliness. The results indicated that plum seed oil had a comparable influence on the sensory and textural properties of the final product to that of caprylic/capric triglycerides. Differences in sensory characteristics were noted in terms of density, with participants reporting a lower density for the emulgel containing plum seed oil. Texture analysis was conducted 7 days, 14 days, and 28 days after preparation of samples. The texture analysis revealed that the presence of plum seed oil was associated with lower hardness (initial hardness of active emulgel was 0.25 ± 0.01 N while the hardness of placebo emulgel was 0.39 ± 0.04 N), leading to better spreadability. Apart from an increase in cohesiveness over time, likely due to the restructuring of the gel matrix, (from 0.85 ± 0.06 mJ to 1.38 ± 0.31 mJ, and from 0.83 ± 0.04 mJ to 1.62 ± 0.45 mJ for placebo and active emulgel respectively), other texture parameters remained statistically unchanged, indicating the physical stability of the emulgels during the study.

Keywords: plum seed oil; sensorial properties; textural properties; texture analyzer; emollient

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1. INTRODUCTION

In addition to long-term stability, safety and efficacy, one of the most important characteristics of topical preparation is the sensation created when applied to the skin. Therefore, the results of the sensory analysis of cosmetic preparations can be utilized during their development in order to create formulations with predefined sensory properties (Pensé-Lhéritier, 2015). Since the sensory characteristics of cosmetic preparation mainly depend on raw materials such as emollients, emulsifiers, rheological modifiers and humectants, replacing a single ingredient can significantly affect the spreadability and distribution of cosmetic products. For instance, a face cream can easily be modified into a body lotion by substituting an appropriate emollient with the desired sensory characteristics (Savary et al., 2013).
Sensory evaluation is defined as the measurement of product quality based on information gathered through the senses and therefore involves volunteers, *i.e.* trained panelists who evaluate cosmetic preparations (Pensé-Lhéritier, 2015). Often, there is a need for a faster, more quantitative, and objective approach to evaluate the applicative properties of preparations. Therefore, instrumental methods, like textural analysis, were developed. The correlation between textural and sensory characteristics is well-known and considered a valuable tool for understanding user preferences (Vieira et al., 2020). According to ISO 5492:2008 (2008), texture is defined as a combination of the mechanical, geometric, and surface attributes of a product perceived through mechanical, tactile, visual, and auditory receptors. Texture analyzers are instruments used for quantitative measurements of product texture. They consist of a probe that simulates the behavior of a human finger touching the surface of a preparation (ISO, 2008; Martinović et al., 2022). Originally, texture analysis was developed in the food industry to determine the sensory and textural characteristics of food. However,

Table 1. Qualitative and quantitative compositions of placebo emulgel (PE) and active emulgel (AE) samples.

Phase	INCI names	Trade names	Suppplier	PE (% w/w)	AE (% w/w)	Function in the preparation according to the CosIng Database
A	Caprylic/Capric Triglycerides	Myrtiol™ 318	Henkel (Germany)	12.0	6.0	Emollient, skin conditioning,
	Isopropyl Myristate	Isopropyl Myristate	BASF (Germany)	4.0	4.0	Emollient
	Butyrospermum Parkii (Shea) Butter	Shea Butter	Sederma (France)	2.0	2.0	Emollient, skin conditioning, viscosity controlling
	Arachidyl Behenyl Alcohol and Arachidyl Glucoside	Montanov 202	Seppic (France)	5.0	5.0	Emulsifier
B	Hydroxyethylcellulose	Natrosol™ 250 HR	Ashland (Oregon, USA)	1.0	1.0	Gelling agent
	Glycerin	Glycerin	BASF (Germany)	10.0	10.0	Humectant
	Phenoxyethanol Ethylhexylglycerin	EUXYL PE9010	Ashland (Oregon, USA)	1.0	1.0	Preservative
	Water	-	Faculty of Medicine (Niš, Serbia)	65.0	65.0	Solvent in the water phase
C	*Prunus domestica* Seed Oil	-	-	-	6.0	Skin conditioning, emollient, cosmetic active ingredient

texture analysis is also widely used in the cosmetic and pharmaceutical industries, for research and development processes and the selection of the best raw materials (Tai et al., 2014). Additionally, changes in the textural characteristics of preparations can indicate potential changes in their stability (Srivastava et al., 2018).

Emollients are the group of cosmetic ingredients that are most closely related to the applicative properties (Parente et al., 2008). Oils represent the most common group of cosmetic raw materials used in personal care preparations, primarily due to their emollient effect, good composition, and natural origin. Plum seed oil, a sustainable and recyclable waste product of plum brandy production, offers a rich yet underutilized source of bioactive compounds, making it a promising domestic alternative to exotic seed oils in cosmetic formulations (Krasodomska and Jungnickel, 2015; Rodríguez-Blázquez et al., 2024). It contains triglycerides of varying chemical structure. The main fatty acids in oil from *Prunus domestica* seeds are oleic, linoleic, palmitic, stearic, and myristic acids. Besides, the oil also contains other beneficial components such as phytosterols and tocopherols (Matthäus and Özcan, 2009; Natić et al., 2020).

In the study by Savić-Gajić et al., (2022), plum seed oil was suggested as a potential raw material for cosmetic purpose due to its good stability, as well as high polyunsaturated fatty acid (PUFA) content. This oil, characterized by light texture, is quickly absorbed by the skin, hydrates it, protects it from premature ageing and improves its elasticity (Savić-Gajić et al., 2022). In our previous study, we extracted and evaluated fatty oils from the seeds of four plum varieties (Požegača, Čačanska lepotica, Čačanska rodna, and Valjevka), cultivated in Bosnia and Herzegovina, using both supercritical and Soxhlet extraction methods. All four oils exhibited desirable characteristics, with Soxhlet extraction yielding slightly better results (Kazanović et al., 2024). Since sensory and textural characteristics play a key role in consumer product selection, we decided to investigate the impact of plum seed oil as an emollient on the applicative properties of emulgel in this study. To the best of our knowledge, this aspect has not been previously explored. Additionally, our goal was to formulate an emulgel with the high percentage of natural ingredients, which is why an eco-friendly emulsifier Montanov 202 of natural origin was used for emulgel stabilization. Therefore, the aim of this study was to determine the sensory and textural characteristics of an emulgel containing 6% (w/w) plum seed oil and a placebo emulgel in which the fatty plum seed oil was replaced with caprylic/capric triglycerides, commonly used in cosmetic formulations. In addition to the initial measurement of textural characteristics, our further goal was to repeat the texture analysis after 14 and 28 days to monitor potential changes in the textural characteristics, which may indicate changes in the stability of an emulgel.

2. MATERIALS AND METHODS

2.1. Materials

For the preparation of placebo emulgel (PE) and active emulgel (AE), raw materials listed in Table 1 were used.

2.2. Preparation of emulgels

In order to check the influence of plum seed oil on the applicative properties of emulgel, emulgels PE and AE (Table 1) were prepared using standard emulgel preparation protocol involving heating and stirring in a sealed glass vessel. The PE was prepared as follows: the oil phase components (A) were melted using a thermostatic heating plate on a magnetic stirrer (IKAMAG, IKA, Germany) and heated to 80 °C. Simultaneously, the water phase was mixed, hydroxyethyl cellulose was gelled and then heated to 85 °C before being added to the oil phase. The mixture was stirred with a propeller rotary laboratory stirrer (RW16 basic, IKA Werke, Germany) until it cooled. The preparation of AE followed the same procedure, with plum

Table 2. The description of attributes used in different phases of sensory study.

Phase	Attribute	Description
Before Application	Consistency (Viscosity)	Ease of dispensing the product from the packaging.
	Shine	The level of shine of the sample in the packaging.
During Application	Spreadability	Degree of spreadability/slipperiness of the sample during application using two circular motions on the back of the hand.
	Stickiness	Degree of stickiness during application – the force required to separate fingers from the skin.
	Density	Perceived density of the sample during application.
	Oily Feel	Degree of oiliness felt during application.
	Shine	The extent to which the sample appears shiny when applied to the skin.
	Absorption rate	The speed at which the sample is absorbed into the skin.
After Application	Residual Film	The amount of residual film left on the skin 10 min after application.
	Stickiness	The degree of stickiness felt on the skin 10 min after application.
	Oily Feel	The degree of oiliness feeling on the skin 10 min after application.
	Shine	The level of shine observed on the skin 10 min after application.

Table 3. Overview of Attributes Used in the Sensory Study and Their Quantitative Features

Attribute	1	2	3	4	5
Consistency	Liquid	Semi-solid	/	/	/
Shine	Matte	Pearly shine	Slightly shiny	Shiny	Very shiny
Spreadability	Very difficult to spread	Difficult to spread	Easy to spread	/	/
Stickiness	Not sticky	Slightly sticky	Sticky	Very sticky	/
Density	Thin	Slightly dense	Dense	Very dense	/
Oily Feeling	Not oily	Slightly oily	Oily	Very oily	/
Absorption rate	Slow	Moderate	Fast	/	/
Residual Film	No film	Moderate film	Pronounced film	/	/

seed oil incorporated into the prepared emulgel at a temperature of 40°C. While PE consists of 12% (w/w) caprylic/capric triglycerides, AE contains 6 % (w/w) caprylic/capric triglycerides and 6 % (w/w) plum seed oil.

2.3. Sensory analysis

2.3.1. Participants

The sensory study involved 29 participants of both genders, selected based on their prior experience in evaluating pharmaceutical preparations for skin application (regular users of such products). The study was conducted with the approval of the Ethics Committee of the Faculty of Medicine, University of Niš (approval number 12-2691/2-2 dated March 9, 2023). All participants signed written informed consent, voluntarily agreed to take part in the sensory analysis, and were fully informed about the course of the study.

2.3.2. Study protocol

The samples were packed in plastic containers and labeled as 1 and 2, representing the PE and AE, to ensure participants remained unaware of which preparation they were using. Before the study began, participants were briefed on the research concept, protocol, and the method for evaluating sensory attributes selected based on literature data. The study took place in a well-lit laboratory with controlled air temperature and humidity. Table 2 provides a detailed description of the sensory attributes evaluated before, during, and after the application of the preparations (Tadić, Nešić, et al., 2021).

2.3.3. Statistical analysis

The results obtained from the sensory study, based on the participants' questionnaire responses, were converted into a quantitative scale in accordance with Table 3. Subsequently, all obtained values were normalized to a scale with a maximum value of 10. This approach enabled numerical description of specific sensory attributes as well as comparative analysis between different attributes. IBM SPSS Statistics Software was used for statistical analysis of the results of texture analysis, one-way analysis of variance (ANOVA) with a post hoc Tukey's test was applied with differences at $p < 0.05$ considered as statistically significant.

2.4. Texture analysis

2.4.1. Study protocol

For the analysis of texture parameters, the CT3 Texture Analyzer (Brookfield, AMATEK Inc, USA) was used. The experimental conditions were as follows:

- Probe speed: 1.50 mm/s
- Deformation: 2.5 mm
- Trigger force: 0.05 N

Samples were placed in the sample cups, filling 75% of their volume without trapping air, and analyzed using a conical probe (TA-STF). The monitored parameters included hardness (during the first and second immersion cycles of the probe), adhesiveness, cohesiveness, resilience, and springiness. The texture analysis was conducted 7 days, 14 days and 28 days after the preparation of samples. The results were presented graphically as the average values obtained from three consecutive measurements ± standard deviation.

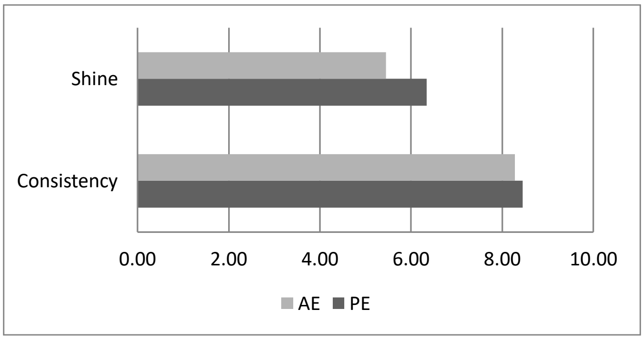

Figure 1. Values of Sensory Attributes Evaluated Before Product Application (AE –active emulgel, PE – placebo emulgel)

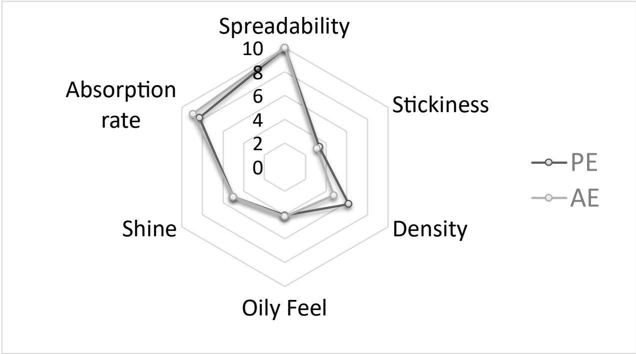

Figure 2. Values of Sensory Attributes Evaluated During Product Application (AE –active emulgel, PE – placebo emulgel)

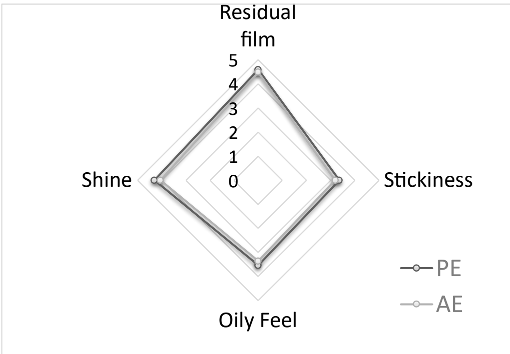

Figure 3. Values of Sensory Attributes Evaluated After Product Application (AE –active emulgel, PE – placebo emulgel).

2.4.2. Statistical analysis

The results of the texture analysis were compared using IBM SPSS Statistics software, version 20. For comparing values obtained across different measurement intervals, as well as between the AE and PE, ANOVA analysis was applied. Values of $p < 0.05$ were considered statistically significant.

3. RESULTS AND DISCUSSION

3.1. Sensory analysis

In the first part of the sensory study, participants were asked to evaluate the product before application to the skin. The consistency of both preparations was described as semi-solid, and both were characterized as slightly shiny. The results are presented in Figure 1.

During the application of both preparations, participants noted their ease of spreadability as well as rapid absorption, which was slightly faster for AE (Figure 2). Stickiness, shine, and oiliness were characterized by lower intensity, while the density of the PE was described as slightly higher than that of the AE. Since density was the only parameter that differed significantly between the tested emulgels, it can be concluded that the presence of plum seed oil as an emollient in the AE, compared to caprylic/capric triglycerides in the PE influenced the consistency of the product. The lower density of the AE contributed to its faster absorption.

Sensory attributes evaluated after the application of both preparations showed no significant differences between the PE and AE (Figure 3).

The results of our study showed that for the tested emulgels (the AE containing plum seed oil and the PE where plum seed oil was replaced with caprylic/capric triglycerides), there were no significant differences in the perception of application properties by the participants. Plum seed oil, aside from its impact on sample density, did not affect the spreadability, stickiness, shine, or oiliness of the emulgel (Table 4).

So far, to our knowledge, no studies have examined the influence of plum seed oil on sensory properties of topical emulgel. However, the results of our sensory analysis align with previous research investigating the impact of natural herbal oils in emulsions (creams or emulgels) on their applicative properties. The raspberries, strawberries, blackcurrants and apples seed oils in concentration of 6% influenced positively the applicative characteristics of oil-in-water emulsions (Krasodomska, 2017). Participants in the sensory study highly rated the cream with argan oil for its spreadability, low stickiness, and quick absorption. These appealing applicative characteristics were attributed

Table 4. Results of Sensory Evaluation of the Tested Emulgel Samples with the Highest Response Percentage.

Phases of Sensory Analysis	Sensory Attribute	Placebo Emulgel (PE)	Active Emulgel (AE)
Before Application	Consistency (Viscosity)	Semi-solid	Semi-solid
	Shine	Slightly shiny	Slightly shiny
During Application	Spreadability	Easy to spread	Easy to spread
	Stickiness	Not sticky	Not sticky
	Density	Slightly dense	Slightly dense
	Oily Feeling	Slightly oily	Slightly oily
	Shine	Slightly shiny	Slightly shiny
	Absorption	Fast	Fast
After Application	Residual Film	No film	No film
	Stickiness	Not sticky	Not sticky
	Oily Feel	Not oily	Not oily
	Shine	Slightly shiny	Slightly shiny

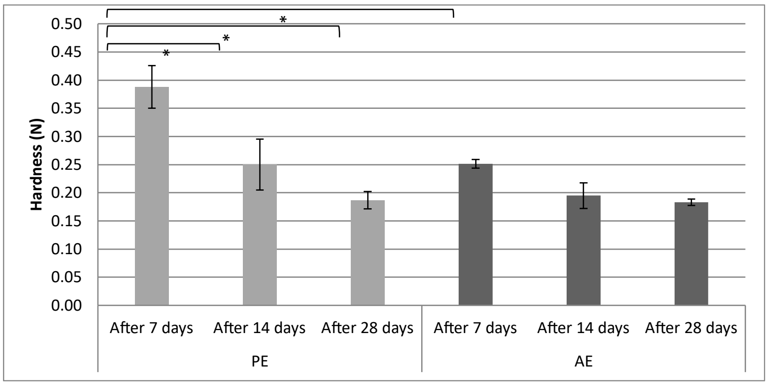

Figure 4. Hardness of tested emulgels (AE-active emulgel, PE-placebo emulgel) Significant differences are marked with * ($p < 0.05$).

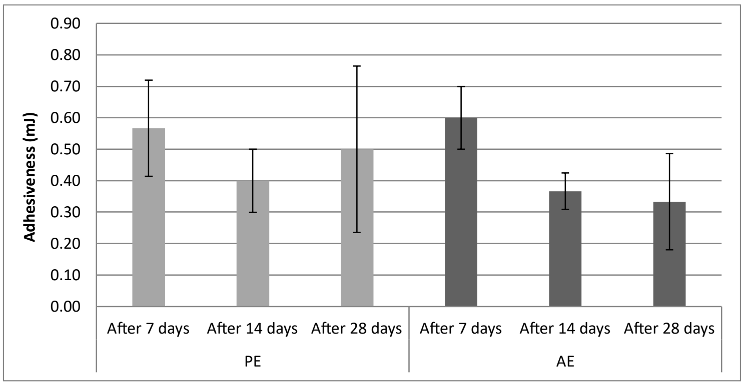

Figure 5. Adhesiveness of tested emulgels (AE-active emulgel, PE-placebo emulgel).

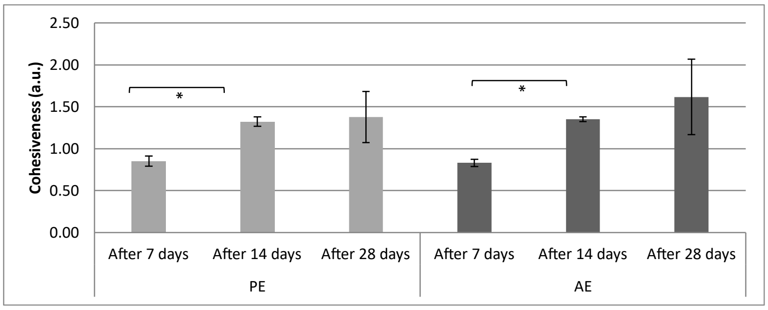

Figure 6. Cohesiveness of tested emulgels (AE-active emulgel, PE-placebo emulgel) Significant differences are marked with * ($p < 0.05$).

to the argan oil as emollient (Bogdan et al., 2016). Similarly, the emulgel with incorporated hemp seed oil was described as non-greasy nor sticky compared to the placebo sample (Tadić, Žugić, et al., 2021) Furthermore, the emulgel containing 1% sunn hemp seed oil was described as the best regarding the after-use feeling, compared to other emulgels with lower concentration or no sunn hemp seed oil (Ditthawutthikul et al., 2024).

3.2. Texture analysis

3.2.1. Hardness

Hardness is defined as the force required for deformation (Trinh and Glasgow, 2012). The results obtained after two cycles of probe immersion into the emulgel are presented in Figure 4. The initial hardness was significantly higher in the PE compared to the AE ($p < 0.05$) which indicates better spreadability of AE. Similar was observed by Andonova et al., in whose study the presence of 8% of babassu oil contributes to lower hardness values and thus better spreadability (Andonova et al., 2024).
Over time, no changes in hardness were observed in the AE, which was not the case with the PE. In the PE, a statistically significant reduction in hardness ($p < 0.05$) was detected on the 14th day and the 28th day compared to the values measured on the 7th day. This result suggests that the presence of plum seed oil in the formulation AE may have contributed to maintaining its hardness over time. This indicates that this natural emollient potentially enhances the stability of the product.

3.2.2. Adhesiveness

Adhesiveness represents the force needed to overwhelm the attractive forces between the probe and the preparation. This texture attribute refers to the stickiness of the tested sample (Trinh and Glasgow, 2012). The results of the adhesiveness measurements are shown in Figure 5.
The presence of different herbal oils can influence the adhesiveness of the formulation (Andonova et al., 2024). However, there was no statistically significant difference in adhesiveness between the placebo and active emulgel. Additionally, no statistically significant changes in adhesiveness were observed in the emulgels over the 28-day period.

3.2.3. Cohesiveness

Cohesiveness is a parameter that represents the degree of strength in the internal bonds of the samples since it refers to the amount of energy needed to deform the sample as the probe is immersed into it (Trinh and Glasgow, 2012). The cohesiveness measurement results are shown in Figure 6.
An increase in cohesiveness was observed in both samples after 14 days (p <0.05), likely due to the formation of the final gel network in the emulgel structure (Martinović et al., 2024). After

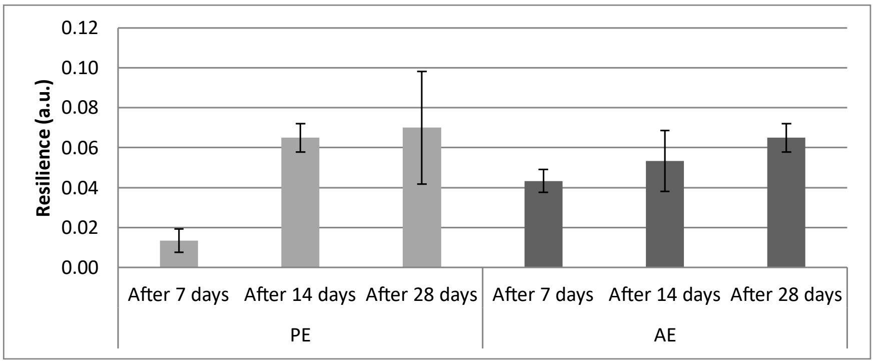

Figure 7. Resilience of tested emulgels (AE-active emulgel, PE-placebo emulgel).

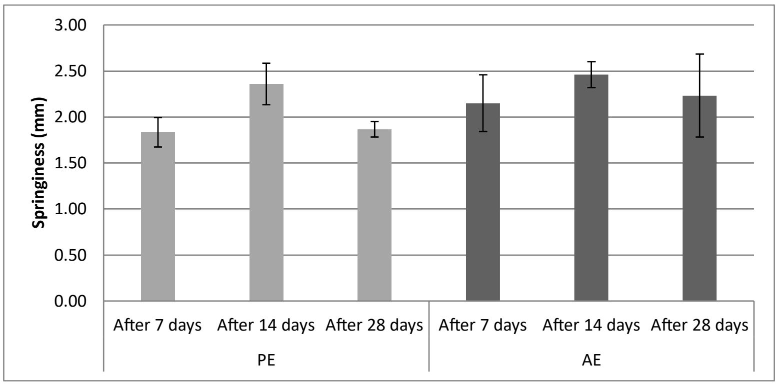

Figure 8. Springiness of tested emulgels (AE-active emulgel, PE-placebo emulgel).

the 14th day, no statistically significant changes in cohesiveness were detected in either the active or placebo emulgel, which is an indicator of the stability of the internal structure of the emulgels. Additionally, there was no statistically significant difference in this parameter between the active and placebo emulgels. In the study where combination of different natural oils was used in oil phase, only the formulations based on babassu oil and camelina oil showed higher cohesiveness values (Andonova et al., 2024).

3.2.4. Resilience

Resilience indicates a material's ability to return to its original state after deformation and is assessed during the first compression cycle. It is determined as the ratio of ascending to descending energy and reflects the energy needed for elastic recovery (Gravelle et al., 2017). The resilience measurement results are shown in Figure 7.

3.2.5. Springiness

Springiness, on the other hand, is assessed during the second compression cycle and represents the elastic recovery following deformation (Gravelle et al., 2017). The springiness measurement results are shown in Figure 8.

Statistical analysis revealed that there were no statistically significant changes in either resilience or springiness for both tested emulgels (AE and PE).

To the best of our knowledge, no studies have been conducted so far on the influence of plum seed oil on the textural characteristics of cosmetic formulations. The results of our study have shown that plum seed oil shows comparable applicative and emollient characteristics as caprylic/capric triglycerides. Caprylic/capric triglyceride, an emollient produced from hydrolyzed coconut oil and glycerin, is marked as GRAS (Generally Recognized as Safe) by the U.S. Food and Drug Agency (FDA) (JHeimbach LLC, 2021). It is one of the most frequently used raw materials in the cosmetic industry, due to its good emollient, as well as desirable sensory and textural characteristic. However, they are obtained through fractionation and esterification, and their production—particularly when derived from palm oil—raises environmental and ethical concerns, such as deforestation and habitat destruction (Fiume et al., 2022). As a more sustainable alternative, plum seed oil, a byproduct of the fruit industry, provides a natural option that aligns with ecological and green principles.

The stability of a topical formulation is a complex term that is accessed through many aspects and tests, where texture and sensory properties might be one of the parameters indicating stability (Franzol et al., 2021). Based on the results of the texture analysis conducted over a 28-day period from the formulation date, it can be concluded that there were no significant changes in the textural properties of the emulgels, which potentially indicates their stability. In addition, during the study, changes in hardness were observed in the PE but not in the AE, which indicates that the presence of plum seed oil influenced the textural properties and potentially the overall stability of the preparation.

Future studies should focus on further evaluating the emulgel with plum seed oil in *in vitro* studies to assess its biological activities, including antioxidant and anti-inflammatory effects. Additionally, the formulation’s effects on biophysical skin parameters should be examined through *in vivo* tests.

4. CONCLUSION

In the current study, the sensory and textural characteristics of an emulgel containing 6% (w/w) plum seed oil were compared to an emulgel in which the fatty plum seed oil was replaced with caprylic/capric triglycerides, one of the most commonly used cosmetic ingredients. The results have shown that plum seed oil, a natural oil obtained from renewable resources, has a comparable influence on the final product’s sensory and textural properties as caprylic/capric triglycerides, which are widely used in cosmetic formulations. The difference in sensory characteristics was observed in terms of density, as participants attributed lower density to the emulgel containing plum seed oil. In terms of textural analysis, lower hardness and thus better spreadability were associated with the presence of plum seed oil.

CONFLICT OF INTEREST

The authors declare that they have no financial and commercial conflicts of interest.

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