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Impact of natural oils and extracts on the moisturizing, physico-mechanical and sensory properties of an organogel formulation

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1. Introduction

With the growth of the environmental movement and increased awareness of its importance [1], consumers have become more conscious of their consumption habits, increasingly opting for sustainable products [2]. This growing demand has driven the cosmetic industry to seek sustainable, biodegradable, and eco-friendly raw materials [3,4].

In this context, oils derived from plant sources are widely used in cosmetic formulations as emollients. These vegetable oils can replace synthetic emollients due to their lower environmental impact [5]. Additionally, the presence of secondary metabolites in plants provides vegetable oils with clinical benefits for skin care, such as antioxidant activity [6].

Brazilian rich biodiversity plays a key role in the discovery of novel raw materials for cosmetic applications, offering both scientific and commercial value. In this regard, oils such as pequi and buriti show great potential for use in cosmetic formulations.

Beyond vegetable oils, other sustainable alternatives are being explored. Sustainability can also be promoted by reducing waste in production chains, for instance, through the use of byproducts such as residual water extracts from Sicilian olive oil. The use of solvent-free techniques for oil extraction, such as the supercritical fluid method applied to avocado and Black Soldier Fly larvae oils, have low impact on the environment since no organic residues are generated [7,8]. Moreover, insect-derived oils also represent another promising source of sustainable raw materials since these insects are capable of converting decomposing organic matter into high-value compounds, such as proteins and lipids [9,10,11].

However, the inclusion of these oils and extracts can alter formulation structure, potentially affecting physical-mechanical and sensory properties. Since formulation composition is a key factor influencing sensory characteristics and consumer acceptance [12], it is essential to evaluate the impact of these substances on physical attributes such as texture and spreadability. In this context, organogels represent an innovative alternative for incorporating various emollients, moisturizers, and active ingredients into cosmetic products [13]. The different fatty acid profiles of oils and the composition of natural extracts may significantly influence the microstructure of the formulations.

Furthermore, biophysical techniques are valuable tools for evaluating the clinical efficacy of cosmetic formulations. These methods provide precise assessments of product effects on the skin, offering deeper insights into the functional benefits of the tested formulations [14].

In summary, a comprehensive assessment of physicomechanical properties, sensory performance, and clinical efficacy is essential in cosmetic product development. The strategic incorporation of vegetable oils enhances the value of cosmetic products and supports biodiversity conservation in Brazil, while the use of sustainable raw materials promotes environmental responsibility.

Therefore, the objective of this study was to develop and evaluate the influence of different oils and a natural extract on the physicomechanical and sensory properties, as well as the moisturizing effects, of a cosmetic formulation based on an organogel system.

2. Materials and Methods

2.1. Development of the formulations

An organogel formulation was developed based on *Helianthus Annuu*s (Sunflower) Seed Oil (and) Polyacrylic Acid (and) Xylityl Sesquicaprylate (and) Glyceryl Stearate (and) *Euphorbia Cerifera* (Candellila) Wax (and) Sodium Hydroxide. The formulation was added or not (Vehicle - FV) with 5% of each oil or 1% of the extract as described below:

- Vehicle formulation FV
- FV + 5% pequi oil (FP) – *Caryocar brasiliense* Camb.
- FV + 5% avocado oil (FA) – *Persea americana* Mill.
- FV + 5% buriti oil (FB) – *Mauritia flexuosa* L.f.
- FV + 5% olive oil (FO) – *Olea europapea* L.
- FV + 5% black soldier fly larvae oil (FF) - *Hermetia illucens* L.
- FV + 1% of extract of residual water from Sicilian olive oil (FE) - *Olea Europaea* (Olive) Fruit Extract (and) Maltodextrin

2.2. Characterization of the formulations

2.2.1. Rheological Behavior

The rheological behavior of the formulations was evaluated using a Brookfield DV3T cone-plate rheometer (Brookfield, USA) equipped with a CP-52 spindle and connected to the RHEOCALCT® software. The formulations were analyzed 24 hours after their preparation. For each analysis, 0.50 ± 0.01 g of formulation was placed on the plate. The rotational speed was progressively increased from 0 to 100 rpm, with 5-second intervals between each speed, generating an ascending curve composed of 8 points. The descending curve was obtained by decreasing the speed. The parameters evaluated were flow index, consistency index, minimum apparent viscosity, and hysteresis area. All measurements were performed in triplicate [12].

2.2.2. Spreadability profile

Spreadability analysis was performed using a TA.XT Plus® texture analyzer, coupled with the Exponent software. All analyses were conducted 24 hours after the preparation of the formulations. Texture properties were calculated through the Texture Exponent 3.0.5.0 software [15].

Spreadability analysis involved the penetration of an analytical probe into the sample [15]. The test was carried out using the TTC HDP/SR probe, which allows the determination of the work of shear of the formulations [12,14]

2.3. Short term efficacy study

This study was conducted following approval by the Research Ethics Committee for Human Studies at the School of Pharmaceutical Sciences of Ribeirão Preto, University of São Paulo (CAAE: 85803825.9.0000.5403 - CEP/FCFRP Protocol No. 7.490.406). Ten female participants were recruited through the clinical study participant database of NEATEC (Center for Advanced Studies in Cosmetic Technology). Inclusion criteria were: healthy women aged between 18 and 30 years, with skin phototypes II and III (Pathak and Fitzpatrick). Exclusion criteria included: smokers, lactating individuals, presence of scars or pigmented lesions on the face that could affect measurements, and known sensitivity or irritation to any formulation component.

Each participant had seven 20 cm² areas marked on the ventral forearm. A 40 µL aliquot of each formulation was applied to the designated area, with formulations assigned randomly.

The test began after a 20-minute acclimatization period in a controlled environment (temperature: 20–22 °C; relative humidity: 45–55%). All participants remained in the room throughout the study period. Instrumental measurements were taken at baseline (T0) and 2 hours post-application (T2) to assess water content and water distribution in the stratum corneum and transepidermal water loss (TEWL).

Transepidermal water loss

Transepidermal water loss (TEWL) was assessed using the Tewameter® TM 210 device. This instrument operates based on Adolf Fick's law of diffusion. The evaluation of water evaporation from the skin surface is related to skin barrier integrity, as higher values are observed when the cutaneous barrier is disrupted or damaged. The results are expressed in $g \cdot m^2 \cdot h^{-1}$[14].

Stratum corneum water content

The water content of the stratum corneum was determined using the Corneometer® CM825 device. This instrument operates based on the principle of electrical capacitance to assess skin hydration. The measurements are related to hydration levels, as the capacitance detected by the device varies according to the water content in the stratum corneum, due to the dielectric properties of water [14]. Five measurements were taken per region, and the results were expressed in arbitrary units (AU), where one arbitrary unit corresponds to 0.2–0.9 mg of water per gram of stratum corneum [16].

Water distribution in the stratum corneum

The distribution of water in the stratum corneum was assessed using the Moisture MAP MM 100 device. This equipment is equipped with a sensor capable of evaluating the penetration of a magnetic field into the skin. Conductive materials, such as water, reflect the generated signal, resulting in dark pixels, whereas non-conductive materials produce light pixels [17]. Therefore, the greater the skin hydration, the darker the resulting image.

2.4. Sensory Properties Analysis

Following approval by the Clinical Research Ethics Committee of FCFRP/USP (CAAE: 85803825.9.0000.5403 - CEP/FCFRP Protocol No. 7.490.406), 16 healthy volunteers (both male and female), aged 18 to 30 years, were recruited. A 20 cm² area was marked on each participant's forearm, and 40 µL of each formulation was applied using twenty circular movements. Participants then completed a questionnaire immediately after application to assess spreadability and tactile sensation. Five minutes after application, they evaluated perceptions of hydration, stickiness, oily residue, and dry touch. Finally, participants ranked the seven formulations from 1 (most preferred) to 7 (least preferred).

3. Results

The formulations under study demonstrated physical stability, with an average pH of 5.5, compatible with the natural pH of the skin.

The incorporation of vegetable oils influenced the firmness of the cosmetic formulations and their rheological behavior. The addition of all of the oil caused a significant ($p < 0.05$) increase in the firmness and work of shear of the formulations (Fig. 1). Notably, the formulation containing pequi oil exhibited the highest values for firmness and work of shear (Figure 1) suggesting greater structural cohesion and resistance under stress. On the other hand, the formulation added with the extract presented a significant decrease ($p < 0.05$) in these parameters.

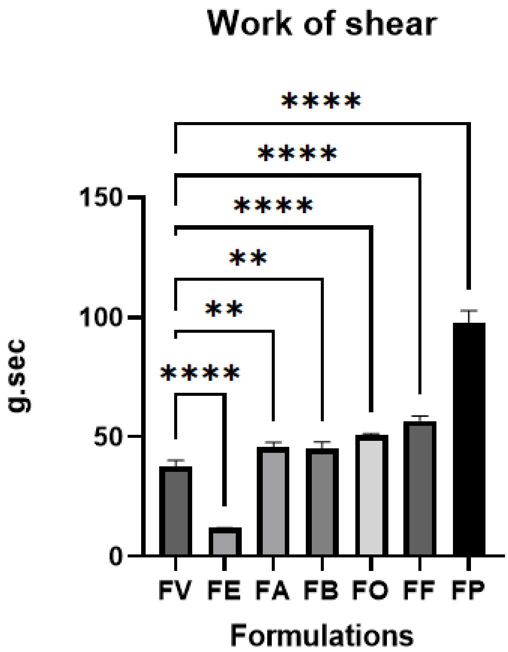

Figure 1: Work of shear of the organogel formulations.

** Significant differences compared to vehicle formulation (FV) ($p < 0.05$)

** Significant differences compared to vehicle formulation (FV) ($p < 0.001$)

FV: Vehicle formulation; FE: Formulation added with 1% of the extract of residual water from sicilian olive oil; FA: Formulation added with 5% of avocado oil; FB: Formulation added with 5% of buriti oil; FO: Formulation added with 5% of olive oil; FF: Formulation added with 5% of Black Soldier Fly larvae oil; FP: formulation added with 5% of pequi oil.

In the rheological behavior evaluation, all formulations exhibited a flow index lower than 1, indicating non-Newtonian behavior. However, only the formulations containing vegetable oils demonstrated thixotropic behavior, while the vehicle formulation and the formulation containing the extract did not.

The clinical study showed that the addition of avocado oil to the formulation led to a significant ($p < 0.05$) decrease in the transepidermal water loss while the addition of the other active substances only showed a tendency to reduce this parameter (Figure 2). Additionally, only the formulation containing avocado oil showed a significant improvement ($p < 0.05$) in water distribution across the skin surface. These findings are consistent with the sensory evaluation, in which the avocado oil formulation was perceived as the most hydrating.

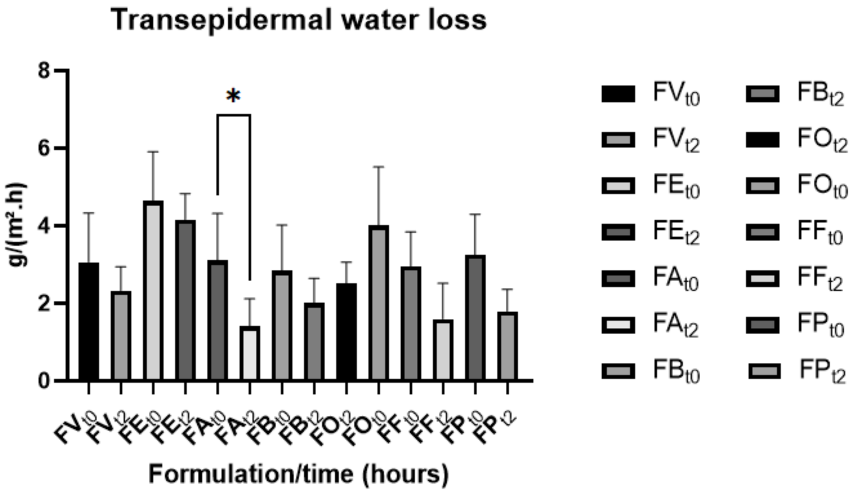

Figure 2: Transepidermal water loss before (t0) and 2 hours after the application of the formulations.

* significant difference to baseline values (p < 0.05).

FV: Vehicle formulation; FE: Formulation added with 1% of the extract of residual water from sicilian olive oil; FA: Formulation added with 5% of avocado oil; FB: Formulation added with 5% of buriti oil; FO: Formulation added with 5% of olive oil; FF: Formulation added with 5% of Black Soldier Fly larvae oil; FP: formulation added with 5% of pequi oil.

All the formulations significantly increased (p < 0.05) the water content in the stratum corneum (Figure 3). However, this increase was most pronounced in the formulations containing the extract (FE) and the pequi oil (FP).

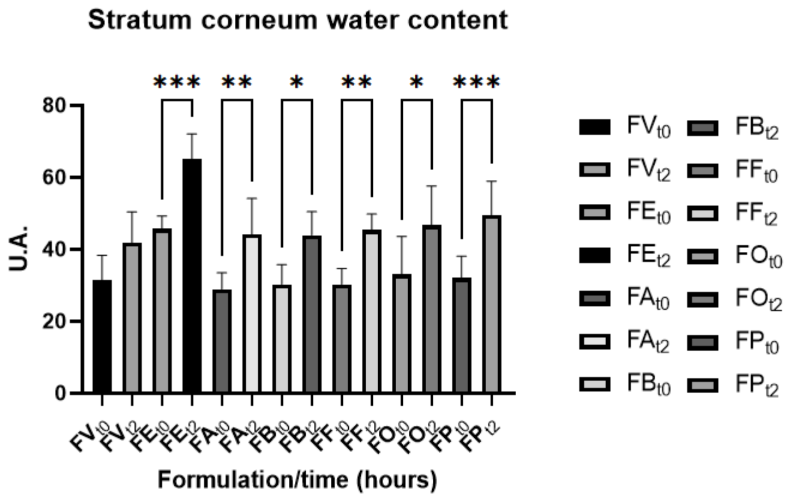

Figure 2: Water content of the stratum corneum (t0) and 2 hours after the application of the formulations.

* significant difference to baseline values (p < 0.05)

*** significant difference to baseline values (p < 0.001)

FV: Vehicle formulation; FE: Formulation added with 1% of the extract of residual water from sicilian olive oil; FA: Formulation added with 5% of avocado oil; FB: Formulation added with 5% of buriti oil; FO: Formulation added with 5% of olive oil; FF: Formulation added with 5% of Black Soldier Fly larvae oil; FP: formulation added with 5% of pequi oil.

Furthermore, the addition of vegetable oils enhanced the sensory properties of the formulations compared to the vehicle.

4. Discussion

The results showed that the oils impacted the structural rearrange of the formulations, since higher values of work of shear and firmness were observed for the organogel added with the oils [13]. These results were pronounced for FP, which presented the highest values for these parameters. Pequi oil is composed mainly of saturated fatty acids (40.04%), with palmitic acid (C16:0) being the most abundant [18]. The presence of saturated fatty acids, due to their lower lipid fluidity, contributes to an increase in the formulation's viscosity [19].

Similarly to pequi oil, Black Soldier fly larvae oil has a high percentage of long-chain saturated fatty acids (48.43%), despite the oil being predominantly composed of unsaturated fatty acids [8], which contributes to the increase in spreadability parameters.

The work of shear is inversely proportional to spreadability [12]. While the addition of oils caused a decrease in spreadability of the formulations, the extract caused a decrease in this parameter, indicating better sensory properties for FE.

The formulations containing the oils presented a thixotropic behavior. Thixotropy is a rheological property whereby the viscosity of a material decreases over time under constant shear stress and returns to its original state once the force is removed. This reversible behavior is characterized by the material becoming more fluid under external forces such as stirring or vibration and then regaining its original viscosity [20]. Literature reports show that even minor compositional changes in cosmetic formulations can influence their final rheological properties [21]. Therefore, the incorporation of vegetable oils can modify the microstructure of the organogel, particularly due to the fatty acid chains present in these oils [22], resulting in thixotropic properties.

The enhancement of the sensory properties with the addition of vegetable oils could be a result of this thixotropic behavior. This rheological property promotes lower viscosity when the formulation is applied, causing better spreadability [23]; while also allows the formation of a film on the skin surface, which could have clinical benefits for the formulation [13, 24].

The clinical efficacy study showed that the addition of the active substances to the formulations maintained the skin barrier function, as shown by the tendency to decrease the transepidermal water loss. However, the avocado oil showed a significant ($p < 0.05$) decrease in this parameter, presenting an improvement in the skin barrier, while also promoting better water distribution across the skin. That indicates a better skin occlusion caused by the oil [5]. Therefore, avocado oil presents higher potential for short term hydration than the other oils.

It is described that oils rich in linoleic acid and saturated fatty acids could be beneficial for skin hydration [25]. Therefore, the effects found for avocado oil could be due to its fatty acid composition, since the oil is mainly composed of linoleic and palmitic acid - a long chain saturated acid [26].

Finally, the application of the formulations containing the active substances caused a significant ($p < 0.05$) increase in the stratum corneum water content. This can be attributed to the emollient capacity of the vegetable oils in maintaining skin hydration [27]. This increase was more pronounced in FP and FE, which indicates that even if pequi oil and the extract of residual water from sicilian olive oil do not have occlusive properties, they are effective in improving skin surface hydration.

5. Conclusion

The addition of the extract into organogel formulations improved its spreadability while vegetable oils improved sensory properties, with notable performance observed in formulations containing avocado oil.

The addition of oils in the formulations enhanced skin hydration. However, avocado oil had a more pronounced hydration effect due to its fatty acid composition.

Moreover, the use of natural ingredients such as pequi and buriti oils highlights the value of Brazilian rich biodiversity, while the inclusion of avocado oil and Black Soldier fly larvae oil and the extract of residual water from Sicilian olive oil obtained through sustainable processes, reinforces the potential of these resources in the cosmetic industry.

In summary, these findings contribute to the development of more sustainable and effective cosmetic products and align with the principles of positive cosmetology, promoting environmental responsibility.

6. References

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