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Research Article

Design and Characterization of Topical Formulations: Correlations Between Instrumental and Sensorial Measurements

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Abstract. The interaction between cosmetic emulsions and the skin's surface is an important factor to consider in the development of topical formulations. Two important ingredients in cosmetic formulations are waxes and polymers. The physical and mechanical properties of formulations directly impact the interface skin-formulation. To evaluate this interaction, it is important to study the rheology, texture, and sensory properties. In this context, the aim of the study was to evaluate the influence of waxes and polymers on the rheological behavior, texture profile, and sensorial properties of topical formulations and the correlation between these parameters. The best combination of a wax and a polymer was determined by full factorial design of experiments and applied to develop eight formulations that were tested in relation to rheological, mechanical, and sensorial properties. The polymer helps with the spreadability of the formulation, and the wax had a strong influence on the parameters related to the structure of emulsions. A correlation between these parameters was observed. This way, it was possible to compare theoretical and practical data, except between the flow index and the work of shear. Finally, it was possible to predict sensorial aspects from rheological and texture parameters, making the formulation process easier and more integrated with all stages of the development of new topical formulations. Thus, the present study introduces a new proposal in the development of cosmetics.

KEY WORDS: polymers; waxes; topical formulations; rheological behavior; mechanical properties; sensory analysis.

INTRODUCTION

Colloid science gives a basis for the development of numerous technologies. From the controlled release of a drug to the induction of plant growth, there are no limits for its application. There are several cosmetics based on colloidal dispersions, for example, gel, cream, hairspray, and deodorant (1). Cosmetic creams are generally formed by an oil-in-water emulsion. Some are classified as a wax-in-water emulsion when a wax is utilized to stabilize them.

Ingredients such as filters, stabilizers, and surfactants can act as thixotropic modifiers by altering the physical structure of the complex (2–4). In emulsions, waxes can promote better adhesion of the particles and can interact with the emulsion interface, promoting a steric barrier to drop fusion (5). Furthermore, studies have shown that the addition of waxes to the emulsion promotes modification in rheological and physical properties, such as structural network strength (6–8). Polymers can also be used to stabilize the emulsion system because they promote steric stabilization through surface particles (1,9). In addition, studies have shown that a polymer can be a texture agent and influence texture and sensorial parameters, such as viscosity and consistency (10–12).

The adequate combination of polymers and waxes, as well as the balanced concentration of these components, is still a challenge in the development of stable and effective cosmetic products with an improved sensory. The oily content of the formulations appears to have a high influence on their physical properties. (13,14). Thus, the present study introduces a new proposal in the development of cosmetics by the prediction of formulation sensory through physical methods that impact the skin-formulation interface (15–17). Polymers and waxes have aggregative action on colloidal particles and can modify rheological, mechanical, and sensory properties of formulations. However, it is not clear how much they affect these parameters and which of them has a stronger effect. Due to this, a combined rheology, texture, and sensory analysis study is very important to elucidate these questions.

In the literature, there are several studies linking these techniques, but these studies are mostly in the food field (18–

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20). Lukic *et al.* (21) demonstrated their utility in cosmetic studies as a sensitive tool, which allows one to optimize the structure of the formulation, to directly influence its behavior and stability, and to provide adequate parameters for sensory use. They demonstrated the dependency of sensory properties in relation to physical and mechanical characteristics of emulsions.

Gilbert *et al.* (22) verified the polymer's positive influence on viscosity and viscoelastic parameters and found a statistical correlation between rheology and texture analysis. Brenner *et al.* (23) showed correlations between similar empirical approaches that are useful to map the expected characteristics of a given formulation. Savary *et al.* (24) tested texture analysis to evaluate the spreading properties of cosmetic emulsions and found that the composition of the oily phase has a significant effect on spreadability, an important sensory attribute.

The work of shear is a predictive parameter of spreadability (16,25) obtained from texture analysis. Due to the importance of the shear and spreadability characteristics of formulations, this parameter was chosen to compose a full factorial design of experiments to evaluate the influence of different waxes and polymers in topical formulations. The statistical design allows for the study of the influence of different variables according to the desired responses, optimizing processes, reducing the number of experiments, and saving time and money (26,27).

In this context, the aim of the present study was to evaluate the influence of wax and polymer in rheological behavior, texture profile, and sensorial properties of topical formulations and the correlation between these parameters.

Firstly, a full factorial experiment was designed with pre-formulations to evaluate the significance of waxes and polymers on the work of shear parameter. After that, formulations were developed with a wax and a polymer, which produced better results, to obtain texture patterns for a characterization and correlation study of rheological, textural, and sensorial properties.

MATERIAL AND METHODS

Development of Pre-formulations

Before the development of the studied formulations, pre-formulations were developed to perform the full factorial design of experiments. It is extremely important to choose the correct wax and polymer to ensure a formulation is pleasant from a sensory perspective.

The raw materials currently available were studied, and two self-emulsifying waxes were chosen: cetearyl alcohol and dicetyl phosphate and ceteth-10 phosphate—Crodafos™CES/Croda Inc. (Wax 1), and mineral oil/paraffinum liquidum/cetearyl alcohol/ceteth-20/glyceryl stearate/PEG-40 hydrogenated castor oil/polyacrylic acid/sodium hydroxide/xylitol/caprylic acid—Emulfeel SSC/Chemyunion (Wax 2). They were provided by Croda do Brasil Ltda (Campinas, SP, Brazil) and Chemyunion Ltda (Sorocaba, SP, Brazil) respectively. Two hydrophilic polymers were also selected: acrylates/C10-30 alkyl acrylate crosspolymer—Pemulen™ TR2/Lubrizol (Polymer 1), and sclerotium gum—Amigel®/Alban Muller (Polymer 2). They were provided by Lubrizol do Brasil Aditivos Ltda (Sao Paulo, SP, Brazil) and Pharmaspecial Especialidades Químicas e Farmacêuticas (Santana de Parnaiba, SP, Brazil) respectively.

With the objective to develop a vehicle for the formulations, the following raw materials were used: cyclopentasiloxane and cyclomethicone (and) dimethicone crosspolymer that were provided by Dow Corning do Brasil Ltd. (Hortolandia, SP, Brazil). Butyl hydroxy toluene, glycerin, phenoxyethanol and parabens, ethylenediamine tetraacetic acid, aminomethyl propanol, and propyleneglycol, were provided from Mapric Produtos Farmacêuticos e Cosméticos (Sao Paulo, SP, Brazil). Ethylhexyl salicylate was provided by Symrise (Galena, Campinas, SP, Brazil).

The purpose was to combine the two selected polymers and the two selected waxes to obtain four emulsions stabilized with hydrophilic colloid. The pre-formulations were developed according to the specifications of the active substances studied, the sensory characteristics, and the interaction of the raw materials used in formulations (Table I).

The aqueous phase was incorporated into the oil phase under heating at 70°C. The preparations were stirred for 20 min and then neutralized with AMP 95 to pH 5.5. The polymer, silicones, and preservatives were then added. Subsequently, homogeneous and stable formulations were obtained. The formulations were tested in terms of preservation against bacterial development using standard tests performed by an external laboratory.

Full Factorial Design of Experiments

To evaluate the effect of the addition of different waxes and polymers in topical formulations and the best combination of them, a full factorial design of experiments was drawn up using the Minitab software (Minitab 17, Minitab Inc., State College, PA, USA). The objective was to evaluate effects and interactions of the polymers and waxes. As spreadability is the ability to spread and deform the product with ease and uniformity, the variable "work of shear" was chosen as the sensory predictor. The lower work of shear, the better the spreadability of the formulation (16,28). The factorial design used was a "factor 2-level" full factorial, with four runs and four replicates. There was no central point, and the number of blocks was one.

Two categoric factors were evaluated, "polymer" and "wax," and also an answer, work of shear, which is a continuous factor. The answer work of shear was obtained from the equipment System of Physical and Mechanical

Table I. Composition of Formulations of Design of Experiments

Ingredients	Composition (*w/w*)			
	F1	F2	F3	F4
Polymer 1	0.2%	–	0.2%	–
Polymer 2	–	1%	–	1%
Wax 1	–	5%	5%	–
Wax 2	6%	–	–	6%

Properties Analysis, model TA.XT/Plus (Stable Microsystems, UK) equipped with the TCC Spreadability rig HDP/SR.

Development of Formulations

With the best wax and polymer combination obtained, eight formulations were developed with the vehicle previously mentioned, combining extreme concentrations of waxes and polymers and the presence or not of them (Table II). Building this scale of texture, it was possible to obtain a texture profile of the formulations and to correlate theoretical and practical results.

Rheology

The rheological behavior was determined using a Rheometer R/S-CPS Plus (cone/plate and plate/plate) Brookfield, with P50 spindle and temperature probe Pt 100 1/3 DIN, coupled with the Rheo software V2.08 version. The shear rates progressively increased from 0 to 120 rpm for 120 s at 25°C, 24 h after its preparation. The procedure was repeated in reverse by gradual decrease of shear rate from 120 to 0 rpm, obtaining an ascendant curve and a descendant curve. Apparent viscosity was obtained from rheograms that were mathematically analyzed according to the Power Law model (Eq. 1) in which τ is the shear stress (Pa), γ is the shear rate, m is the consistency index (Pa.s^n), and n is the flow behavior index (9).

$$\tau = \mathrm{K}.(\gamma)^{\mathrm{n}} \qquad (1)$$

Texture Analyses

The texture analyses were performed using a TA.XT plus Texture Analyzer (Stable Microsystems, United Kingdom). To evaluate the work of shear parameter, the system was equipped with the TTC Spreadability rig HDP/SR. To evaluate the parameter index of viscosity, consistency, and cohesiveness, it was equipped with a Back Extrusion rig A/BE of 35 mm for formulations FA, FB, FD, FE, and FG, and rig A/BE of 45 mm for formulations FC, FF, and FH. The formulations were loaded in 125-mL containers with 50-mm diameter. Measurements were made in triplicate. The textural properties of the formulations were calculated *via* the instrument software. In the spreadability analysis, the work of shear is given from the area under the positive curve. The probe conditions were return distance 100 mm, return speed 20 mm/s, and contact force 30 g. In back extrusion analysis, consistency is given by the area under the positive curve, cohesiveness from the maximum value of the negative curve, and index of viscosity from the area under the negative curve. For this test, the probe conditions were return distance 25 mm, return speed 20 mm/s, and contact force 30 g.

Sensory Analysis

To evaluate the sensory characteristics of the formulations, a trained panel of ten volunteers, with age between 18 and 30 years, was used and this phase was approved by the ethical committee (CEP/FCFRP n°. 381). The volunteers attended the two training sessions in a sensory analysis cabin. The first training session was based on a protocol where panelists were trained in definitions of sensory analysis to validate their opinions (29). The second session consisted in a training with simple formulations, based on the technical reports of the wax and the polymer. After these training sessions, an evaluation of the study formulations was made with a simple scale from 1 to 5, which corresponded to very low, low, intermediate, high, and very high, respectively. The volunteers classified the formulations in relation to spreadability, consistency, cohesiveness, and viscosity.

Statistical Analysis

The data obtained from texture analyses were considered normal and correlated in pairs, using unpaired Student's *t* test. The ranking of sensory analysis was compared by a Kruskal and Wallis one-way analysis of variance test and Dunn's posttest ($\alpha = 0.05$). The rheological, texture, and sensory results were correlated by Spearman's rank correlation test (16,30,31).

RESULTS

Full Factorial Design of Experiments

The first test analyzed the following factors: wax (A), polymer (B), and the wax and polymer interaction (AB). After the factorial regression, it was observed that only the factors A and AB significantly influenced the response work of shear ($\alpha = 0.05$). A Pareto chart was obtained with the absolute effect of the factors. It demonstrates the magnitude and importance of the effects (Fig. 1). It was possible to observe that the factors "wax" and "interaction between wax and polymer" were statistically significant, as they crossed the reference line (2.31 point).

Table II. Concentrations of Wax and Polymer

Ingredient	Formulation							
	FA	FB	FC	FD	FE	FF	FG	FH
Wax 1	10%	10%	1%	1%	10%	1%	–	–
Polymer 1	0.50%	0.15%	0.15%	0.50%	–	–	0.50%	0.15%

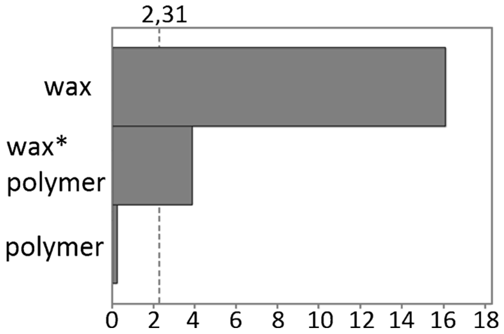

Fig. 1. Absolute effect of the factors “wax,” “polymer,” and “interaction between wax and polymer”

Regarding the polymers, both did not significantly influence the work of shear in a different manner. Knowing which factors are significant, it was possible to create factorial plots to assess the main effects. The graphs show the effect of waxes and polymers on the work of shear separately (Fig. 2). In graph A, it is observed that Wax 1 contributed to a lower work of shear value, while Wax 2 contributed to higher values. Graph B shows that the two polymers had a similar influence on the work of shear, obtaining values around 700 g/s. Polymer 1 provides lower work of shear values.

Equation 2, where X_1 is the wax, X_2 is the polymer, and X_3 is the interaction between wax and polymer, is the regression equation that demonstrates the influence of the factors on the work of shear of the formulations. This agrees with that observed in Fig. 1: the higher influence of wax and the interaction between wax and polymer.

$$\text{Work of shear} = 696.3 + 311.3\,X_1 + 4.1\,X_2 - 74.2\,X_3 \tag{2}$$

Thus, the most effective combination of polymer and wax chosen to compose the formulation vehicle was Wax 1 and Polymer 1. The utilized concentrations were 1 and 10% for Wax 1 and 0.15 and 0.5% for Polymer 1 to obtain maximum and minimum standards. From them, interacting or not, it was possible to see clearly the different influence between wax and polymer.

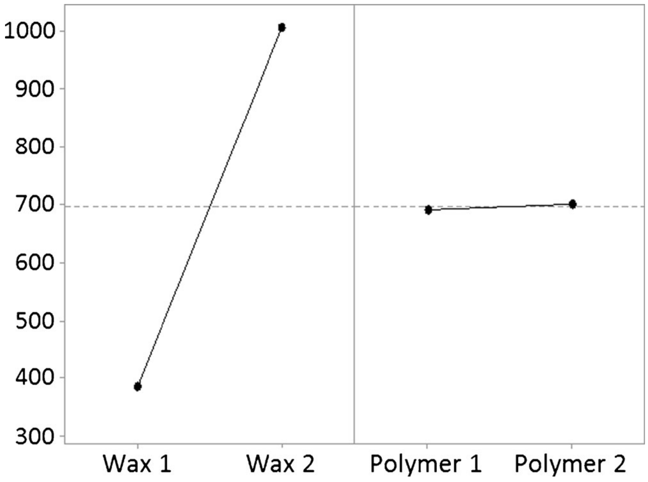

Fig. 2. Main effects of waxes and polymers on work of shear (g)

Rheology

Different rheological behavior was observed between the formulations. The formulations with the combination of wax and polymer, FA, FB, FC, and FD, and the formulation with maximum concentration of wax, FE, presented higher values of shear stress when compared to the other formulations, and also, formulations FA, FB, FD, and FE presented thixotropy (Fig. 3). The formulation FG with maximum concentration of polymer presented low values of work of shear and the formulations FF and FH presented values close to 0.

Regarding the flow index, we observed that the interaction between the wax and the polymer at different concentrations resulted in low difference in the flow rate (Table III). However, high wax and polymer concentrations resulted in a larger resistance of the material.

The presence of wax demonstrated more influence on the flow index than polymer concentration. From formulation FE, with a high concentration of wax and no polymer, to formulation FF, with a low concentration of wax and no polymer, an increase in the flow index was observed. To complement that, the formulations without wax, FG and FH, obtained higher flow index values.

Regarding apparent viscosity, the association between the wax and the polymer in high concentrations and in minimum concentrations resulted in large differences, mainly because of the wax. The minimum concentrations of wax and of polymer, formulations FF and FH, provided values close to zero, indicating that the association between the wax and the polymer results in higher apparent viscosity.

Texture

The texture analysis results (Table IV) showed some tendencies between the parameters and formulations. In all of our analyses, formulations FA and FB had no significant difference. That result means that with a high concentration of wax, the polymer did not influence textural parameters.

When the wax concentration decreases to 1%, as in formulations FC and FD, there was a significant decrease in textural parameters, independent of the polymer concentration. However, in the case of these formulations, a variation in the concentration of polymer from maximum to minimum results in significant changes in textural parameters, showing that the wax has less influence in minimum concentrations.

Regarding work of shear, high concentrations of wax resulted in more difficulty to shear the formulations. Changes in wax and polymer concentrations produced significant variations in the work of shear. Formulation FC, with 1% wax and 0.15% polymer, formulation FF, with 1% wax and formulation FH, with 0.15% polymer, demonstrated no significant difference in this parameter. This means that in minimum concentrations, the influence of wax and polymer, separately or together, is the same for the work of shear. For the other parameters, index of viscosity, consistency, and cohesiveness, the wax and polymer interaction resulted in higher values than those observed in formulations with the separate ingredients. The results of formulations FA, FB, and

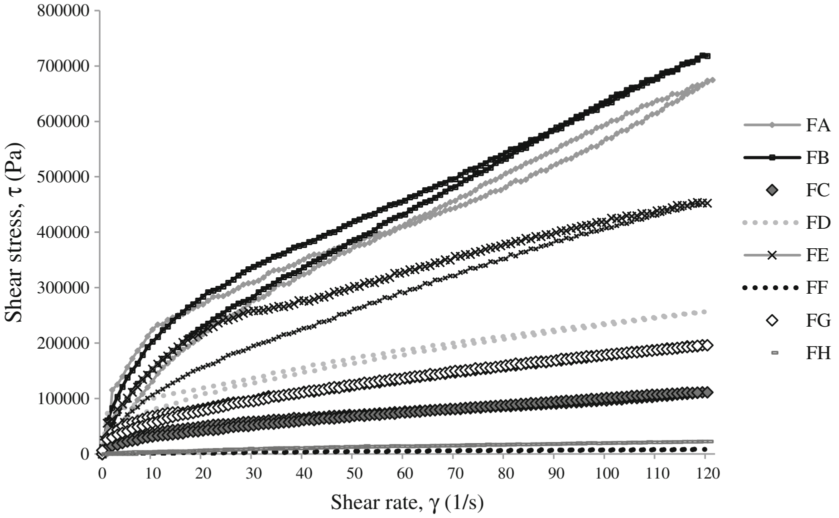

Fig. 3. Shear stress as a function of shear rate of the formulations

FE, which had maximum concentration of wax, were not significantly different. Thus, the removal of the polymer in formulation FE did not change these texture characteristics. Also, an impressive increase in texture parameters was observed from formulation FD to FE, when the wax concentration goes to maximum and the polymer was removed from the formulation. In summary, for the texture parameters, the wax had more influence than the polymer, and an increase in the wax concentration results in an increase in texture parameters.

Sensorial

Our sensorial analysis confirmed the previous steps by a radar chart (Fig. 4). Notably, the spreadability behavior was different from the others. The spreadability score followed the decrease in the amount of wax and the increase in the amount of polymer. According to statistical analysis and to the trained panel, formulations FC, FF, FG, and FH were significantly easier to spread when compared to formulation FA.

In relation to viscosity, consistency, and cohesiveness, formulations with a maximum concentration of wax (formulations FA, FB, and FE) obtained the highest score for these parameters, and they were significantly more viscous, consistent, and cohesive compared to formulations FF, FG, and FH.

Table III. Rheological Parameters Obtained from Ostwald Model

Formulation	Flow index	Apparent viscosity (Pa s)	Consistency index (Pa s^n)
FA	0.5	1082.0	63.1
FB	0.5	598.2	53.1
FC	0.4	123.9	13.2
FD	0.4	760.1	36.9
FE	0.4	496.3	56.6
FF	0.7	1.7	0.3
FG	0.5	299.5	20.5
FH	0.7	3.3	0.8

Spearman's Rank Correlation

One of the goals of this study was to establish a correlation between rheological, texture, and sensory variables to in turn possibly compare theoretical and practical data. Based on Spearman's rank correlation, it was possible to establish correct associations between similar parameters among the analyses (31). The correlation matrix obtained is reported in Table V.

DISCUSSION

The factorial design step demonstrated that the waxes significantly influenced the work of shear of the formulations, agreeing with previous studies (14,24) that demonstrated that the constituents of the oil phase had a significant effect on the spreading of emulsions.

Phosphate derivative surfactants, such as Wax 1, are very stable and have the ability to form stable emulsions (32). Furthermore, the presence of phosphate groups provides better compatibility with skin, influencing the sensory perception of the formulations. Polymer 1 is a hydrophobically modified co-polymer that can act as an emulsifier and viscosity-enhancing agent. Its relation with oil ingredients has been studied and the polymer obtained good results in terms of stability and rheological properties (12,13).

The formulations showed non-Newtonian behavior and pseudoplastic character (flow index < 1), which is desired for formulations because there is a decrease in viscosity when the shear rate increases (33). A decrease in the flow index when the oil concentration increased may result in a shear-thinning behavior associated with creaming (34).

The formulations FB, FD, and FE presented hysteresis area, or thixotropy, a natural characteristic of pseudoplastic formulations. This thixotropic behavior implies that these formulations took more time to rebuild their viscosity after

Table IV. Texture Parameters of the Formulations (mean ± SD)

Formulation	Work of shear (g s) Mean ± SD	Index of viscosity (g s) Mean ± SD	Consistency (g s) Mean ± SD	Cohesiveness (g) Mean ± SD
FA	759.3 ± 32.6^{a}	2061.4 ± 47.5^{a}	2561.0 ± 174.5^{a}	211.6 ± 9.2^{a}
FB	727.7 ± 37.1^{a}	1993.2 ± 74.4^{a}	2337.3 ± 164.4^{a}	198.9 ± 8.4^{a}
FC	34.2 ± 2.3^{c}	491.0 ± 16.8	943.3 ± 6.1	54.1 ± 0.6
FD	141.5 ± 5.3	574.6 ± 10.9	983.5 ± 3.6	59.8 ± 0.8
FE	424.2 ± 20.9	1993.9 ± 96.2^{a}	2268.5 ± 94.9^{a}	205.5 ± 23.7^{a}
FF	13.3 ± 0.4^{c}	133.6 ± 15.2^{bc}	456.1 ± 13.4^{c}	22.1 ± 1.2^{c}
FG	45.3 ± 3.7	156.1 ± 3.9^{c}	448.9 ± 9.3^{c}	19.4 ± 0.05
FH	17.5 ± 4.6^{c}	129.1 ± 3.7^{b}	439.5 ± 1.9^{c}	21.3 ± 0.1^{c}

Means with the same letter are not significantly different ($P < 0.05$)

being sheared. This property is related to structure recovery properties (2). This may be related to the presence of the wax, which is a consistency agent. Formulations with thixotropy and pseudoplastic flow have a resistance to spreadability that generates a more protective film to the skin (4). Rheology results are consistent with previous studies that observed a high influence of the oil phase, a complex system, on the macroscopic structure of the emulsions, notably spreadability, viscosity, and consistency (13,14,16).

The wax and the polymer showed a synergistic effect. On the one hand, the oil concentration may increase the apparent viscosity independent of the emulsifier used and contribute to shear-thinning behavior (16,35). On the other hand, the polymer chosen has already been shown to act as a good emulsifier and viscosity-enhancing agent (12). There seems to be a direct relationship between the polymer concentration and the formulation apparent viscosity (26). Confirming the results obtained in the mentioned studies, the high concentration of wax, formulation FE, and high concentration of polymer, formulation FG, produced higher values of apparent viscosity. This influence is clear when the apparent viscosity of the formulations with the minimum concentration of wax, formulation FF, and of polymer, formulation FH, is analyzed. The flow index and apparent viscosity did not have a direct relationship as described in the literature (26).

Concerning consistency, the formulations with a high concentration of wax, formulations FA, FB, and FE, demonstrated a high consistency index. Once more, the association between the wax and the polymer seems to bring better results; but in this parameter, wax had a bigger influence. The effect of the wax ratio on the material properties was previously studied (7). It was discovered that the addition of solid wax increases the network strength, and the mechanical properties are governed by the arrangement of the network.

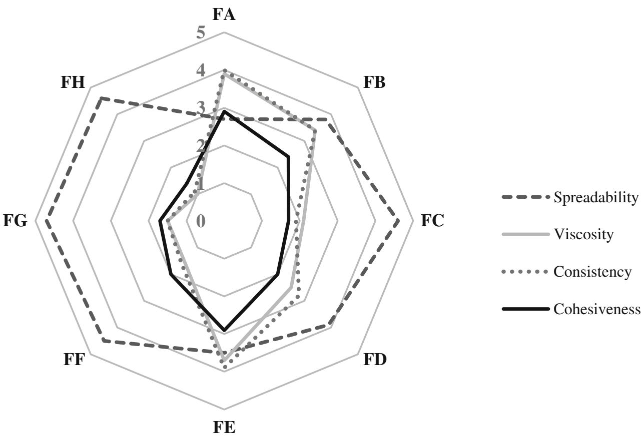

Fig. 4. Radar chart of sensory analysis

Beri, Norton, and Norton (7) demonstrated that the addition of solid wax provides greater connections, increasing the network strength. Binks and Rocher (5) showed that the stability provided by the wax depends on the concentration. In our study, lower concentrations of wax resulted in a greater synergistic effect with polymer in terms of texture parameters.

Regarding index of viscosity, consistency, and cohesiveness, formulations FA, FB, and FE presented the same behavior. This contradicts a previous study that affirms that Polymer 1 influences these texture parameters (36). The removal of the polymer did not influence these texture characteristics.

Agreeing with the literature, the sensorial spreading results agreed with the work of shear values (16,25,28). The formulations FA, FB, and FE, which have high values of work of shear, presented lower values for that spreading and the formulations FC, FF, FG, and FH presented opposite results. The stratum corneum, localized in the epidermis, is the most external layer of the skin. The sensory perception of a given formulation is related to the interaction between the skin surface and physical-chemical properties, reflected in the skin lipid film. The surface lipids are responsible for some parameters, such as the adhesion of solid particles and the skin surface energy, and give the skin surface a more hydrophilic character (37). Therefore, this hydrophilic character can increase the ease of spreadability for a given formulation with minimum or without wax content, as was the case for formulations FC, FD, FF, FG, and FH.

Because these sensorial parameters are more related to the physic-mechanical properties of the emulsions (15,16,18,19,21,24,36,38), it was possible to see the major influence of wax in these formulations.

In general, strong correlations were found among the parameters studied. The only negligible correlation occurred between the work of shear and flow index variables. With a correlation coefficient of 0.102, they do not seem to be related. The correlation between the flow index and sensorial spreadability presented a moderate positive correlation with a coefficient of 0.641. The flow properties can be measured to

Table V. Correlation Matrix of Parameters

		FI	AP	CI	WS	CH	CO	IV	S	CHS	COS	VS
Rheology	Flow index (FI)	1	–	–	–	–	–	–	–	–	–	–
	Apparent viscosity (AP)	0.046	1	–	–	–	–	–	–	–	–	–
	Consistency index (CI)	0.046	0.925	1	–	–	–	–	–	–	–	–
Texture	Work of shear (WS)	*0.102*	0.944	0.981	1	–	–	–	–	–	–	–
	Cohesiveness (CH)	0.065	0.794	0.869	0.850	1	–	–	–	–	–	–
	Consistency (CO)	0.084	0.850	*0.888*	0.906	0.963	1	–	–	–	–	–
	Index of viscosity (IV)	− 0.010	*0.888*	0.963	0.944	0.944	0.963	1	–	–	–	–
Sensorial	Spreadability (S)	*0.641*	− 0.317	− 0.392	*− 0.373*	− 0.533	− 0.486	0.011	1	–	–	–
	Cohesiveness (CHS)	0.161	0.733	0.845	0.817	*0.920*	0.911	0.904	− 0.598	1	–	–
	Consistency (COS)	0.027	0.831	*0.906*	0.888	0.981	*0.981*	0.981	− 0.505	0.939	1	–
	Viscosity (VS)	0.013	*0.864*	0.939	0.920	0.967	0.977	*0.995*	− 0.472	0.925	0.995	1

evaluate the behavior of emulsions subject to shear (4), but they should be compared with sensorial spreadability (24) because the flow index does not seem to be related with the work of shear parameter.

Savary *et al*. (24) demonstrated with another test that spreading measured in a texture analyzer can be linearly related to spreading predicted by the sensory panel. In our study, the inverse parameters work of shear and spreadability presented a low negative correlation with a coefficient of − 0.373. As previously stated, a formulation with a high work of shear value will be difficult to spread on the surface of the skin and also the reverse is true. Thus, this theoretical parameter can be used as a predictor of spreadability (16,28).

The following correlations were classified as high positive, with correlation coefficients ranging from 0.864 to 0.888: apparent viscosity/index of viscosity, consistency index/consistency, and apparent viscosity/sensorial viscosity. For these correlations, when a parameter increases, their follower increases too.

The strongest correlations were between consistency/sensorial consistency with a coefficient of 0.906; consistency index from rheology/sensorial consistency, with a coefficient of 0.981; cohesiveness/sensorial cohesiveness with a coefficient of 0.920; and index of viscosity/sensorial viscosity, which has the higher correlation coefficient of 0.995. They presented a very high positive correlation, indicating that the texture parameters are highly related to their respective sensorial parameter.

Finally, this work has an important contribution once showed that is possible to correlate physical and mechanical and sensorial parameters with the help of a trained panel, which can help the development of topical formulations predicting the performance into the skin.

CONCLUSION

Different waxes present a greater effect on the work of shear, a parameter that indicates spreadability. The interaction between the wax and the polymer also influenced this parameter. The best combination of wax and polymer was applied to develop eight formulations. The wax showed more impact compared to the polymer in relation to rheological, texture, and sensorial data, except for the work of shear and spreadability, where the polymer acted as a spreadability balancer. The relationships between the rheological, texture, and sensory variables were verified. In this way, it was possible to predict sensorial aspects by rheological and texture parameters, making the formulation process easier and more integrated with all stages of the development of new topical formulations.

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