Quantitative sensory interpretation of rheological and tribological parameters of emulsions: impact of the nature of the emollient on key sensorial attributes

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Introduction of research

The success of a cosmetic product is highly dependent on the consumer's perception and the sensorial profile of the product. Previous studies have shown that both emulsifiers and emollients affect the skin feel of emulsions, in the early phases (appearance, pick-up and rub-out) but also in later stages (after-feel) of the consumer's experience [1,2].

There is an increasing body of evidence in the literature that instrumental methods like rheology (science of flow and deformation of matter) and tribology (science of interacting surfaces in relative motion) can be used during the formulation developmental stage for the quantitative assessment of sensorial attributes of cosmetic emulsions [3,4]. Some of these methods are well correlated with visual or tactile perceptions such as *softness/hardness/firmness, thickness, spreadability, slipperiness, greasiness,* or *stickiness* of skin care products, as assessed by trained sensory panels [4-7].

The main objective of this study is to use a simple, reliable, and cost-effective tribo-rheological protocol [8] to assess the impact of a novel natural-derived multifunctional emollient, Dimethicone PG-Sunflowerseedate (DSF) [9], on the sensorial properties of oil-in-water emulsions, in comparison with other natural (sunflower seed oil), synthetic (mineral oil) and silicone (dimethicone) oils.

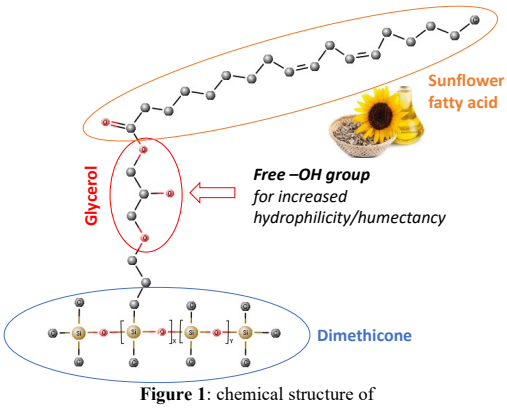


Figure 1: chemical structure of Dimethicone PG-Sunflowerseedate (DSF)

Materials & Methods

DSF is a multifunctional sunflower-derived emollient in which sunflower fatty acids, dimethicone and glycerol have been grafted together to provide enhanced sensorial benefits and ease of formulation in skin and hair products. Its chemical structure is shown on Figure 1.

Seven oil-in-water emulsions were prepared according to the same ingredient list and process. They differed only by the nature of the Emollient 1 in the oil phase, used at a concentration of 10% w/w (Table 1).

Phase	Function	INCI	Composition (% w/w)						
			I	II	III	IV	V	VI	VII
A	Emollient 1	Sunflower Seed Oil	10					5	8
		Dimethicone (10cS)		10					
		Dimethicone (350cS)			10				
		Mineral Oil				10			
		Dimethicone PG-Sunflowerseedate					10	5	2
	Emollient 2	Isopropyl Myristate	10	10	10	10	10	10	10
	Emulsifier	Cetearyl Alcohol (and) Polysorbate 60 (and) Oleth-10 (and) PEG-75 Lanolin (and) PEG-100 Stearate (and) Ceteth-20	5	5	5	5	5	5	5
B	Humectant	Glycerine	5	5	5	5	5	5	5
	Thickener	Carbomer	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Carrier	Water	68.6	68.6	68.6	68.6	68.6	68.6	68.6
C	pH adjuster	Triethanolamine	q.s. pH 6						
D	Preservative	Benzyl Alcohol (and) Dehydroacetic Acid	1	1	1	1	1	1	1
D	Chelating agent	EDTA	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 1: Composition of oil-in-water emulsions I to VII. Process: mix Phase A items to 60°C until appearance is clear; mix Phase B items to 60°C for 30 min; slowly add Phase A into Phase B and mix for 30 min at 60°C; begin cooling while mixing; at temperature less than 50°C, add Phase C until pH 6; at temperature less than 40°C, add Phase D and keep mixing until 25°C. Homogenize for 15min at 25°C.

An instrumental protocol was designed and applied for the quantitative assessment of the sensorial attributes of the different oil-in-water emulsions, by correlating simple sensory lexicons to rheological and tribological parameters (Table 2).

For each sensorial attribute, a score of 1 to 4 was defined according to the range of the corresponding physical parameter, as described in Table 3.

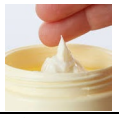
Moment of User Experience	Sensorial Attribute	Description of Physical-Sensorial Relationship	Instrument / Protocol / Physical Parameter	Level of Physical-Sensorial correlation
Appearance & Pick-up 	*Firmness*	The degree to which the product can keep its shape or structure in the presence of force.	Rheometer / Oscillatory stress sweep, 25°C / Yield Stress (Pa)	High [5]
Rub-out & After-feel 	*Spreadability*	The force required to make the product flow or to spread it on a surface.	Rheometer / Shear rate sweep, 32°C / Viscosity (Pa.s) under high shear rate (1000 s^{-1})	High [6]
	Slipperiness	The ability of the product to reduce friction between contacting sliding surfaces.	Tribometer / Sliding speed sweep, 32°C / Coefficient of friction at 10mm/s	Low to Medium [4,7]

Table 2: Proposed protocol of rheological and tribological parameters-sensory attribute pairs, their description, and level of correlation.

Score	Yield Stress (Pa) - *Firmness*	Viscosity (Pa.s) under high shear rate (1000 s^{-1}) - *Spreadability*	Coefficient of friction at 10mm/s - *Slipperiness*
1-low	<100	>0.425	0.10-0.11
2-medium	100-140	0.350-0.425	0.09-0.10
3-high	140-180	0.275-0.350	0.08-0.09
4-very high	>180	0.200-0.275	0.07-0.08

Table 3: Correlation of the range of yield stress, viscosity under high shear rate and coefficient of friction to *firmness, spreadability* and *slipperiness* scores (1-4), respectively

Results

Appearance & Pick Up: the nature of the emollient has a slight impact on the *firmness* of O/W emulsions. Among the five oils tested as Emollient 1, mineral oil gives the thicker and firmer structure to the emulsion.

Rub-Out & After-feel: results show that the nature of the emollient impacts both the *spreadability* of the product and the *slipperiness* of the cosmetic film during the later rub-out stage of the application.

As shown in Figure 2, the sensory profiles of emulsions IV and V, obtained with Dimethicone PG-Sunflowerseedate and mineral oil, respectively, are very similar. Both have medium-high *firmness,* very high *spreadability* and high *slipperiness*, an appealing sensorial profile which can also be found in existing commercial benchmark day creams.

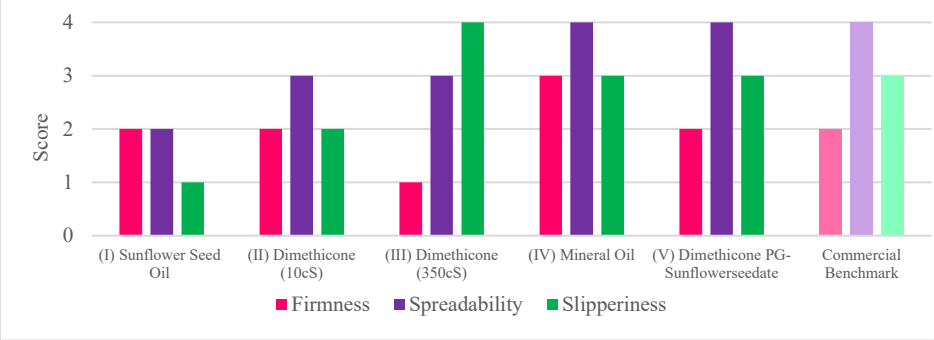


Figure 2: Influence of Emollient 1 on *firmness, spreadability* and *slipperiness* scores of O/W emulsions I-V, compared to a commercial benchmark day cream (Estée Lauder Revitalising Supreme Light).

Multi-functional properties of Dimethicone PG-Sunflowerseedate (DSF):

DSF is a 3-in-1 ingredient, which was designed to have triple benefits in cosmetic formulation: 1/ the sunflower oil-derived lipophilic pendant chains provide moisturizing, conditioning, emollience and compatibility with other polar oils ; 2/ the silicophilic dimethicone backbone provides glide, occlusive skin barrier, shine, smoothing characteristics, non-greasy feel and compatibility with other silicones; 3/ slightly hydrophilic di-substituted glycerol linkers are used to bridge the lipophilic and silicophilic moieties and provide increased water compatibility, moisturizing and humectancy (Figure 1).

As detailed in Figure 3, the *in vitro* sensory profile of O/W emulsions can be also strongly influenced by the concentration of DSF in the oil phase. The higher the DSF content, the easier to spread and the more slippery the emulsion is upon rub-out.

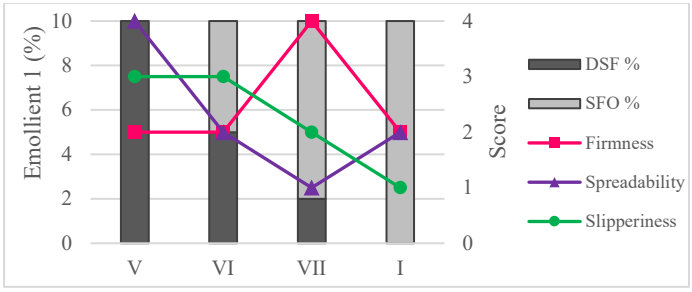


Figure 3: impact of different ratios of Dimethicone PG-Sunflowerseedate (DSF) vs Sunflower Seed Oil (SFO) on *firmness, spreadability* and *slipperiness* scores of O/W emulsions I, V, VI and VII.

Interestingly, when used at lower concentration (2%), DSF can bring dramatic viscosity/*firmness* enhancement benefits to emulsions (Formula VII, Figure 3). The reasons for the unexpected properties of the emulsion VII with 2% DFS need to be further investigated, but given its slight hydrophilicity, one can assume that DSF probably acts more as an emulsifier (positioned at the oil/water interface) than an emollient (in the oil phase) at this concentration.

Conclusion

Using a convenient and cost-effective instrumental protocol, which correlates the rheological and tribological parameters of emulsions with perceivable attributes such as *firmness*, *spreadability*, and *slipperiness*, the sensorial impact of a new multi-functional ingredient, Dimethicone PG-Sunflowerseedate was assessed. When used at 10% in the oil phase of O/W emulsions, it functions as an emollient and gives similar sensorial profile as mineral oil in terms of *firmness, spreadability* and *slipperiness*. Compared to sunflower seed oil it brings more *spreadability* and lubrication in the rub-out experience. Interestingly, it can also be used as a thickening agent at lower concentration (2%).

References

(1) Wiechers J. W., Taelman M.-C., Wortel, V. A. L., Verboom C., Dederen J. C., "Emollients and Emulsifier Exert their Sensory Impact in Different Phases of the Sensory Evaluation Process but How Does One Demonstrate the Absence of Such Influence?", *IFSCC Mag.,* **5** (2), 99–105 *(2002).*
(2) Chandler M., O'Lenick T., "Inverting the tables on emulsion sensory and performance", *Household and Personal care Today,* **14(2)**, 22-25 *(2019)*
(3) Adejokun D.A., Dodou K., "Quantitiative Sensory Interpretation of Rheological Parameters of a Cream Formulation", *Cosmetics* ,**7**, 2 *(2020)*.
(4) Guest S., McGlone F., Hopkinson A., Schendel Z.A., Blot K., Essick G., "Perceptual and Sensory-Functional Consequences of Skin Care Products" *Journal of Cosmetics, Dermatological Sciences and Applications*, **3**, 66-78 *(2013).*
(5) Greenaway R.E., "Psychorheology of Skin Cream", Ph.D. Thesis, University of Nottingham, Nottingham *(2010).*
(6) Wegener M.R., "A Psycho-Rheological Study of Skin-Feel", Ph.D. Thesis, University of Bristol, Bristol *(1997).*
(7) Van Der Heide E., Zeng X., Masen M.A. "Skin Tribology: Science Friction?", *Friction*, **1(2)**, 130-142 *(2013).*
(8) https://www.rheologylab.com/articles/pharma/spreadability-topical-products/
(9) https://elecorporation.com/new_product/pel-sil-sfd/

About the speaker

Séverine Jeulin, is the Director of New Product Development for Personal Care at Elé Corporation. She holds a Ph.D. in Organic Chemistry from Paris 6 University, France and has 15 years of international experience as R&D team and project leader in cosmetic and pharmaceutical industries, across Asia, Europe, and the USA. Her main expertise is the design, development, and evaluation of innovative cosmetic ingredients, leading to 8 patents and over 15 product launches for international cosmetic brands.