

Instrumental–Sensory Correlations for Predicting Application Performance in O/W Sunscreen Emulsions

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INTRODUCTION

The **sensory properties** of cosmetic products strongly influence consumer perception and application behavior, particularly for **sunscreens**, where pleasant textures can support correct and consistent use (1). While sensory panel tests provide valuable information, they are time-consuming, costly and inherently variable (2).

AIM OF THE STUDY: Combining **Quantitative Descriptive Analysis (QDA)** with **rheology**, **texture analysis** and **tribology** to investigate the relationships between sensory perception and instrumental properties of O/W sunscreen emulsions, aiming to identify objective and predictive descriptors of sensory performance and support a faster, data-driven formulation approach.

MATERIALS & METHODS

Nine O/W emulsions sharing a common formulation backbone were investigated across three SPF levels (SPF 0, SPF 15, SPF 30) and three texture profiles (Light, Medium, Rich) (Table 1).

Table 1: List of the analysis performed on samples.

TEST	INSTRUMENT	SETTING	PARAMETERS
Rheology	Anton Paar MCR 302e Rheometer	PP50/P2 sensor (gap 1 mm) at 23°C ± 0.05°C - Controlled Shear Rate: 0.001–1000 s ⁻¹ - Amplitude sweep: strain (γ) 0.01% - 1000% (1 Hz); - Frequency sweep: 10 Hz - 0.01 Hz, fixed strain (within the Linear Viscoelastic Region LVER).	Viscosity η [Pa.s]; complex modulus G* [Pa]; loss factor tanδ; stress τ [Pa] and strain γ [%] at LVER and crossover.
Texture analysis	TMS-Pro Texture Analyzer (Food Technology Corp.)	Immersion/de-immersion test (depth 10 mm, speed 80 mm/min), load cell 10 N, nylon spherical probe (φ 2 cm).	Firmness [N], Consistency [N.mm], Cohesiveness [N], Adhesiveness [N.mm], Stringiness [mm].
Tribology	Anton Paar MCR 302e Rheometer	Ball-on-three-plates (glass sphere/PDMS) at 37°C Normal Force 2 N; sliding velocity: 10 ⁻⁸ –1 m/s.	Friction coefficients COF throughout the Stribeck's curve: X1, X2, X3, X4.
Sensory analysis	QDA Quantitative Descriptive Analysis	Trained sensory panel (n = 10), 3 independent sessions; structured 1–10 intensity scale.	Thickness, consistency, spreadability, residual feel.
Statistical analysis	IBM SPSS Statistics software	Pearson's correlation analysis between instrumental and QDA data.	Pearson's correlation coefficient (R _p); correlation maps.

RESULTS

Rheological and texture analysis consistently differentiated the formulations according to their structural properties (Figure 1).

Increasing texture richness was associated with higher viscosity and G*, together with increased firmness, consistency, adhesiveness, and cohesiveness, indicating a progressively stronger and more resistant internal structure. Higher SPF levels further increased the mechanical response, both quantitatively and qualitatively, reflecting the structuring contribution of UV filters and the higher solid content.

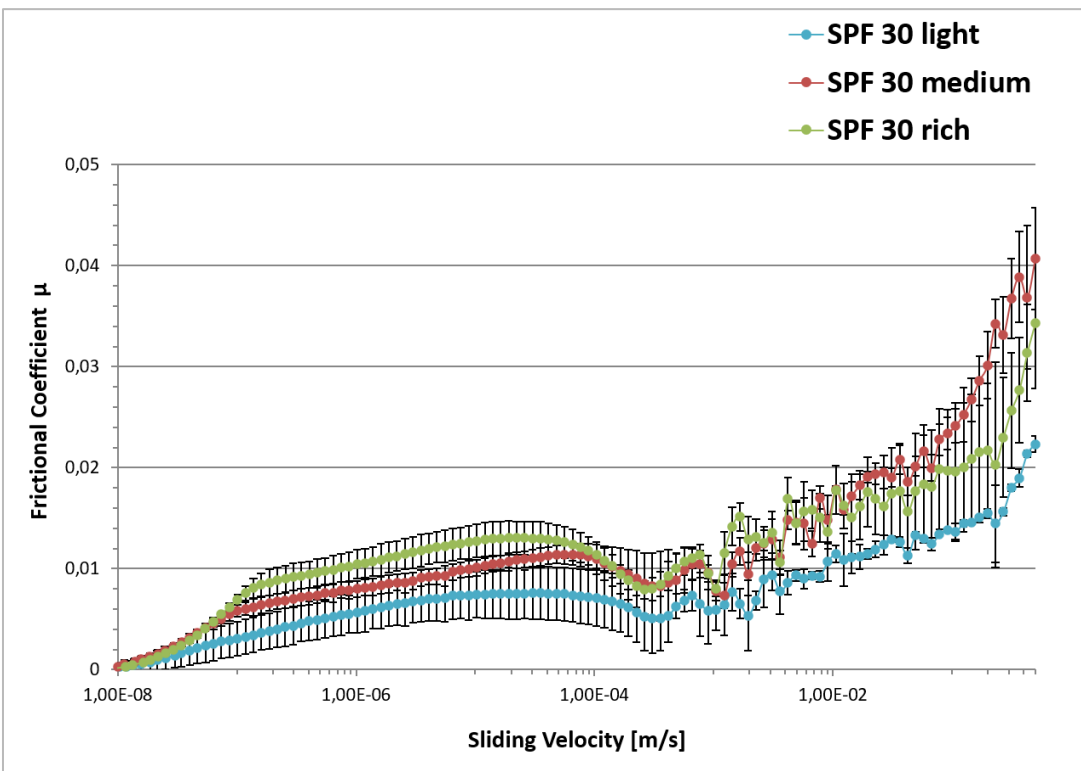


Figure 2: Stribeck curves of SPF 30 formulations.

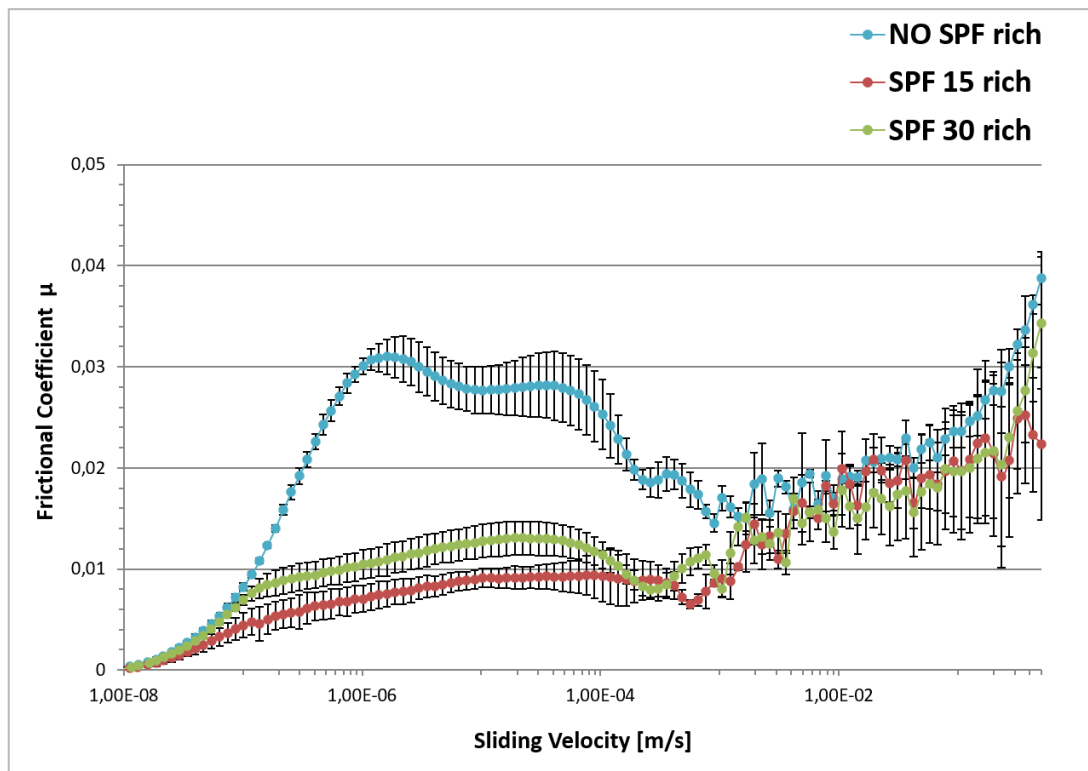


Figure 3: Stribeck curves of rich formulations.

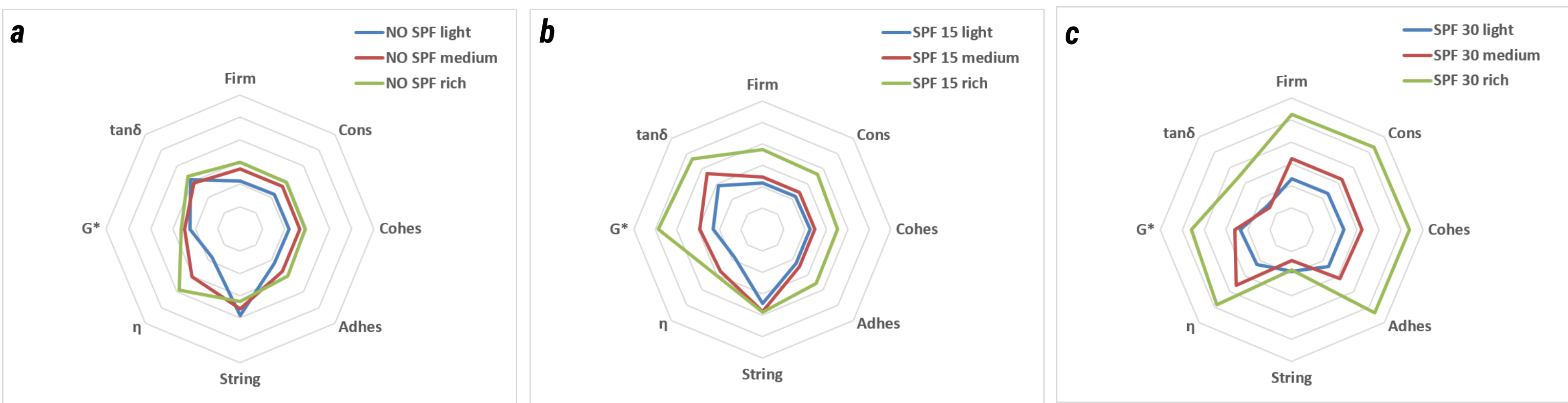


Figure 1: Rheological and texture parameters measured for formulations with no SPF (a), SPF 15 (b) and SPF 30 (c).

Tribological analysis provides complementary information on friction and lubrication phenomena occurring during application. Stribeck curves revealed distinct lubrication profiles across formulations.

Light formulas showed lower COF, indicating better lubrication and easier spreading, while Rich ones exhibited higher values, consistent with increased drag and more persistent films (Figure 2).

SPF level also affected lubrication: SPF 15 and 30 showed lower boundary friction (X2) than their SPF 0 counterparts, likely due to UV filters and increase in the emollient phase (Figure 3).

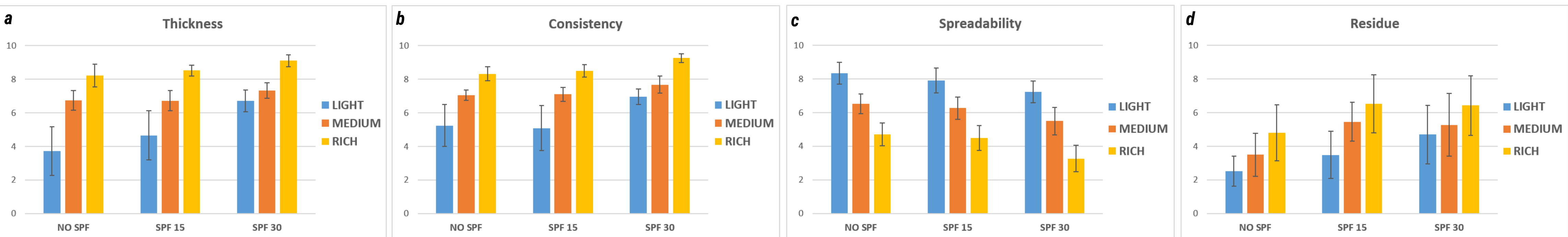


Figure 4: QDA sensory profiles of the formulations, showing mean panel ratings for Thickness (a), Consistency (b), Spreadability (c), and Residual (d).

Correlation analysis confirmed strong relationships between instrumental structure and sensory perception. Thickness and Consistency positively correlated with η, G*, textural parameters (firmness, consistency, cohesiveness and adhesiveness), and, to a lesser extent, with tribology X4. Spreadability showed negative correlations with the same structural descriptors (Table 3). Residual Feel showed weaker and more variable correlations, reflecting the greater complexity of after-feel perception.

CONCLUSION

Instrumental analysis can support the prediction of sensory performance, enabling faster and more data-driven **formulation screening** and **claim substantiation**. Complex attributes such as **after-feel remain difficult to predict instrumentally**, confirming the complementary role of sensory evaluation. Further validation across broader and more diverse formulation platforms is needed to assess the general applicability of the approach.

Table 3: Correlation matrix: Pearson's coefficient. Significance codes: * = significant at 0.05; ** = significant at 0.01.

	Viscosity	G*	tanδ	γ G'=G''	γ end LVER	τ G'=G''	τ end LVER	Firmness	Consistency	Cohesiveness	Adhesiveness	Stringiness	x1	x2	x3	x4
Thickness	0.78**	0.70**	0.24	-0.07	-0.21	0.75**	0.60**	0.75**	0.74**	0.71**	0.72**	-0.14	-0.04	0.28	-0.11	0.55**
Consistency	0.81**	0.82**	0.45*	-0.25	-0.32	0.85**	0.67**	0.85**	0.83**	0.81**	0.83**	0.14	-0.11	0.19	-0.01	0.53**
Spreadability	-0.76**	-0.82**	-0.46*	0.04	0.35	-0.83**	-0.64**	-0.82**	-0.81**	-0.78**	-0.80**	-0.07	0.26	-0.14	-0.00	-0.61**
Residual	0.37	0.34	0.18	-0.35	-0.04	0.38	0.24	0.35	0.39*	0.32	0.31	-0.19	-0.01	0.13	-0.05	0.39*

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