# Rheological and Textural Properties of Cosmetic Emulsions

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**Abstract:**
A set of 31 cosmetic emulsions, as the most frequent cosmetic dispersions, comprising lotions and creams (o/w, w/o), was analyzed by rheological procedures (RheoStress 300, Thermo Fischer Scientific) and by sensory profiling. The power law model was used for pseudoplastic body lotions and the Herschel-Bulkley model for viscoplastic creams to get basic rheological parameters (apparent viscosity, consistency parameter, yield stress value, plastic viscosity and flow behaviour index). The content of $TiO_2$ in sun lotions probably caused better agreement with viscoplastic creams. Rheological analysis proved to be more suitable for the storage stability testing of the emulsion than sensory evaluation. Psychorheology was applied as a suitable complex method. Rheological parameters were compared to sensory texture attributes (removing from a package, ease of spreading, skin feel and thickness). Almost 60% of relationships among rheological and sensory parameters were statistically significant ($P$ = 0.05). Considering relationships only between rheological and sensory characteristics (with each other), 46 % were statistically significant ($P$ = 0.05). In the case of apparent viscosity and removing the lotion from a bottle the relationship was reliable enough (correlation coefficient 0.91) to estimate the sensory attribute by fast rheological measurement. The other statistically significant relationships (correlation coefficients 0.53–0.80) proved that the sensory texture acceptability of a cosmetic emulsion could be partly predicted by rheological analysis.

**Zusammenfassung:**
31, größtenteils häufig verwendete kosmetische Dispersionen, darunter Lotionen und Cremes (o/w, w/o), wurden rheologisch und durch Erstellung eines sensorischen Profils charakterisiert (RheoStress 300, Thermo Fisher Scientific). Für die pseudoplastischen Körperlotionen wurde das Potenzgesetz-Modell und für die viskoelastischen Cremes das Herschel-Bulkley-Modell angewandt, um die grundlegenden rheologischen Parameter (scheinbare Viskosität, Konsistenzparameter, Fließspannung, plastische Viskosität und den Fließkurvenindex) zu ermitteln. Der TiO2-Gehalt in den Sonnencremes führte zu einer besseren Übereinstimmung mit den viskoelastischen Cremes. Die Analyse der rheologischen Größen erwies sich als geeigneter für die Stabilitätsversuche als die Sensorevaluation. Psychorheologische Methoden wurden ebenfalls als geeignete komplexe Methode angesehen. Die rheologischen Parameter wurden mit senorischen Größen verglichen (Fließen aus dem Behälter, Einfachheit der Verteilung der Dispersion, Hautgefühl und Dicke). Fast 60% der Beziehungen zwischen den rheologischen und den sensorischen Größen waren statistisch ausreichend signifikant (P = 0.05). Die Beziehungen zwischen den rheologischen und sensorischen Größen alleine waren zu 46% statistisch signifikant (P=0.05). Im Falle der scheinbaren Viskosität und des Entleerens eines Behälters war die Korrelation ausreichend zuverlässig (Korrelationskoeffizient 0.91), um die sensorischen Größen durch schnelle rheologische Messungen zu ermitteln. Die weiteren statistisch signifikanten Korrelationen (Korrelationskoeffizient 0.53–0.80) zeigten, dass die Akzeptanz der sensorischen Größen einer kosmetischen Emulsion teilweise durch eine rheologische Größe vorhergesagt werden kann.

**Résumé:**
Un ensemble de 31 émulsions cosmétiques, pris comme dispersions cosmétiques les plus fréquentes, comprenant des lotions et des crèmes (h/e, e/h), a été analysé à l'aide de procédures rhéologiques (RheoStress 300, Thermo Fischer Scientific) et de profilométrie sensorielle. La loi de puissance a été utilisée pour modéliser les lotions corporelles pseudo plastiques, et le modèle de Herschel-Bulkley pour les crèmes viscoplastiques, afin d'obtenir les paramètres rhéologiques (viscosité apparente, paramètre de consistance, valeur de la contrainte seuil, viscosité plastique et index du comportement d'écoulement). La quantité de TiO2 dans les lotions solaires est probablement à l'origine du meilleur accord avec les crèmes viscoplastiques. L'analyse rhéologique s'est avérée être plus appropriée pour tester la stabilité durant le stockage des émulsions plutôt que l'analyse sensorielle. La psychorhéologie a été appliquée comme une méthode complexe convenable. Les paramètres rhéologiques ont été comparés aux attributs de texture sensorielle (extraction de l'emballage, facilité d'étalage, épaisseur et sensibilité sur la peau). Environ 60% des relations entre les

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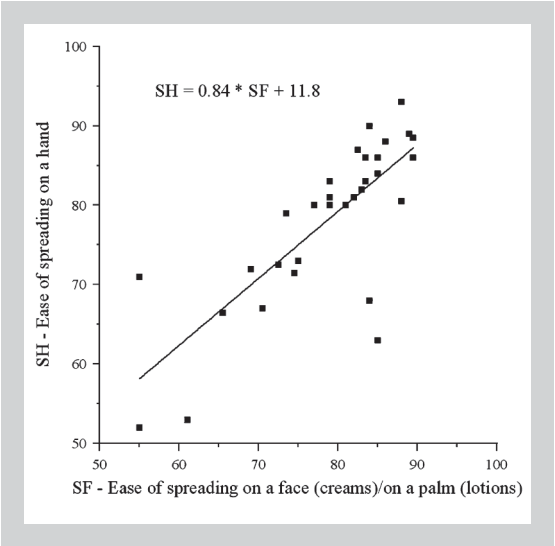


*Figure 2 (left): Relationship between the SF - ease of spreading on face/palm and SH - ease of spreading on hand (N = 31, correlation coefficient 0.74, P = 0.05).*

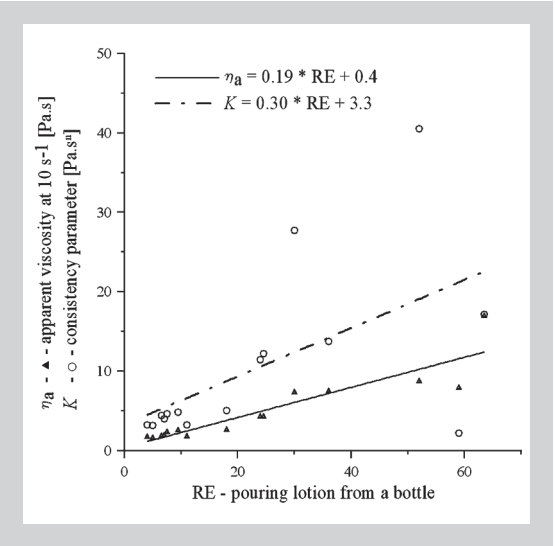


*Figure 3: Relationship between the RE - pouring from a bottle and $\eta_a$ - apparent viscosity (solid line: N = 15, correlation coefficient 0.91, P = 0.05) and RE and K - consistency parameter (dotted line: N = 15, correlation coefficient 0.57, P = 0.05).*

*Table 6: Correlation coefficients between rheological and sensory results (P = 0.05).*

sample. Considering all samples, the mean value of removing the cream from a pot is 46, pouring lotion from a bottle is 18, the difference between both emulsion characters is evident. Assessment of the ease of spreading (SF, SH) gives mean value 80 (both SF, SH) for creams and 84 (SF) and 83 (SH) for lotions, similar results for creams and lotions mean low impact of emulsion character on its ease of spreading. Descriptor FE of the skin feel after cream application is 75, thickness (TH) for body lotions is 41, in mean values. The mean standard deviation of the results is 18 (from 16 at TH assessment to 21 at FE assessment).

The emulsion stability was evaluated by both rheological (stability at shear stress) and sensory tests (storage stability), the sensory analysis assessed only one sample (lo5) as unstable – the separation of oil and water phase was visible. The other samples, which were rheologically declared as unstable, exhibited no visible changes during sensory assessment. It can be summarized that rheological analysis of stability at shear stress can detect microscopical changes in the emulsion structure leading to instability, before these changes become visible and so observable for sensory testing. When comparing the sensory results using correlation coefficients, almost 90% of relationships were significant ($P$ = 0.05). The highest correlation was found between pouring lotion from the bottle and thickness (correlation coefficient was 0.81). As the assessment of ease of spreading gives very similar mean values on face/palm (SF) and on the back of hand (SH), the correlation coefficient between SF and SH is only 0.78, see Figure 2. It seems to be sure to assess the ease of spreading on two different places.

### *3.3 RELATIONSHIPS BETWEEN RHEOLOGICAL AND SENSORY VARIABLES*

Involving all rheological and sensory analysis results, total number of statistically significant relationships is 23 out of 39 combinations - 59 %. This value is affected by a higher number of reliable relationships among sensory attributes (89 %). More important is to compare rheological data to sensory assessment with each other (see Table 6), 46 % of relationships were statistically significant (in bold). This is quite good ratio considering high diversity of both methods used and great variability among samples.

Figure 3 depicts a relationship between sensory characteristic RE (pouring from a bottle) and rheological parameter, apparent viscosity at low shear rate (10 $s^{-1}$) for body lotions. Here close relationship was expected and is confirmed by the highest correlation coefficient (0.91). In this case the rheological measurement of apparent viscosity can predict the sensory attribute – how difficult is to pour the lotion from a bottle. Figure 3 also shows a relationship between RE and consistency parameter, with correlation coefficient 0.57. This is still statistically significant result, but not enough to use the relationship for the prediction of texture property using rheological measurement.

Figure 4 describes other selected statistically significant relationships, between ease of spreading on a back of hand (SH) and consistency parameter or apparent viscosity. Correlation coefficients are -0.75 and -0.72 respectively, this values are not high enough to enable the prediction of ease of spreading by instrumental methods. Further investigation involving more samples and more determinations could improve the reliability of these relationships, then fast rheological analysis could replace demanding sensory testing of the ease of spreading.

| sample | | RE* | SF* | SH* | FE* | TH* |
|---|---|---|---|---|---|---|
| Creams (N = 16) | $\tau_o$ | **0.80** | **-0.68** | -0.30 | **-0.53** | - |
| | $\eta_{pl}$ | 0.44 | -0.23 | 0.12 | 0.03 | - |
| | n | 0.02 | -0.25 | -0.36 | -0.46 | - |
| Lotions (N = 15) | K | **0.57** | **-0.74** | **-0.75** | - | **0.65** |
| | p | -0,01 | 0.23 | 0.19 | - | -0.26 |
| | $\eta_a$** | **0.91** | **-0.71** | **-0.72** | - | **0.76** |

* see Table 2 (RE - removing from the package, SF - ease of spreading on face/palm, SH - ease of spreading on hand, FE skin feel, TH - thickness) - no constitutive correlation
** $\eta_a$ apparent viscosity at shear rate 10 $s^{-1}$





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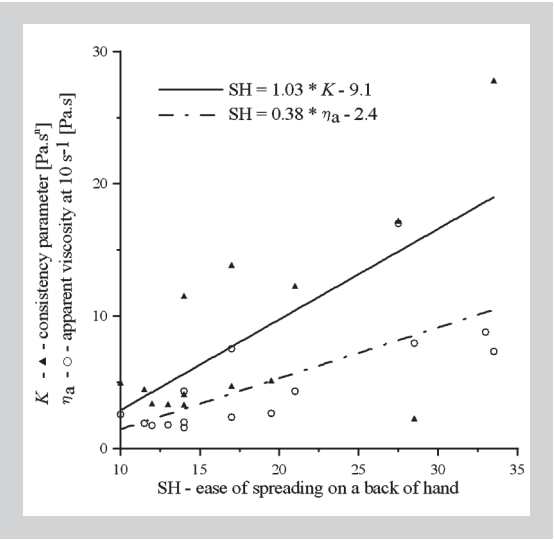


*Figure 4: Relationship between the SH - ease of spreading on a back of hand and K - consistency parameter (solid line: N = 15, correlation coefficient - 0.75, P = 0.05) and SH and $\eta_a$ - apparent viscosity (dotted line: N = 15, correlation coefficient - 0.72, P = 0.05).*

## 4 CONCLUSIONS

A set of 31 cosmetic emulsions, involving lotions and creams, was subjected to rheology analysis and sensory profiling. Rheology analysis proved that even a small change in the ingredients affects the final rheological characteristics of the emulsions. Sensory analysis assessed a difference between lotions and creams only at some texture attributes. At evaluation of the storage stability of emulsion, rheological analysis proved to be more suitable than sensory assessment. To describe the relationships among different rheological and sensory descriptors, results of both analyses were compared. Considering great variance among samples and difference of used methods, still many statistically significant relationships ($P$ = 0.05) were found on statistic evaluation (23 significant relationships out of 39 combinations). Part of them was observed between rheological and sensory characteristics, that confirms close relationships between the sensory acceptability and rheological values. The closest relationship was found between the apparent viscosity of a lotion and pouring the lotion from a bottle, in this case the fast rheological analysis could predict the sensory acceptability. The other relationships were statistically significant, but not enough reliable to enable the prediction of sensory evaluation. If more samples or more evaluation are included in the measurement, the reliability would rise. These close relationships would mean great simplification for cosmetic emulsion's producers, as the fast and objective rheological analysis could replace time and money consuming sensory assessment.

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