Rheological Characterization of Body Lotions

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Abstract:
This study is attempted to demonstrate the application of rheological measurements in characterization of cosmetics products. As part of this study, several rheological tests were carried out on three common, commercially available body lotions to analyze their complex properties. The tests described in this study were simple and predictive in which the viscoelastic properties were successfully related with the end-use performance properties such as applicability, processing behavior, temperature sensitivity and storage and thermal stability.

Zusammenfassung:
Diese Untersuchung soll die Anwendung rheologischer Messungen zur Charakterisierung von kosmetischen Produkten zeigen. Verschiedene rheologische Tests wurden an drei gebräuchlichen, kommerziell erhältlichen Body Lotions durchgeführt, um ihre komplizierten Eigenschaften zu bestimmen. Die hier beschriebenen Tests sind einfach rheometrischer Struktur und es kann gezeigt werden, dass die gemessenen viskoelastischen Eigenschaften erfolgreich mit den "End-use" Eigenschaften wie Applikation, Verarbeitungsverhalten, Temperaturempfindlichkeit sowie Lager- und thermische Stabilität verknüpft werden können.

Résumé:
Cette étude s'essaye à démontrer l'utilité des mesures rhéologiques pour la caractérisation de produits cosmétiques. Dans une partie de cette étude, plusieurs tests rhéologiques ont été entrepris sur trois lotions pour le corps, disponibles dans le commerce, afin d'analyser leurs propriétes complexes. Les tests décrits dans cette étude sont simples et prédictibles, dans le sens ou les propriétés viscoélastiques furent reliées avec succès aux propriétés de performances finales telles que, applicabilité, comportement lors de la mise en oeuvre et le conditionnement, sensibilité à la température, ainsi que les stabilités thermiques et d'entreposage.

Key words: Cosmetics, body Lotions, viscoelasticity, rheology

1 INTRODUCTION

Creams and lotions require a complex array of rheological and thermal testing in order to characterize them and control the quality for the end user satisfaction. When applied to the skin of the human body, they need to spread easily on the skin without feeling greasy or sticky. To be effective, they should leave a thin and uniform coating of the key ingredients, which can penetrate quickly into the skin. During the shelf storage in the retail stores, the ingredients of the products should not separate or settle in the container; otherwise the product would feel lumpy or grainy when applied to the skin. When the product is poured or squeezed from the packaging container, it should not be too hard or too runny (like water). The product has to be formulated just right to meet the consumer satisfaction.

Since 1960's rheological measurements has been becoming increasingly important to be able to characterize the "consistency" of semisolid gels, ointments and creams, ("so-called complex or structural fluids"), in a meaningful fashion [1-5]. Rheological measurements are now required in various pharmaceutical and cosmetics industries [6], including but not limited to the (a) quality control; (b) storage stability under various weather and transportation conditions; (c) correlation with sensory assessment and consumer evaluation; (d) effects of formulation on consistency; (e) prediction of flow behavior under manufacturing or production environment conditions (e.g., pumping, mixing, milling and packaging).

Different cosmetic products require different rheological behavior. For instance, body lotions require a certain yield stress (or high viscosity) at rest in order to stay in the hands of the consumer while being taken out of the bottle. However a subsequent shear thinning behavior (or low viscosity at high shear) is required for ease of spreading and applying the lotion onto the skin. The low viscosity at high shear is also important for lotion to form a uniform thin layer that will more easily penetrate the skin and help the skin absorb the active ingredients without feeling greasy or sticky. This study demonstrates how to characterize body lotions through simple rheological measurements. Basically the following performance criteria of body lotions are considered for this study:

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Figure 9 shows plots of complex viscosity, η^*, versus stress for dynamic stress sweep test at 25°C. The point of stress at which η^* drops can be regarded as yield stress. Stress control rheometers that allow a gradual increments in stress can make this type of yield stress measurements directly with the stress sweep test. It can be seen that Lotion A and Lotion C have the almost same yield stress values, and Lotion B has a lower yield stress value. The yield stress value is range from 15 to 35 Pa. The state of the lotion at stress level below yield stress value corresponds to low shear process or at rest. The state of the lotion at stress level higher than the yield stress value corresponds to higher shear processes like pumping, extruding, bottling and spreading. From analyzing the yield stress values and viscosity at high stress, we can say that Lotion A and Lotion B are easier to bottle than Lotion C. The same is also true for pumping and extruding processes, Lotion A and B are easier than Lotion C.

Fig. 10 shows the data of steady stress ramp loop test. The same conclusions deduced from Fig. 9 can also be arrived at from analyzing the results from Figure 10. The order of yield stress values for the three lotions is Lotion C ≅ Lotion A > Lotion B. The values are very comparable with those determined from dynamic test (Fig. 9). It can be clearly seen that in order to maintain the flow at a high shear rate, the order of required stress is Lotion C > Lotion B > Lotion A. In addition, the Lotion A has much higher gap in the thixotropic loop test than the gap in the thixotropic loop tests for Lotion B and Lotion C. Thixotropic loop test shows the characteristic "hysteresis loop", the size of which is related to the degree of thixotropy and recovery time. Structure recovery of Lotion A seems to be slower than Lotion B and Lotion C. Thus with Fig. 9 and Fig. 10, we can easily understand that squeezing or pumping out a body lotion is easily done, if the lotion viscosity is lower at high shear and the lotion has a low yield stress value.

3.4 *APPLICABILITY*

At the final stages of their use, the body lotions are usually spread on the body by rubbing in. First, body lotion is taken out of the container into the hands. Sometimes, the lotion is directly applied to the part of the body. Then, the lotion is spread on the outer skin of the hands to some extent forming a thin uniform layer. Finally, the hands are rubbed to continue to spread the lotion on the skin. For the good applicability, a body lotion must be fairly thin at high shear to be able to spread easily; yet it must not run or drip off the hand between the time it is taken out of the bottle and the time it is applied to or rubbed in on the skin. During the application on the body, the temperature of lotion should be close to body temperature of 37°C. Thus the measurements were conducted at 37°C for this purpose.

Fig. 11 shows the data of frequency sweep for Lotions A, B and C at 37°C. Figure 12 shows the data of dynamic stress sweep for Lotions A, B and C at 37°C. The data in Fig. 11 indicates that all of them have gel-like structure (similar to the procesability test at 25°C in Fig. 8), and they should not have problem in staying on the hand and skin. Being different with their data at 25°C, Lotion C has a quite higher storage modulus, G', than the G' values for Lotion A and Lotion B. Lotion A has almost identical G' values at 37°C as the G' values for Lotion B at 37°C.

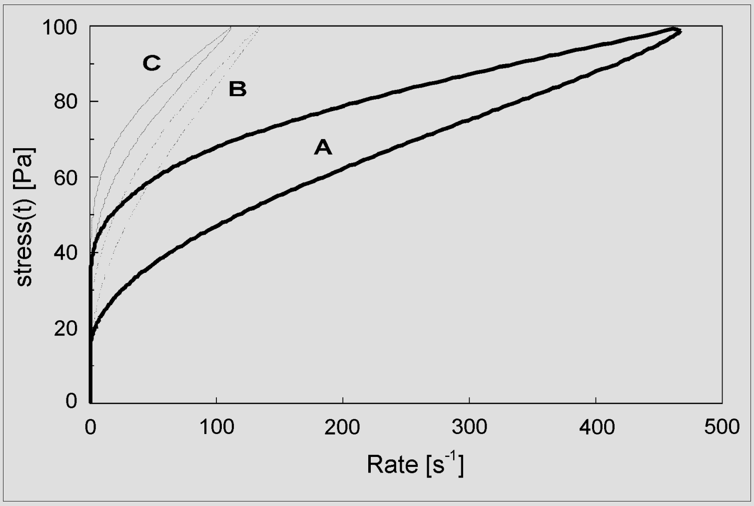

Figure 10: Thixotropic loop of shear stress versus shear rate.

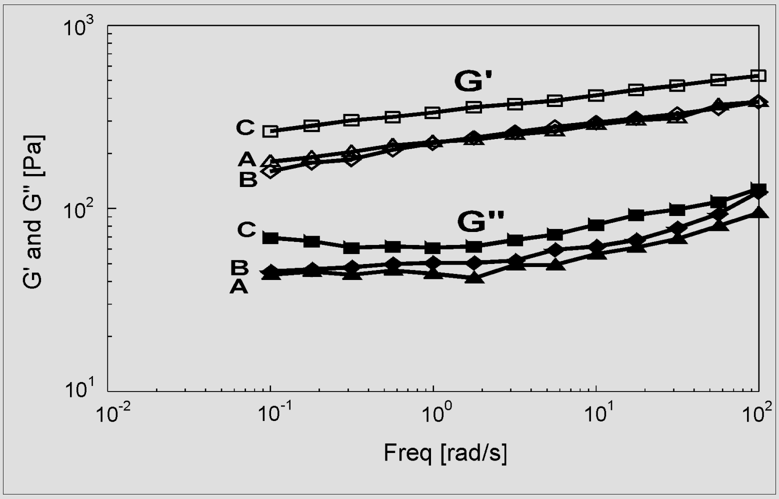

Figure 11: Frequency dependence data at 37°C.

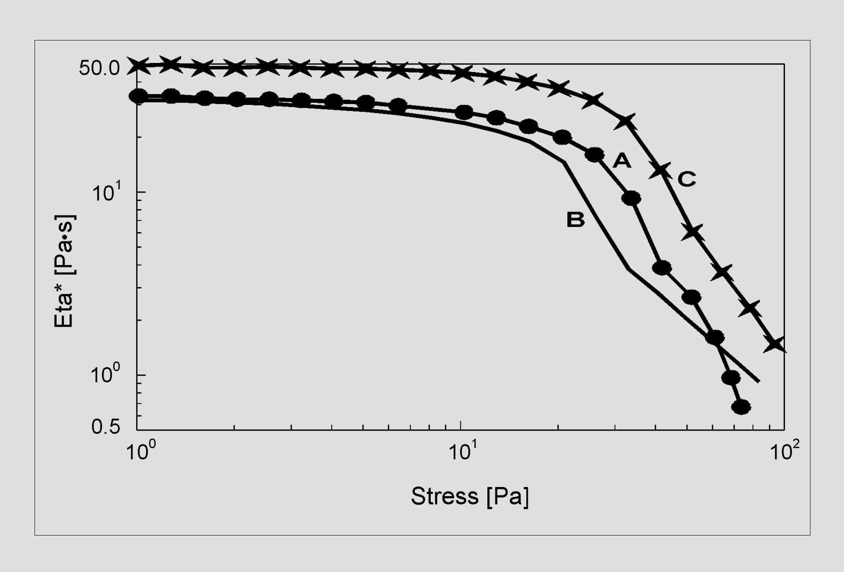

Figure 12: η versus stress plot at 37°C.*

The data in Fig. 12 indicates that Lotion C has a higher yield stress value than Lotion A and Lotion B. At high stress (i.e., high shear), Lotion A has the lowest viscosity, Lotion B is the second lowest viscosity and Lotion C has the highest viscosity. From these data we can say that Lotion A has best ease of applicability (lower yield stress and lower viscosity at high shear), Lotion C has worst ease of applicability (higher yield stress and higher viscosity at high shear).

SUMMARY

Applied rheology is very useful methods for evaluation of the application behavior, manufacturing processing, and thermal storage stability of lotions and other personal care products. The tests described in this work are meaningful and predictive. Since rheology is a very sensitive probe of the microstructure of material, including lotions, it can be used to relate their viscoelastic parameters, viscosity and elasticity, to end-use performance. Using the Rheological tests, new formulations can be quickly evaluated, thereby avoiding expensive and time-consuming trial market evaluations.

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