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"Correlating Triborheology to the Sensory Profile of Cosmetic Formulations"

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1. Introduction

Connecting the insights gained in consumer testing, such as the feel of a product, to a scientific metric is one of the major challenges facing the personal care and beauty industries. Tribology is the study of friction between two interacting surfaces. Triborheology can used to study the frictional effects and lubrication and wear between two surfaces. The applications of triborheology are vast with some examples include food and beverage (e.g. quantify mouthfeel) [1] and personal care (e.g. quantify skin-feel) [2]. Triborheology differs from shear rheology as instead of imposing a shear at a fixed gap, a fixed normal load is applied to the sample and the friction can be measured as a result. In this study we measured the triborheological response of model water/glycerol mixes to verify out technique as well as three commercial creams. Prior to this the three commercial samples were subjected to a consumer preference test. The results of the consumer preference test were then compared to the triborheology measurements to ascertain any insights into the data.

2. Materials and Methods

The consumer preference test was conducted by selecting three different skin cream products of varying price and viscosity. The three selected skin creams were Cetaphil Daily Moisturising Cream, Cetaphil Rich Night Cream and Vichy Laboratories Mineral 89. This study had 9 participants who blind tested the 'feel' of the product and their preference based upon the feel. Participants were asked to describe the feel of each of the products using three descriptors: silky, tacky or wet. To test the feel of the products a small amount of each subject had a small amount of product dispensed onto their hand and was asked to rub the product into their skin. Once rubbed in they ran a clean finger over the region where the product was applied, and their description of the feeling was noted. After all, three products were tested all volunteers were asked to rank the three products based on the feel of the product. Volunteers were asked to describe the feel of each product with one of the following: wet, silky or tacky.

The triborheology measurements were done on a KINESIS Ultra rheometer, fitted with a bespoke geometry created for specifically for triborheological measurements. Small samples, approximately 1-2mL, were deposited onto a metal plate with a glass slide fixed on with vacuum grease. A PDMS probe mounted on to the top plate of the rheometer is then lowered to till in contact with the sample. The PDMS probe was chosen as it can produce similar pressure

to a human finger. A constant load 0.1N is imposed on the sample throughout the measurement, the angular speed is then varied from 0.04rads^{-1} to 40rads^{-1}. Once completed a reverse sweep is performed 40rads-1 to 0.04rads^{-1}. In addition to three skin cream samples three water/glycerol mixes were made at three different viscosities: 10mPa, 100mPa and 1000mPa, to construct a standard Stribeck curve for comparison. All measurements were repeated three time to assess the reproducibility of the procedure. Figure 1 shows a schematic of the triborheological set up.

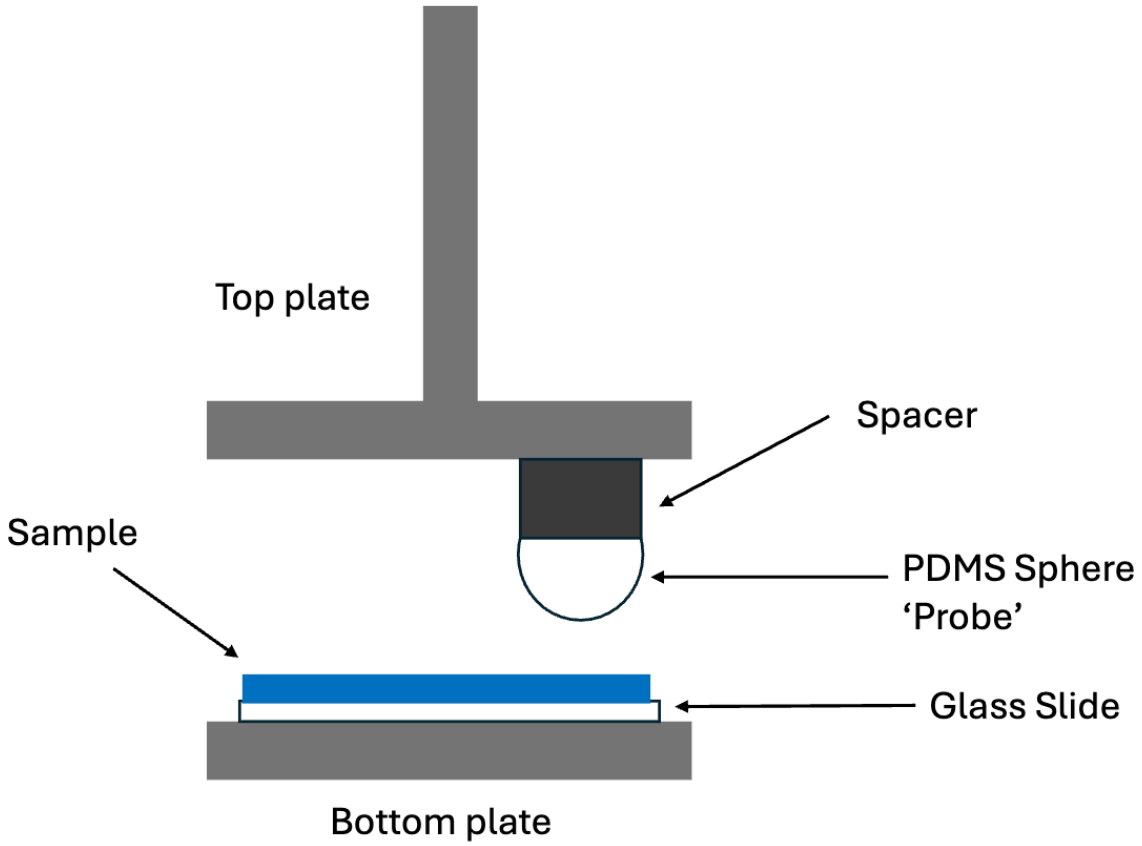


Figure 1. Schematic of the triborheology set up used in this study.

Viscosity measurements were done on an ARES G2 rheometer using a 40mm 1° cone and plate geometry attached at room temperature. The shear rate was varied from 0.1s^{-1} to 100s^{-1} and the viscosity and shear stress were recorded at 5 points per decade. All measurements were repeated three times to assess the reproducibility of the procedure.

3. Results

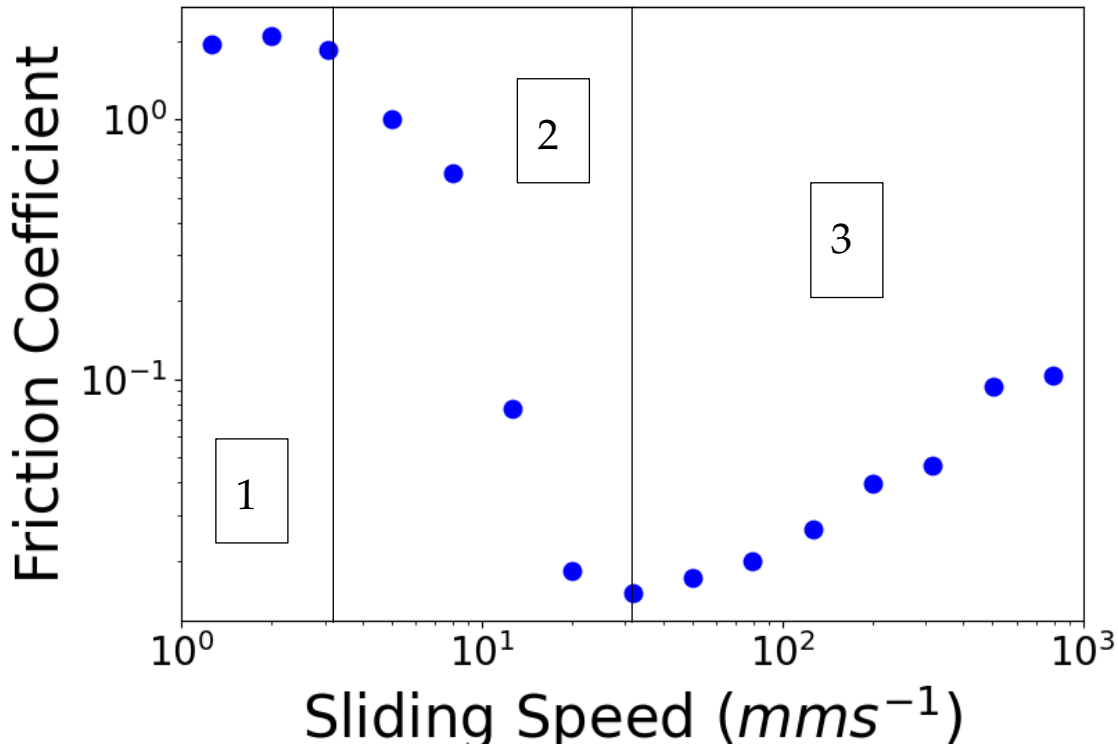
3.1 Triborheology and Viscosity Measurements

Table 1 shows the average viscosity measurements for the three commercial skin creams. This was calculated by averaging the three repeat measurements of each product at 0.1s^{-1} and at 100s^{-1}, the standard deviation is also calculated from these measurements.

Table 1. This shows the average viscosities of the three commercial samples and the three water/glycerol mixes calculated from taking the average of the three repeat measurements of each product at $0.1s^{-1}$ and at $100s^{-1}$

Sample	Average Viscosity at 0.1 s^{-1} (Pas)	Average Viscosity at 100 s^{-1} (Pas)
Water/Glycerol 1	0.01	0.01
Water/Glycerol 2	0.1	0.1
Water/Glycerol 3	1	1
Cetaphil Daily Moisturising Cream	51 +/- 3	0.31 +/- 0.02
Cetaphil Rich Night Cream	506 +/- 22	2.18 +/- 0.15
Vichy Laboratories Mineral 89	527 +/- 63	2.02 +/- 0.09

Figure 2 shows the results of the water/glycerol mix plotted as friction as a function of sliding speed (angular velocity multiplied by the radius of the top plate). Figure 3 shows a superposition of the three curves where each has been rescaled by the viscosity of the curve. The three characteristic regimes have been marked and are as follows: the first is the boundary regime where the solid surfaces are in direct contact, where the load is supported by the asperities on the surfaces, the second regime is called the mixed regime where the load is supported by both the asperities and the liquid and the final regime is called the hydrodynamic regime where the load is entirely supported by the liquid lubricant [3]. Figures 3-5 shows the frictional response plotted as a function of rescaled sliding speed for the three commercial samples. The rescaled sliding speed is a product of the radius of the geometry, the angular velocity and the radius of the PDMS probe and is divided through by the normal load.



(**a**) (**b**)

Figure 2. Shows the friction plotted as function of sliding speed for Water/Glycerol Mix 1. The three different regimes are marked on and labelled: 1 being the Boundary regime, 2 being the Mixed Regime and 3 being the hydrodynamic regime.

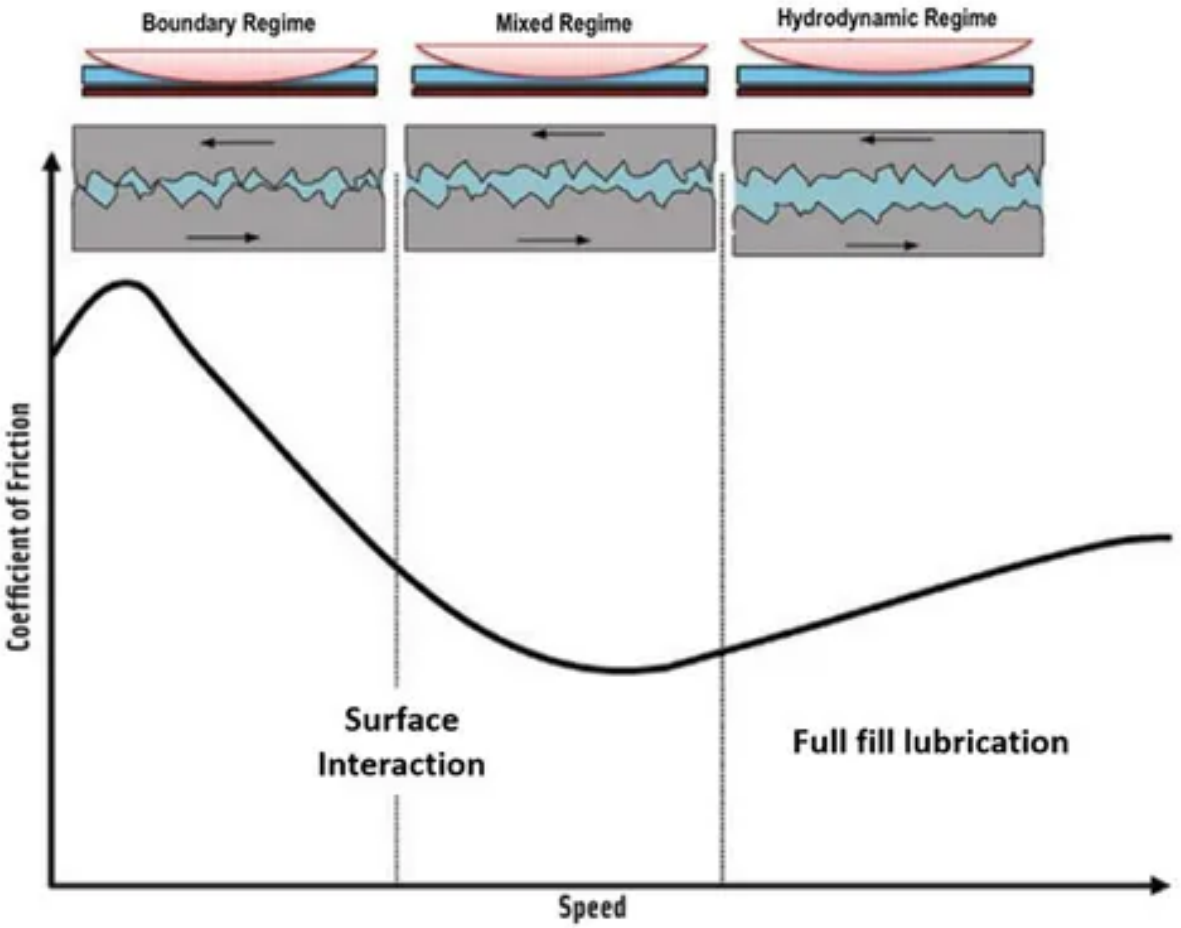


Figure 3. A schematic curve showing the friction verses speed showing the three different friction regimes. Taken from [3].

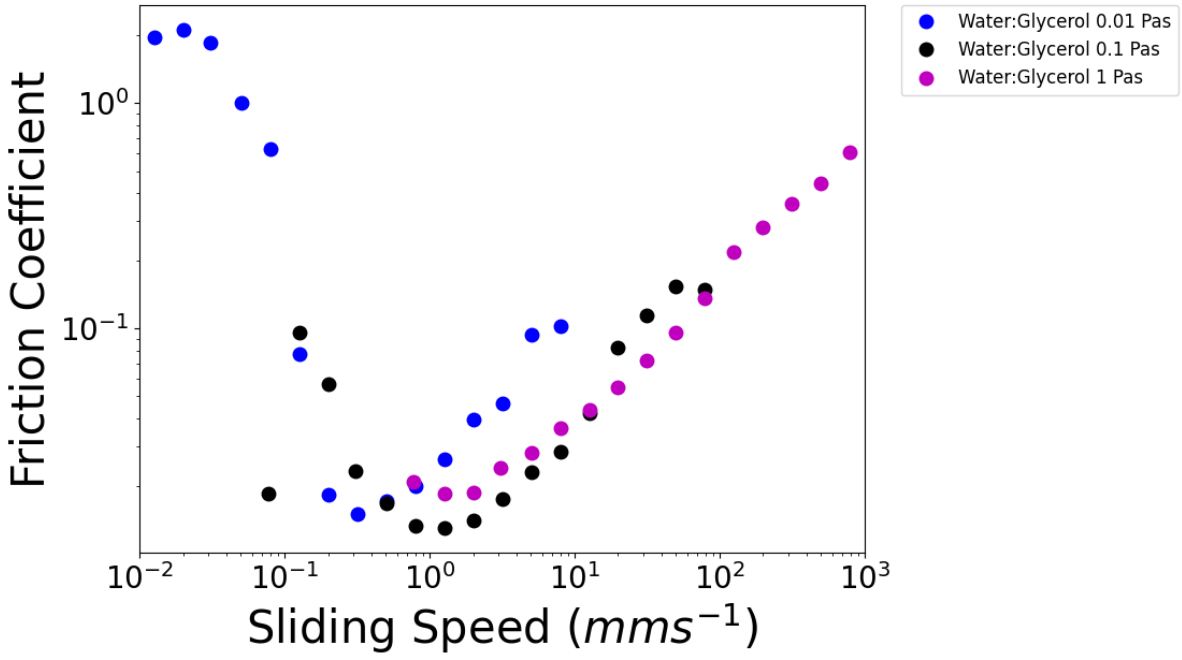


Figure 4. Shows a master curve for of the frictional response of all three water/glycerol samples, where the sliding speed has been rescaled with the viscosity of each sample respectively.

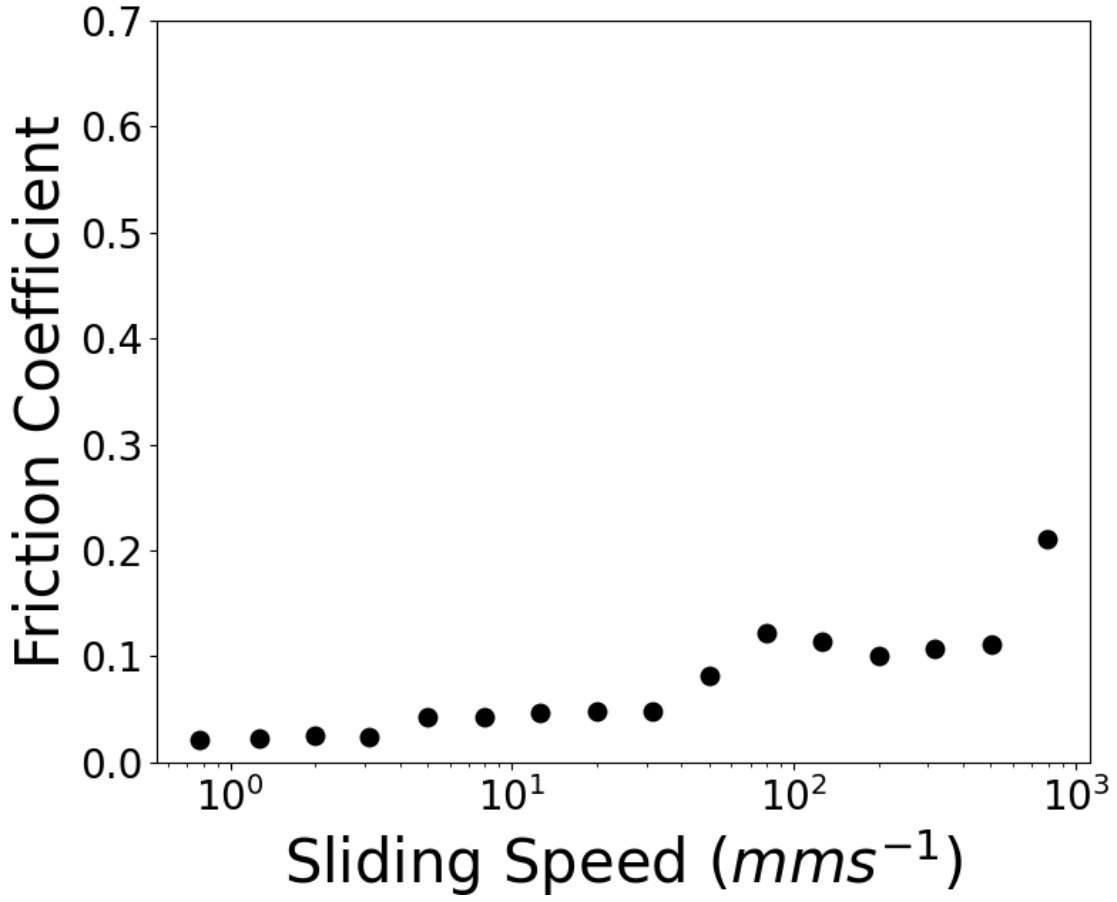


Figure 5. Friction coefficient plotted as a function of sliding speed for the Cetaphil Daily Moisturising cream.

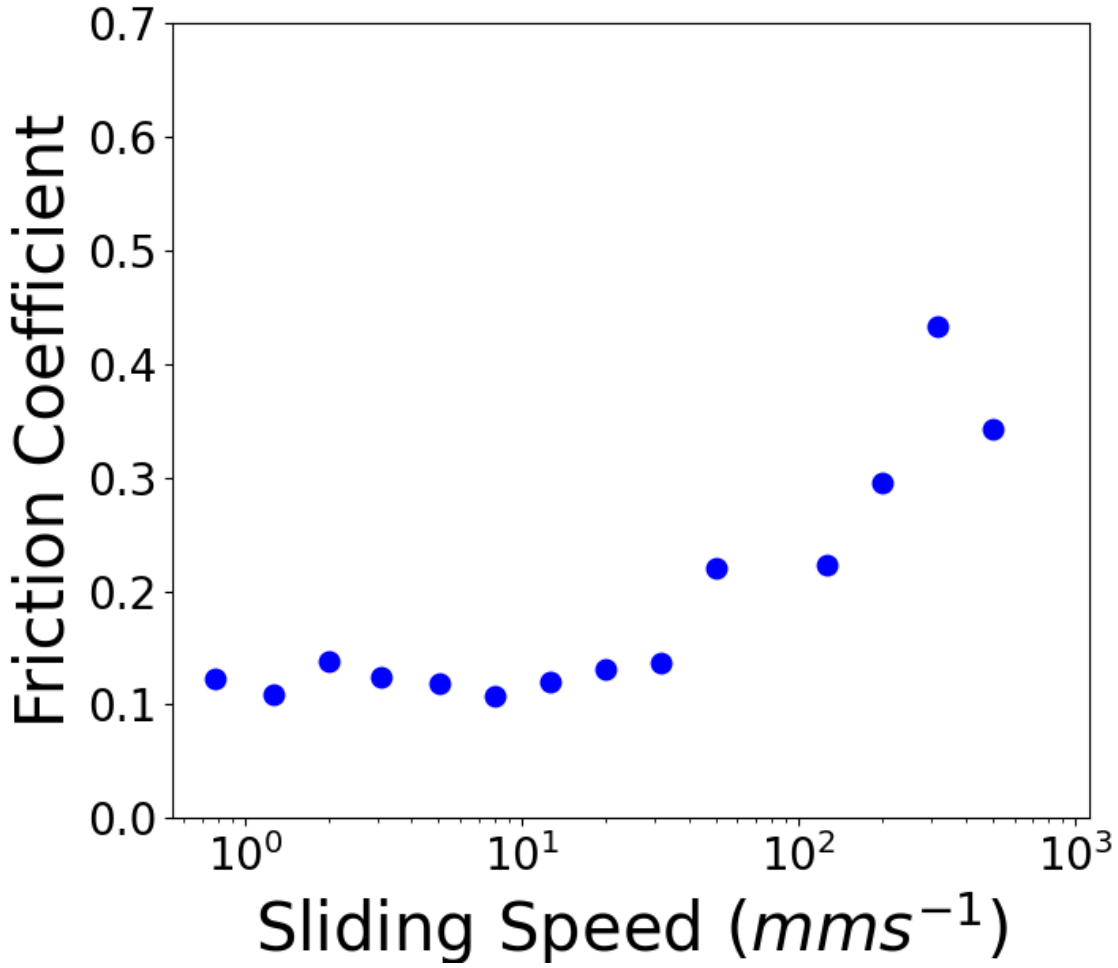


Figure 5. Friction coefficient plotted as a function of sliding speed for the Cetaphil Rich Night cream

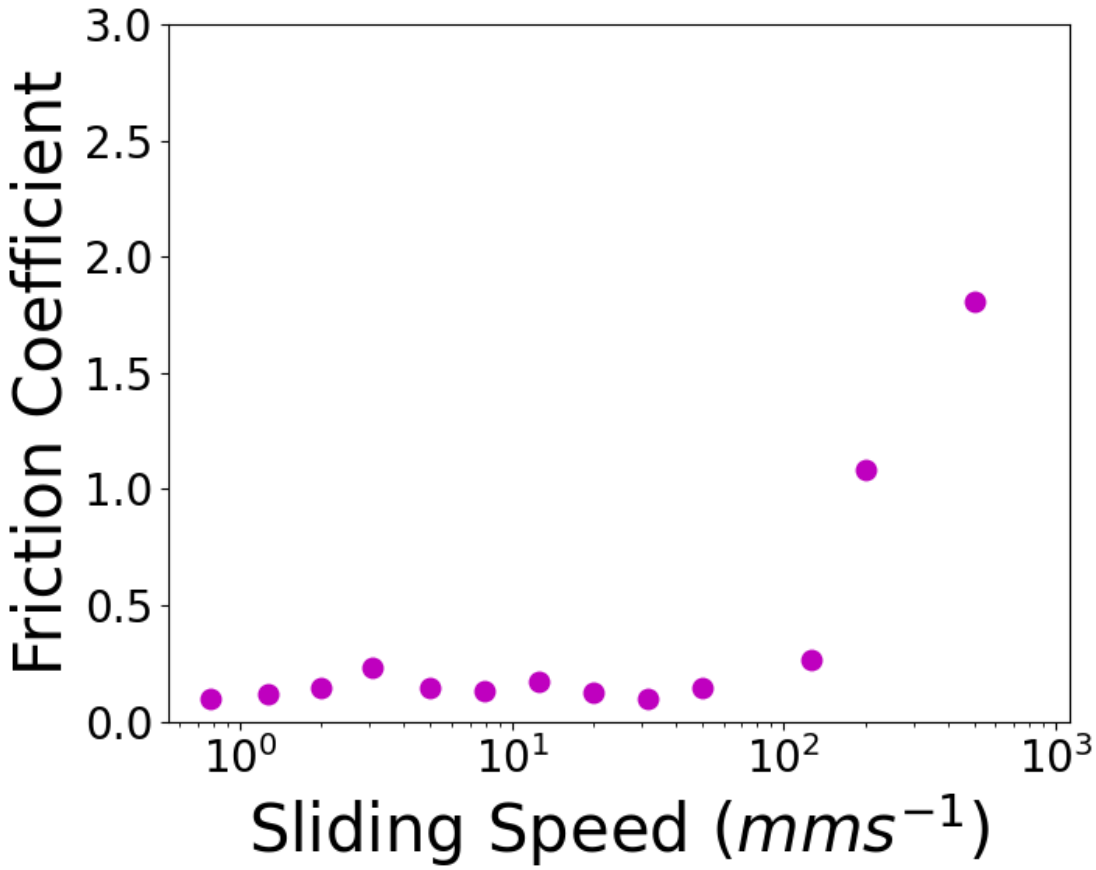


Figure 6. Friction coefficient plotted as a function of sliding speed for the Vichy Laboratories Mineral 89.

3.2 Consumer Preference Test

Table 2 below shows the results of the consumer preference test it shows the number of votes for each descriptor per product and the number of volunteers who ranked each product their first choice or last choice (3rd).

Table 2. This table shows the results of how consumer preference study.

Sample	**Descriptor**	**No of responses**	**1st Choices Responses**	**3rd Choice Responses**
Cetaphil Daily Moisturising Cream	Silky	2	3	5
	Wet	7		

Cetaphil Rich Night Cream	Tacky	0	3	3
	Silky	4		
	Wet	2		
	Tacky	3		
Vichy Laboratories Mineral 89	Silky	5	3	1
	Wet	0		
	Tacky	4		

4. Discussion

In terms of the results of the triborheology the water/glycerol mixes produced a nearly idealised Stribeck curve. All three regimes can be clearly seen in Figure 2, and this was shown to be repeatable. This was an important result as it verified that with a well characterised fluid (Newtonian) we can accurately recreate standard results. Furthermore, by accounting for differences in viscosities we can access all three regimes if needed as shown in Figure 4. However, it should be noted that approach can be done here as the water/glycerol mixes are Newtonian fluids, their viscosities is independent of shear rate.

For the three commercial skin creams all appear to be in the hydrodynamic regime. This is deduced by comparing to the water/glycerol results. The shapes are similar to the hydrodynamic regime. Interestingly the friction values range are higher for Vichy and the night cream, which at higher sliding speeds than the Cetaphil Daily moisturising cream. These higher speeds are comparable to shear rates most humans typically rub in creams in by hand, typically 10^3-$10^5 s^{-1}$ [4]. Whereas the lower speeds measurements are more associated to initlal skin feel.

In terms of the of the consumer perception test the results indicate that all three creams were ranked the favourite equally among the nine volunteers. However, in terms of the least favourite Cetaphil Daily Moisturiser came up ranked the lowest with five votes whereas the Vichy Laboratories 89 was most favoured as it only had one vote for the least favourite product. Most subjects expressed it was difficult to tell the difference of the ‘feel’ between the night cream and the Vichy samples, most likely due to their low shear viscosities being very similar. The most used descriptor for each cream varied between the samples also with Cetaphil Daily Moisturiser being on average described as ‘wet’, this product had considerably lower low shear viscosity than the other two products. In terms of the triborheology had the Daily moisturizer had lowest average friction values. The Vichy laboratories product was almost evenly split between ‘silky’ and ‘tacky’; this product had the highest viscosity of the three samples and the triborheology results low friction at low speeds however, the highest friction values at the high sliding speeds. Finally, the Cetaphil Night Cream had a similar viscosity to the Vichy Laboratories product and showed the same response in the triborheology frictional response. Furthermore, the nigh cream had the widest spread of descriptors, with four describing as ‘silky’ and

three describing as ‘tacky’. The split between ‘tacky’ and ‘silky’ for the highest viscosity samples is most probably an individual perception i.e., for some people these creams may feel two thick whereas others prefer thinner creams. However, given that the Cetaphil Daily Moisturiser was the least popular in terms of volunteer choice it does indicate if your product has too low a frictional value the consumer may perceive them as lower quality. By comparing the triborheology results of the night cream and the Vichy mineral cream both frictional profiles are similar. At low speeds the night cream had a higher frictional response however, at higher speeds the Vichy mineral cream had a highest frictional response. This result indicates that consumer may prefer a certain level of friction when using skin creams

5. Conclusion

In this study we successfully measured the triborheology of three commercial skin creams and three water/glycerol mixes using a bespoke triborheological set-up. We generated qualitative results which demonstrates how the frictional response changes with sliding speed changes and compared this to a short consumer study. In future work we will create model systems to systemically investigate the role of specific ingredients and chemistries and how these contribute to the frictional response of products and ultimately how these relate to the consumer experience.

References

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