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TRIBOLOGICAL RESPONSE OF HYDROXYETHYLCELLULOSE GELS AS A FUNCTION OF ISOPROPYL ALCOHOL CONCENTRATION AND ANGULAR VELOCITY PROFILE

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PURPOSE

The skin feel of topical products can heavily depend on their smearing properties. The smearing properties of hydrogels are commonly evaluated through a Stribeck curve (velocity sweep). However, a velocity sweep does not inform the time-dependent gliding of hydrogels at a determined velocity (i.e., time sweeps).

The **purpose** of this study was to compare and assess the tribological profiles of hydroxyethyl cellulose (HEC) gels with varying isopropyl alcohol (IPA) concentrations as affected by constant vs increasing angular velocities. It is hypothesised that upon prolonged rubbing of a topical product, the IPA evaporates, and the hydrogel formulations exhibit varying shear dependent flows that likely, change their gliding forces.

METHODS

HEC (2.2% w/w) gels with 15% (w/w) polyethylene glycol (PG), 0.8% (w/w) 2-phenoxyethanol, and varying IPA (20%, 30%, 45%, or 50% w/w) concentrations were used.

Friction profiles over velocity sweeps (0.1-100 rad/s) and time sweeps (600 secs at 0.25, 1, 10, and 25 rad/s) were measured on a Discovery RH-1 (TA Instruments Ltd.) tribometer attached with a 3-ball on plate steel geometry, at 32°C and 4.5 N of normal load. The tribometer plate was covered with a double film setting (used as a substrate for skin) consisting of 100% soft silicone tape at the bottom and Transpore™ tape as a top layer, onto which 400 µL of the sample was placed.

Shear sweeps tests were conducted from 0.01 Pa to 1000 Pa on a ARG2 rheometer (TA Instruments Ltd.) attached with a 40 mm diameter parallel plate geometry. Both the geometry and Peltier plate surfaces were covered with sandpaper (120 grit). The samples were analysed at 32 °C, using a 500 µm gap, with a pre-shear at 1/s for 60 s, followed by 120 s of equilibration. Zero-shear viscosity was predicted by fitting a linear model to the low-shear Newtonian plateau of the flow curve. A Power-Law model was fitted to the shear-thinning zone of the flow curves to estimate the consistency index parameter (K), flow behaviour index (n), and the viscosity at 900/s of shear rate.

In addition, the **volatile loss** of the gels was measured gravimetrically for 1 h at 32 °C.

RESULTS

The coefficient of friction vs. velocity profiles in Figures 1 and 2, are an indication of the gels' ability to glide between rubbing surfaces (i.e., geometry and substrate). High friction coefficients (FC) denote low tendency for gliding, and vice versa. The lubricating properties of the gels were affected by the angular velocity (shearing extent and profile) and by the IPA concentration, which affected the viscosity and shear-thinning profile of the gels (Table 1).

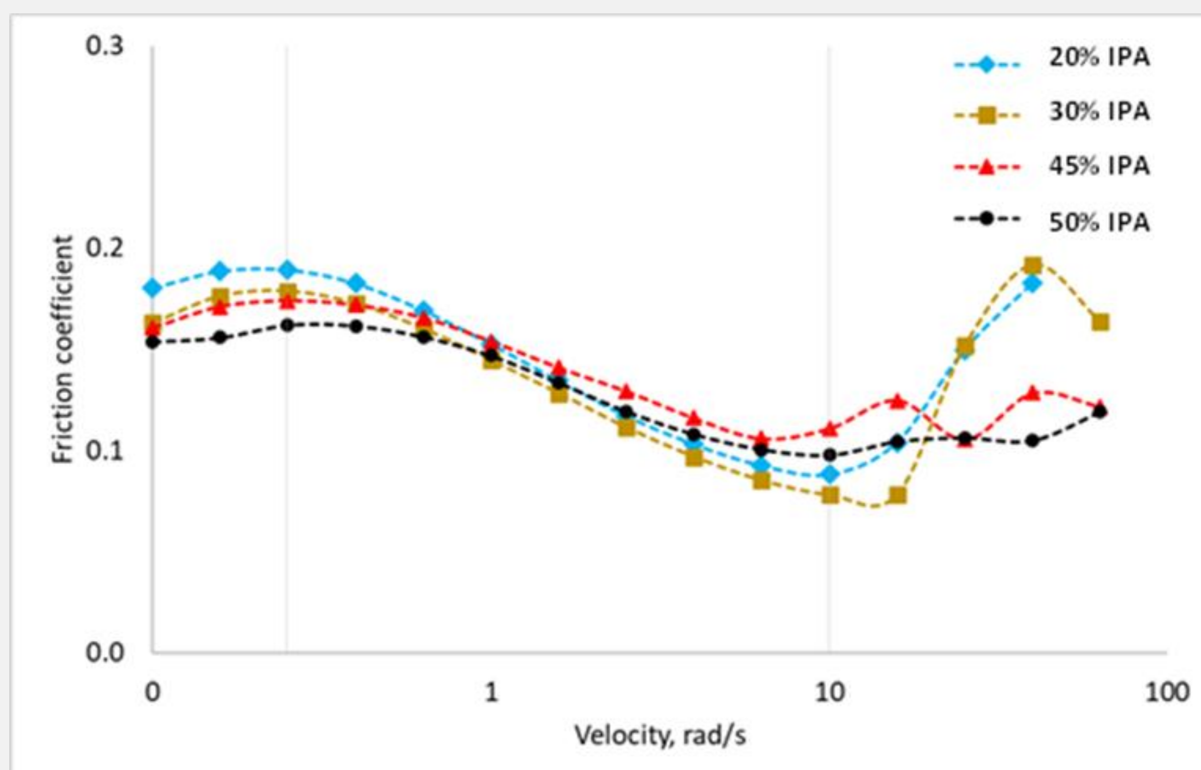

Figure 1. Friction coefficient of topical gels with varying isopropyl alcohol (IPA) concentration as a function of angular velocity at 4.5 N normal load and 32 °C. Data are presented as the average of N=3.

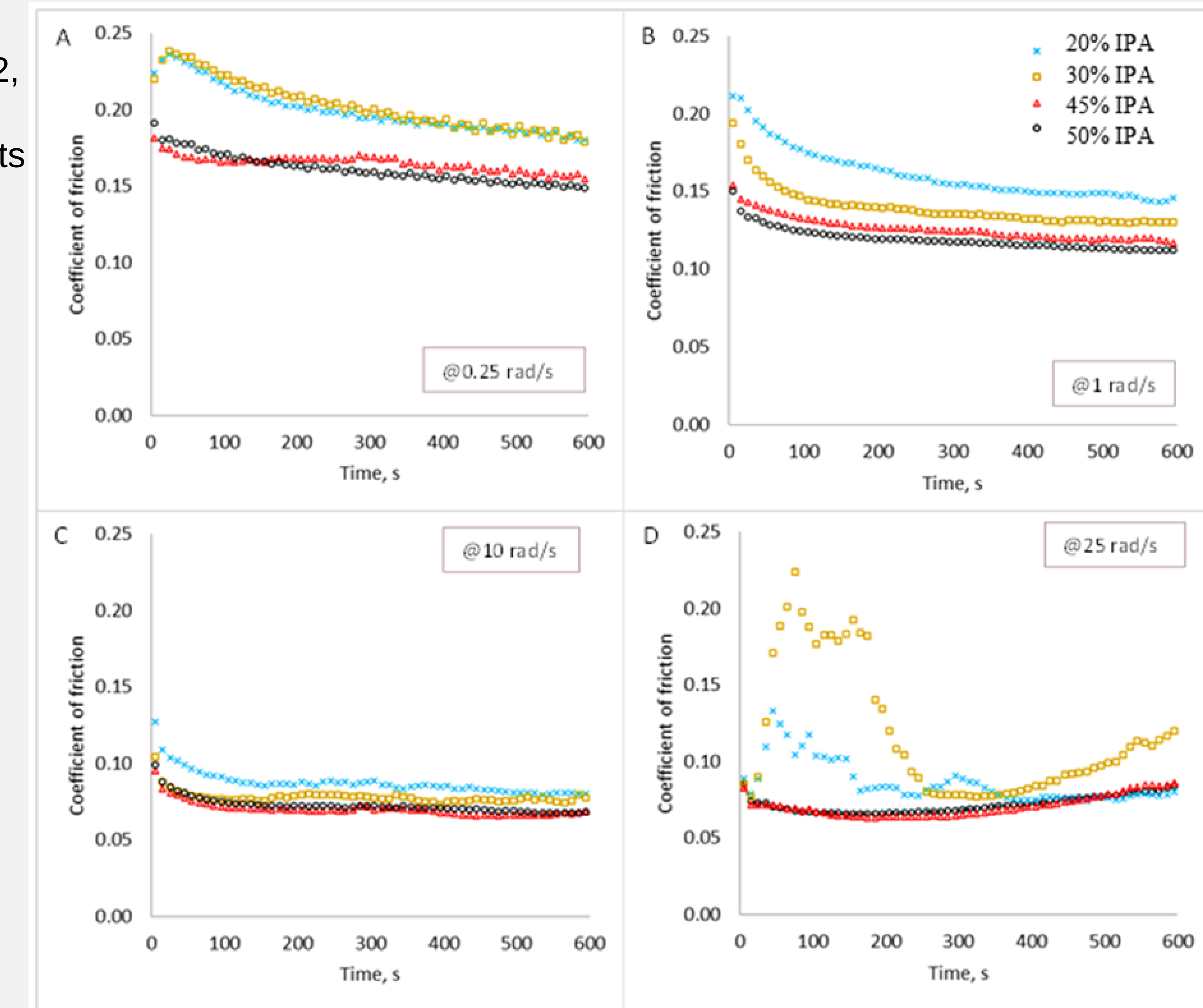

Figure 2. Friction coefficient of topical gels with varying isopropyl alcohol (IPA) concentration as a function of time at different velocities. A: 0.25 rad/s, B: 1 rad/s, C: 10 rad/s, D: 25 rad/s. Data are presented as the average of N=3.

The velocity sweep (Figure 1) revealed similar friction profiles among gels at 1 rad/s, followed by decreasing FC up to around 10 rad/s, beyond which samples with ≤30% IPA showed a steep increase in FC and samples with ≥45% IPA showed relatively levelled curves. On the other hand, the time sweeps (Figure 2) showed decreasing FC for each gel at increasing angular velocities up to 10 rad/s, beyond which, gels with ≤30% IPA concentration exhibited increased friction before stabilization, agreeing with the greater variability observed in the velocity sweep.

At 1 rad/s in the time sweep, each gel's lubrication effect was more evident, suggesting a more distinctive sensorily perceived lubrication. On the other hand, at 10 rad/s in the time sweep, lubricating properties of the gels seem to stabilize, and the FC appears to be time-independent, suggesting elastohydrodynamic gliding befitting a transition velocity.

However, at 25 rad/s, gels with lower viscosity (≤30% IPA) couldn't sustain lubrication and the friction raised, likely due to increased axial force, enhanced solid contact friction, and viscous dissipation.

Regarding the IPA concentration, gels with ≤30% IPA displayed lower zero-shear viscosity and higher friction profiles than ≥45% IPA gels, which also showed a potential ability to reduce perceived roughness during continuous rubbing. (Table 1).

CONCLUSIONS

This study provides insights on the tribological response of HEC gels as affected by change in the concentration of IPA in the formulation and the varying shearing conditions involved during practical use.

The findings from this study illustrate that the smearing properties of hydrogels might vary based on the shearing extent and profile involved, which indicates the importance of the tribological methods employed when evaluating the friction profile of hydrogels and correlating tribological properties of hydrogels with sensorial attributes, such as lubrication.

Table 1. Viscosity at 0/s and 900/s, flow behaviour, and cumulative volatile loss at 5 min and 10 min. (n= flow behaviour index, K= consistency index, and CM= cumulative volatile loss). Data are presented as the average ± SD, N=3

IPA (%)	0/s Viscosity (Pa s)	900/s viscosity (Pa s)	K	n	CM_5min (%)	CM_10min (%)
20	37±1b	0.42±0.02a	19.1±0.6c	0.44±0.01a	9.3±0.6a	18.6±0.4a
30	338±84a	0.43±0.01a	27.4±0.4ab	0.40±0.00a	11.4±0.4a	19.8±0.2a
45	1617±601a	0.43±0.05a	48±8a	0.28±0.02b	12±2a	22±2a
50	928±146a	0.28±0.01b	24±2bc	0.32±0.0b	13.2±0.8a	22±1a

*Values that do not share a letter in a single column are significantly different (P≤0.05).

GRANTS / ENCORE / REFERENCE OR OTHER USE

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