Reformulation of Hair Conditioner to Improve Sustainability and Usability with the Help of Rheology

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197

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INTRODUCTION

- Looking ahead to industrial production and big volumes of hair conditioners, promoting cold manufacturing processes represent a substantial opportunity to reduce carbon dioxide emission.
- Conventional hair conditioners, containing waxy components such as fatty alcohols and cationic agents, require hot manufacturing [1, 2]. Despite its effectiveness, some constraints were reported: change in consistency over time [3], viscosity variations after manufacturing [4] that can finally disturb the distribution outside the packaging during use, especially from spray pumps, and affect the formulation spreadability on hair.
- The purpose of this work was to reformulate a hot-processed hair conditioner in a cold-processed formulation while maintaining its stability, similar textural and sensory properties, and improving its usability.

Materials & Methods

• Optimization of hair conditioner formulation

(DHR2 from TA Instruments; Aluminum cone 40mm/2°)

- Starting from the Reference, removal one by one the waxy components and replacing their association by a liquid thickening-stabilizing-conditioning polymer (Acrylamidopropyltrimonium Chloride/Acrylates Copolymer & Isohexadecane & Coceth-7), looking for the optimized dosage and a cold manufacturing process.

Manufacturing process	80°C	80°C	80°C	RT
INCI name / % (w/w)	*Reference*	*HC1*	*HC2*	*HC3*
Water	90.5	90.5	90.5	90.5
Acrylamidopropyltrimonium Chloride/Acrylates Copolymer & Isohexadecane & Coceth-7	-	1.5	3.0	3.5
Steartrimonium Chloride & Water & Isopropyl alcohol (25% Active Matter)	3.0	2.0	3.0	3.0
Cetearyl Alcohol	3.0	2.0	-	-
Steareth-20	0.5	0.5	0.5	-
Glycerin	2.0	2.0	2.0	2.0
Preservative	1.0	1.0	1.0	1.0
pH	≈ 5.3	≈ 5	≈ 5	≈ 5
Brookfield viscosity 1 month after manufacturing (mPa.s, Spindle 4; Speed 6)	≈ 8,100	≈ 14,500	≈ 12,500	≈ 13,500
Stability at RT & 45°C	Stable > 3 months at RT and 1 month at 45°C			

• Rheology analysis

(DHR2 from TA Instruments; Aluminum cone 40mm/2°)

- Flowing experiments at 20°C → Global flowing profile; Rate index (Herschel-Bulkley analysis); Yield stress (steady state flow protocol; Onset mode).

- Oscillatory experiments: frequency sweep at 20°C (0.1 to 100 rad/s); temperature sweep 0°C-80°C (frequency 1Hz/ anti-evaporation cap) → Viscoelasticity by following evolution of storage modulus (G') and mean G'/G" ratio.

• Texture analysis

(TA XT- PLUS from Stable Micro System; hemispheric probe Ø 50mm)

- Standard cycle protocol at 20°C up to a depth of 4 mm (5 replicates) → Maximum force and compression energy as indicators of the product firmness; ratio Adhesion energy/ Compression energy as representative of behavior during the product pick-up [5].

• Sensory evaluation

(Bleached caucasian hair tresses; Level II)

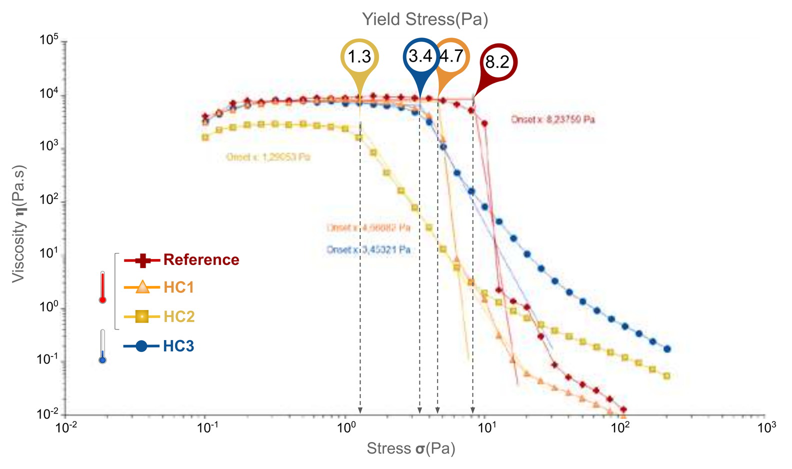
- Application of hair conditioner on wet hair (0.4g of product/ tress) after a standard pre-washing + 5 minutes pause before rinsing. Tresses dried at room temperature for 24 hours with 45% Relative Humidity.

- Triangular sensory random test with an expert panel specifically dedicated to hair care (10 panelists, trained since 2017; Statistical analysis using Tastel® software) → Evaluation of ease of combing, shine, volume, sliding effect, residual oily sensation, natural feeling.

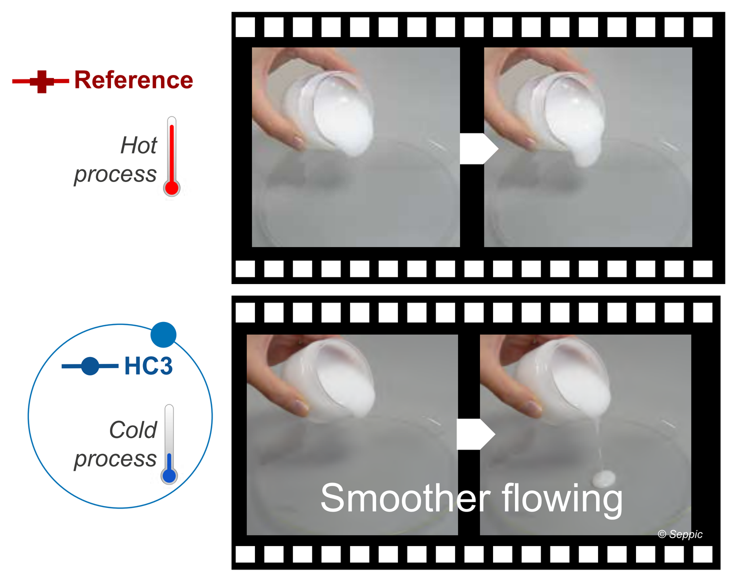
Results & Discussion

• Impact of reformulation on the rheology profile

Similar shearthinning profile (rate index moving from 0.34 to 0.4 for HC3) with no thixotropy of the cold-processed formula (slight thixotropy for Reference).



Decreasing yield stress in line with a smoother flowing, despite higher viscosity than Reference.

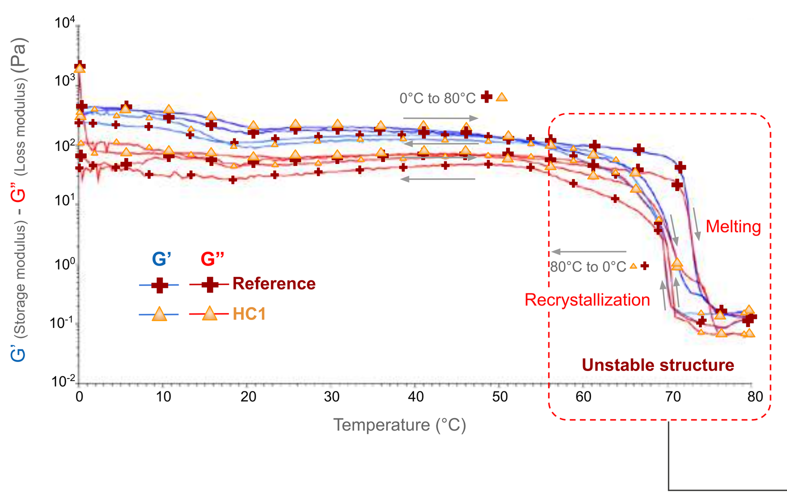


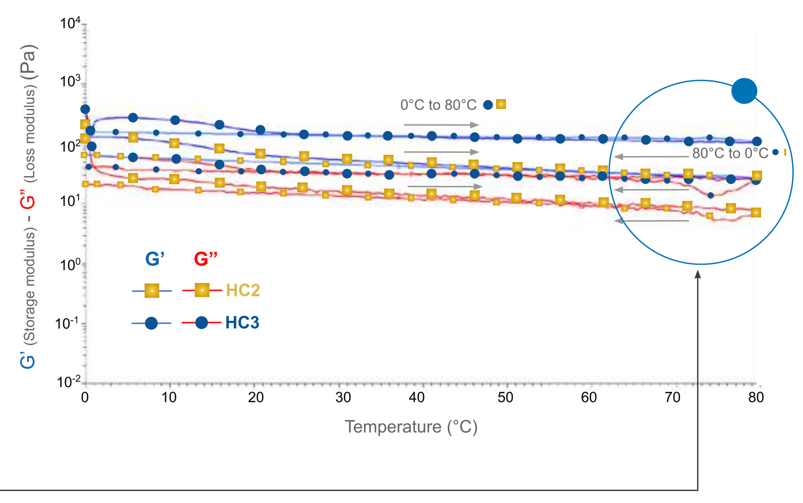
➔ Expected to solve distribution issues from pump packaging while maintaining easy spreading on hair.

Characterization of elastic structure			Reference	HC3
7 days after manufacturing	Frequency sweep	G' (Pa)	59	51
		G'/G	4.5	5.1
After 1 month of storage in cycles oven -5/40°C	Frequency sweep	G' (Pa)	242	47
		G'/G	3.5	2.2

- Elastic structure demonstrated for all the formulas. Similar level of structure of cold-processed HC3 and the Reference.
- No evolution of the structure after storage in freeze-thaw conditions with HC3, contrary to the Reference (large increase of G' value).

➔ Expected to solve distribution issues and reported texture evolution during ageing.

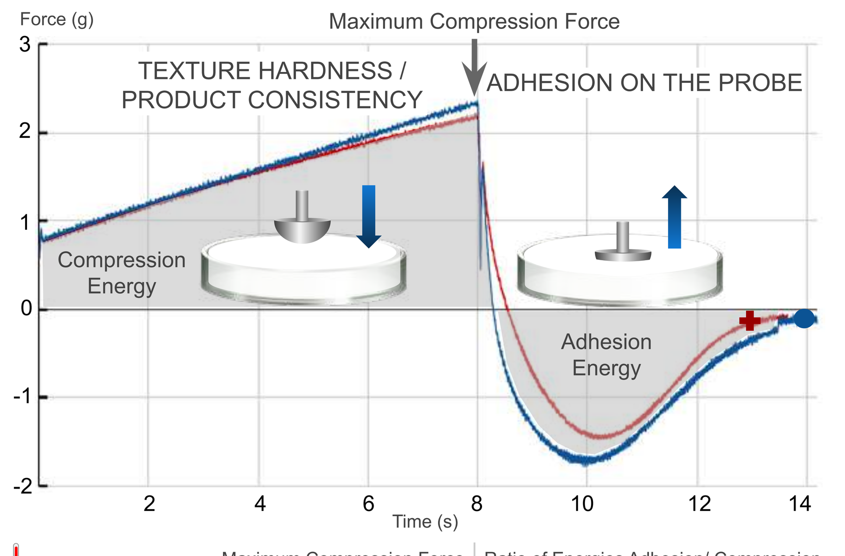




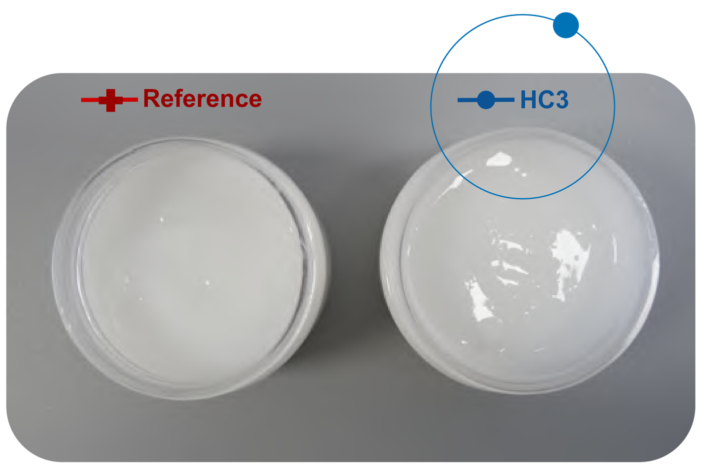
Due to fatty alcohol removal, no sensitivity to temperature variations of HC2 and cold-processed HC3.

➔ Cold-processed formulation with expected good stability from 0°C to 80°C → Great safety of use for the whole supply chain.

• Texture profile of cold-processed formula ≈ Reference

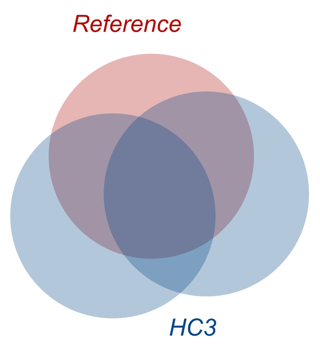


	Maximum Compression Force	Ratio of Energies Adhesion/ Compression
Reference	2.24 g ± 0.12	0.3
HC3	2.38 g ± 0.09	0.4



➔ Similar visual texture.

• Sensory profile of cold-processed formula ≈ Reference



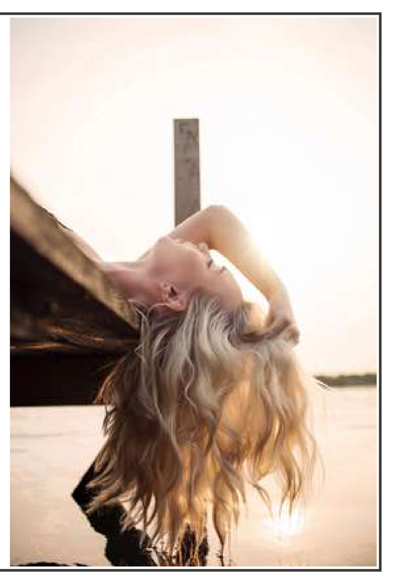
➔ Similar effect on hair tresses, at 98.93%.

- Combing
- Shine
- Volume
- Sliding
- Residual feeling

Very light texture of HC3 with quick break effect during application on the tresses, compared to the body given by the reference.

CONCLUSION

- Rheology helped to better understand the effects of the substitution of the waxy components and support the optimization of a cold-processed formula using a liquid thickening-conditioning polymer.
- Cold-processed hair conditioner showed similar effects on hair tresses than the reference while enabling to reduce carbon emissions and improved usability (smoother flowing; stable structure up to 80°C and after freeze-thaw cycles).
- Cold manufacturing process reduced energy consumption by 95% compared to the Reference and divided the production time by 3, on the basis of a 5 Kg pilot batch.



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