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"Innovate in the formulation of hair products through quantitative sensory analysis and an expert panel on treated strands."

***Caroline Mombelli*[1], *Marjorie Lassalle*[1], *Elodie Wallon*[1], *Marc Lavarde*[1,*], *Selçan Tokgoz*[1]**

[1] *UPR EBINNOV, Ecole de Biologie Industrielle, Cergy, France*

1. Introduction

The skinification trend has seamlessly integrated skincare principles into hair care, with a strong emphasis on scalp health and benefits for all hair types. Some products [1] are specifically formulated for individuals undergoing medical treatments, particularly oncology patients. Drawing from cultural traditions, certain plant extracts have long been used in hair care routines. Scientific studies [2–3] have demonstrated that these natural ingredients possess physicochemical properties and biological activities that support both hair and scalp health.

This inclusive and holistic approach has increased consumer demand for more effective and innovative hair care solutions, driving the cosmetic industry to develop new ingredients, products, and evaluation methods. As these products are highly user-oriented, it is essential to evaluate them from a sensory perspective. Sensory evaluation-defined as the scientific discipline that analyzes and interprets human responses to product characteristics perceived by the senses-focuses on organoleptic properties, i.e., those that stimulate the sensory organs.

To assess these properties, a wide range of standardized methodologies has been developed, depending on the objective: trained experts may evaluate specific sensory attributes [4], while consumer acceptability may also be assessed. Initially designed for diet-related research [5], the foundations of sensory analysis were established after World War II. In the 1990s, these methodologies were adapted for use in non-food sectors [6], including the automotive, materials, perfumery, and cosmetics industries.

While the performance of active ingredients remains a key consideration, as illustrated by studies on nanoparticle-based technologies [7], sensory analyses are comparatively less frequent [8]. Existing guidance can be found in ASTM standards [9] and some industry-driven initiatives. Consumer behavior research in this context is influenced by various factors, including emotional and multisensory dimensions—particularly relevant in the hair care sector [10].

Given these challenges, we aimed to develop a set of sensory attributes for constructing sensory profiles with trained experts, following ISO guidelines [4]. To ensure test repeatability and reproducibility, we chose to work with natural hair strands. First, descriptors were generated by a panel trained in the sensory evaluation of emulsion textures, though not specifically for rinse-off products. Next, product boundaries were established by deformulating commercial formulations. Finally, the attributes were tested and refined using an internal panel.

2. Materials and Methods

2.1. Panel sessions

Two distinct sensory panels were involved in this study: a generation panel, responsible for developing sensory attributes across a wide range of hair care products, and a validation panel, whose role was to confirm and refine the definitions of these attributes. The list of products used for each panel is shown in Table 1.

Table 1. List of all products used to generate the attributes and to validate them.

Panel	List of products
Generation panel sessions	*Shampoo*: Shampoing aux œufs DOP *, Shampoing cheveux hydratés coco SO'BIO, Shampoing douche fraicheur intense Ushuaïa, Douce argile shampoing régulateur Dessange , Age sublime blanc chic Dessange , Activateur de reflet John Frieda
Validation panel sessions	*Conditionner:* Lisse intense démêlant L'Oréal Elseve, Après-shampoing mangue Klorane, Pure riche soin démêlant L'Oréal Expertise, Crème riche soin démêlant - DermaXpro *Oil*: Huile extraordinaire L'Oréal Elseve *Mask*: Masque ultra doux avocat et beurre de karité Garnier *Retail products:* Dessage - Shampoing Age sublime, Klorane Après-shampoing mangue, L'Oréal Crème de soin, L'Oréal Shampoing Multivitaminé , Lovea Shampoing au monoï, Bepanthen Pommade bébé, Dessange Huile sublime, Dessange Huile sublime , John Frieda Shampoing reflets blonds, L'Oréal Elseve Low Shampoo, L'Oréal Huile Elseve, Vivel Dop Gel coiffant *Formulated products*: Reference Sweet Hair care Kit, Reference spreadability Hair care Kit, Reference Greasy Hair care Kit, Reference Foaming Hair care Kit

For all the sessions, the products were presented in a single-blind fashion using a 3-digit code. The allocation was divided into balanced blocks according to Williams squares.

The first consisted of 27 students trained in cosmetic texture evaluation using the EBITOUCH® sensory kit. This panel was responsible for generating sensory attributes, defining specific handling gestures for hair tresses, and developing a standardized rinsing protocol. These activities were performed using 12 commercially available hair care products from the French retail market. Sensory evaluations were conducted on both treated and bleached hair strands in a controlled laboratory environment maintained at 20 ± 2 °C. Treated and bleached natural strands (25cm) were used and the water used to rinse the strands was maintained at 37°C ± 2 °C. Approximately 0.2 g of each product was applied to the hair tresses.

Attributes were assessed during three phases-pick-up, application, and evaluation-on both wet hair (rinsed after application) and dry hair.

During the evaluations at wet, products were applied to rinsed hair directly by the panelists. For dry hair assessments, the products were applied beforehand by a preparer wearing gloves, who distributed the product on the upper part of the strand and massaged it in with gloved hands.
In a subsequent phase, specific reference products were internally formulated to correspond to each generated attribute. These formulations were then used for training and refining attributes with a second internal panel of 15 volunteers. For these validation session, bleached strands and natural brown and untreated strands were used and the water used to rinse the strands was maintained at 20°C ± 2 °C.

The following washing protocol was validated by two triangular tests during the generation phase:

- Rinse thoroughly with lukewarm tap water so that all hair was wet.
- 0.5 mL of fragrance-free Urtekram shampoo was placed on the index finger.
- 5 strokes with the thumb and index finger from top to bottom over the wet strand of hair.
- 5 strokes with the thumb and index finger from top to bottom using horizontal movements to apply the product to all hair.
- Repeat the previous rinsing/cleansing step until the lather has completely disappeared.
- Once rinsed, make another stroke with the thumb and index finger to remove as much water as possible from the strand.
- Air dry the strand of hair using a clothespin and an extended thread.
- Comb the strand once dry.

2.2. Formulation of references

All experiments were carried out in the formulation laboratory of Ecole de Biologie Industrielle using VMI Turbotest benchtop agitator. Demineralized water obtained after passage on resins at the laboratory was used. Acrylates/C10-30 Alkyl Acrylate Crosspolymer was provided by Lubrizol. Behentrimonium Chloride was provided by INOLEX. C14-22 Alcohols (and) C12-20 Alkyl Glucoside was provided by Seppic. Cera Alba was provided by Aromzone. Cetearyl Alcohol was provided by Croda. Chlorure de sodium was provided by Cooper. Cocamidopropyl Betaine was provided by BASF. Coco-Caprylate/Caprate was provided by BASF. Cocos Nucifera Oil was provided by Cooper. Disodium EDTA was provided by BASF. Glycerin was provided by Cooper. Huile d'amande douce was provided by Cooper. Hydroxyethyl Acrylate/Sodium Acryloyldimethyl Taurate Copolymer was provided by Seppic. Isostearyl Isostearate was provided by Stearinerie Dubois. Panthenol was provided by BASF. PEG-40 Hydrogenated Castor Oil was provided by Seppic. Phenoxyethanol & Methylparaben & Ethylparaben & Propylparaben & Butylparaben was provided by Seppic. Polyacrylamide & C 13-14 isoparaffin & laureth-7 was provided by Seppic. Polymethyl methacrylate was provided by Seppic. Polysorbate 80 was provided by Croda. Ricinus Communis Seed Oil was provided by Cooper. Sodium Benzoate was provided by Cooper. Sodium laureth sulfate & aqua was provided by BASF. VP/Dimethylaminoethylmethacrylate Copolymer was provided by Ashland.

3. Results

The study was carried out in three main phases. First, sensory attributes were generated for the evaluation of hair products applied to hair tresses. In parallel, reference formulations

were developed, and a panel study was conducted to validate the attribute definitions and refine the evaluation protocol.

3.1. Generation of the attributes

In three sensory attribute generation sessions, panelists explored the evaluation gestures, application on wet strands, rinsing, and evaluation on dry strands. The terms generated in the sessions by gesture are grouped in Figure 1.
After an evaluation of weight of interest in Figure 1. Definitions were identified on wet hair regarding ease of application, homogeneity, foaming and penetration, and on detangling, softness and greasiness after rinsing on damp hair or after drying. On the foaming, two interesting definitions were generated: foam speed and foam quality.

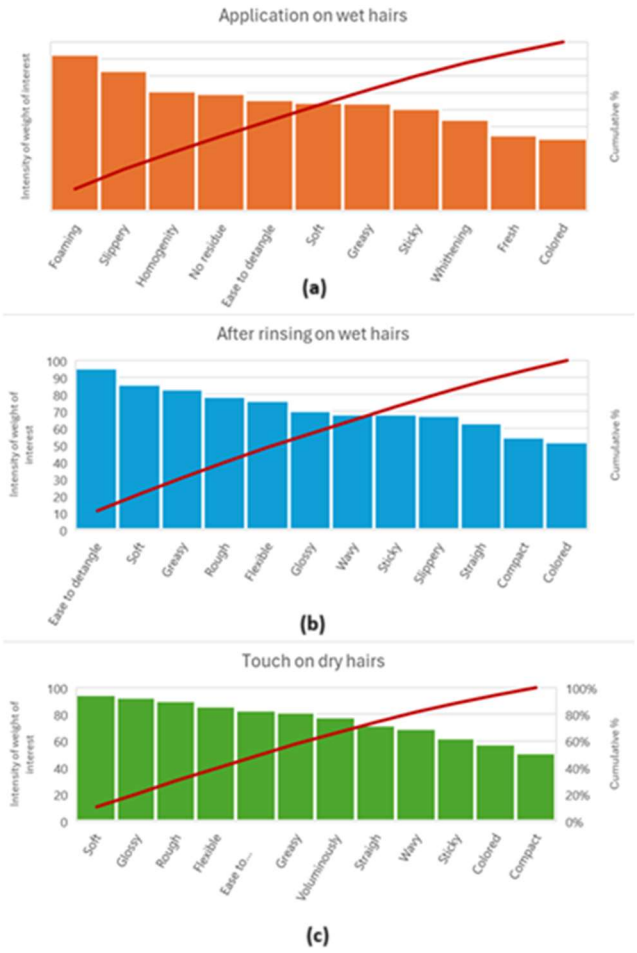

Figure 1. This figure shows the citation rates of terms by phase in the form of a Pareto diagram.: (a) Corresponds to application on wet hair strands; (b) To the rinsing phase; (c) To the working phase on dry strands.

For each of these attributes in figure 2, boundary proposals were formulated in the laboratory using the definitions developed in sensory analysis.

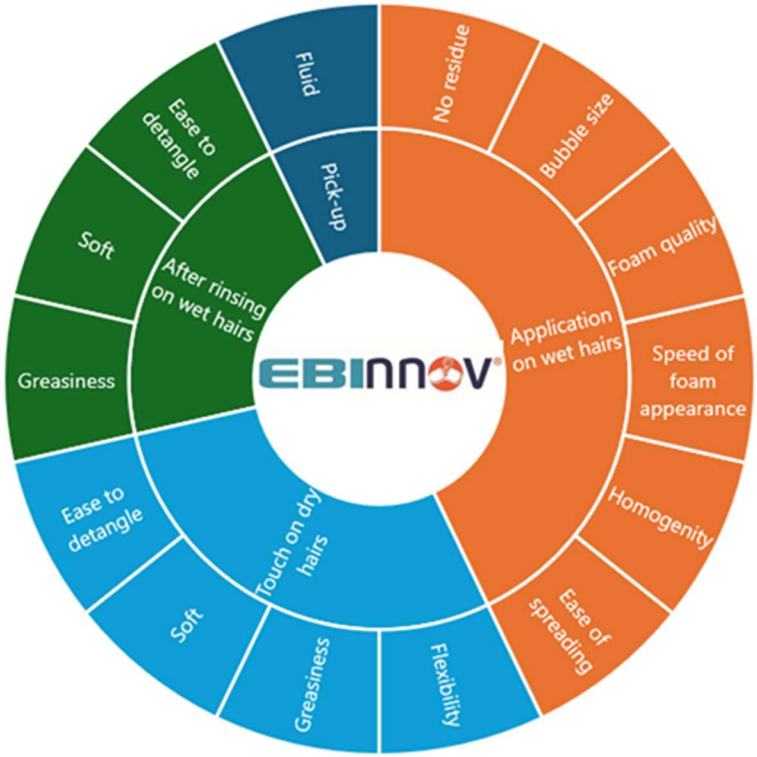

Figure 2. This figure shows the attributes generated in phases following the first panel related to term generation.

Following the focus groups conducted at the end of each generation session, the first definitions were made for the different evaluation phases. The finalized definitions were grouped in Table 2.

Table 2. Table of definition based on focus groups of the generation panel sessions.

Evaluation phase	Attribute name	Definition
Application on the wet strand	Spreading	No resistance to movement is felt when spreading the product along the entire length of the strand.
	Homogeneity	When examined under the lamp and by touch, the distribution of the product on the wick is homogeneous.
	Foaming	When examined under the lamp and after 10 seconds, the amount of foam formed at the top of the wick is close to that indicated in the image attached to the form.
	No residue	By wringing and then sliding it over the wick, the product is absorbed and no residue is left behind.
After rinsing on wet strand	Detangeling	Easy passage of the comb along the strand.
	Soft	The touch is not rough and no sliding resistance is perceived.
	Greasy	Presence of a film of product between the fingers.
Dry strand	Detangeling	As before rinsing.
	Soft	As before rinsing.

Greasy	On examination under the lamp, the wick is compact and the touch is sticky with the presence of a film.
Flexibility	The hair is malleable and easy to handle.

3.2. Formulation of the references

First, we looked at products and market trends. It seems that hair product users are increasingly concerned about the products they use on their scalp, particularly in search of organic products, anti-dandruff products, anti-hair loss products, and coloring products. Consumers want more neutral compositions with fewer harmful compounds such as parabens, aluminum compounds, etc. Organic products are more natural and gentler on the scalp and do not affect hair quality. Currently, the most popular product remains shampoo, and more specifically anti-dandruff shampoo. In fact, one in two people uses anti-dandruff shampoos. There are two categories of hair cosmetic products, these are distinguished by their mode of use. Indeed, there are rinse-off products and leave-in products. Rinse-off products are applied directly to the hair before being rinsed with water. They therefore act temporarily. Leave-in products, on the other hand, remain on the hair after application and do not require rinsing. They therefore act for a long time. There are many dosage forms among hair cosmetic products. More and more solid hair products are emerging, such as solid shampoos. This limits the consumption of plastic bottles. Among the dosage forms, we can find:

- Gels (e.g., styling gel)
- Emulsions (e.g., shampoo)
- Oils (e.g., moisturizing oils and serum)
- Aerosols (e.g., hairspray)
- Mousses (e.g., styling mousse).

In a second phase, we analyzed commercial haircare products to identify their key functional ingredients. Surfactants were categorized into four types based on their ionic charge: anionic (e.g., sodium lauryl sulfate), cationic (e.g., behentrimonium chloride), amphoteric (e.g., cocamidopropyl betaine), and nonionic (e.g., decyl glucoside), each contributing differently to cleansing, conditioning, or formulation stability. Texturizing agents included natural thickeners (e.g., xanthan gum), synthetic polymers (e.g., carbomers), waxes and fatty alcohols (e.g., cetearyl alcohol), and clays (e.g., bentonite). Additional functional groups included silicones (e.g., dimethicone) for smoothness, humectants (e.g., glycerin, hyaluronic acid) for moisture retention, emollient oils and butters (e.g., argan oil, shea butter) for nourishment, and preservatives (e.g., phenoxyethanol, parabens) to ensure microbiological stability. This formulation mapping informed the selection of ingredients for developing sensory reference samples.

We then carried out laboratory tests to formulate proposals for the terminals of a sensory reference system. Since we have not protected the formulas, we will limit ourselves to giving a simplified list of the formulas. The simplified formulas are given in Table 3.

Table 3. Table of candidate formulas for sensory references

Reference	INCIl list
Spreading	Aqua, prunus amygdalus dulcis oil, C14-22 Alcohols, C12-20 Alkyl Glucoside, Hydroxyethyl Acrylate, Sodium Acryloyldimethyl Taurate Copolymer, Phenoxyethanol, Methylparaben, Ethylparaben, propylparaben, butylparaben
No foaming	Aqua, polymethyl methacrylate, C 13-14 isoparaffin, polyacrylamide, laureth-7, phenoxyethanol, methylparaben, ethylparaben, propylparaben, butylparaben

Foaming	Aqua, sodium laureth sulfate, sodium lauryl sulfate, cocamidopropyl betaine, sodium chloride, phenoxyethanol, methylparaben, ethylparaben, propylparaben, butylparaben
Ease to rinsing	Aqua, cocamidopropyl betaine, sodium laureth sulfate, phenoxyethanol, methylparaben, disodium EDTA, ethylparaben, propylparaben, butylparaben
Detangling	Aqua, cetearyl alcohol, polysorbate 80, behentrimonium chloride, ricinus communis seed oil, dimethicone, panthenol, cocamidopropyl betaine, phenoxyethanol, sodium benzoate, methylparaben, ethylparaben, propylparaben, butylparaben
No detangling	Aqua, Dimethylaminoethylmethacrylate Copolymer, VP, PEG-40 hydrogenated Castor Oil, Acrylates/C10-30 Alkyl Acrylate Crosspolymer, Panthenol, Propylene glycol, Phenoxyethanol, Methylparaben, Ethylparaben, Propylparaben, Butylparaben
Soft	Coco caprylate Caprate, Isostearyl Isostearate, Tocopherol
Greasy	Aqua, Ricinus Communis Seed oil, Cocos Nucifera oil, Dimethicone, Cera alba, Glycerin, Cetearyl alcool, C14-22 Alcohols, C12-20 Alkyl glycoside, Sodium Acryloyldimethyl Taurate Copolymer, Hydroxyethyl Acrylate, Phenoxyethanol, Methylparaben, Ethylparaben, Propylparaben, Butylparaben
No greasy	Aqua, C13-14 isoparaffin, Laureth-7, polyacrylamide, Phenoxyethanol, Methylparaben, Ethylparaben, Propylparaben, Butylparaben

3.3. Validation panel session

Over the course of twenty-one-hour sessions, an internal panel was trained on the sensory attributes previously established. In the initial phase, panelists familiarized themselves with the handling techniques and attribute definitions using commercial hair care products. This training phase included iterative refinement and clarification of the attribute definitions, ultimately leading to the validation of x descriptors. Both the reference terminals and selected market products were evaluated. Final validation of the panel's repeatability and reproducibility is still ongoing; however, in 13 sessions, the panel has allowed the definitions as followsin Table 4 to be refined. And several sessions have been conducted with ANOVAs for all descriptors and associated judge effects. These results are grouped in Table 5.

Table 4. Final list of attributes for wet and dry evaluation at application and after the application.

Attribute	Definition (Presence)	Definition (Absence)
Spreading	When the product is placed on the application area of a thoroughly damp tress and spread by sliding it between the thumb and index finger from top to bottom, no resistance is felt during the movement.	When the product is placed at the top of a thoroughly damp tress and spread by sliding it between the thumb and index finger, resistance is felt along the full length of the hair.
Speed of Foam Appearance	On a thoroughly damp tress, 10 circular movements are performed with the thumb in the application area, and foam appears from the first rotation.	On a thoroughly damp tress, 10 circular movements are performed with the thumb in the application area, and no foam is observed.
Foam Quantity	After 15 thumb rotations, foam is collected by sliding the tress between the index and middle fingers; the amount of foam produced is assessed.	After 15 thumb rotations, very little or no foam is collected by sliding the tress between the index and middle fingers.
Cushioning Effect of the Foam	When the foam is gently compressed (2 times) between the	When the foam is gently compressed (2 times) between the

	thumb and fingers, a bouncing effect is perceived.	thumb and fingers, no bouncing effect is perceived.
Ease of Rinsing	After pouring a predefined amount of water on the application area and rubbing the tress along its length, the product is visually and tactilely assessed to have disappeared.	After pouring water and rubbing the tress, the product is perceived to persist visually and to the touch.
Ease of Detangling	The comb glides through the tress with no perceived resistance. *Note: the height at which the comb gets caught is not considered.*	The comb does not glide easily through the tress, and resistance is perceived. *Note: the height at which the comb gets caught is not considered.*
Softness	When the tress is passed between the thumb and index finger from top to bottom, the motion is smooth, and no roughness is felt.	When passed between the fingers, the motion is not smooth, and the surface feels rough.
Greasiness	When the tress is passed between the thumb and index with light pressure, an oily sensation and residue are felt between the fingers.	No oily sensation or residue is observed when passing the tress between the fingers.
Roughness	When rubbed from top to bottom, the tress gives a dry, straw-like sensation.	When rubbed, no dry or straw-like sensation is perceived.
Shininess	When the tress is bent into a curved arc under a lamp, it reflects light.	The tress does not reflect light under the lamp when bent into a curved arc.

Table 5. In this table, the evaluated products and descriptors were grouped by session with the product effects and judges of two-way ANOVA classification.

Session	Products	Attributes	P-values of products	P-values of panelists
1 to 3	Garnier - Masque Ultra Doux avocat (164), Klorane - Après-shampoing mangue (004), L'Oréal - Elseve Low Shampoo (612), L'Oréal - Shampoing Multivitaminé (169)	Fluid	0	0.002
		High peak	<0.0001	0.66
		Slipperiness	<0.0001	0.004
5	Le petit olivier - Masque Soin réparateur (815), L'Oréal - Crème de soin (263), Lovea - Shampoing au monoï (547), Dop - Shampoing au miel (053)	Fluid	0.001	<0.0001
		High peak	<0.0001	0.012
		Slipperiness	0.131	<0.0001
7 to 8	Lovea - Shampoing au monoï (547), John Frieda - Shampoing reflets blonds (291), Klorane - Après-shampoing mangue (004)	Spreading	0.029	0.29
		Speed of foam appearance	<0.0001	0.968
			<0.0001	0.599
		Foam quantity	0.001	0.455
		Cushing effect		
9 to 10	Garnier - Masque Ultra Doux avocat (164), Klorane - Après-shampoing mangue (004), Vivel DopI Gel coiffant (960), No residue reference fro EBI-TOUCH (600)	Ease of rinsing	0	0.56
		Detangling (wet)	0.011	0.58
		Detangling (dry)	<0.0001	0.455
11	Dessange Huile sublime (330), Untreated strand (117)	Shiny	0.004	0.134
		Soft	0.002	0.348
		Roughness	0.03	0.01
		Greasy	0	0.109
12	L'Oréal Huile Elseve (433), Dessange Huile sublime (330), Geasy reference (239)	Detangling (dry)	<0.0001	0.206
		Shiny	0.041	0.04
		Soft	0.002	0.975

13	Foaming reference (489), Not spreading reference (321), Ease of rinsing reference (702), No residue reference (600)	Roughness	0.204	0
		Greasy	<0.0001	0.254
		Spreading	<0.0001	0.358
		Speed of foam appearance	<0.0001	0.1
		Foam quantity	<0.0001	0.136
		Cushing effect	0.001	0.251
		Detangling (wet)	0.184	<0.0001
		Ease of rinsing	<0.0001	0.682

4. Discussion

The attribute generation sessions enabled the identification of sensory properties consistent with those described in relevant standards and prior literature [8–9]. These attributes were grouped into synonym clusters, as illustrated in Figure 2. The high number of generated terms and their frequent citation highlight the complexity of the sensory space under investigation. The definitions developed during focus group sessions (Table 2) further support this observation. Application gestures, as well as the quantities of water and product used, significantly influenced the panelists' ability to evaluate foaming properties. The term foam quality was found to encompass several distinct, one-dimensional sensory attributes. Consequently, we propose distinguishing between foam quantity, bubble size and density, and foam texture. This differentiation was confirmed during expert panel training, which led to a necessary reduction in the number of attributes for operational feasibility.

A substantial portion of the reference product development was completed prior to training the validation panel. During training, panelists used these reference products to anchor the low and high ends of the sensory scales. As shown in Table 4, the definitions have become more precise since the generation phase, now including both low and high value descriptors. Additionally, as training progressed, sensory profiles were constructed using both commercial and reference products. Table 5 shows that for most attributes, the product effect yielded statistically significant p-values, indicating the panel's ability to discriminate between products. However, judge effects were also observed, suggesting inter-individual variability during evaluation. Some attributes, such as fluidity and slipperiness, required multiple sessions to reach consistent panel consensus. On dry hair, roughness and shininess, and on wet hair, detangling, also led to divergence among panelists. We recommend retaining the evaluation of dry detangling, while the reference products used for shininess and roughness may require further refinement. To explore this aspect further, we can work on the formulation of limits by further developing our bibliography with the help of the review work of Cunningham et al [11].

5. Conclusion

This work enabled us to develop a protocol and methodology for the sensory evaluation of hair care products on hair tresses by an expert panel. We were able to explore the sensory attributes of hair products, and following the training of an expert panel, we selected some of the attributes and specified the definitions and gestures. However, all the formulated boundaries still need to be evaluated. These were used for the training of the panel, but the level of these boundaries remains to be validated on sensory scales from 0 to 10.
Sensory evaluations will provide precise data on the properties of hair products and allow us to study the dose-dependent effects of formulations. Additionally, these evaluations will facilitate comparisons of ingredient impacts on the quality of the finished product and, ultimately, help identify perceived quality by combining sensory mapping with consumer studies.

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