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B. Seelig, A. Ptock, A. Stork

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abstract

The rise in sustainable consumerism is having a major impact on the personal care industry. Natural ingredients, biodegradability and microplastic-free claims as well as reduced greenhouse gas (GHG) emissions are key topics for the ecologically sensitive consumer. At the same time, consumers also expect products that make no compromises in performance at affordable prices. To meet all three demands, BASF has developed a comprehensive formulation strategy that balances ecological responsibility with consumer satisfaction, helping brands maintain their competitive edge.

Introduction

BASF's comprehensive formulation strategy investigates the synergy between performance, sustainability, and affordability in the creation and application of cosmetic products. By optimizing entire formulations, this approach allows for greater flexibility in identifying the ideal balance between these three dimensions.

Affordability – In 2024, consumers increasingly adopted strategies to maximize the value of their beauty and personal care purchases. This includes actively seeking discounts and promotions, using social media to find deals, and following "deinfluencers" who highlight overhyped products. Instead of merely reducing their spending, consumers are now on the lookout for dupes – affordable alternatives that offer benefits similar to those of more expensive items. This trend has become an indication of savvy shopping rather than a source of embarrassment, especially among Generation Z, who often have less purchasing power compared to older generations [1].

Performance – The performance of personal care products is vital for consumer satisfaction and brand loyalty in a competitive market. Effective formulations deliver desired results, such as hydration, cleansing, or styling, while also enhancing the overall user experience through appealing textures and fragrances. As consumers increasingly seek high-quality, multifunctional products, performance emerges as a key factor that influences purchasing decisions. Additionally, the challenge of integrating sustainable ingredients without compromising effectiveness underscores the importance of performance in meeting evolving consumer demands and fostering long-term relationships in the personal care industry.

Sustainability – The cosmetics industry's shift toward sustainability is exemplified by the rapidly growing market for natural ingredients, which is expected to increase from USD $642 million in 2022 to USD $1,095 million by 2030. This trend signifies a notable transformation in consumer behavior, as more than 40% of shoppers now prioritize natural components in their beauty and personal care products. The rising

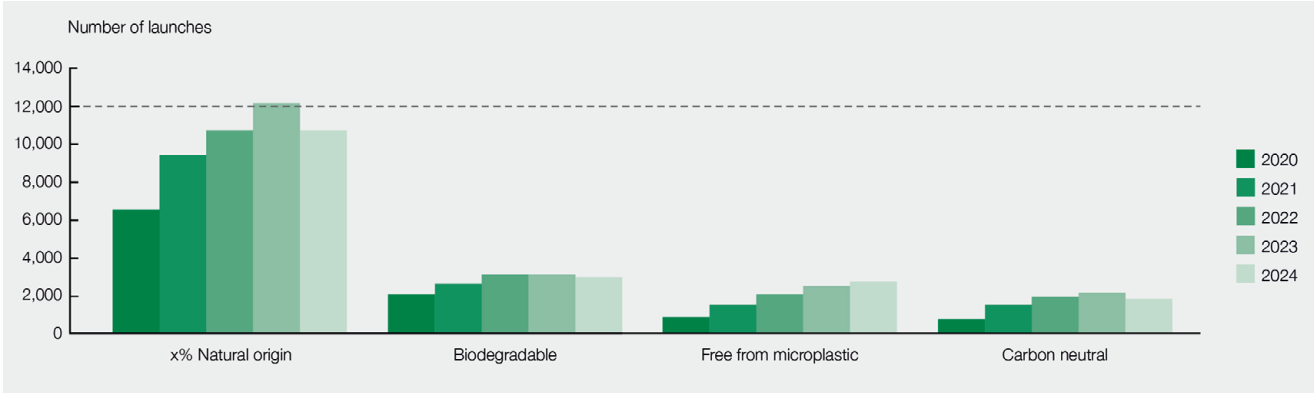


Fig. 1 Sustainability Claims 2020 – 2024, Personal Care. *Source: Mintel GNPD, Europe, Beauty & Personal Care.*

demand for environmentally sustainable and safe cosmetics is influencing product formulation and driving an uptick in research efforts [2]. Key market drivers for sustainability include an emphasis on natural ingredients, biodegradability, the absence of microplastics, and carbon neutrality, all of which are reflected in the growing number of product launches over the past five years (see **Figure 1**).

Sustainability claims

1) Natural Origin

As consumers increasingly seek natural and eco-friendly beauty products, their confusion often grows due to unregulated green claims and branding, which is intended to be addressed by the Green Claims Directive and the Empowerment of Consumers Directive. Ecolabels can assist consumers in selecting eco-conscious beauty products that align with their beliefs and values. Additionally, these labels can enhance a brand's credibility by demonstrating genuine commitment and trustworthiness within the marketplace. Selecting the most appropriate ecolabel for a product or brand involves finding a balance between consumer values, product performance, and cost. The ISO 16128 standard serves as a practical tool, offering an accessible calculation system that is easy for everyone to understand [3].

ISO 16128 comprises two parts [4]. The first, ISO 16128-1, provides definitions for natural and organic cosmetic ingredients, along with other ingredient categories that may have specific restrictions that are necessary for formulating natural and organic products. The ingredients are categorized as natural, natural mineral, organic, derived natural, derived mineral, derived organic, and non-natural. The second part, ISO 16128-2, outlines methods for calculating indexes for natural, natural origin, organic, and organic origin based on the ingredient categories defined in ISO 16128-1. It is important to highlight that ISO 16128 does not address product communication, environmental safety, human safety, socio-economic factors, packaging materials, or regulatory requirements for cosmetics; these responsibilities fall to the manufacturer and the appropriate regulatory authorities.

2) Biodegradability

As public interest increases about the environmental impact of the products they use, the personal care industry must carefully evaluate the ingredients employed to ensure a minimal ecological footprint. In this context, the development of biodegradable cosmetics is an essential requirement.

Biodegradability refers to the ability of a substance to decompose through the action of bacteria or other living organisms, thereby preventing pollution. Various biodegradation standards exist, depending on the environment in which the biodegradation occurs. Substances that enter the aquatic environment through wastewater interact with microorganisms in sewage treatment. This serves as the foundation for assessing aquatic biodegradation, as outlined in the OECD 301 test method [5].

According to this standard, biodegradation is assessed in sealed glass vessels that contain a buffer solution, microorganisms from a sewage treatment plant, and a specified amount of the sample used as the sole carbon source. Over a testing period of 28 days, the biodegradation process is monitored by measuring of CO_2 evolution or oxygen consumption. A key aspect of this assessment is the 10-day window, which stipulates that the limit value of 60% biodegradation must be achieved within 10 days after a minimum of 10% degradation has occurred (see **Figure 2**) [6].

3) No Synthetic Polymeric Microparticles (SPM)

Linked to the growing trend towards more natural-based personal care ingredients and, in particular, due to the European Chemicals Agency's (ECHA) restriction of Synthetic Polymeric Microparticle (SPM) under the REACh regulation, there is an increasing demand for alternatives to synthetic polymers, that are derived from petrochemicals.

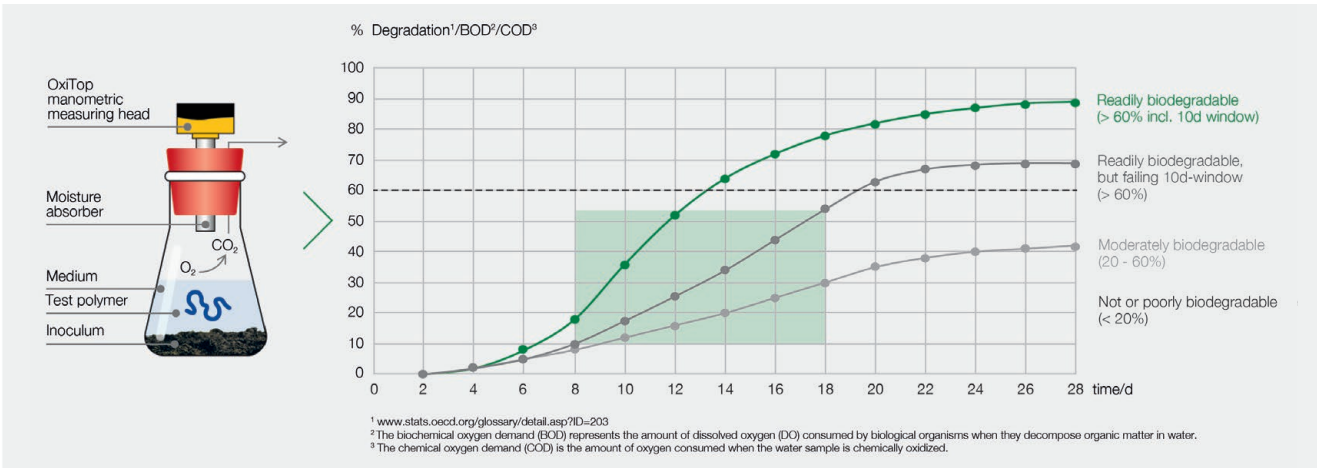


Fig. 2 Measuring biodegradability. OECD 301 test method.

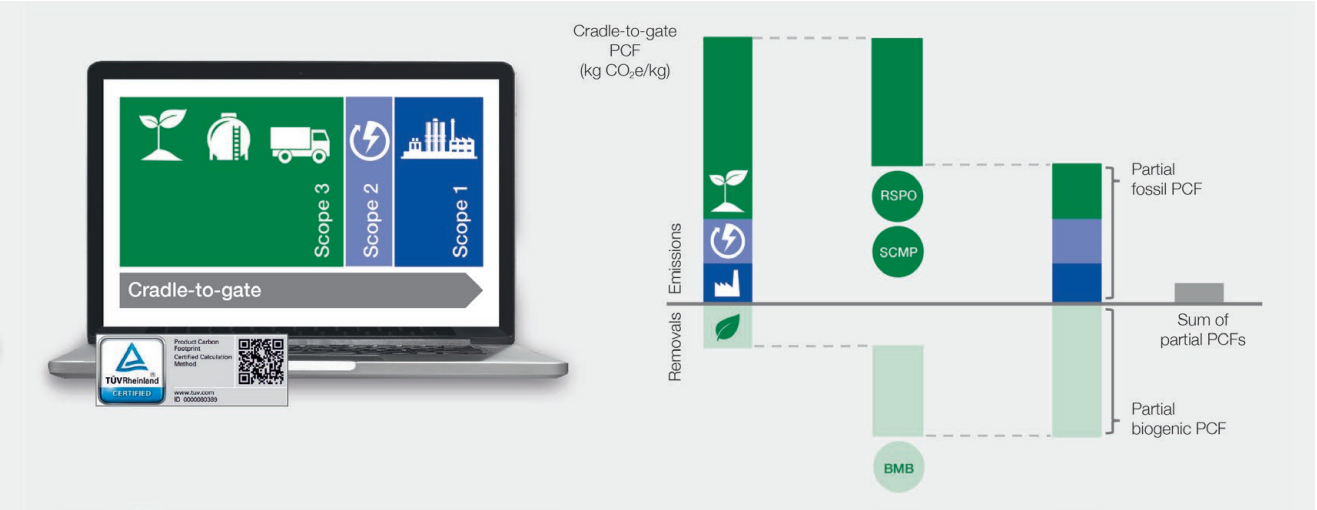


Fig. 3 Levers for Product Carbon Footprint Reduction.

According to the definition of SPM [7], these are solid polymers that are either contained within particles, constituting at least 1% by weight of those particles, or form a continuous surface coating on particles, where at least 1% by weight of those particles meets one of the following criteria: **(a)** all dimensions of the particles are equal to or less than 5 mm; or **(b)** the length of the particles is equal to or less than 15 mm, with a length-to-diameter ratio greater than 3. Exceptions include natural polymers that have not been chemically modified, as well as polymers that are biodegradable or water-soluble, or that consist of a carbon-free structure. The impact of the SPM restriction is that SPMs cannot be marketed as standalone substances or included in mixtures at a concentration of 0.01% by weight or higher if they are present to provide a specific desired characteristic.

4) Carbon Footprint

The personal care industry, along with the broader chemical sector, is confronted with an urgent need to implement sustainable practices and decrease its carbon footprint. The calculation of Product Carbon Footprints (PCF) is crucial in tackling these challenges.

As defined by ISO 14067:2018, "Carbon Footprint of Products – Requirements and Guidelines for Quantification," a product's carbon footprint is the total of its greenhouse gas (GHG) emissions and removals within a product system, expressed as CO_2 equivalents, which serves as a measure of its impact on climate change [8].

Figure 3 illustrates the cradle-to-gate PCF of a personal care product. The light green section represents biogenic removals, the dark blue indicates direct emissions related to the production process, the light blue denotes emissions resulting from purchased energy, and the dark green reflects emissions associated with raw materials. For each of these categories, there are potential levers for CO_2 reduction. On average, the most significant contribution to the carbon footprints of personal care products comes from raw materials, which includes indirect emissions (scope 3 upstream) as well as biogenic removals, a natural characteristic of biobased raw materials.

Consequently, BASF has launched its Supplier CO_2 Management Program (SCMP) [9]. In the program's initial phase, the primary objective was to achieve transparency concerning the CO_2 emissions linked to the raw materials sourced from suppliers. In the following "improvement phase," the company is collaborating closely with its suppliers to identify effective strategies and establish targets to reduce greenhouse gas (GHG) emissions.

Another strategy being implemented is the transition from conventional palm kernel oil (PKO) to a sustainably certified alternative. The most notable certification scheme for sustainable PKO is offered by the Round Table on Sustainable Palm Oil (RSPO) [10]. PKO produced under RSPO standards has a lower global warming impact of approximately 35% compared to non-certified production [11]. By selecting the RSPO-certified alternative, the PCF of the final product can be reduced in proportion to the PKO content. A significant advantage of this approach is that the product specifications and quality of RSPO-certified and conventional products are identical, enabling a reduction in the carbon footprint of the final personal care formulation without the need for reformulation.

Another option for reducing GHG emissions is the Biomass Balance (BMB) approach. This method involves replacing fossil feedstock with renewable resources. Specifically, a certain quantity of renewables is incorporated into BASF's production network, and this amount is allocated to the specific BMB-based product. For BASF, this process is verified by an independent third-party certification body under the REDcert^2 standard, ensuring the accurate allocation of renewable resources [12]. The reduction in the PCF of BMB-based products

Ingredients	INCI	Function	% by weight	
Water, demin.	Aqua	Water	75.55	75.55
Calcium Chloride	Calcium Chloride	Complexing agent	0.10	0.10
Sodium Benzoate	Sodium Benzoate	Preservative	0.55	0.55
Eumulgin® SG	Sodium Stearoyl Glutamate	Emulsifier (O/W)	0.20	0.20
Glycerin	Glycerin	Humectant	5.00	5.00
Verdessence® Alginate	Algin	Rheology modifier	1.00	1.00
Emulgade® PL 68/50	Cetearyl Glucoside, Cetearyl Alcohol	Emulsifier (O/W)	2.00	2.00
Cutina® HVG	Hydrogenated Vegetable Glycerides	Consistency agent	5.00	5.00
Dimethicone 5cSt	Dimethicone	Emollient	10.00	
Cetiol® CC	Dicaprylyl Carbonate	Emollient		2.87
Cetiol® OE	Dicaprylyl Ether	Emollient		5.46
Cetiol® Ultimate	Undecane, Tridecane	Emollient		1.67
Parfum Soft Blossom Natura (Düllberg)	Perfume	Fragrance	0.50	0.50
Citric Acid (50% solution)	Citric Acid	pH adjustment	0.10	0.10



Fig. 4 Monadic (formulation level) sensory comparison between the 100% natural-based day care face cream formulation and one containing Dimethicone 5 cSt.

is attributed to the increased biogenic CO_2 uptake resulting from the transition from fossil to renewable raw materials. Moreover, the BMB approach maintains the same product specifications and performance, making it an easy drop-in solution. Additionally, implementing this concept helps to conserve fossil resources.

Formulation examples

Leave-on: Day Care Face Cream

Skin care applications commonly utilize fossil-based dimethicones with viscosities ranging from 1 to 50 cSt for two main reasons: First, these silicones serve as sensory-enhancing emollients and are typically used in substantial amounts for this purpose. Second, they help mitigate the soaping or whitening effect that can occur when skin care emulsions are applied to the skin, which is an undesirable sensory experience. However, with an increasing consumer demand for natural and biodegradable products, formulators face the challenging task of identifying high-performing, natural alternatives to dimethicones, often under tight deadlines. A promising strategy to tackle this challenge involves leveraging digitization, scientific modeling, and the advantages provided by advanced computing power [13].

The efficacy of this method has been evaluated using a benchmark day care face cream that contains 10% dimethicone, which is commonly found in the market. **Figure 4** illustrates a sensory comparison between the formulation with dimethicone 5 cSt and a formulation featuring biodegradable, natural-based emollient mixtures. The results of this comparison indicated that the natural-based formulations delivered an almost identical sensory experience during the application of the day care face cream as the formulation containing dimethicone. Furthermore, the natural origin content (excluding the implications of the manufacturing process) could be increased from 53% to over 99%. Additionally, the mass percentage of readily biodegradable ingredients, according to the OECD 301 guidelines, improved from 57% to 98%, while the formulation contained no Synthetic Polymeric Microparticles (SPM). The formulation costs are categorized as medium to high, largely due to the significant proportion of relatively expensive emollients used.

Assuming an average weight composition that includes up to 80% water, over 10% emollients, and smaller quantities of emulsifiers, thickening agents, and other components, emollients are the primary contributors to CO_2 emissions in oil-in-water (O/W) skin care emulsion systems (see **Figure 5**). Potential strategies for reducing greenhouse gas (GHG) emissions include transitioning from conventional palm-based ingredients to those certified by the Roundtable on Sustainable Palm Oil (RSPO) and utilizing natural-based emollients with a low product carbon footprint (PCF).

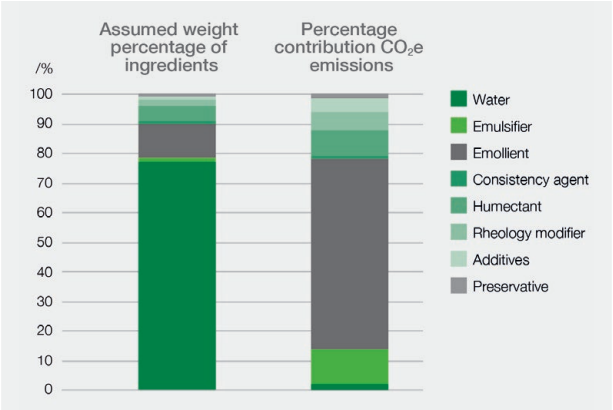


Fig. 5 Impact of ingredient types. Leave-on frame formulation.

Rinse-off: Crystal-clear Shower Gel

In personal care cleansing products, surfactants serve as the key ingredients that clean the skin and generate foam. For many years, sulfate-containing surfactants have formed the foundation of these formulations because they effectively meet these requirements. They are easy to thicken, resulting in viscous products that are user-friendly. The quality of

Ingredients	INCI	Function	wt%
Water, demin.	Aqua		49.50
Sodium Benzoate	Sodium Benzoate	Preservative	0.50
Plantacare® 1200 UP	Lauryl Glucoside	Surfactant	5.50
Dehyton® MC	Sodium Cocoamphoacetate	Surfactant	17.00
Dehyton® AB 30	Coco Betaine	Surfactant	6.50
Plantapon® LGC SORB	Sodium Lauryl Glucose Carboxylate (and) Lauryl Glucoside	Surfactant	18.00
Lamesoft® PO 65	Coco-Glucoside, Glyceryl Oleate	Lipid layer enhancer	3.00
Citric Acid (50% solution)	Citric Acid	pH Adjustment	q.s.

Foam Image Analyzer
(dilutions with 10% product in 15° dH water)

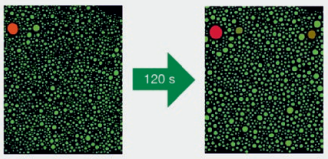


Fig. 6 Pure Shower Gel - nature inspired, crystal-clear cleansing and care.

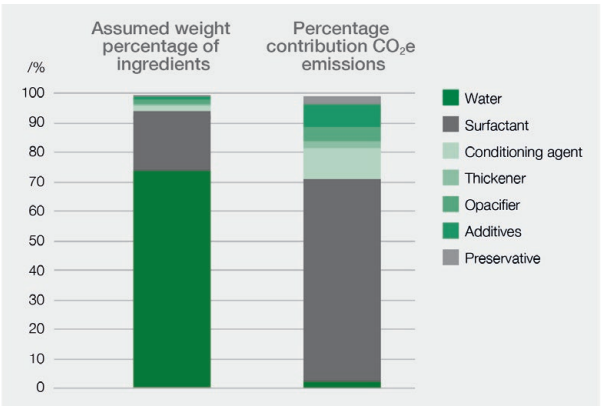


Fig. 7 Impact of ingredient types. Rinse-off frame formulation.

a cosmetic product is often judged by consumers based on critical factors such as the appearance, density, and longevity of the foam, as well as the tactile experience when the product is applied. Conversely, there is a growing demand among consumers for more sustainable cosmetic ingredients, leading them to increasingly seek alternatives to sulfate surfactants. Many of these alternatives are appreciated for their gentleness on both skin and hair. Nevertheless, formulating alternatives to sulfate surfactants poses a challenge, particularly in creating products that yield rich foam and can be easily thickened.

Figure 6 illustrates a shower gel formulation that utilizes alternatives to sulfate surfactant systems. Despite being free of ether and alkyl sulfates, this formulation boasts high viscosity, an appealing appearance, and excellent foaming properties. The content derived from natural sources is 83%, while the mass percentage of readily biodegradable ingredients, in accordance with OECD 301 guidelines, is 100%. Additionally, the formulation contains no Synthetic Polymeric Microparticles (SPM). Its affordability is rated at a relatively low price level, owing to the use of cost-effective alternatives to sulfate surfactants.

An average weight percentage of personal care rinse-off formulations typically consists of more than 70% water, 10-15% surfactants, and small amounts of conditioning agents, thickeners, and other additives. In this context, surfactants are the primary contributors to CO_2 emissions (refer to **Figure 7**). Transitioning from conventional palm-based ingredients to those certified by the RSPO, as well as substituting fossil-based ingredients with BMB alternatives, offers a significant opportunity to reduce the carbon footprint of these formulations.

Styling: Soft and Smooth Textured Hair Gel

Hair styling products are designed with a focus on performance. Polymers are key components that create a film over the hair, providing a barrier against humidity and offering mechanical support to the hair's surface. These polymers facilitate various styling benefits, such as straightening curly hair, preventing frizz, creating curls for those with straight hair, or enhancing the definition of naturally curly hair. While most styling solutions currently available are synthetic, there is a growing trend among consumers towards eco-conscious choices. This shift has led to an increased demand for sustainable, biobased, and biodegradable cosmetic products, and hair styling formulations are no exception. As a result, the beauty industry is faced with the urgent need to embrace the transformation towards green chemistry, all while ensuring the product performance remains uncompromised – this represents one of the most significant challenges to overcome.

Ingredients	INCI	Function	wt%
Water, demin.	Aqua		93.92
Glycerin	Glycerin	Humectant	3.00
Calcium Chloride (50% solution)	Calcium Chloride	Complexing agent	0.44
Sodium Benzoate	Sodium Benzoate	Preservative	0.50
Verdessence™ Glucomannan	Glucomannan	Rheology modifier (and) Fixative	0.66
Verdessence™ Alginate	Algin	Rheology modifier (and) Fixative	0.66
Verdessence™ Tara	Caesalpinia Spinosa Gum	Rheology modifier (and) Fixative	0.66
Citric Acid (50% solution)	Citric Acid	pH Adjustment	0.16

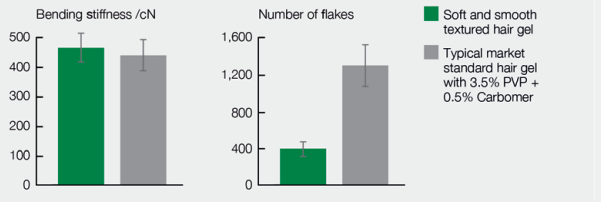


Fig. 8 Soft and Smooth Textured Hair Gel.

The hair styling gel depicted in **Figure 8** is formulated with biopolymers. This formulation incorporates a blend of three different film-forming biopolymers – Glucomannan, Algin, and Caesalpina Spinosa Gum – serving as fixatives and thickeners. It demonstrates exceptional performance, characterized by excellent hold and curl retention, along with minimal flaking and tackiness. The natural origin content exceeds 99%, while the mass percentage of readily biodegradable ingredients, in accordance with OECD 301 guidelines, stands at 100%. Additionally, the formulation contains no SPMs. In terms of pricing, this formulation is classified as medium to expensive, as natural-based polymers generally come at a higher cost compared to standard synthetic polymers such as PVP or PV/VA.

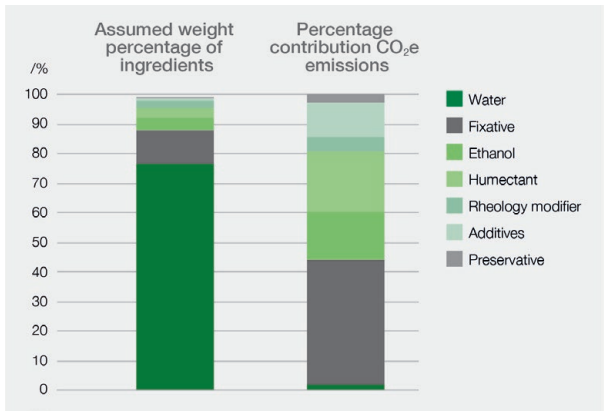


Fig. 9 Impact of ingredient types. Styling gel frame formulation.

A typical styling gel frame formulation consisting of up to 80% water, more than 10% fixatives and a minor amount of ethanol humectants and other components. Fixatives are the main emission drivers in styling gel applications, closely followed by ethanol and humectants (see **Figure 9**). The carbon footprint of a styling gel frame formulation can be reduced significantly by using BMB alternatives for fossil-based ingredients or through the use of natural based styling polymers and rheology modifiers.

The road ahead

The current landscape of personal care formulations is exceedingly complex, necessitating a careful balance between three critical dimensions: performance, affordability, and sustainability. The focus on sustainability emphasizes formulations based on natural ingredients that are biodegradable, do not contain microplastics, and are designed to minimize GHG emissions. BASF recognizes this imperative and supports its customers with a comprehensive product portfolio created to meet these evolving demands. Additionally, BASF continually develops innovative solutions to drive sustainable solutions in the personal care sector.

For example, BASF has entered into an innovation partnership with RiKarbon on emollients that are partly derived from bio-waste. The successful R&D work at RiKarbon has demonstrated the conversion of bio-waste to new, unique emollient chemical structures. This innovative technology produces a clear, odorless emollient imparting excellent soft and silky sensory properties to personal care formulations. BASF intends to develop the RiKarbon technology in house and bring products to the market [14].

In personal care rinse-off products, surfactants serve as the key ingredients. BASF is partnering with Acies Bio to drive the sustainable production of personal and home care ingredients. Both partners have entered into a transformative partnership to further develop a platform for fermentation technology from green methanol for the production of fatty alcohols. Fatty alcohols are essential building blocks for several ingredients in the home and personal care markets, in particular surfactants [15].

By prioritizing sustainability while ensuring high performance and cost-effectiveness, BASF is well-positioned to meet the evolving demands of the market and contribute to a more sustainable future.

References:

[1] https://www.cas.org/resources/cas-insights/the-rise-of-natural-ingredients-for-cosmetics

[2] https://www.euromonitor.com/article/top-trends-shaping-the-beauty-and-personal-care-industry-in-2024

[3] *Olioso, B*, Green cosmetic labels (ecolabels), an overview on the most influential ones, HPC today, Vol. 14(1), 2019.

[4] https://www.iso.org/standard/62503.html.

[5] Biologische Abbaubarkeit — SNS UMTHES

[6] Test No. 301: Ready Biodegradability | OECD Guidelines for the Testing of Chemicals, Section 3 : Environmental fate and behaviour | OECD iLibrary

[7] REACh COMMISSION REGULATION (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles

Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC

[8] ISO 14067:2018 - Greenhouse gases — Carbon footprint of products

[9] BASF, Product Carbon Footprint of Raw Materials, available online: https://www.basf.com/global/en/who-we-are/organization/suppliers-and-partners/sustainability-in-procurement/product-carbon-footprint-of-raw-materials.html (last access October 19, 2023).

[10] Round Table on Sustainable Palm Oil. Cultivating Sustainability for People and Planet, https://rspo.org (last access October 17, 2023).

[11] *Jannick Schmidt, Michele De Rosa*. Certified palm oil reduces greenhouse gas emissions compared to non-certified, Journal of Cleaner Production, Volume 277, 2020, available at: https://doi.org/10.1016/j.jclepro.2020.124045

[12] REDcert – Your partner for sustainability certification, available online: https://www.redcert.org/en/redcert-systems.html (last access October 19, 2023).

[13] *Riedel, H., Baek, YY*, Replacing Dimethicone by AI-Modelling, Expression Cosmétique Ingredients Guide 2024.

[14] Joint News Release - BASF announces innovation partnership with RiKarbon on emollients derived from bio-waste https://www.basf.com/global/en/media/news-releases/2022/09/p-22-347

[15] BASF partners with Acies Bio to drive sustainable production of Personal and Home Care ingredients https://www.basf.com/global/en/media/news-releases/2024/11/p-24-313

authors

Dr. Bianca Seelig, Dr. Arne Ptock, Anja Stork

BASF Personal Care & Nutrition GmbH,
Monheim | Germany

www.personal-care.basf.com