Principles of Moisturizer Product Design

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ABSTRACT

Moisturizers provide significant benefit in dermatology – as adjuvant therapy for many clinical conditions, as a key player in anti-aging regimens, and as a core component in maintaining healthy skin barrier function. Although they have been a mainstay for decades, lotions and creams are no longer formulated with a one-size-fits-all approach, where thickness was the primary cue for efficacy. In fact, moisturizer design today has become an art as well as a science. Product efficacy, aesthetics, and packaging are all engineered in a variety of ways, to create an expansive market of products that meet many consumer needs. The addition of specific types of functional ingredients can make a noteworthy difference as well. This article will explore the myriad approaches for moisturizer development and debunk some of the long-standing myths that have pervaded the marketplace.

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INTRODUCTION

Moisturizers refer to a wide range of consumer products – lotions, creams, serums, and oils designed for the face, body, eyes, hands, and feet. While a primary function is to increase skin hydration, moisturizers deliver other advantages as well, such as improving skin appearance, enhancing skin softness and smoothness, and supplying benefit agents to skin.[1] Moisturizers have broad utility within dermatology and can be particularly important as adjuvant therapy for those conditions associated with skin barrier defects, such as atopic dermatitis, to help alleviate symptoms and improve barrier function.[2] Research has also indicated that early use of emollients can help reduce the rate of the development of atopic dermatitis.[3] For conditions such as acne, where treatments like retinoids and others can worsen barrier dysfunction and increase (TEWL) transepidermal water loss, concurrent moisturizer use can be beneficial.[4]

Efficacy is a top consideration when selecting a moisturizer for a patient. However, notably, product aesthetics (also known as sensory effects) have become increasingly important to consumers, especially when contemplating the use for body vs face. Consequently, a balance should be struck between efficacy and product aesthetics to encourage daily product use.

For decades, moisturizers have been perceived to be formulated in just two ways. Lotions were thinner and known to contain more water; they absorbed faster and were not greasy or unctuous, and thus believed to be less efficacious. Creams, on the other hand, were thicker, oilier, and more dramatically altered the visual appearance of dry skin immediately. As a result, creams were believed to be more moisturizing. However, moisturizer formulation design has become an art as well as a science, and the adage that creams are simply better than lotions because of their consistency is outdated and no longer true. In today's market, with an explosion of product formats and new scientific techniques for combining ingredients with novel packaging, efficacy, the way a product feels, and what it can deliver to skin can be manipulated in a variety of ways. For example, through the careful selection of emulsifiers, polymers, or thickeners, moisturizer consistency is easily transformed to be thinner or more viscous. With the inclusion of key actives in combination with other moisturizing ingredients, efficacy can be dialed up or down.

It should also be noted that price may not be indicative of the degree of effectiveness. Our own internal studies have shown that the clinical efficacy of $100 creams is parity to or even inferior to mass market products containing similar ingredients. Price is most often set by the brand appeal and consumer willingness to pay, rather than the efficacy of the product.

This article will discuss the myriad ingredients that are utilized in moisturizers, describe the ways in which formulas can be engineered to create specific, desired outcomes, and debunk some of the long-standing myths that have pervaded the industry. This understanding is crucial for those who are recommending products to consumers or patients.

Moisturizers 101: The INCI

Differentiating between moisturizers starts with understanding the key components, which can be found on the ingredient label. This label lists the ingredients, by INCI (International Nomenclature Cosmetic Ingredient), in the order of percentage inclusion in the formulation (in most markets). An exception to this rule is that in the US, for ingredients whose inclusion levels are less than 1%, the INCI can be listed in any order irrespective

FIGURE 1. Typical INCI for **(A)** a body lotion[5] and **(B)** a high occlusive/emollient cream.[6]

(A) **INGREDIENTS:** WATER(AQUA), PETROLATUM, CAPRYLIC/CAPRIC TRIGLYCERIDE, STEARIC ACID, GLYCERIN, SODIUM HYDROXYPROPYL STARCH PHOSPHATE, GLYCOL STEARATE, PEG-100 STEARATE, GLYCERYL STEARATE, CETYL ALCOHOL, PHENOXYETHANOL, METHYLPARABEN, ISOPROPYL MYRISTATE, ALKYL ACRYLATE CROSS POLYMER, DISODIUM EDTA, CEDROL, TOCOPHERYL ACETATE, TITANIUM DIOXIDE (CI77891)

(B) **INGREDIENTS:** WATER(AQUA), GLYCERIN, STEARIC ACID, ISOPROPYL PALMITATE, GLYCOL STEARATE, PEG-100 STEARATE, MINERAL OIL, DIMETHICON, GLYCERYL STEARATE, PETROLATUM, CETYL ALCOHOL, PHENOXYETHANOL, ACRYLATES/C10-30 ALKYL ACRYLATE CROSSPOLYMER, METHYL-PARABEN, TRIETHANOLAMINE, PROPYL PARABEN, STEARAMIDE AMP, DISODIUM EDTA, ISOPROPYL MYRISTATE, CEDROL.

of its actual inclusion level. Figure 1 shows the ingredient lists of a standard body lotion and a high oil body cream.

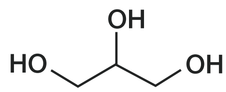
Whereas deciphering the ingredient levels from an INCI is not easy, insights into a formula can be gained by understanding certain principles that apply to all moisturizers. First, in both lotions and creams, water is often the first ingredient. Typically, a lotion contains more water-soluble moisturizers, which are typically humectants. In a cream, occlusives and emollients tend to be the primary moisturizers. Though this is generally the case, it is not always. For example, the first three ingredients of a highly recommended body cream, CeraVe™ Moisturizing Cream, are: purified water, glycerin, ceteareth-20, and cetearyl alcohol. This product is not a cream in the above sense since oils and occlusives do not fall among the first four ingredients on the INCI. This is one example among many that demonstrate that just because a product is labelled a cream and is in a jar, it should not be assumed to be high in occlusive and emollients, and as described below, it is not necessarily more moisturizing. The INCI needs to be examined to gauge whether the product truly meets the need for which it is being recommended.

Another general guide is that polymers, fragrances, preservatives, colorants, and dyes are often present at levels <1%. Since many functional ingredients are efficacious at levels >1%, if a product promotes an ingredient, a user may be well served by ensuring that the promoted ingredient is listed before these ingredients on the INCI. While this is a general rule, there are exceptions such as retinol, which is typically formulated at around 0.1%.

Common Ingredients: Benefits and Issues

In a standard moisturizer, one can find several classes of ingredients: moisturizing ingredients, emulsifiers, polymer/thickeners, sensory modifiers, and preservatives. In addition to these ingredients, there are often advanced benefit ingredients as well, such as anti-oxidants, vitamins, lipids, or sunscreens. In the sections below, we elaborate on these ingredients with details on usage levels and conditions required for efficacy and watch-outs.

FIGURE 2. Chemical structure of glycerin (or glycerol).



Moisturizing Ingredients

There are three key classes of moisturizing ingredients: humectants, occlusive, and emollients.

Humectants are hygroscopic conditioning agents containing multiple hydroxy (-OH) functionalities (Figure 2). By their chemical nature, they attract and bind water. They are water soluble, which means that while they are key moisturizing ingredients in leave-on formats, they are not easily retained on the skin from wash off products like cleansers. The most common humectant is glycerin.

Glycerin can be found in most moisturizers – whether face or body, lotion, or cream. The level ranges generally from 1% to 25% or more with the maximum improvement in hydration seen between 20% to 40% depending on the chassis.[7,8] Beyond hydrating the skin surface, glycerin has been proven to aid in barrier recovery including the stratum corneum integrity, cohesion (UL), and mechanical properties.[7] Glycerin has also been shown to enhance desmosomal degradation.[9]

Occlusive ingredients in skin care products help regulate water in the stratum corneum by preventing excessive water loss from the surface of the skin to sustain a moisturized environment. They are by nature not 100% occlusive but allow for the transfer of water that is necessary for normal skin function.[10] A consequence of this increased water content is that it accelerates barrier recovery.[10] Most occlusives do not contain hydroxy functionalities in their chemical structure, so they cannot bind water. However, since they form uniform hydrophobic films, they effectively seal moisture into skin.

The most common occlusive is petrolatum or petroleum jelly. Petrolatum is a highly refined blend of short and long-chain alkanes (Figure 3), microcrystalline wax, and mineral oils, and is a semi-solid at RT. When rubbed onto skin, petrolatum liquifies and penetrates the stratum corneum where it re-crystallizes forming a strong *interstitial* occlusive system (*not as superficial* as is commonly thought), substantially decreasing transepidermal water loss.[10] At the same time, according to our testing on Vaseline jelly, petrolatum is non-comedogenic. Other occlusives include high molecular weight mineral oils and dimethicones (Figure 4).

Emollients are materials such as oils and lipids that are water insoluble but do not form an occlusive film. In some cases, the difference between an emollient and an occlusive is the molecular weight of the material. Examples of this are low molecular weight hydrocarbons and dimethicones that spread and absorb easily. They are often used for their ability to soften and smooth skin and impart a silky skin feel. Other classes of emollients include fatty alcohols and triglycerides, which are a key source of fatty acids for the skin. Examples of these include cetyl or cetearyl alcohol, cetylcaprylic/capric triglyceride, or oils such as grapeseed, soybean, or sunflower seed oil (Figure 5). Sunflower seed oil (SSO) is a triglyceride precursor to alpha-linoleic acid, an essential fatty acid that is incorporated into stratum corneum ceramides. The type and level of emollient is determined by the consumer needs – the relevant benefit and the clinical need as well as the desired sensory.

The efficacy of a basic moisturizer is determined by the levels of humectants, occlusive, and emollients. A good moisturizer needs a balance of the three. High humectant lotions restore moisture levels to skin but cannot immediately decrease trans-epidermal water loss. High emollient or occlusive creams can immediately reduce TEWL but it takes some time for the skin hydration levels to be restored. It should, therefore, not be assumed that a cream containing high levels of occlusives or emollients is automatically more efficacious. A combination of these ingredients at adequate amounts is necessary to replenish moisture and maintain it creating an environment where the skin barrier can be repaired. This combination can be designed in a cream or a lotion since the thickness can be manipulated independent of efficacy. A final point to be made is that glycerin, petroleum jelly, and dimethicone are amongst the most commonly used, safest, and most beneficial ingredients for the skin.

Emulsifiers and Polymers

Moisturizers are usually emulsions or kinetically stabilized colloidal suspensions of two immiscible liquids meaning there is no appreciable phase separation and the in-use experience remains consistent over the product's usable lifetime. Emulsions require the use of emulsifiers for stability. Emulsifiers can range from simple monomeric surfactants to much larger polymeric surfactants, particles, and lamellar liquid crystal aggregates.

An interesting property of emulsifiers is that they usually have long carbon chains like skin lipids, which makes it possible for an emulsifier to also impart skin benefits. In fact, the closer the chemistry of the emulsifier is to skin lipids, the more skin benefit can be imparted. Long chain emulsifiers, identified on an ingredient label as "palmitic" or "cetyl" (16 carbons or C16), "stearic" or "stearyl" (C18), and "behenic" or "behenyl" (C22), are compatible with and beneficial to skin, help maintain emulsion stability, and are not irritating. Stearic acid, a fatty acid with a C18 chain and carboxylic acid head group, is a good

FIGURE 3. Chemical structure of a simple alkane chain. Higher alkanes, with 9 carbons or more, such as nonane shown here, are the basis of mineral oil.

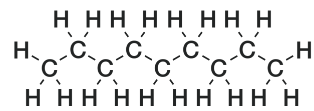


FIGURE 4. Chemical structure of a simple dimethicone showing the siloxane (-SiO-) backbone.

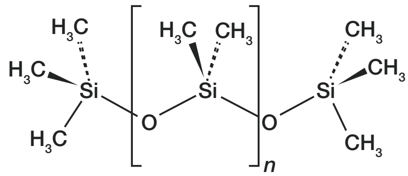


FIGURE 5. Chemical structure of an example triglyceride with 3 carbon chains attached to a glycerin backbone.

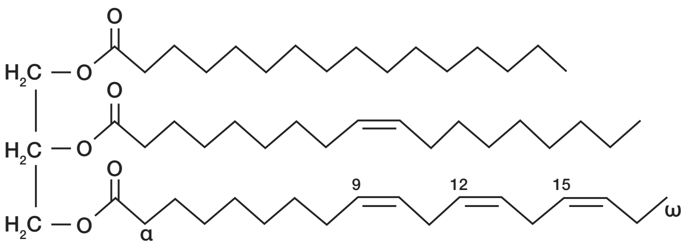
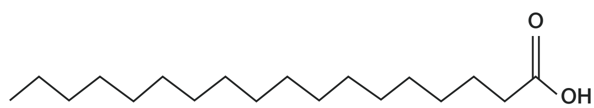


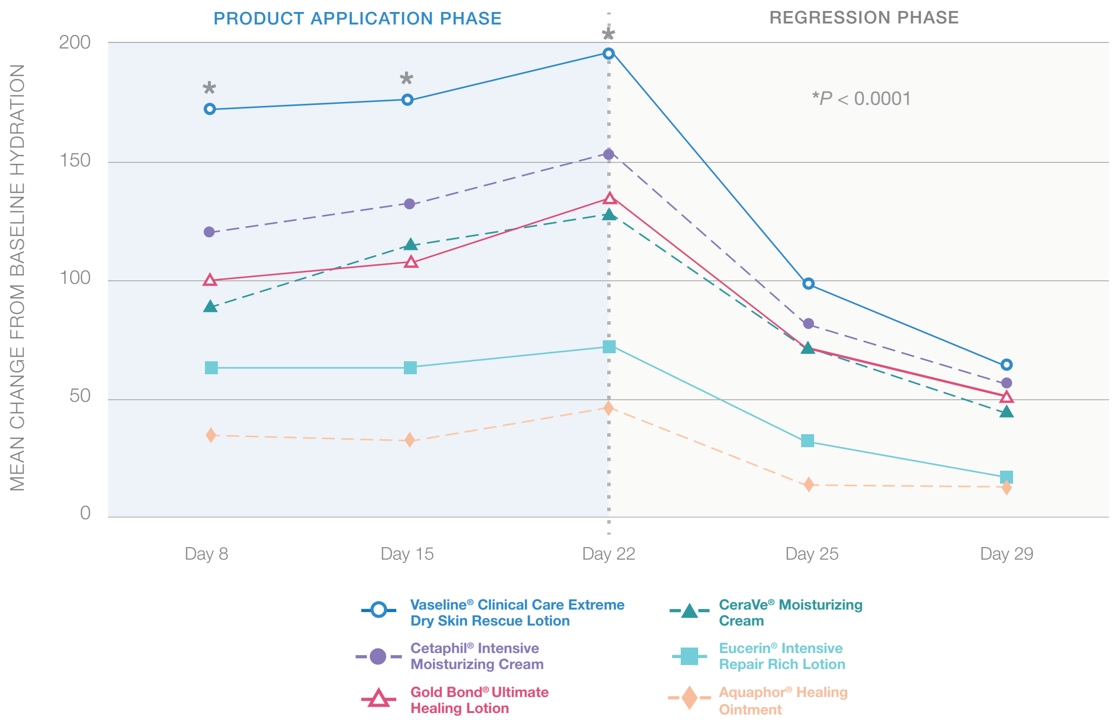
FIGURE 6. Chemical structure of stearic acid.



example of an emulsifier with skin benefits that Unilever uses extensively. Fatty acids are an integral component of the lipid matrix, and topically applied stearic acid has been demonstrated to incorporate into the lipid matrix improving the quality of the stratum corneum.[11, 12]

Another class of materials used to improve the stability, impact thickness and texture, and modify sensory feel of moisturizers is polymers. These could include synthetic polyacrylate type polymers or natural ones like starch (a polysaccharide based polymer). The feel and look of emulsions changes dramatically depending upon the polymer and emulsifier used. For example, culinary enthusiasts are aware that using a starch versus gelatin results in radically different textures. Similarly, in cosmetics, availability of novel polymers and emulsifiers have provided the formulator with a unique ability to modulate the feel and texture of moisturizers independent of its efficacy.

FIGURE 7. Comparison of moisturization between marketed "therapeutic" creams and lotions (SKICON hydration scores, CFB; 2016).



Moisturization Efficacy: Cream or Lotion?

It is a widely held belief that creams are more moisturizing than lotions, and hence more effective in treating dry skin, for example. While this may have been true when such consumer products first appeared in the market, this is not the case anymore. Today, the difference between creams and lotions is largely related to the types of moisturizers and the consumer sensory expectations. Creams tend to be thicker; however, this can be easily modified by using the right combinations of polymers and emulsifiers. Creams can contain more oils than lotions as in the case of emollient creams, and lotions can contain more humectants, for example, Vaseline™ Intensive Care Deep Moisture Jelly Cream and Vaseline™ Intensive Care Advanced Repair Unscented (See Figure 1 above), respectively. However, this is not always the case. In determining moisturization efficacy, the total level and combination of moisturizers in the product is the most important factor. This is clearly demonstrated in Figure 7, where hydration scores from a 3-week moisturization efficacy study with a 2-week regression phase were compared across different marketed cosmetic therapeutic creams (represented by dashed lines) and lotions (represented by solid lines). There was no direct relationship found between the format and efficacy, in fact, the most efficacious product in the study was a lotion. The entirety of the formulation is responsible for the product efficacy, but this data does suggest that glycerin and total moisturizer levels is a better indicator of performance than product format.

If there is no clear relationship between product format and efficacy, how does one select the right product? There are multiple considerations. First, it should be ensured that the product contains the right moisturizer combinations and levels (per INCI understanding as described earlier in this article) to address the patient's moisturization needs. Second, functional ingredients to address a patient's secondary skin concerns should be considered and, based on personal experiences, specific ingredients that are not suitable for their skin or have caused issues or reactions in the past such as fragrances, should be avoided. Several key functional ingredients are described in more detail below. Finally, consumers should choose a product that meets their personal sensory preference and price tolerance so they can easily incorporate the product into their daily routine as using a product every day is a key factor to full realization of efficacy.

Functional Ingredients

In addition to the core skin lotion and cream ingredients described in the sections above, it is common to include one or more bioactive ingredients that target specific pathways in the stratum corneum and underlying epidermis.

Niacinamide (Vitamin B3)

Niacinamide (Figure 8) is the physiologically active form of vitamin B3. This water-soluble vitamin has a variety of dermatological therapeutic benefits and is often included in many good moisturizers.

Niacinamide stimulates ceramide synthesis,[13] reduces hyperpigmentation,[14,15] provides anti-inflammatory and anti-bacterial benefits,[16] and contributes to anti-aging benefits like appearance of facial fine lines and wrinkles as proven at the concentrations used in the products (roughly 3%). One potential side effect of products containing niacinamide is flushing, particularly in consumers of Asian descent. The culprit ingredient is niacin, which is another form of vitamin B3 and can occur as a contaminant if the quality of the raw material is not properly controlled. Manufacturers of quality topical products know to screen raw materials for this contaminant.

Alpha Hydroxy Acid (AHA)

Alpha hydroxy acids (AHAs) are a class of organic carboxylic compounds including naturally-derived glycolic acid, lactic acid, malic acid, citric acid, and tartaric acid (Figure 9).[17] AHAs have been used at various concentrations to enhance desmosomes resolution and stimulate desquamation, with positive benefits for the epidermis and dermis.[18,19,20] At lower concentrations (5-10%), AHAs are available in over-the-counter products that can be used daily for improved barrier function and to improve the appearance of skin related to sun-damage, wrinkling, and hyperpigmentation benefits. At higher concentrations (20-70%), AHAs are used as chemical peels by dermatologists, beauty, and health spas.[18]

PPARs

Peroxisome proliferator-activated receptors (PPARs) are well recognized for their effects on skin barrier development and maintenance,[21,22] and on increasing keratinocyte differentiation.[23,24,25] They enhance the production of barrier important lipids such as ceramides and fatty acids,[26,27] and increase epidermal thickness and filaggrin synthesis leading to anti-aging benefits such as reduction in appearance of overall photodamage, mottled hyperpigmentation, and fine lines and wrinkles.[28,29]

PPAR ligands are often naturally occurring unsaturated fatty acids such as conjugated linoleic acid (CLA). Such compounds are unstable, rapidly oxidize when exposed to air, and lose efficacy. Hence, historically, PPAR ligands have required the use of airless pack for stability leading to a higher cost product. In 2015, Unilever successfully introduced 12-hydroxy stearic acid (12-HSA) as a stable, gentle, and inexpensive PPAR ligand for the mass market (Figure 10). 12-HSA contains no unsaturated bonds obviating the need for high cost, airless packaging.

Vitamins C and E

The skin barrier is altered when exposed to external oxidative stresses such as UV irradiation and pollution.[30] Vitamin C (ascorbic acid) and E (α-tocopherol) are two of the most important antioxidants to protect skin from these external oxidative stresses. Although these are powerful ingredients, vitamins C and E are extremely unstable upon exposure to air. More stable forms of these vitamins like magnesium ascorbyl phosphate and vitamin E acetate are available; however, these need to be absorbed and converted into the active form within the skin. It is important to recognize that not all vitamin C and E formulas have similar physiological activities active.

Hyaluronic Acid (HA), a disaccharide polymer (Figure 11), is an integral component of the extracellular matrix where it plays

FIGURE 8. Structure of niacinamide.

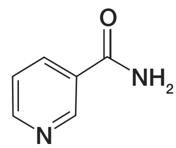


FIGURE 9. Example AHA structures. **(A)** glycolic and **(B)** lactic acids.

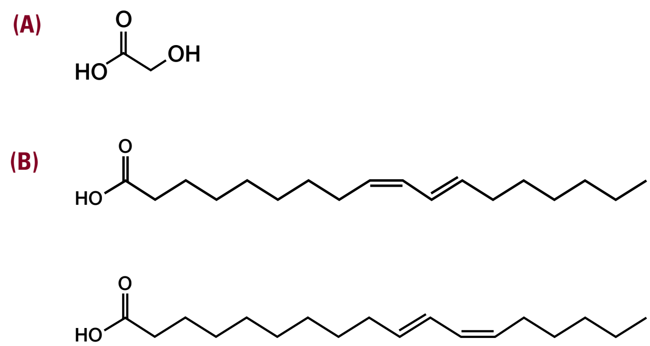


FIGURE 10. Structures of **(A)** 12HSA and **(B)** CLA.

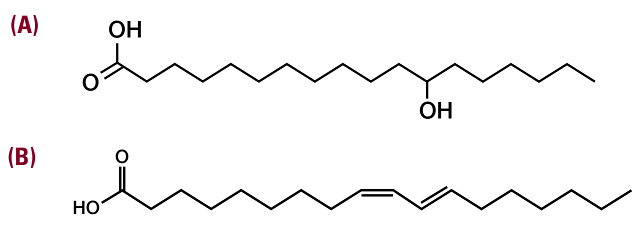


FIGURE 11. Chemical structure of hyaluronic acid.

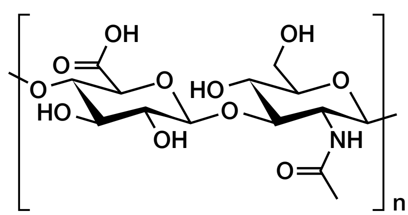
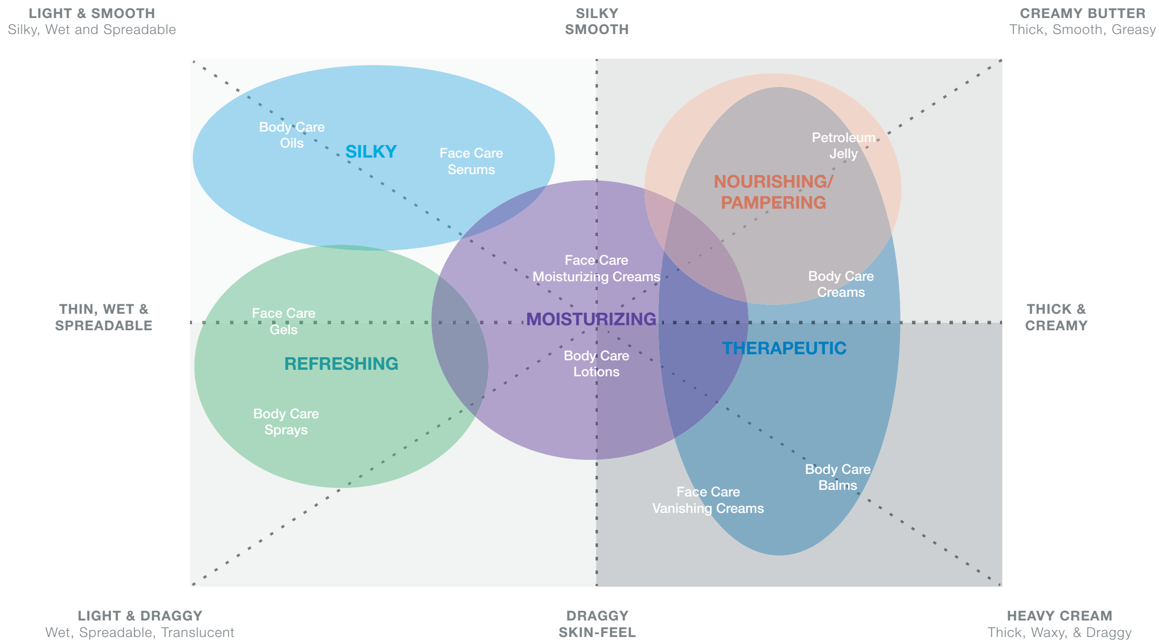


FIGURE 12. Generalized map of face and body moisturizer formats indicating typical sensory domains.



a key role in keratinocyte proliferation, migration, and wound repair. Because of the numerous -OH moieties, HA is exceptionally hygroscopic and is often touted as a wonder ingredient in skin-care products. However, due to its large molecular weight, topically dosed hyaluronic acid may not penetrate sufficiently into the skin for biological effects.

Product Sensories

Today, consumer experiences vary widely across moisturizing products. Also, most possible combinations of ingredients are available in almost any product format. In Figure 12, we have mapped different products and formats by their typical skin feel sensories as well as by the perceived consumer benefits associated with the different sensory domains.

Products in the center of this map are designed for normal dry skin and daily use. They are typically easy to apply, absorb quickly, and *feel* moisturizing. Formulations on the right side of the map are thicker, creamier products and are associated with consumer benefits such nourishing and pampering. Thicker, creamier aesthetics also suggest to the consumer that the products will provide more therapeutic benefits such as longer-lasting moisturization and efficacy for drier skin. These formulas generally use higher levels of solid based emulsifiers and polymers to achieve their thicker texture. High emollient creams fall here with thick, smooth textures and greasier after-feel. Because these aesthetics strongly suggest superior efficacy (whether clinically true or not), products for people with very dry skin and its associated symptoms tend to fall in this space in the sensory map.

Compositions spanning the left side are typically thinner, wetter, and spread more easily. These are often polymer-structured liquids with a lower level of liquid-based emulsifiers. The lower left quadrant is associated with refreshing and hydrating benefits and includes gel and spray formats. These are especially suited for hot, humid climates. On the other hand, most face care products tend to lie in the upper quadrants because they often contain silicones and silicone elastomers to impart a silky skin feel.

It is important to note that it is entirely possible to create any possible experience on this map by simply altering the type of emulsifiers, polymers, sensory modifiers, and emollients. Moisturizing ingredients and actives play a role in sensory, but not as overwhelmingly as is often believed.

CONCLUSION

This article is intended to describe the art and science of moisturizer product design and to start a conversation about long-standing beliefs about cosmetic products, specifically that some pre-conceived relationships between experience and efficacy and cost may not always be accurate. For example, it is erroneously assumed that creams are more efficacious than lotions. Clinical studies performed by Unilever and others using many creams and lotions have disproven this myth. In fact, cosmetic moisturizers covering a wide variety of formats can give the consumer their personally desired combination of efficacy and hedonics. Price is not often a guarantor of product efficacy and the best strategy is to examine the INCI, be armed with information, and seek expert advice.

DISCLOSURE

Christine Lee, John Bajor, Teanoosh Moaddel, Vivek Subramanian, Jian-Ming Lee, Diana Marrero, and Sheila Rocha are employees of Unilever R&D.

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