Creating a Streamlined and Inclusive Shade Palette for the USA and the UK

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Abstract

Background: The demographics of the world's population continually evolve. Many cosmetic companies offer foundation shade palettes exceeding 50 skin tones. This may not be practical, economical, or environmentally favorable for companies to manufacture. The purpose of our study was to create a smaller; more efficient foundation palette that could address consumer needs to satisfy individual skin tones in both the USA and the UK.

Methods: We focused on formulating shades based upon the existing CIE L.a.b. (CIELAB) or LCH (CIELCh) data for skin tones available from various sources. We conducted our own measurements with multiple colorimeters and sensory visual evaluations. Qualitative and quantitative methods were used. Panel studies were conducted to select the optimal shade palette.

Results: We developed a pigmented W/O emulsion base with pigments that were surface treated with stearoyl glutamic acid and polyhydroxystearic acid to be easily dispersible. The ingredients used within the formulation fulfill the "Clean and "Natural Origin" criteria. The shades were aligned to mathematically fit the skin tone values agreed upon through the use of design of experiment and color software. Our panel testing confirmed that the shades were diverse and could address consumer needs both in the USA and the UK.

Conclusion: We were able to streamline a foundation palette that could be adapted quickly as demographics change. The shade line can be more economical for manufacturers addressing the wide diversity of skin tones. In addition, there are environmental and logistical benefits to a more compact, optimized shade palette.

1. Introduction.

Companies marketing color cosmetics for face may update their color palette over time and the data introduced within this body of work can be used for new product introductions. The majority of color products in the face category within the marketplace are currently divided by skin tone rather than by age or other factors.

The demographics of the USA in 2020 were: 60.1% White or Caucasian, 18.2% Hispanic or Latino, 12.2% Black or African American, 5.6% Asian, 0.6% American Indian/Alaska Native, 0.2% Native Hawaiian, 3.1% Multiracial or all other ethnic groups combined. The multiracial population in the USA has increased by 276% since the 2010 census [1]. According to the UK Census 2011, the ethnic distribution is approximately: 87.1% White or Caucasian, 7.0% Asian, 3.0% Black/African/Caribbean, 2.9% Multiracial or all other ethnic groups combined [2].

Many brands offer a large number of foundation shades, up to and even sometimes exceeding 50. However, such a wide number of SKUs may not be practical or economical for smaller companies to manufacture. In-store shelf space is also limited whether it be mass market or department stores. The purpose of our study was to create a foundation palette that would satisfy consumers for the various skin tones in the USA and the UK. Oftentimes, the focus is entirely on making products deep enough without considering which undertones help make the shade a perfect match.

Creating shades for skin tones is not just about matching colors. There is a complicated structure of color and optics within the skin. The epidermis contains a heterogeneous color distribution. The genetics of each person is what determines how much melanin is produced and how it is distributed throughout the skin. Melanin (pheomelanin and eumelanin), hemoglobin, beta carotene, and bilirubin are the primary skin pigments absorbing light. Melanin can be found in two primary forms. Eumelanin exists as black and brown. Pheomelanin provides a red and yellow color. More melanin is produced in darker skin (5% in epidermis) than pale skin (1% in epidermis). A Mexameter can measure the amount of melanin in the skin, as well as hemoglobin.

Carotene is found in the stratum corneum of the epidermis and the deepest layer of the skin, the hypodermis. The hemoglobin is found in the blood vessels of the middle layer of our skin, the dermis, as described in the next paragraph. The bluish-white connective tissue under the dermis and the hemoglobin circulating in the veins of the dermis determine much of the skin color of people with light skin. Light scattering is also produced by the fibrous structure of the dermis.

Undertones are the colors that lie within and beneath the anatomy of the skin, referring to the more subdued tones within the shade palette. Beneath the epidermis in the dermis there is collagen, capillaries, veins and then blood vessels all which are scattered, refracted and reflected providing an undertone. Larger, deeper vessels may also contribute to the color of skin. Cosmetic science and cosmetologists usually describe undertones as warm, cool, or neutral.

The proposed shade palette would address a wide range of skin tones; however, the number of SKUs would be formulated to be considerably smaller by optimizing the individual shades and color values. The mapping of skin tones in many cases is significantly clustered within specific areas, mostly in the upper range of the lighter skin tones. Individual shades within that lighter cluster can be developed to be acceptable to multiple skin tones when the distance in color space is limited to a smaller, more specific range. Where there are significant and wider differences in the color space for shade, we devoted a larger portion of the palette to address these issues on a more personalized level. There are distinct differences in skin color among groups of individuals. A wide range of L* values is associated with Black or African American and also Asian groups. In addition, the opacity, transparency and translucency need to be carefully engineered as foundation products can be too chalky on individuals with darker skin [3].

In addition, ECHA and the cosmetic industry continue to evolve towards standards that limit, restrict, or ban certain substances in order to protect human health and the environment. We used the most recent ECHA regulations and information from consumer-based NGOs to update our ingredients as we moved along the formulation path to address these issues. The terms “Clean” and “Natural or “Natural Origin” are accepted by consumers and many of them search to find products that conform to ingredients that fit these descriptions.

2. Materials and Methods.

1. Formulation

We focused on formulating shades based upon the existing CIE L.a.b. (CIELAB) or LCH (CIELCh) data for skin tones available from cosmetic trade journal articles, books and our own research & measurements. We created a shade matrix in Excel based upon color equations that aided us in shade selection. In addition to these values, we learned from our previous work in this area that opacity and transparency were key factors for acceptability of shades amongst diverse consumers. We formulated with nano and non-nano titanium dioxide and zinc oxide and transparent & pigmentary iron oxides to address the criteria. Mineral sunscreens, zinc oxide and titanium dioxide, are recognized as GRASE in the United States and are approved in the UK/Europe. We have our own customized SPF calculator in-house that predicts the sunscreen protection factor (SPF), as well as the ultraviolet A protection factor (PFA).

As we know, the Fitzpatrick scale is used for assessing the risk of developing sunburn. L.a.b. color values can help to provide skin measurements for testing sunscreens: L* measures skin pigmentation, a* measures erythema and b* measures tanning ability. In the United States, the most common Fitzpatrick skin phototype (FST) is FST III (48%), with FST I or II in 35% of the population [4]. However, there is a significant amount of crossover in ethnicity for skin tone related to FST III. To address these issues and formulate a diverse shade palette, we have targeted two shades each for Type I and Type II. For Type III and Type IV we formulated four shades each. And finally, for Type V and Type VI we matched three shades each. So, for Hispanic, Asian, and Black/African American individuals there are 12 available shades in the palette.

Pigments that are surface treated with stearoyl glutamic acid and polyhydroxystearic acid (ASGP) helped to provide the best version of the formulation as the colors could be processed with limited amounts of shear and produced vibrant results [5]. We used the ASGP-treated mineral sunscreens in combination with a natural sunscreen booster consisting of argan oil (argania spinosa kernel oil), tocopheryl acetate and bisabolol. The natural booster provides antioxidant and photoprotective benefits to the formulation, as well. The carotenoids of which some are also partially responsible for skin undertone are found in argan oil as carotenes and xanthophylls (e.g., neoxanthin, violaxanthin and zeaxanthin). The amount of carotene present in our formulation is about 0.02%.

We also included color options in the form of ultramarine pigments, blue and violet, which we had studied previously and optical variable pigments in order to address undertones and provide additional effect to the overall tonal range. Optical variable pigments (OPV) in skin-toned cosmetics behave differently than traditional metal oxide coated mica effect pigments. They bond an appropriate reflection color to an appropriate skin tone, enhance that skin tone and neutralize undertones or uneven pigmentation. An orange-red pigment works best in light skin countering the yellow-green undertones. Blue-green OPV is effective in countering gray also in Caucasian skin neutralizing red tones. A green-gold pigment is suitable for light yellow Asian skin tones, as it will correct red and some blue undertones. A violet reflection complex works similarly, but for light brown to olive skins. Lilac reflections will enhance and correct from olive to medium dark to dark brown skin neutralizing yellow [6]. For any ultramarine pigment that might be needed for additional shading we adjusted the pH of the internal water phase to be in the range of 7.0-7.5 for those specific batches, even though it was a W/O emulsion.

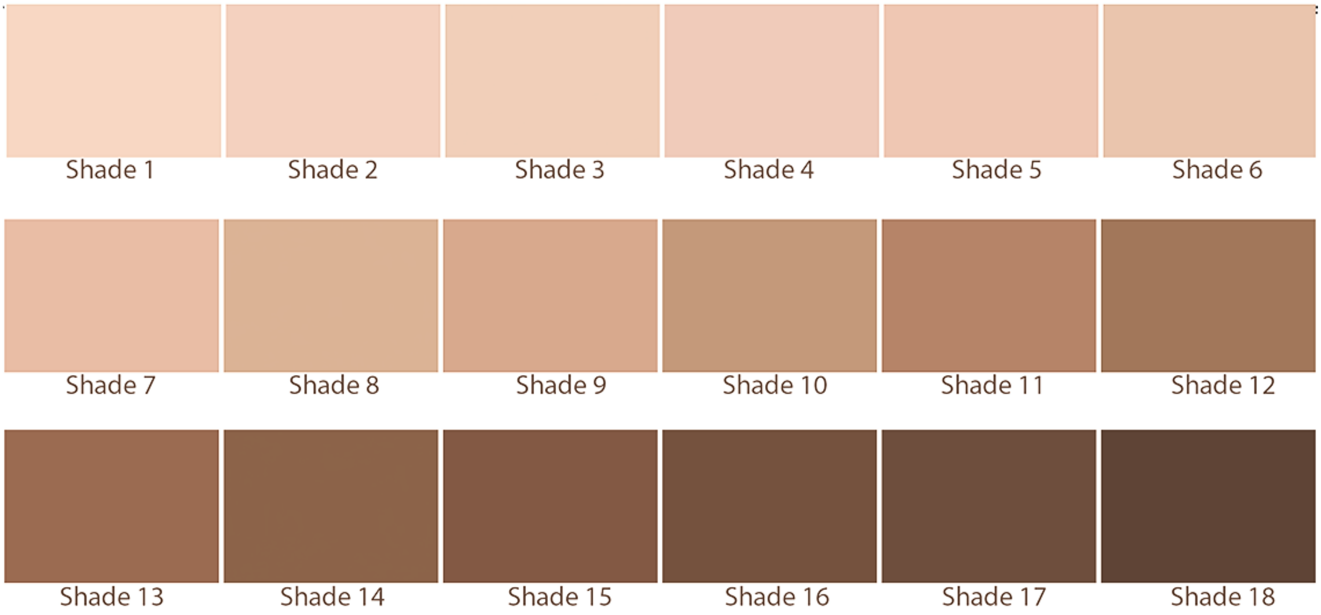
Table-1. General formulation for creating the 18 shade palette.

Ingredient - INCI Name	% W/W
OIL PHASE - Part I.	
Squalane	13.87
Dicapryl Carbonate	5.50
Argania Spinosa Kernel Oil (And) Tocopheryl Acetate (And) Bisabolol	5.00
Polyglyceryl-3 Polyricinoleate (And) Polyglyceryl-3 Diisostearate	4.00
Isopropyl Isostearate	3.00
Polyglyceryl 3 Diisostearate	1.50
Isodecyl Citrate	1.00
Glyceryl Caprylate (and) Glyceryl Undecylenate	1.00
Hydrogenated Lecithin	0.30
PIGMENT PHASE - Part II.	
Zinc Oxide (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	7.00
Titanium Dioxide (And) Alumina (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	3.00
Titanium Dioxide (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	1.50
Iron Oxides (CI 77492) (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	2.27
Cellulose (And) Stearoyl Glutamic Acid	1.00
Iron Oxides (CI 77491) (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	0.75
Iron Oxides (CI 77499) (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	0.35
Mica (And) Stearoyl Glutamic Acid (And) Polyhydroxystearic Acid	1.63
AQUEOUS PHASE - Part III.	
Water	41.68
Sodium Chloride	1.00
POLYSACCHARIDE PHASE - Part IV.	
Propanediol	4.00
Xanthan Gum	0.15
PRESERVATIVE PHASE - Part V.	
Phenethylalcohol (And) Caprylhydroxamic Acid (And) Glycerin	0.50
Total	**100.00**

2. Color

There are a number of well-designed and existing studies and sources that show L.a.b. values for different skin types. We utilized both virtual and physical sampling to determine the overall satisfaction of the 18 shade palette that we created for collecting data from both direct and indirect sources. The L.a.b. data from these were used for color matching when the methodologies showed a high degree of similarity between them. After combining and integrating the sources, we used Adobe Photoshop to create three original palettes of 18 shades each, encompassing the L.a.b. values that we calculated by applying an algorithm to them. We then distributed these three palettes to a large group of consumers in the USA, the UK, and Europe asking them to visually find and indicate the shade number and palette number that most closely matched their skin tone. With these results we fine-tuned the optimal shade palette for color formulation.

Fig.-1. One of several shade palettes we created in prototype form for visual evaluation by consumers.



Our measurements involved the use of several Datacolor Microflash D200 spectrophotometers, a Datacolor 500 spectrophotometer and a WR 18 colorimeter made by Shenzhen Wave Optoelectronics Technologies. Color was measured according to the CIE L∗a∗b System using our spectrophotometers with several apertures. When testing drawdown we took three measurements of each Leneta surface N2A-3 and averaged them. Similarly, we did this for facial skin with cheek and forehead measurements.

The devices were set for D65 illuminant and a measurement angle of 10° for obtaining the variables lightness (L∗) and the chromaticity coordinates a∗(red-green axis) and b∗ (blue-yellow axis). This data internally calculates the hue angle (h∗) and the saturation (C). The color difference (Δ E∗) and change in saturation (ΔC) were determined according to Charrier et al. (2002) and Okino et al. (2009) [7]. These variables were employed to compare the colorimetric values (L∗, a∗ and b∗). In addition to spectral measurements for color we referred to and used the British Standard ISO 11037:2011 “Sensory analysis – Guidelines for sensory assessment of the colour of products”. This is the UK implementation of ISO 11037:2011.

3. Shade Palette

We created monochromatic extenders for the primary colors within the formulation: white, yellow, red, black, ultramarine blue, ultramarine violet, and base emulsion. To achieve more consistent color across the shade line we varied the levels of nano-sized zinc oxide and titanium dioxide, as well as the pigmentary size type of titanium dioxide. This provided enough transparency in the formulation to address the deepest skin tones with the addition of iron oxide colorant blends.

We placed the extender L.a.b. values for the monochromatic batches within the Design Expert (DOX) software program. This is a different, but similar approach to using color matching formulation software. We used a D-optimal Quadratic Design Mode to then create and produce shades that could be adjusted to fit the L.a.b. values in our 18 shade palette. From this collected data we created the shades in our natural origin formulation for consumers to apply to their skin and assess their overall satisfaction with the products. As demographics change, the shades can then be updated accordingly in the future through Design Expert software without repeating the same work and it can be worked on by multiple people in different locations.

We processed the 18 shade palette in the laboratory using Silverson LM5A high shear homogenizers, IKA-WERKS lab mixer and Premier Mill 1 HP dispersators. Once the shade palette was completed we provided samples of several shades to consumers to assess their satisfaction in addressing their skin tones. We also did the same with an expert sensory panel that we have in-house on our facilities.

3. Results.

We were able to develop a W/O emulsion base that was inclusive for USA and UK skin tones meeting our objective. These shades were aligned to mathematically fit the skin tone values that we set up and agreed upon through the use of design of experiment software. When properly configured, the software presents formulations requiring only very small adjustments to meet the intended targets for ethnicity. We measured and evaluated the foundation on skin and also on unsealed Leneta charts as drawdowns using Cabnal smartheat technology.

The hue values for what we would forecast for individuals with “warm undertones” generally measured $> 54°$ while those for “cool undertones” were $< 49°$. “Neutral undertones” were characterized with a blend of the two undertones ranging in hue from $\leq 49°$ to $\geq 54°$. As mentioned in the previous section, undertones are a reflection of the translucency of skin and that which composes the entire matrix, including the color of veins, concentration of carotene, and other associated factors. The lightness/darkness scale varied from about ≥ 67 to 73 for Caucasian shades, >50 to < 67 for Hispanic/Asian/American Indian shades and from >30 to < 50 for African-American skin tones. The skin tone related to the surface color of your skin can change where the melanin is most concentrated. However, your undertone beneath the skin generally does not change.

We matched shades in the foundation base to the target values that we had developed through creating our shade charts. The values fell within a Delta-E (dE) of < 1.50.

The visual assessment of Delta-E (dE) for L.a.b. color can be defined as:

Table-2. Visual assessment of color differences.

Delta-E (dE)	Visual assessment
<= 1.0	Not perceptible by the human eye
1-2	Perceptible through close observation
2-10	Perceptible at a glance
11-49	Colors are more similar than the opposite
100	Colors are exactly the opposite

We had consumers evaluate our three shade charts for 18 skin tones. The final tabulation proved one chart to be preferred as it had a wider distribution of tones which the consumers found to be more acceptable when tested visually as a match for their skin tone. This allowed us to proceed with our shade development work of the base formulation.

As part of the overall design we followed the most recent standards for “Clean” and “Natural Origin” with respect to the raw materials that we formulated with. The importance of a sunscreen foundation that can be used daily cannot be underestimated for protection of the skin. The 18 actual finished formulations were packaged in transparent plastic tottles and were given to consumers for their evaluation. They could select their first preferred shade from the palette and if it did not achieve total satisfaction then they could continue to select other shades. Our final results achieved a high degree of satisfaction with their rating of the product matching their skin tone when selected from the 18 shade palette. Not only were the shades acceptable in addressing both light and dark skin tones, but also the relative importance of the undertone hue was also achieved.

4. Discussion.

In developing this foundation make-up it was important to understand the variation in skin color and possible cultural influences, as well as the structure of the skin. In one of the referenced studies for Asian skin, it is noted that preferred base makeup products usually were found to be of slightly brighter color than the actual skin tone, i.e., people may inherently want their skin to be slightly lighter [8]. We developed foundation shades with the specific needs for each ethnicity in mind.

Other studies have shown that hyperpigmentation in the people of color community is more common because of the over production of melanin that is already found within the epidermis. Products with adequate SPF can offer protection from the sun’s harmful UV rays and also help to prevent hyperpigmentation. Sunscreen is the single most important factor in improving most causes of hyperpigmentation.

There is a high degree of variation and difficulty in selecting shades from palettes that may have 30 or more SKUs. An 18 shade palette has the potential to eliminate many of the issues. It is easier for the customers’ eyes to focus more quickly upon the few shades that may fit the individual’s skin tone. In addition, the relative number of batches that need to made, as well as labeling, and testing are reduced significantly by a reduced 18 shade palette. By allowing consumers to visually rate the three shade charts on their own monitors we were able to capture results from a more broad and diverse panel test. Offering three shade palettes as part of our testing gave us a better overview of what the consumers needs were as opposed to us assuming one shade palette that we created would be viable.

5. Conclusion.

Understanding skin from a multicultural perspective will enable cosmetic companies to achieve their technical targets and satisfy a broader category of consumers with a global shade palette. Selecting pigments at the correct levels and with corresponding needs, such as UVA/UVB balance, can help to deliver products with optimal colour and additional suncare benefits [9]. Special care and consideration was taken to formulate only with ingredients that fit our criteria for “Clean” and “Natural Origin”. These proved to be compatible with our overall objective. We were able to streamline a foundation palette that could be adapted quickly over time through the use of design of experiment software. Our analysis of the data and methodology previously available and when coupled with our experience in color matching of skin tones proved invaluable for this project. We believe that our more economical approach to consolidating a foundation line can assist formulators when resources or marketing opportunities may be limited. A smaller offering of SKUs for a shade line can potentially prove to be more economical and environmentally beneficial.

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7. Conflict of Interest Statement.

The authors declare that they have no conflict of interest.

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