Colour matched cosmetic foundations for black skin tones

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Abstract

This study focuses on the development of a cosmetic foundation that is effective in colour matching a range of black skin tones by performing *in vivo* colour measurements and using a new type of pigment.

A group of females (n=10) of black ethnicity (Fitzpatrick phototypes V and VI) were recruited and their skin melanin level assessed using Mexameter® MX18 (Courage and Khazaka, Germany). Spectrophotometer (Konica Minolta, Japan) was used to measure the CIELAB lightness (L), chroma (C) and hue (h) values from six sites on the face. The average baseline L*C*h value (± 10%) was used as a guidance to formulate a range of foundation shades. A liquid water/silicone foundation was formulated with a mixture of silicone treated pigments (TiO_2; red, yellow and black iron oxides) to produce the required skin colour shades. Purple and green pigments were added to create a dark skin tone. Various ratios of pigments were used in order to match the average baseline L*C*h values of the participants. *In vivo* efficacy evaluation was done by colour measurements before and after foundation application. Full face images with and without the formulated foundations were taken for the self-evaluation analysis by participants.

The percentage of TiO_2 was gradually reduced from 78% to 0 and black pigment increased from 2% to 20% in order to achieve the L* value that was within the average baseline range. Reducing the amount of white pigment significantly increased the C* value, which was prevented by the addition of a purple pigment. The h* value was brought within the range by reducing the amount of red pigment and increasing the yellow and green pigments. Wet and dry colour measurements of the final prototypes have shown that there was no statistically significant difference between the average baseline L*C*h* value and the L*C*h* value of the dry foundation sample. Self and instrumental evaluation have shown that the formulated foundations were colour matching the black skin tones; however, they could be improved to provide a higher level of coverage.

The results of this study may be a useful contribution to the development of colour matched cosmetic products and their *in vitro* and *in vivo* efficacy assessment.

1. Introduction

Cosmetic foundations are the most commonly used facial decorative cosmetics on the market. It has been identified that a natural looking finish is one of the most preferred performance attribute of foundations, arousing pressure for the development of new products with better similarities to the consumer's skin tone (Rus et al., 2007, Libby, 2013).

The process of colour matching cosmetic foundations to the true colour of the skin is a challenging area for the cosmetics industry. Different biological factors which define skin colour need to be taken into consideration and transposed into the correct blend of cosmetic pigments, which defines the colour of the foundation.

Our market research has demonstrated that in the United Kingdom the range of cosmetic foundations available for dark skin tones (Fitzpatrick V/VI) is considerably disproportionate to the range of products available for light skin tones (Fitzpatrick I/II). Of a total of 343 foundation shades observed in mainstream retailers, 9% of these were considered suitable for consumers with dark skin, in comparison to 67% that were considered suitable for light skin tones. In addition, it was also found that consumers with dark skin tones are not satisfied with the commercially available foundations, meaning that their needs are not being met by the cosmetics industry.

As the ethnic population continues to increase across the country, this study focused on the development of a cosmetic foundation that is effective in colour matching a range of black skin tones by performing *in vivo* colour measurements and using new pigments and modifying their ratio.

2. Materials and Methods

Pigments. Surface treated pigments (Table 1) have been blended in different ratios and incorporated into a water-in-silicone (W/Si) foundation (Table 2) at the level of 5% (w/w) to produce a range of dark skin colour shades. Guidelines from UK suppliers were initially used when deciding the ratio of each pigment to use. This frame formulation involved mixing white pigment (TiO_2) with yellow, red and black iron oxides to create a required skin tone. Pigment levels were then increased, decreased, removed or added (e.g. violet and green) to the blend in order to match the skin colour of the subjects. Eighteen pigment blends were created and formulated into the foundation base [Foundations 1-21 (FDT001-FDT018)].

Table 1. Overview of surface treated pigments

INCI	Colour	Supplier
CI 77491 (and) Dimethicone	Red	Azelis (United Kingdom)
CI 77492 (and) Dimethicone	Yellow	
CI 77499 (and) Dimethicone	Black	
CI 77891 (and) Dimethicone	White	
CI 77891 (and) Mica (and) Dimethicone (and) Tin oxide	Green	
Ultramarines (and) Triethoxycaprylylsilane	Violet	Kobo Product Inc.(United States)

W/Si foundation. A cold process liquid W/Si foundation formulation (Table 2) has been adapted from Shlossman (2009). Pigment blends were prepared separately and incorporated into the formulation.

Table 2. Qualitative and quantitative formula of the W/Si foundation

INCI	Supplier	%w/w
Phase A		
Cetyl PEG/PPG-10/1 Dimethicone	Thor Specialties, Ltd. (United Kingdom)	2.50
Cyclopentasiloxane (and) Disteardimonium Hectorite (And) Propylene Carbonate	Elementis Specialities	5.00
Hydrogenated Polyisobutene (and) Silica	Kobo Product Inc. (United States)	0.50
Tocopheryl Acetate	Azelis (United Kingdom)	0.25
Cyclopentasiloxane	Azelis (United Kingdom)	10.00
Cyclopentasiloxane (and) Dimethicone Crosspolymer	Dow Corning (United States)	5.00
Cyclopentasiloxane (and) Dimethiconol	Azelis (United Kingdom)	5.00
Phase B (Pigment blend)	-	5.00
Phase C		
Aqua	-	Ad 100
Polyurethane-1	BASF (Germany)	7.50
Sodium Chloride	-	1.00
Phenoxyethanol (and) Methylparaben (and) Ethylparaben	Azelis (United Kingdom)	0.25

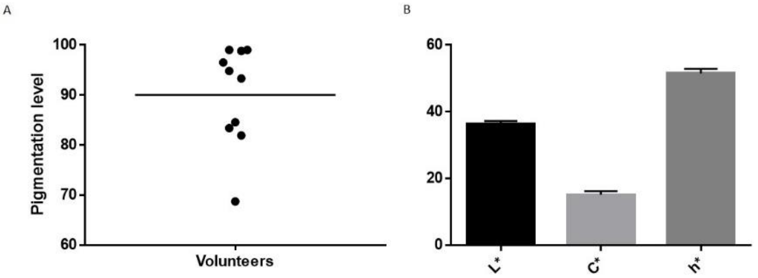
***In vitro* and *in vivo* colour analysis.** Skin melanin level was assessed using the Mexameter® MX18 (Courage and Khazaka, Germany) and a spectrophotometer (Konica Minolta, Japan) was used to measure the CIELCh coordinates lightness (L), chroma (C) and hue (h) values from six sites on the face. Eighteen pigment blends were created, incorporated into the foundation base, and assessed on the colour they produce. *In vitro* wet and dry colour measurements were taken using hiding power charts (Sheen, United Kingdom). *In vivo* efficacy evaluation was done by colour measurements before and after foundation application. The Visioface® 1000D (Courage and Khazaka, Germany) was used to take full face images with and without the formulated foundations for self-evaluation analysis by participants. All data were statistically analysed using the statistical program R (R Foundation for Statistical Computing, 2014).

Experimental design. A group of female study participants (n=10) of black ethnicity (Fitzpatrick phototypes V and VI) were recruited. Melanin and baseline skin colour measurements were taken for each subject on six designated areas of the face (medial left and right on the forehead, upper and lower left and right sides of the cheeks). On each site, three readings were taken and averaged. Subjects with similar melanin and skin colour values were then selected (n=6). The average L*C*h* values (± 10%) of the selected subjects was used as a guidance to formulate a range of foundation shades. Different pigment blends were prepared and incorporated into the W/Si foundation in order to match the skin colour of the subjects. Wet and dry *in vitro* colour measurements were taken. Continuous trials of the formula were carried out until wet and dry *in vitro* L*C*h* values fell within the baseline range. Formulations that fitted within the range were further tested by *in vivo* colour measurements. Full face images were taken before and after foundation application and volunteers were asked to complete a questionnaire. The data has been statistically analysed using the R program (R foundation for Statistical Computing, 2014) and GraphPad Prism. All statistical analysis was performed at the 5% level of significance.

3. Results and Discussion

3.1. *In vivo* skin colour analysis

Skin melanin levels were taken into consideration and used to group volunteers with similar melanin content. For the purpose of this study only data from subjects with a melanin level of over 90 were used for L*C*h measurements (Fig. 1A). The average was taken for L*C*h* values of each of the six sites across all the selected volunteers (Fig. 1B). These six sets of L*C*h* means values were used to calculate a guidance range (± 10%) of L*C*h* co-ordinates to formulate towards when making the pigment blend (Fig.1C).



CIELCh	Average ± 10%
L*	36.38 ± 10%
C*	15.13 ± 10%
h*	51.53 ± 10%

Figure 1. *In vivo* skin colour analysis. Pigmentation level of each volunteer (Fig.1A); L*C*h* values ± S.D of the selected volunteers (Fig.1B); and guidance range L*C*h* values ± 10%.

3.2. Development of a colour matched foundation and *in vitro* colour evaluation

The combination of white, yellow, red and black pigments can produce a range of skin colour shades. However, to create a darker skin tone colour, violet and green pigments had to be included. In Figure 2, an overview is given of the wet and dry colour measurements for each prototype (FDT001-FDT018).

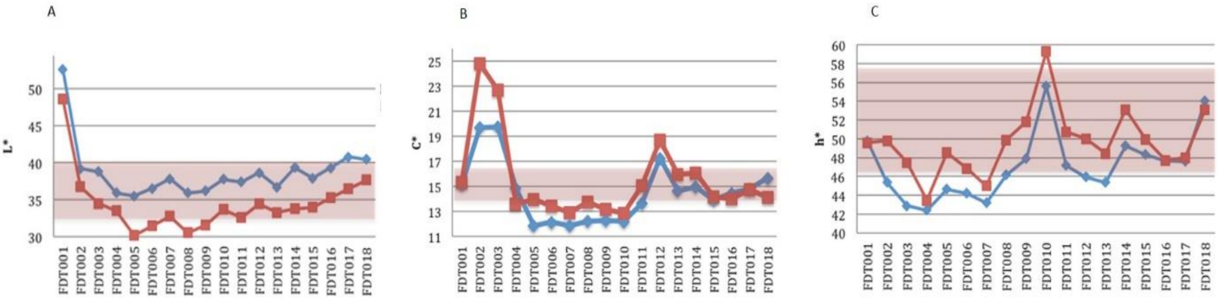


Figure 2. Formulation of the colour matched foundation. Overview of the wet (blue line) and dry (red line) colour measurements and the guidance range (highlighted area) for L* (Fig.2A) , C* (Fig.2B) and h* (Fig.2C).

The L* values of the frame formulation (FDT001) were exceedingly high for both wet and dry samples. As a result, the percentage of TiO_2 was gradually reduced in order to decrease the L* value (making a darker colour) from 78% to being completely removed. As the amount of TiO_2 in the formulation was decreased, other pigments had to be increased, especially the darker pigments. The black pigment was increased from around 2% to 20% in the final formulation. This resulted in L* values for all foundations to fall within the guidance range for wet measurements, excluding FDT017 and FDT018 (Figure 2). The dry L* value has decreased from FDT001 to FDT005, where it was too low to be within the guidance range. The L* was within the guidance range from FDT010 on and continued to stay within the range through FDT018.

Reducing the amount of TiO_2 affected the C* value (FDT001-FDT002). The decreased amount of white pigment increased C* resulting in a more vibrantly coloured foundation.

The C* value was not within the guidance range (too high) and the foundation appeared to have high vibrancy. The violet pigment was added to the formulation at 7.5% (FDT003) and 14% (FDT004) in attempt to decrease the C* value and cause foundation to appear duller. A large decrease in C* was observed from FDT003 to FDT004. C* values increased from FDT010 to FDT012 due to higher levels of the purple pigment (27%-29%). From FDT013 on (< 24% purple pigment), the C* values remained within the guidance range.
The h* values decreased in the development from FDT001 to FDT004. A large increase was observed from FDT004-FDT010, where it eventually decreased and stayed within the guidance range. Increasing the h* value corresponds to making the foundation more yellow and decreasing the h* value will make the foundation appear redder. Initially, green pigment was added to the blend in attempt to increase the h*. The h* values were increased, although, the level of green pigment was too high and dispersing high levels of this pigment was challenging due to the fact that it cannot be ground. By modifying the levels of red and yellow pigments, the h* values were brought within the guidance range. As a final result, the formulations FDT016, FDT017, and FDT018 were within the guidance L*C*h* range and were presented to the subjects.

3.3. *In vivo* efficacy evaluation of foundation prototypes

The volunteers who have provided the guidance baseline L*C*h* range were asked to apply a prototype shade, which they believed best matched the tone of their skin, from the range of FDT016-FDT018. Before and after foundation application, the L*C*h* readings were taken on six sites of the face. In addition, full face images were taken and participants were required to complete a self-evaluation questionnaire.

In Figure 3, the average L*C*h* values before and after foundation application are shown. No significant differences were observed for L*, C* and h* values before and after foundation application, indicating that the foundations match the colour of the subjects' skin.

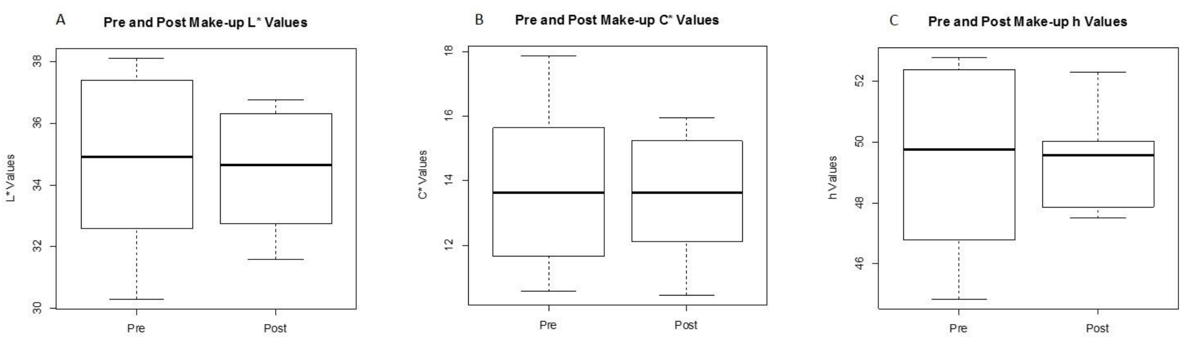


Figure 3. Baseline (pre) and post foundation application skin colour values.

Participants were asked to rate the functionality of the tested formulations, and score on a scale of 1-10 if they agree (10) or disagree (1) with five statements. Figure 4 shows that the participants strongly agreed that the foundation matched and unified their skin tone, however, participants were not satisfied with the coverage.

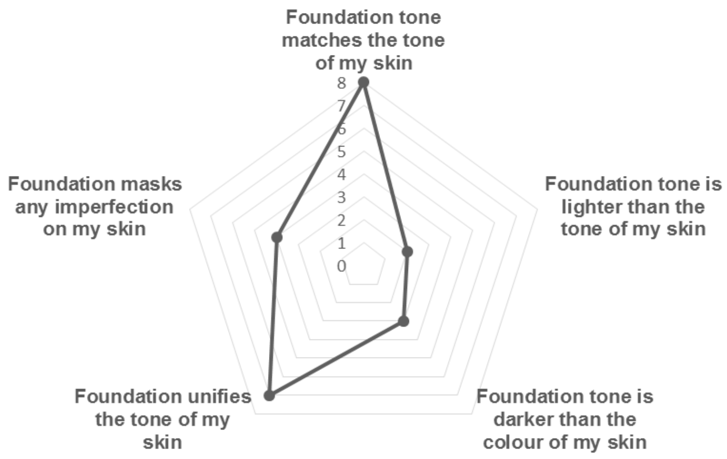


Figure 4. Self-evaluation analysis comparing pre and post foundation ful face images using five statements and a rating scale from 1-10 (10 being strongly agree).

Participants were also asked which full face image (data not shown) they preferred when comparing a selection of three: 1) baseline (no foundation application); 2) post foundation application (subjects own foundation); and 3) post foundation application (formulated foundation). All participants selected the image with their own foundation as their preference, while 80% selected the formulated foundation as their second choice. 80% also stated that their least preferred image was the image with no foundation. It is speculated that the subjects preferred their own foundation due to the insufficient coverage provided by the formulated foundation, hence not being able to mask skin imperfections.

4. Conclusion

This study explored a novel approach to the development of cosmetic foundations that are effective in colour matching black skin tones. This systematic process requires a formulator to establish a baseline L*C*h* combination (as a guidance), which is then matched by iteratively changing the type and level of pigments, based on the information obtained from the L*C*h* measurements of each prototype. The *in vitro* and *in vivo* findings of this study suggest that it is possible to formulate successful colour matched foundations using the above approach.

However, further research is needed in terms of producing better coverage of minor skin imperfections without impacting the overall skin colour.

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