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"Reducing the Color Shift of Long Lasting Liquid Foundations"

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1. Introduction

The use of makeup dates back to ancient civilizations and has long served both decorative and symbolic purposes [1]. In modern times, makeup delivers not only aesthetic benefits but also high-performance attributes such as long wear, coverage, different finishes, and even skincare functionality [2]. Among these, color stability remains one of the most critical parameters for consumer satisfaction.

Color shift, a perceived change in shade after application, can undermine user confidence and product credibility. This phenomenon is associated with factors such as pigment instability, oxidative reactions, interactions between formulation components, and volatility [3]. To mitigate these issues, the industry has adopted surface-treated pigments, which offer enhanced affinity with emollients and skin, improving shade uniformity and transfer resistance [4]. However, final color performance also depends heavily on the choice of emollient, which affects pigment dispersion, film formation, and evaporation behavior [5].

To better understand the extent of this challenge, a preliminary evaluation was conducted using commercial long-wear liquid foundations. Two different brands and three shades - light, medium, and dark - were selected for testing. A standardized application was performed on the forearm within a designated 4 × 4 cm area, applying 0.10 grams of foundation per test site. Sequential photographs were taken at 0 (T0), 1, 2, 5, and 10 (T10) minutes after application under a controlled D65 light environment to visually document color changes.

At the 10-minute mark, once the initial application had dried, a second application of the same foundation (0.10g) was placed adjacent to the original area, enabling direct visual comparison between freshly applied (T0) and dried (T10) foundation samples. ΔE (Delta E) values were then calculated using image analysis software, comparing T0 and T10 conditions.

ΔE within the CIELAB color space quantifies color differences using three coordinates: L* (lightness), a* (green–red axis), and b* (blue–yellow axis). A $\Delta E < 1$ is typically imperceptible to the human eye, while values above 3 indicate visible shade changes. In this initial evaluation, all tested foundations exhibited ΔE values well above the threshold of perceptibility, with visible tonal shifts confirmed both instrumentally and visually - validating the relevance of color stability as a critical formulation challenge.

Building on these findings, this study explores the impact of different emollients on color stability (ΔE) in formulations containing Isopropyl Titanium Triisostearate and Dimethicone hybrid-treated pigments [6]. The goal is to identify combinations that minimize tonal variation while maintaining formulation integrity, ultimately contributing to the development of more stable, consumer-preferred foundations.

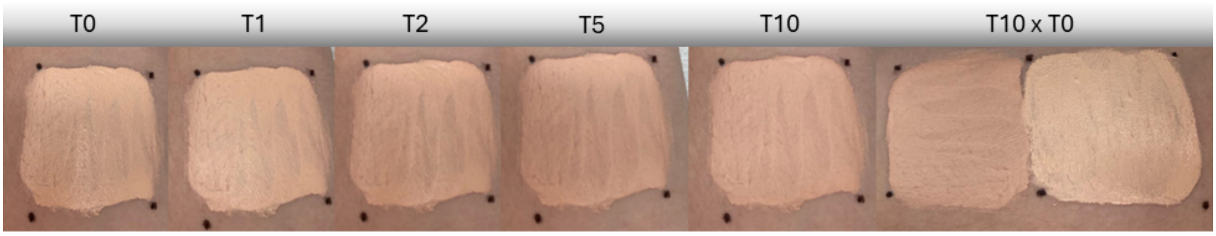

Figure 1. Benchmark Brand 1 – Light shade. Images captured at (a) 0 min, (b) 1 min, (c) 2 min, (d) 5 min, and (e) 10 min after application on the forearm under D65 lighting. Subfigure (f) shows a side-by-side comparison between the initial application (T0) and after 10 minutes (T10), highlighting the shift in

ΔE Comparison – Brand 1 Vs Brand 2

	Brand	Shade	ΔE
1	Brand 1	Light	9.8
2	Brand 1	Medium	8.54
3	Brand 1	Dark	7.72
4	Brand 2	Light	8.26
5	Brand 2	Medium	8.01
6	Brand 2	Dark	7.17

Table 1. *ΔE results of Benchmark Brand 1 and 2*

2. Materials and Methods

2.1 Materials

- Leneta chart (white and black substrate): used as the application surface to ensure uniform background reflectance.

- 3 mm film applicator (extensor): enabled consistent film thickness across all samples.

- Drying oven (set at 60 °C): used to simulate the drying process under accelerated and reproducible conditions.

- Portable colorimeter: used to measure color coordinates (L*, a*, b*) before and after drying.

2.2 Method

After confirming the presence of color shift in commercially available foundations, a new experimental methodology was designed to isolate and better understand the factors contributing to this instability. To reduce formulation complexity and minimize variability, a standardized approach was developed - the full details of which are described later in this paper.

As a first step, a preliminary screening was conducted to observe the visual interaction between a commercially available hybrid-treated pigment dispersion, selected for its relevance to long-lasting cosmetic applications.

A medium shade blend was prepared by mixing the pigment dispersion with five distinct emollients at fixed ratios: Isododecane, Cyclopentasiloxane, Dimethicone 2 cSt, Coco-Caprylate, and C9-C12 Isoalkane.

Emollient	Volatility	Viscosity (cSt)	Polarity	Chemical Type
Isododecane	High	1.6	Non-polar	Hydrocarbon
Cyclopentasiloxane	High	0.65	Non-polar	Silicone
Dimethicone 2cSt	Low	2.0	Low polarity	Silicone
Coco-Caprylate	Low	5.0	Medium polarity	Ester
C9–C12 Isoalkane	Medium	2.5	Non-polar	Hydrocarbon

Table 2. *Physicochemical properties of the emollients evaluated in this study. Data obtained from supplier technical datasheets [7-11]*

These initial mixtures were simply homogenized and then in a ratio of 1:1 and observed under controlled lighting to assess immediate color behavior and appearance.

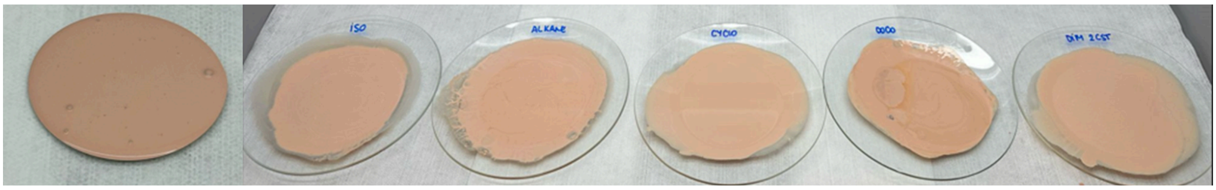

Figure 2. Visual observation of hybrid pigment dispersion pure and mixed with different emollients (1:1). From left to right: (a) Medium shade blend of dispersion pure, (b) Isododecane, C9–C12 Isoalkane, Cyclopentasiloxane, Coco-Caprylate and Dimethicone 2 cSt.

Following the preliminary screening, a standard base formulation was developed to serve as a reference for further evaluations.

The formulation was designed to keep all ingredients constant except for the emollient phase, which was varied across experiments to investigate its influence on color shift. Although different emollients were used in each formulation, the concentration of emollients was kept the same across all samples. The goal was to isolate the effect of each emollient on pigment compatibility and ΔE variation over time.

Ingredient	Isododecane	Cyclopentasiloxane	Dimethicone 2 cSt	C9–C12 Isoalkane	Coco Caprylate
Dimethicone 6 cSt	8.000	8.000	8.000	8.000	8.000
Isododecane	26.632	0.000	0.000	0.000	0.000
Cyclopentasiloxane	0.000	26.632	0.000	0.000	0.000
Dimethicone 2 cSt	0.000	0.000	26.632	0.000	0.000
C9–C12 Isoalkane	0.000	0.000	0.000	26.632	0.000
Coco Caprylate	0.000	0.000	0.000	0.000	26.632
Thixotropic agent	2.000	2.000	2.000	2.000	2.000
Film former	6.000	6.000	6.000	6.000	6.000
Emulsifier A/Si	5.000	5.000	5.000	5.000	5.000
White pigment dispersion	16.145	16.145	16.145	16.145	16.145
Yellow pigment dispersion	1.470	1.470	1.470	1.470	1.470
Red pigment dispersion	0.292	0.292	0.292	0.292	0.292
Black pigment dispersion	0.061	0.061	0.061	0.061	0.061
Deionized Water	29.000	29.000	29.000	29.000	29.000
Sodium Chloride	1.000	1.000	1.000	1.000	1.000
Preservative	1.200	1.200	1.200	1.200	1.200
Humectant	3.000	3.000	3.000	3.000	3.000
Aqueous thickener	0.200	0.200	0.200	0.200	0.200

Table 3. Standard Base Formulation shows the exact ingredients and the used amounts

Each foundation sample was applied uniformly on a Leneta chart using a 3 mm extensor to ensure a consistent film thickness. Immediately after application, an initial color measurement was taken using a portable colorimeter. The sample was then placed in an oven pre-heated to 60 °C for 10 minutes to accelerate and the drying phase.

After 10 minutes, a second color measurement was taken from the same area. The color shift was calculated based on the ΔE value. All measurements were conducted in triplicate to ensure statistical reliability and reproducibility.

Figure 3. *Pictures of Leneta charts at T10 (after 10 minutes of drying at 60 °C) following application of a 3 mm uniform film.*

4. Results

Colorimetric Evaluation at T10 (ΔE values)

Emollient	Evaluate 1	Evaluate 2	Evaluate 3	Mean ΔE
Isododecane	1.2	1.5	1.6	1.43
Cyclopentasiloxane	2.8	2.7	2.9	2.80
Dimethicone 2cSt	4.4	4.3	4.4	4.37
Coco Caprylate	0.8	0.9	0.8	0.83
C9–C12 Isoalkane	1.0	1.4	1.6	1.33

Table 4. *ΔE values at T10 for experimental formulations containing hybrid-treated pigments combined with different emollients. ΔE values were obtained using a portable colorimeter directly on Leneta charts, following application of a 3 mm uniform film. Measurements were taken before and after 10 minutes of drying at 60 °C under controlled conditions.*

Figure 4. Visual comparison of pigment dispersion and foundation formulations arranged by ascending ΔE. From left to right: (a) hybrid-treated pigment dispersion without emollient (baseline), followed by formulations containing (b) Coco-Caprylate, (c) C9–C12 Isoalkane, (d) Isododecane, (e) Cyclopentasiloxane, and (f) Dimethicone 2 cSt. All samples were applied on Leneta charts using a 3

mm film applicator and photographed at T10 (after 10 minutes of drying at 60 °C). This sequence illustrates the visual impact of each emollient on pigment behavior.

Emollient	Mean L	Mean a	Mean b	ΔE (vs. Dispersion)
Isododecane	76.67	14.13	26.23	**8.56**
C9–C12 Isoalkane	76.77	14.10	26.43	8.74
Coco-Caprylate	76.43	14.00	27.10	9.31
Cyclopentasiloxane	74.83	15.77	29.43	12.17
Dimethicone 2 cSt	74.43	16.27	30.17	13.08

Table 5. *ΔE values of each emollient formulation compared to the medium shade blend of dispersion. Lower ΔE values indicate greater color similarity to the original pigment dispersion.*

5. Discussion

The findings of this study reinforce the importance of emollient selection in achieving color stability in long-wear liquid foundations. All formulations, including market benchmarks, showed visible shade changes over time, confirming that color shift remains a relevant challenge in cosmetic emulsions.

Formulations containing Coco-Caprylate, C9–C12 Isoalkane, and Isododecane maintained the most consistent color over time, as evidenced by ΔE values below 2. These combinations helped preserve the original shade appearance and outperformed the commercial references tested.

Cyclopentasiloxane delivered moderate results, while Dimethicone 2 cSt was associated with more intense shade changes (ΔE > 4), suggesting limitations in maintaining pigment uniformity during the drying and wear process. Interestingly, despite the hybrid pigment treatment including a silicone component, formulations based on silicone emollients did not outperform those using alternative systems. This indicates that compatibility cannot be assumed solely based on chemical similarity, reinforcing the need for empirical evaluation of each formulation. These findings align with previous studies linking shade instability to pigment dispersion behavior and drying performance.

Visual analysis of the Leneta charts supported the instrumental measurements and showed consistent patterns across all three test replicates, confirming the reliability of the evaluation method.

Although this study focused on the role of emollients, it is essential to remember that a high-performance foundation is the result of interactions between all ingredients in the formula. Improving one aspect, such as color stability, should not compromise others like texture, coverage, or wear. Future studies should take a broader approach to ensure that final products deliver well-rounded, consistent performance.

6. Conclusion

This study confirmed that the choice of emollient has a direct impact on the color stability of long lasting foundations. Emollients such as Coco-Caprylate, C9–C12 Isoalkane, and Isododecane delivered the most consistent results, while Dimethicone 2 cSt led to greater color variation, despite the pigment's silicone-based treatment.

These findings highlight the importance of testing emollient-pigment interactions beyond theoretical compatibility. While ΔE is a key metric, it must be evaluated within the broader context of formulation performance.

Ultimately, this work offers meaningful direction for creating foundation products that are not only more stable, but also more reliable from the perspective of the consumers. It reinforces the value of a formulation-driven approach - one that balances performance, aesthetics, and user expectations - to truly innovate in the world of color cosmetics.

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Conflict of Interest Statement

All authors are employees of Natura & CO. However, the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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