Study on the factors affecting the darkening of liquid foundations

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Abstract

Liquid foundation, a popular makeup subcategory, brightens skin color and covers defects. Unfortunately, it is well known among Asian consumers that a liquid foundation on skin may gradually darken during wear, an issue negatively affecting consumer experience.

To better understand the darkening phenomenon, we developed a concept of "darkening evaluation index" to characterize the darkening effect.

Based on color spectrophotometer measurements and focusing on brightness difference ΔL, we were able to characterize impacts of possible factors to darkening, including sebum, sweat and foundation oxidation under light.

The study results show that sebum is the biggest contributing factor to the darkening of the liquid foundation, while sweat and light have less impact. Surface treatment of pigment and certain filler powders may help minimize sebum's darkening impact. With fundamental understandings of the causation of liquid foundation darkening, it may help both raw material development and liquid foundation formulation efforts towards better use experience for consumers.

Key words: liquid foundation darkening; sebum; sweat; light; color spectrophotometer

Nowadays, color cosmetics follows the trend of fashion, and its market share increases year by year. The color cosmetics consumer market has basically taken shape in China [1, 2]. In a wide variety of color cosmetics, makeup products are an indispensable part of daily makeup that including liquid foundation, cream foundation, concealer, BB/CC cream, BB/CC cushion cream, etc. It plays the role of brightening skin color, covering defects and so on [3]. Liquid foundation, as a basic makeup product, can make facial skin appear in a natural and perfect state. It is one of the products that most consumers choose. However, it will appear darken during use, which affects the consumer's experience.

For a long time, the problem of liquid foundation darkening has always existed, which needs to be solved urgently, but there are few studies in this area. To investigate the main factors that cause the darkening of the liquid foundation and find a reasonable way to minimize it, not only can it provide technical support and evaluation ideas for researchers to improve the darkening of liquid foundation, but also help promote liquid foundation products and enhance brand image.

According to research and analysis, the causes of liquid foundation darkening mainly include four aspects. 1 Sebum and oil: sebum secretion combine with the liquid foundation makes liquid

foundation transparent and dark (makeup dissolving); oxidation of oil itself in liquid foundation causes darkening. 2 Light influence: Liquid foundation has a tendency to be oxidized under light, which can cause darkening. 3 Sweat influence: The liquid foundation becomes darkening and transparent when fused with sweat. 4 The wrong shade choice of liquid foundation: When applying a liquid Foundation, its shade is not matched to the skin tone (whiter than skin tone), the foundation overlaps with face tone, which looks ashy and dark [4-6].

This study was carried out from three dimensions: sebum, sweat and light. Titanium dioxide and filling powders with different treatment were selected to prepare the liquid foundation. The darkening phenomenon of the liquid foundation was analyzed using color spectrophotometer technology. The experimental results were analyzed and discussed. Based on the data and analysis, methods to minimize the darkening of liquid foundation were suggested. It provided a quantitative evaluation method for researchers to objectively evaluate the darkening of liquid foundations and choose raw materials during product development.

1 Experiment

1.1 Reagents and instruments

Artificial leather (black, commercially available); Cyclopentasiloxane (provided by raw material supplier); Base formula of liquid foundation (self-made, see Table 1); Different treatments of titanium dioxide and different types of filling powders (provided by raw material suppliers); Artificial sebum (self-made); Artificial sweat (commercially available, Jiang Cheng instrument); Titanium dioxide dispersion (self-made); Liquid foundation test formula sample (self-made: Add appropriate amount of titanium dioxide dispersion or fillers to the Base formula of Table 1). RW 20 digital type agitator (IKA); T 18 digital ULTRA TURRAX homogenizer (IKA); TR50M Three Roll Mill (TRILOS); VS450 color spectrophotometer (X-Rite); Pipette (Lichen Instrument); Automatic coating machine (Shanghai Jiuran).

Tab.1 Base formula of liquid foundation

Phase	Raw material	*w*/%
Oil phase	Emulsifier	4.00
	Oil/Esters	20.00
Water phase	Polyol	8.00

	Water	To 100
Powders	Iron oxides	proper amount
	Filling powders	3.00
Other	film formers, preservative, active ingredients and fragrance, etc.	proper amount

1.2 Experimental method

1.2.1 Powder selection

In this study, the particle size of 250 nm titanium dioxide powders were selected, which mainly included samples treated with organosilane, organosiloxane, amino acid, and fluorine. The specific labels are as follows: A company organosilane treatment (A-OTS), organosiloxane treatment (A-DS), amino acid treatment (A-AM), fluorine treatment (A-FS), company B organosilane treatment (B- OTS), fluorine treatment (B-FS), C company organosilane treatment (C-OTS), amino acid treatment (C-AM), D company amino acid treatment (D-AM), E company organosilane treatment (E-OTS) .

Filling powders play the role of filling, improving texture or lubricating in the liquid foundation, mainly including inorganic fillers (talc, silica, mica), organic fillers (nylon powder, polymethyl methacrylate), modified Starch (aluminum starch octenyl succinate), etc [7-9]. The selected powders for this study include: hydroxyapatite, polymethyl methacrylate, nylon-12, synthetic fluorophlogopite + hydroxyapatite, silica-1 (organosilane treatment), silica-2 (organosilane treatment), Mica (organosilane treatment), talc (organosiloxane treatment), barium sulfate (organosiloxane treatment), alumina, methyl methacrylate cross-linked polymer, perlite.

1.2.2 Preparation of liquid foundation sample

Weigh different treated titanium dioxide and cyclopentasiloxane, mix in a certain proportion and grind them in a three-roll mill to make uniform titanium dioxide dispersions. Use a scraper fineness meter to ensure that the particle size of the dispersions is less than 10 μm. Take 10 prepared titanium dioxide dispersions respectively, add to the base formula in Table 1 (the mass fraction of titanium dioxide dispersion is 19.00/%), and emulsify to form liquid foundation for later use.

Take the prepared 12 different powder fillers respectively, sample and add them to the base

formula in Table 1 (the mass fraction of the filling powder is 5.00/%). Emulsify to form liquid foundation for later use.

1.2.3 Test method for darkening of liquid foundation

Sebum impact test: place a 10.00 cm × 20.00 cm flat artificial leather on the automatic applicator, and divide it into 2 areas. Add 130 μ L of artificial sebum to half of the area (the other half area for blank test), and spread evenly with coating rod. Absorb the excess artificial sebum on the leather surface with oil absorbent paper. On the leather coated with artificial sebum, add 3g of the liquid foundation to be tested and spread evenly to form a film using a coating rod. At the same time, the blank test without artificial sebum was performed. Allow the coated leather samples dry for 24 h at room temperature. Cut the coated samples to be tested into appropriate size and measure with color spectrophotometer. Instrument parameters: coating rod thickness 10μm; Artificial sebum coating speed 12 mm/s, foundation liquid coating speed 12 mm/s. The color spectrophotometer is set to aperture: 8 mm, select 9 points at a time, and repeat test 3 times.

Sweat impact test: A 10.00cm×20.00cm liquid foundation artificial leather sample was prepared by using an automatic coating machine. Half of it was immersed in a beaker filled with artificial sweat, and soaked for 15 minutes. then taken out, and dried at room temperature for 24 hours before testing. Test a blank sample that was not soaked in artificial sweat simultaneously. The test method and measurement parameters are the same as above.

Light impact test: use an automatic coating machine to prepare a 10.00cm×20.00cm artificial leather sample coated with liquid foundation. Expose half of it to the sun light, and the other half for shading, and test it after 24 hours. The test method and measurement parameters are the same as above.

Darkening evaluation index: The color spectrophotometer is used to test the prepared samples. The most commonly used color representation in the color cosmetics field is the *L*a*b* value [10, 11], which the calculation formula involved in the color difference is as follow:

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$$

Among them, ΔE: color difference value; ΔL: brightness difference value, the value from negative to positive means from dark to bright; Δa, Δb: hue and chroma, the *a* value from negative to positive means that the color changes from green to red; the *b* value from negative to positive

indicates that the color changes from blue to yellow. Since the ratio of red, yellow, and black color added in the base formula of the liquid foundation are the same, the slight color change of the liquid foundation caused by the different treatments of the titanium dioxide and the powder fillers can be ignored. Based on the actual situation, only the brightness value L is selected for measurement. The brightness difference ΔL is compared to evaluate the darkening. The greater the absolute value of the negative value, the more obvious the darkening.

2 Results and discussion

2.1 Sebum

The brightness difference results of the liquid foundation sample treated with sebum are shown in Fig.1 and Fig.2. It can be seen from the graph that the brightness of the liquid foundation treated with sebum coating has a brightness difference (ΔL) of -1 ~ -6 , compared with that of the liquid foundation sample without sebum coating, which indicates darkening appears. This darkening is due to the sebum wet and fused with the liquid foundation and causes the color tone to become dark.

As to titanium dioxide, even the surface treatment type is the same, the darkening effect could vary from company to company due to different ratio of the treatment agent and production process applied at different companies. The liquid foundation containing titanium dioxide treated with organosilane from Company B resulted in obvious darkening effect, with the brightness difference of -4.27. The liquid foundation with the same treatment from Company A has no obvious darkening effect, and the brightness difference is -1.04.

For the liquid foundation containing different powder fillers, the liquid foundation containing polymethyl methacrylate and perlite has the largest difference in brightness, which are -5.95 and -5.96, respectively, indicating that the sebum makes the darkening the most obvious. The brightness difference of organosilane treated silica-1 is -1.97, showing that it is less affected by sebum. In addition, sebum has less effect on liquid foundations containing hydroxyapatite, nylon-12, barium sulfate (organosiloxane treated) and alumina.

The filling powders labeled as follow: 1 Hydroxyapatite, 2 Polymethylmethacrylate, 3 Nylon-12, 4 Synthetic fluorophlogopite + hydroxyapatite, 5 Silica-1 (organosilane treatment), 6 Silica-2 (organosilane treatment), 7 Mica (organosilane treatment), 8 Talc (organosiloxane

treatment), 9 Barium sulfate (organosiloxane treatment), 10 Alumina, 11 Methyl methacrylate cross-linked polymer, 12 Perlite.

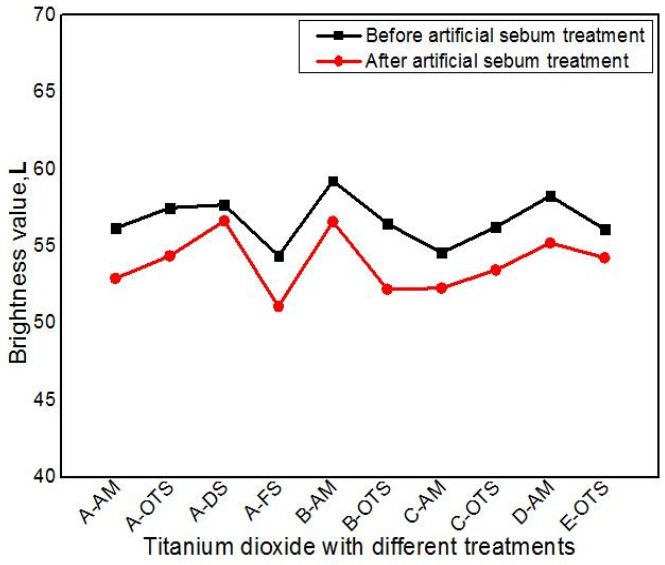

Fig.1 The effect of sebum on the darkening of liquid foundation with different treated titanium dioxide

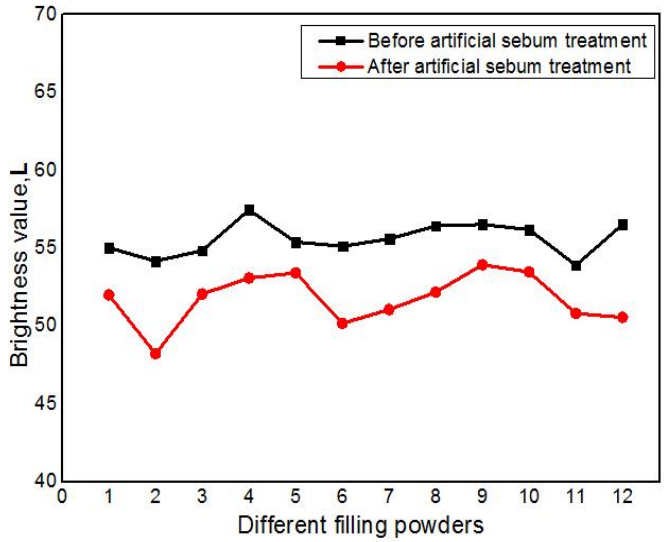

Fig.2 The effect of sebum on the liquid foundation darkening with different filling powders

2.2 Sweat

The brightness difference of the liquid foundation samples treated with artificial sweat are shown in Fig.3 and Fig.4. The brightness value of the liquid foundation samples soaked in the artificial sweat are within -1, as compared to the liquid foundation samples without the artificial sweat treatment, indicating that sweat has little effect on the darkening of the liquid foundation.

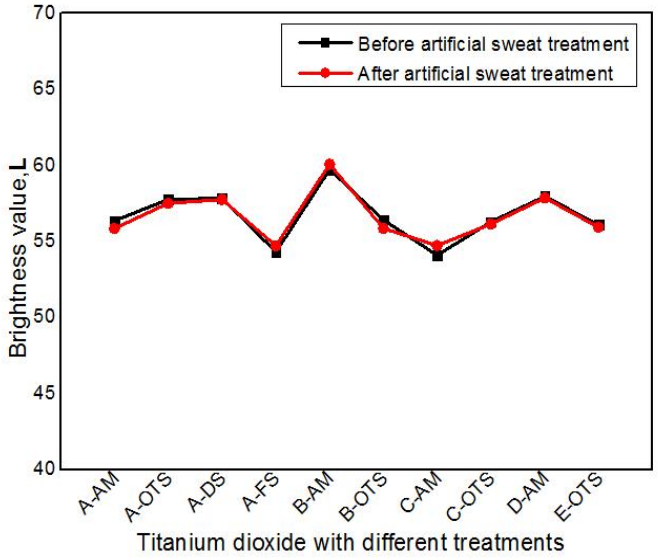

Fig.3 The effect of sweat on the liquid foundation darkening with different treated titanium dioxide

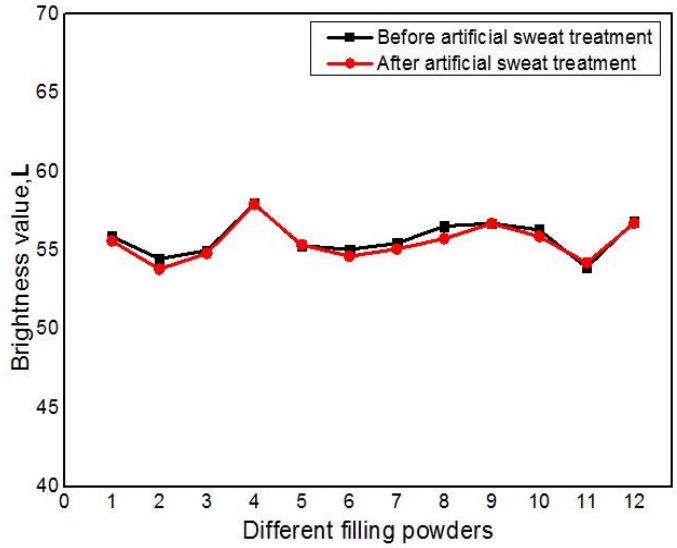

Fig.4 The effect of sweat on the liquid foundation darkening with different filling powders

2.3 Light

Fig.5 and Fig.6 shows the light effect on the brightness difference of liquid foundation. For the liquid foundation samples under light, the differences in brightness are within -1 as compared to the liquid foundation samples that are protected from light, indicating that light has little effect on the darkening of the liquid foundation.

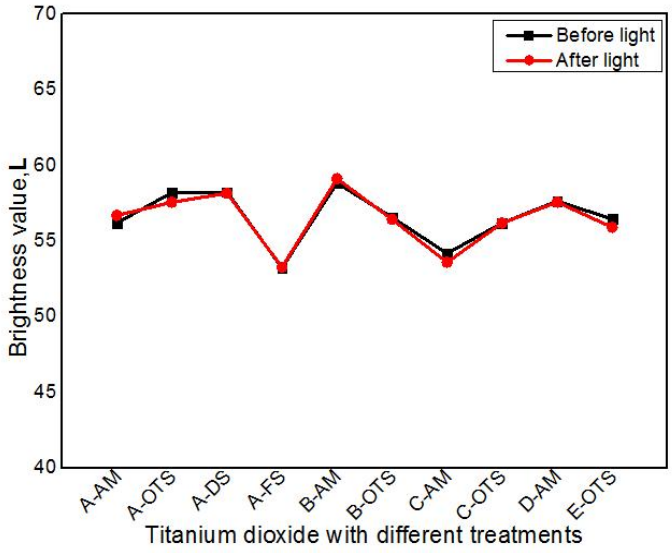

Fig.5 The effect of light on liquid foundation darkening with different treated titanium dioxide

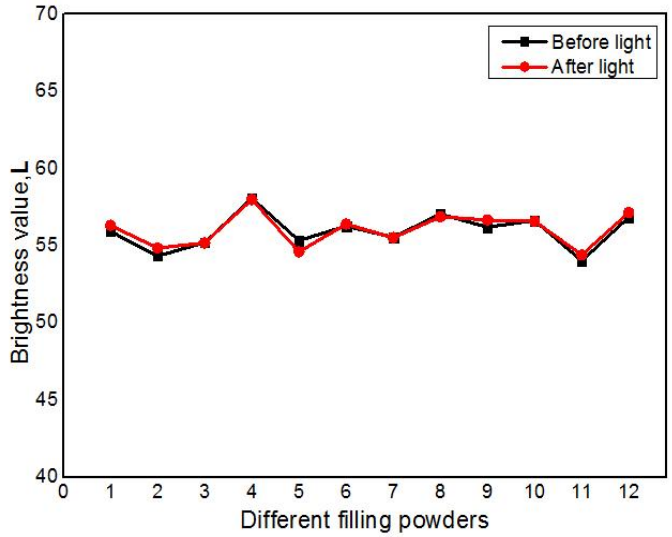

Fig.6 The effect of light on liquid foundation darkening with different filling powders

3 Conclusions

Different treated titanium dioxide and filling powders are selected to measure the brightness difference with a color spectrophotometer to quantify the darkening. The experimental results show that sebum has the greatest effect on the darkening of the liquid foundation, while sweat and light have less influence. That is, the sebum oil secreted by the human body largely causes the darkening of the liquid foundation. The organosiloxane treated titanium dioxide from company A is less affected by sebum, and the darkening is not obvious. The liquid foundation containing the filling powders of silica-1 (organosilane treated), hydroxyapatite, nylon-12, barium sulfate

(organosiloxane treated) and alumina is less affected by sebum, and the darkening is also not obvious.

In order to reduce the darkening of liquid foundation and promote product development, measures should be taken to minimize this phenomenon in formula construction. Since the darkening of the liquid foundation is mainly affected by the secretion of sebum oil by the human body, focus can be on improving the oil resistance of the liquid foundation. According to the experimental results, titanium dioxide and filling powders or other oil-absorbing powders that are less affected by sebum oil can be selected. In addition, ingredients such as oil-resistant film formers can be added to reduce darkening.

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