Original Article

Water-in-Silicone Emulsion – The Approach to an Ideal BB Cream

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ABSTRACT

Silicone is a widely-used cosmetic ingredient, whose advantages are perceived as detackification, soft and non-greasy feeling, and excellent spreading quality. Therefore, in this work, we aim to formulate BB cream based on W/Si emulsion to make the most out of these benefits. Two different emulsifiers namely PEG/PPG-18/18 Dimethicone – a common silicone emulsifier and Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone – a new silicone emulsifier, were tested. Upon completion, the properties and stabilities of two samples were investigated to compare their emulsifying ability. At the concentration of 3%, BB Cream made from Lauryl PEG-10 Tris(Trimethylsiloxy) silylethyl Dimethicone appears to be more stable compared to its counterpart, which was proven explicitly by physical appearance, viscosity, and microscopic observation in our study. Our formulated BB Cream was successfully undergone stability tests, then proceeded to a sensory evaluation in comparison with a commercial BB Cream. With good properties testifying for Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone from our studies, the developed composition is expected to represent a real asset in future make-up formulations.

Key words: Silicone, BB Cream, W/Si emulsion, Dimethiconol, Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone.

INTRODUCTION

"I admire a person with beautiful natural skin and want to create the same look", nearly half of respondents came up with this answer when being asked about the reasons for wearing makeup in a survey conducted in four major cities namely Tokyo, Bangkok, Paris, and New York.[1] Applying makeup to make the face and skin more attractive has become a daily ritual of women worldwide, but none of them expects their makeup foundation to be spotted by others. The dire need for a product that can offer a natural-looking finish, yet still retains its basic functions such as coloring and concealing, gives rise to our development, W/Si BB Cream.

Blemish Balm Cream, known as BB Cream, is the new trend in cosmetics. It is capable of providing multifunction and solving tough questions including moisturizer, foundation and sunscreen all at once in the least aggressive way. The idea was born in the 1950s, when the dermatologist Christine Schrammek devises it to protect his patient's skin after cosmetic surgery, such as dermatological peels, dermabrasion, or laser treatments.[2] This proceeded to the wide popularity of BB Cream in every corner of the world, contributing to improvements in other aspects. Apart from its original purpose, more functions are also required such as moisturizing and nourishing skin with active ingredients that prevent skin aging and protect skin from UV arrays. However, the multifunctional skincare products would have their own drawbacks, especially in long-term stability. Therefore, BB Cream, in its most ideal form, should be made up of the three requirements in Figure 1 to satisfy customers' needs.

Submission Date: 02-06-2021;
Revision Date: 06-11-2021;
Accepted Date: 29-12-2021.

DOI: 10.5530/ijper.56.2.57

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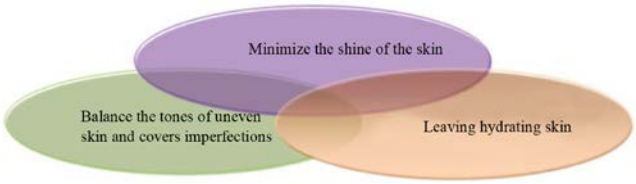

Figure 1: Desirable criteria of a perfect BB cream.

The high-maturity market of beauty-care products acts as a precursor to constant innovations to meet demands on both functionality and economical aspects. To fulfill the expectations, more efforts have been put into the development of emulsion technologies. The results of such progress have led to the introduction of various foundations:[3]

1. **Emulsions of the oil-in-water (O/W) type in cream and lotion forms:** Oil-in-water emulsions dominated the personal care market given their superiority in affordable cost, flexibility, and especially moisture-retaining properties.[4] However, to prevent sedimentation from W/O emulsions, materials such as triethanolamine, KOH, and arginine are added, but overusing them can lead to safety issues.[5] Another demanding feature of BB cream recently is the ability to protect skin from ultraviolet (UV). While this can be achieved by introducing titanium oxide and zinc oxide into the formulation, the stability of O/W emulsions can be affected.
2. **Anhydrous fatty systems (oils and waxes) in solid, paste, and liquid forms**: Water-in-oil emulsions, despite the provision of missing elements in O/W emulsions such as wash-off resistance and long-lasting film, are less popular due to exorbitant price, difficult technology, and oily feel.[6-8]
3. **Dry powders in loose, cake, or compact form**: This type of product contains almost 80% of powders in their content,[5] which will potentially engender pore-clogging and thickness after long-term wearing.

In general, reflecting on the three requirements in Figure 1, none of these live up to makeup users' expectations.

Recently, silicone has gained wide popularity in personal care and cosmetics. Silicone refers to the raw materials made of bonding between Si and O. Thanks to the inherent property of their Si–O bond - a much more flexible bond compared to a C–C bond, it allows the silicone polymer to maintain a high molecular weight yet remain liquid at room temperature, a property to which make them suitable for cold process manufacturing.[9] The application of new raw materials made of silicone has opened new doors for cosmetic chemists, which can be used to make a product with a moist feel, but more with powder-rich and refreshing finishes at the same time.[10] The tendency to incorporate silicones into cosmetic compositions can be attributed to either their unique properties such as superior aesthetics and sensory benefits or their low level of use compared to other conventional materials.

However, the unique structure of silicone comes at a cost, causing trouble to mingle well into the formulation. Due to the incompatibility in neither water nor organic oils,[10] silicones can only be used at concentrations; otherwise, the aesthetic or stability of the product will be exacerbated. [11] To make silicone useful in formulations containing water, these are two possible approaches: 1) delivering silicone in the form of emulsions; 2) using silicone emulsifiers to increase the solubility in water.[12] The former is more popular, which can be recognized by several BB creams products in the market such as Maybelline. While this method allows the formulators to add large amounts of silicone oils into aqueous phase without changing any other ingredients, several limitations including splitting over time, free-thaw properties can be exposed.[12] To overcome the problems with silicone emulsions and neat silicone oils, the latter approach, called silicone emulsifiers, has been developed.[12] These compounds contain a silicone-soluble group and at least one water-soluble or oil-soluble group in the same molecule. Consequently, it is completely possible to disperse silicone well in either aqueous phase or oil phase.

The development of silicone emulsifiers contributes to the manufacturing of W/Si emulsion – a perfect bridge between factors absent in the three mentioned systems, and a direct response to the wishes of makeup users. With increasing consumer demands and trends moving towards natural-looking makeup, there is a strong drive to create superior makeup products based on W/Si emulsions. Although there is widespread interest and experimentation conducted on PEG/PPG-18/18 Dimethicone - a widely-used emulsifier in making water-in-silicone emulsions (Figure 2),[13] very limited research on the use of Lauryl PEG-10 Tris (Trimethylsiloxy) silylethyl Dimethicone was conducted (Figure 3). The present work was aimed at formulating stable W/Si emulsions from these two ingredients. This creation will encapsulate the difference between PEG/PPG-18/18 Dimethicone and Lauryl PEG-10 Tris (Trimethylsiloxy) silylethyl Dimethicone as well as facilitate cosmetic formulators with important insights into the ability of Lauryl PEG-10 Tris (Trimethylsiloxy)silylethyl Dimethicone to disperse uncoated pigments, balance

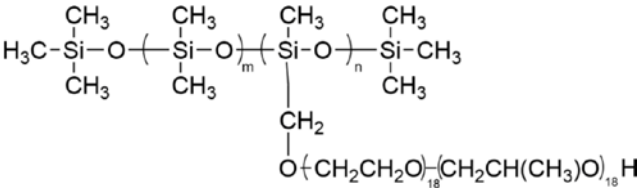

Figure 2: The structure of PEG/PPG-18/18 Dimethicone.

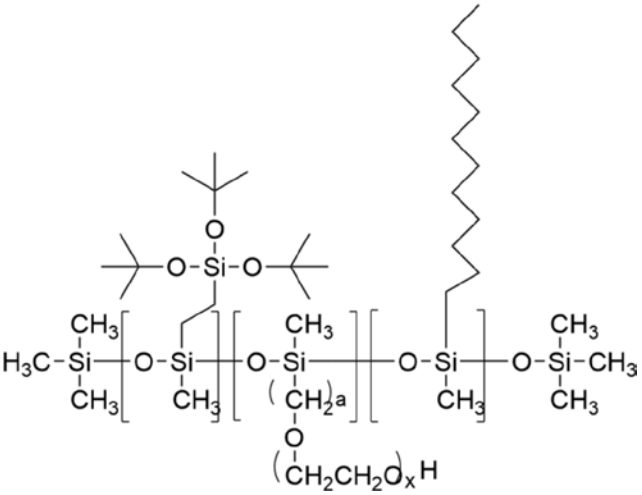

Figure 3: The structure of Lauryl PEG-10 Tris(Trimethylsiloxy) silyl Dimethicone.

the stability and create better sensory feelings compared to a popular market product.

MATERIALS AND METHODS

Materials

The origin, concentration, and function of ingredients used to manufacture BB Cream are listed in Table S1 of Supplementary Materials.

Methods

The procedure of making BB Cream is briefly demonstrated in Figure 4 and carefully explained as follows:

1. In the main vessel, combining phase A ingredients in order and mix well at 400 rpm in 10min.
2. In the side beaker, slowly adding listed ingredients in phase C and mix well at 600 rpm in 10min.
3. Using a ceramic mortar and pestle set to grind all color pigments, adding phase D slowly into this mixture until they are uniform.
4. Combining phase C and the mixture of colors together, stirring vigorously at 1000 rpm in 30min.
5. Adding the mixture in step 4 very slowly to the main vessel, mix well at 1000 rpm in 30min.

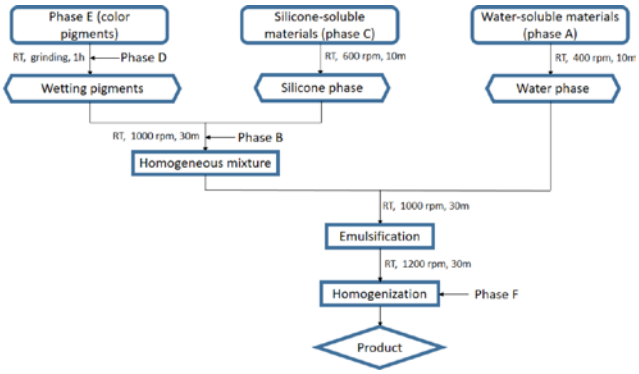

Figure 4: The process of making W/Si BB Cream.

6. Increasing the stirring speed to 1200 rpm in the next 30 min to get a homogeneous and smooth emulsion.

One strong point of this method is that it is a cold process and easy to carry out due to the least requirement of modern machines. IKA® RW 20 digital overhead stirrer was employed to make the emulsion. In fact, most of the processes making creams use homogenizers to achieve the most aesthetic and functional product. However, by using an overhead stirrer – the most common machine in every cosmetic lab, manufacturing BB cream seems to be easier and more applicable. However, the obstacle in this process was the crushing of color pigments into silicone oil volatile. Normally, the coated pigments rather than uncoated ones were used in makeup formulations. The flexibility in the creation of favorite colors is at the cost of a longer time for preparation.

Microscopic observation

The droplet morphology of the prepared emulsions was observed with an optical microscope at the magnification of 40 times and 400 times the actual size. Surface morphologies of the emulsions were further examined on a scanning electron microscope (SEM).

Stability studies of the developed emulsion in final packaging

The successful formulation of cosmetic products requires that the products should be placed under certain conditions and tested to determine their stability over a fixed period. The geographic climate of the target market should be kept in mind when stability studies are performed. Therefore in this study, two formulated products were stored at room temperature and 45°C for one month.

Homogeneity test

The test was carried out by pressing a small quantity of the formulated cream on glass slides. The consistency of the formulations and the appearance of the coarse

particles were used to evaluate the homogeneity of the formulations.

Viscosity measurement

A Brookfield viscometer DV-I (Brookfield Engineering Laboratories, Middleboro) was used with a concentric cylinder spindle SC4-64 to determine the viscosities of the different topical formulations. The tests were carried out at 25°C. The spindle was rotated at 20RPM.

Sensory evaluation

The tolerance study was performed on ten Vietnamese volunteers (6 men, 4 women) at different ages. Participants were asked not to apply any skin products to their faces during the study. Additionally, they were required not to wash the test areas during the test periods. All participants will be offered two BB creams (our formulation and a market product) without any information about their origin. Each applicant applies the same amount of the two BB Creams into their face skin for four hours, and then ends up giving reviews about these two. The blind test was conducted for one week, along with a poll for quantitative assessments of the product after use. The question poll was given in the Supplementary materials (Table S5).

RESULTS AND DISCUSSION

Formulation consideration

There are several process parameters affecting the performance of the product. By proper adjustments of water and silicone phase constituents, a stable emulsion can be achieved. In our invention, while the silicone phase comprises uncoated pigments dispersed in a volatile solvent, emulsifier and elastomer, the water phase consists of water, film-forming material, and other components for the sake of emollience. Additional components may appear in either phase, depending on the affinity thereof.

Silicone phase/Continuous phase

The dispersion of uncoated pigments

BB cream formulations tend to mimic the natural color of the skin by the incorporation of pigments originating from iron oxides and titanium dioxide. Iron oxides are useful in the cosmetic and personal care industry since they can provide shades of red, orange, brown, and black. Noticeably, titanium dioxide, a whitening color pigment, is in charge of UVR protection at the same time.[4] Cosmetic formulators make use of them to include color to decorative products like eye shadow, blush, face powders, lipstick, and mineral makeup because they are proven safe for use in cosmetics by the FDA.[14] However, the dispersions of these color pigments into the formulation is a matter of great concern due to their agglomeration, thus causing emulsion sedimentation over time. The answer to this perceived issue is:

1) Using surface treated powders of iron oxides and titanium dioxide.

2) Transmitting these pigments into the system well by suitable vehicles such as emulsifiers, volatile silicones, and silicone elastomers.

We claim that our research is of great benefit for further studies in untreated or uncoated pigment. Generally, there are two types of pigments: coated pigments and uncoated pigments in correspondence to the first and second approaches mentioned above. While the former is modified by various treatment processes with various chemical coatings, the latter has not undergone any coating processes that materially alter their hydrophobic or hydrophilic character. The use of coated pigment can be advantageous for certain formulations. For example, if the pigments are coated with hydrophobic groups, the treated pigments would be more hydrophobic and thus would be dispersed with ease in the oil phase of an O/W emulsion. However, the treated pigments can be restrictive when dispersing these pigments in other phases such as aqueous phase or silicone phase.[15]

Specifically, we used a silicone volatile oil with the viscosity of 1.5 cst to disperse the mixture of pigments before transmitting into the silicone oil phase. At first, pigments were placed in a smaller beaker with dimethicone for pigment dispersion and ball milled as shown in Figure 5 and Figure 6. Once checked with glass slides to ensure no undispersed pigments are found in the small beaker, contents are added to the main beaker. Different trials should be carried out before reaching the desired colors of formulators, and the two portions, Natural Skin Color (Figure 7) and Pinky Skin Colour (Figure 8) were the most identical and preferable skin colors according to our formulation.

Elastomer

Another integral part of a W/Si system is silicone elastomer.[16] In fact, elastomer is not a must-have ingredient in all cosmetic formulations. However, with our silicone-based system to which rotating freely is a prominent feature, adding silicone elastomer into the formula to improve rheological behaviors of the system is recommended. Silicone elastomer usually has its INCI name dimethicone or vinyl dimethicone crosspolymer.[17] Herein we made use of dimethicone crosspolymer delivered by silicone fluid named cyclopentasiloxane as a silicone oil thickening agent to stabilize the carrier fluid

Figure 5: Composition of color pigments.

Figure 6: Dispersed color pigments in silicone volatile oil.

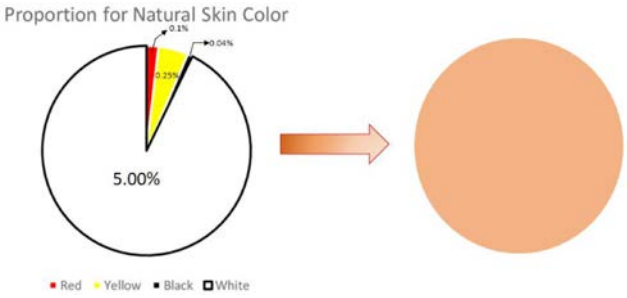

Figure 7: Percentages of iron oxides and titanium oxide blended to give Natural Skin Color.

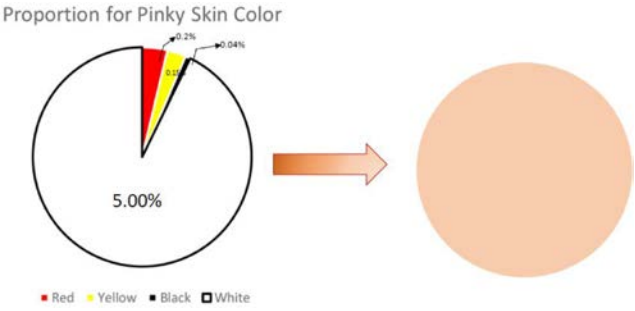

Figure 8: Percentages of iron oxides and titanium oxide blended to give Pinky Skin Color.

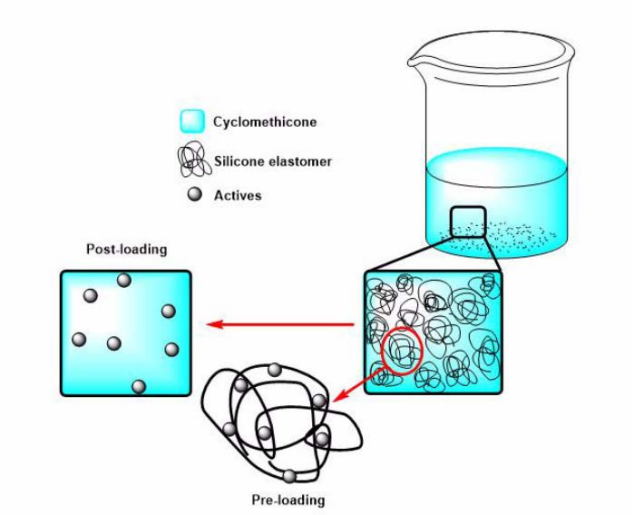

Figure 9: Mechanism of dimethicone crosspolymer.

– dimethicone and color pigments added in the previous step.

In this formulation, we included silicone elastomer into the silicone oil phase and stirred them in advance until the homogeneous mixture was obtained. To the best of our knowledge, the incorporation of silicone are made up of two continuous steps: 1) actives entrapped and immobilized within the elastomer gel network, 2) complete incorporation with a carrier fluid, explained by the mechanism in Figure 9.

Thanks to the use of elastomer, five color pigments in our W/Si BB Cream system were incorporated well into a reactive mixture (Figure 10). The appearance of the oil phase was completely distinguishable from the mixture of pigments wetted by silicone oil solely (Figure 6). Not only effective the application of silicone elastomer is in terms of stability of the system, but it also contributes to the post-application process, in which it will facilitate the spreading and gradual release of the actives incorporated gradually when solvent/ carrier fluid evaporates.[18,19]

Emulsifier

Many formulators use "aggressive" emulsifiers in the composition of products for the treatment of oily

Figure 10: Physical appearance after adding silicone elastomer.

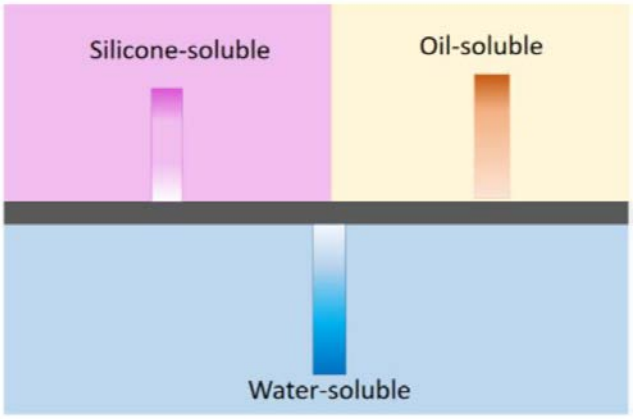

Figure 11: The depiction of the emulsifier structure with silicone-loving, oil-loving and water-loving groups of Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone.

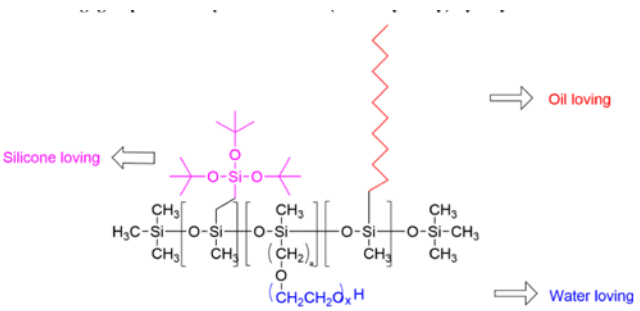

Figure 12: Chemical structure of Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone.

skin, in order to partially incorporate the lipids that this type of skin produces in excess. This strategy has only an immediate effect because over time the sebaceous glands respond to this external disturbance by producing even more sebum. Rather, an ideal emulsifier should be able to incorporate the high amount of water to prevent skin dehydration but still remain good stability. Given the structure stemming from dimethicone with polyoxylated substituents (ethylene oxide), a alkyl dimethicone copolyol emulsifier named Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone improves its water hydrophobicity with details provided in Figure 11 and Figure 12.

Lauryl PEG-10 Tris (Trimethylsiloxy) silylethyl Dimethicone was selected as an emulsifying agent to stabilize the system. Since there are many parameters influencing an emulsification process namely phase ratio, emulsifier level and silicone viscosity and shear, we focused on the two main factors, phase content and emulsifier level and kept the other two constant. Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone was examined regarding the capacity for emulsion formation. To determine an optimal value for water/silicone volume ratio in the least number of experiments, the emulsions were prepared at a fixed level of emulsifier at 3%, and the ratio between silicone phase and aqueous phase were adjusted accordingly with different ratios listed in Table S2 (Supplementary Materials).

Five different cream bases were formulated using various compositions of silicone phase and aqueous phase. The exact amount of each ingredient in cream formulation is given in Table S3 (Supplementary materials). Initally, we conducted three trials namely B1, B2 and B3 to build the formula of the cream according to the these ratios: W:Si:E = (1) 80:17:3; (2) 75:22:3; (3) 70:27:3, and also to identify the percentage of distilled water and silicone oil (a and b1, b2 respectively in Table S1). In the formulation B1, we failed to add the entire aqueous phase into the silicone phase, causing the coalescence of pigments as a result. To fix this problem, we decreased the internal phase content to W:Si:E = 75:22:3 while kept the emulsifier level constant. The change in ratio enabled us to mingle the discontinuous phase well into the continuous phase. However, the aesthetics of cream in the second trial was not as good as expected, which forced us to make the next alteration between W/ Si ratio. Further decrease of the internal phase led to the aesthetics and homogeneity of the formulation and the dramatic increase in viscosity to 20,546 cPs from the starting point at 12,525 cPs of the first ratio. To testify the effects of color ratio on the physical appearance of the formulation, the two different sets of color pigments studied in the Dispersion of uncoated pigments section were applied to make BB cream from Lauryl PEG-10 Tris(trimethylsiloxy)silylethyl with different favourable colors including Natural Skin Color and Pinky Skin Color

(Figure S1 of Supplementary Materials) in association with B3 and B4 formulation.

Also, to compare the capacity of emulsification between dimethicone copolyol and alkyl dimethicone copolyol, the two respective emulsifiers namely Lauryl PEG-10 Tris(trimethylsiloxy)silylethyl and PEG/PPG-18/18 Dimethicone were selected as the representative of each classification. The successful formulation (W:Si:E = 70:27:3) was applied to make a similar BB Cream with the replacement of emulsifier, switching from Lauryl PEG-10 Tris(trimethylsiloxy)silylethyl to PEG/PPG-18/18 Dimethicone to produce formulation B5. Initially, after mixing well, formulation B5 was less resistant to flow and thus having lower viscosity, yet still gives an aesthetics and homogeneity as B3. The two finished BB Cream were given in Figure S2 and Figure S3 of Supplementary Materials.

To sum up, formulations B1 to B5 were prepared with the same ingredients but with different concentration and different emulsifiers. Three of the cream formulations including B3, B4 and B5 were observed to have similarity in consistency. No apparent change in the physical appearance were observed with these three compositions. Further stability tests were carried out to examine the ability to stay dispersed instead of settling or segregating out of the two compositions.

Water phase

Water repellent agent

Makeup smear is regarded as a huge struggle for wearers. Due to sweat and sebum released from the skin, one may have to apply a plethora of makeup to avoid reapplication or bleach. This tendency is not only detrimental to skin owing to the pore-clogging and pimple formation, but also creates an artificial makeup finish.

To cope with this problem, we used Acrylates Copolymer (and) Acrylates/Polytrimethylsiloxymethacrylate Copolymer – a silicone acrylate film former to develop a water in silicone emulsion that guarantees skin persistence and longer-wearing life over the application. Apart from excellent resistance to sebum, rub-off and wash-off, it is also advantageous to the emulsification process thanks to its dissolution in water.

In our present invention, the film-forming polymer was used at the amount of 1%. It should be noted that the most preferable percentage of use is from 1% to 10%.[20] We chose the minimum level at 1% because it is only in support of our W/Si system, in which silicone is the continuous phase and thus can hardly be smeared in oil or wash-off by water.

Other components

Particularly preferred embodiments of the present make-up formulations are skin care formulas used as makeup compositions. Hence, our formulation also includes humectants such as propylene glycol and natural moisturizing agents originated from amino acid-based ingredients for skin conditioning and freshness in case of long-term application.

All of these ingredients were dispersed into water with ease by magnetic stirrer within 10 to 15min. This uniform mixture was then added slowly into the oil silicone phase while stirring vigorously at 1000 rpm.

Evaluation

Physicochemical properties

The physicochemical properties of the five formulations were given in Table 1. From the results, it can be concluded that formulations B3, B4 and B5 incorporated color pigments extremely well with good textures and consistency whereas the reverse was seen in formulations B1 and B2. The main reason determined the separation of color pigments from the emulsion might be the amount of water used in the formulation. The best ratio for stable emulsion is W:Si:E = 70:27:3.

Stability test

Just as unstable is the nature of emulsified products, so are multiple stability tests carried out to ensure their stability and final performance. The homogeneity test after completion in

S4A and S4B (Supplementary Materials) indicated that both respective formulations B3 and B5 were homogeneous and absolutely absent in roughness. Though formulation B3 is thicker, making it more difficult to spread out on the slide (Figure S4A). The viscosities for the formulated products at 20 rpm were found to be 13,874 cPs for B5 and 20,645 cPs for B3. This result holds true since the resistance to flow of formulation B5 was lower compared to B3.

However, after one month storing in the oven at 45°C, formulation B5 appeared unstable due to a slight phase separation on the surface (Figure S4D), whereas formulation B3 remained unchanged with good appearance (Figure S4C). The change in viscosity indicated in Table S4 (Supplementary Materials) is in accordance with the instability shown in formulation B3. More specifically, the viscosity of formulation B5 dropped gradually from 13,662 cPs to 13,002 cPs after one month at 25°C and to 12,467 at 45°C; meanwhile, that of B3 hovered around the mark of 20,500 cPs (Table S4 in Supplementary Materials).

Table 1: Physicochemical properties evaluation.

Formulation	Physical appearance	Color	Texture	Phase Separation
B1		Brown	Rough	No
B2		Light brown	Rough	No
B3		Wheat (Skin color)	Homogeneous	No
B4		Pink (Pinky Skin Color)	Homogeneous	No
B5		Wheat (Skin color)	Homogeneous	No

Microscopic observation

Since the destabilization process of a product can be attributed to the droplet size distribution, we continued to analyze our products by the observation under optical microscope (x40), followed by SEM micrographs.

The microscopic observation implies the possibility that the dispersed phase in the formulation B3 when stored at 45°C is due to coalescence. Water droplets at several areas were not uniform when being zoomed out to 400 times larger than the actual size. Figure 13B shows examples of droplets with significantly bigger size of the B5 formulation compared to the relatively identical size of droplet of B3 in Figure 13A. It is possible that droplets from B5 have collided and coalesced to form larger droplets at higher temperature (Figure 13B).

This explanation was also supported by scanning electron micrographic (SEM) analysis, which exhibits the stronger connection between internal molecules of B5 emulsion (Figure 14A). However, a more compact structure can possibly be the driving force of restructuring of droplet aggregates.[21] To be more specific, it can be seen from Figure 14C and 14D that droplet size in the B3 emulsion is relatively smaller than B5. While the droplet size of B3 formulation ranges from 1µm to 2µm (Figure 14C & 14D), that of B5 is measured from 1.5µm to 3µm (Figure 14A and 14B).

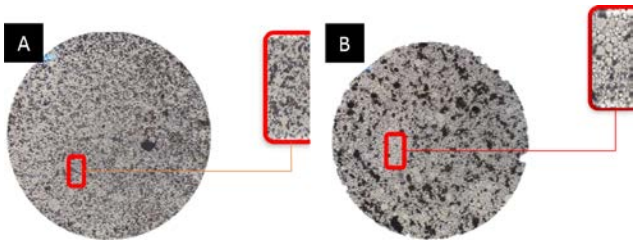

Figure 13: Microscope images of the prepared W/Si emulsions inspected with a light microscope at x40 and x400 magnification:
A/ Formulation B3 B/ Formulation B5.

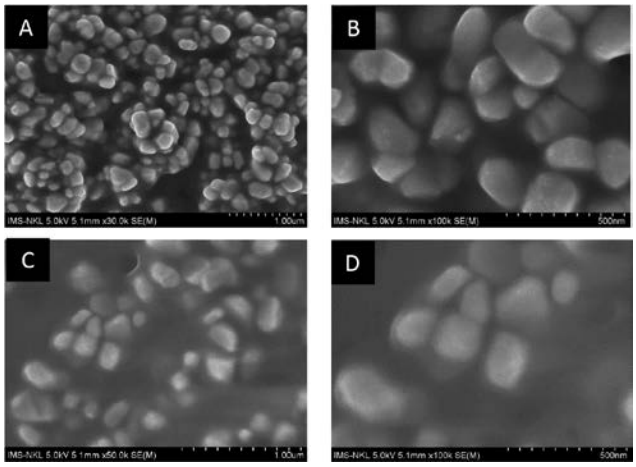

Figure 14: SEM photographs of the prepared emulsions
A/ B5 emulsion at x30.0k magnification
B/ B5 emulsion at x100k magnification
C/ B3 emulsion at x50k magnification
D/ B3 emulsion at x100k magnification

The most distinguishable feature between the two emulsions observed through Figure 14 is that droplets from B3 arrange evenly and distantly whereas the structure of B5 is more compact which was probably the driving force of coalescence and deformation. The clear evidence can be witnessed in Figure 15 in which two droplets (Figure 15A) and three droplets (Figure 15B) are going to combine and in similar forms of arrested coalescence.[5,21,22]

Sensory evaluation

A sensory evaluation between our B3 formulation and a popular BB cream on the market was conducted on a panel of 10 volunteers. This commercial BB Cream is a W/O emulsion with the inclusion of silicone oil in form of emulsions (Details of the formulation given in the Table S6 of Supplementary materials), stabilized by Sorbitan isostearate – a non-ionic W/O emulsifier. The purpose of the test was to quantitatively identify the sensations of two different types of emulsions through

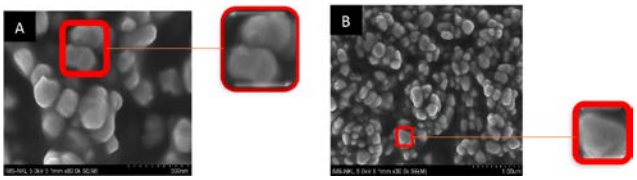

Figure 15: The coalescence observed in the formulation B5. A/ Doublet shape B/ Triplet shape

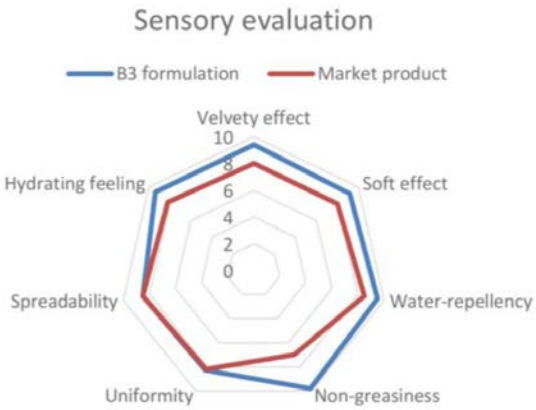

Figure 16: The sensory assessment comparing the tested BB cream and a market BB Cream

the use of sensory descriptors relating to: velvety effect, soft effect, water-repellency, non-greasiness, uniformity of the colors, spreadability and sensation of hydration. After using the product for a week as instructions, the survey showed that our prepared BB cream was superior in all aspects, especially in after-feel effects. The data were collected and summarized in Figure 16. There was no report on undesired effects in both samples. Clearly, the most outstanding feature of our formulated W/Si BB Cream was non-greasy feeling, which attained nearly maximum scores from all volunteers, compared to the seemingly unpleasant feeling of the market product with 7 points in average. Strengths in after-feel effects including velvety, softness, skin hydration were also well illustrated in the chart.

The lowest points of our prepared BB Cream went to Spreadability and Uniformity. The fact that both of BB Creams are in the form of cream rather than lotion makes it harder to spread on the skin. In term of uniformity, despite the ability to balance uneven skin colors, our sample failed to cover scars and blemishes. This shortcoming can be attributed to the absence of aluminum hydroxide, mica and silica, known as fillers in our formulation. However, they can conversely cause thickness and pore-clogging in long-term application. Our future research may try to balance out further ingredients well to keep the strong points and overcome the weaknesses highlighted in this survey.

CONCLUSION

A simple method of preparing W/Si BB Cream from two types of emulsifiers namely Dimethicone Copolyol and Alkyl Dimethicone Copolyol has been proposed. Both emulsions successfully incorporated a high level of discontinuous phase – water and color pigments by means of silicone oil. However, the emulsion made of Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone is more stable over time with the viscosity standing at around 20,500 cPs in contrast to the drop from 13,874 cPs to 13,002 cPs in BB Cream from PEG/PPG-18/18 Dimethicone, proving the capability of Alkyl Dimethicone Copolyol to stabilize W/Si emulsion at the same level of use. The coalescence and instability of the emulsion made of PEG/PPG-18/18 Dimethicone was explained by the formation of arrested coalescence of doublet and triplet droplets thanks to microscopic observation and SEM micrographs. Additionally, the sensory evaluation comparing our formulated BB Cream and a W/O market counterpart considerably justifies the effectiveness of W/Si emulsion in pleasant skin feels. Therefore, our findings could be applied quite reliably in other cosmetic contexts including decorative and skincare formulations without a degradation in performance.

ACKNOWLEDGEMENT

We are grateful for Connell Bros. Limited Company for supporting us materials during the implementation. We also want to express our deepest gratitude for Department of Chemistry and Department of Biology of College of Natural Sciences, Can Tho University for assistance in stability tests and microscopic observations.

Highlight (Strong Points for Publication)

An introduction to the formulation of W/Si BB Cream with high-level content of water (70%) and pleasant feelings even in long-lasting application.

- Our formulated emulsion maintains long-term stability with droplet size ranging from 1µm to 2µm.
- The ability to incorporate a large number of untreated color pigments into the emulsion allows maximum flexibility over the creation of different skin colors.

ABBREVIATIONS

W: Water; **O:** Oil; **S:** Surfactant; **E:** Emulsifier; **W/O:** Water/Oil; **O/W:** Oil/Water; **W/Si:** Water/Silicone; **INCI:** International Nomenclature Cosmetic Ingredient; **Rpm:** Rotation per minute; **Min:** Minute; **UV:** Ultraviolet.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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SUPPLEMENTARY MATERIALS

Table S1: List of phases for W/Si BB Cream

No	INCI	Market names	Function	%(w/w)
Phase A				
1	Water	Distilled water	Solvent	a
2	Disodium EDTA	Disodium EDTA	Chelating agent	0.1
3	Propylene Glycol	Propylene Glycol	Humectant	3.00
4	Acrylate, Copolymer, Acrylates, Polytrimethylsiloxymethacrylate, Copolymer	Epitex 99®	Water-repellency	1.00
5	Sodium PCA	Ajdew NL 50®	Humectant	3.00
6	Betaine (and) Sodium PCA (and) Sodium Lactate (and) PCA (and) Serine (and) Alanine (and) Glycine (and) Glutamic Acid (and) Lysine HCl (and) Threonine (and) Arginine (and) Proline (and) Water	Prodew 600®	Humectants	2.00
Phase B				
7	Lauryl PEG-10 Tris(trimethylsiloxy) silylethyl Dimethicone	Dowsil ES-5300®	Emulsifier	2.80
Phase C				
8	PPG-14 Butyl Ether	Ucon fluid AP®	Emollience	5.00
9	Caprylyl Methicone	Dowsil FZ 3196®	Silicone oil	5.00
10	Cyclopentasiloxane (and) Dimethicone Crosspolymer	Dowsil 9045®	Oil phase thickener	4.00
11	Dimethicone	Xiameter PMX® 200, 1.5cs	Silicone oil	b1
Phase D				
12	Dimethicone	Xiameter PMX 200®, 1.5cs	Carrier fluid	b2
Phase E				
13	Iron oxide	Red	Colorant	0.1
14	Iron oxide	Yellow	Colorant	0.25
15	Iron oxide	Black	Colorant	0.04
16	Titan dioxide	Titan	Colorant/ UV filter	5.00
Phase F				
17	Phenoxyethanol	Neolone PHCG®	Preservative	0.80
18	Fragrance	Takasago	Fragrance	0.50

Table S2: Five trials conducted to clarify the suitable ratio.			
Trial	**W:Si:E**	**%Weight (W:Si:E)**	**Variables**
1	80 : 17 : 3	74.65 : 15.86 : 2.8	a = 65.55 b1 = 0.00 b2 = 1.86
2	75 : 22 : 3	69.98 : 20.53 : 2.8	a = 60.88 b1 = 1.53 b2 = 5.00
3	70 : 27 : 3	65.32 : 25.19 : 2.8	a = 56.22 b1 = 6.19 b2 = 5.00
4	70 : 27 : 3	65. 32 : 25.19 : 2.8	a = 56.22 b1 = 6.19 b2 = 5.00
5	70 : 27 : 3	65.32 : 25.19 : 2.8	a = 56.22 b1 = 6.19 b2 = 5.00

Table S3: Percentages of ingredients in five trials							
No	**INCI**	**Phase**	**B1**	**B2**	**B3**	**B4**	**B5**
Phase A							
1	Water	Water	**65.55**	**60.88**	**56.22**	**56.22**	**56.22**
2	Disodium EDTA		0.1	0.1	0.1	0.10	0.10
3	Propylene Glycol		3.00	3.00	3.00	3.00	3.00
4	Acrylate, Copolymer, Acrylates, Polytrimethylsiloxymethacrylate, Copolymer		1.00	1.00	1.00	1.00	1.00
5	Sodium PCA		3.00	3.00	3.00	3.00	3.00
6	Betaine (and) Sodium PCA (and) Sodium Lactate (and) PCA (and) Serine (and) Alanine (and) Glycine (and) Glutamic Acid (and) Lysine HCl (and) Threonine (and) Arginine (and) Proline (and) Water		2.00	2.00	2.00	2.00	2.00
Phase B							
7	Lauryl PEG-10 Tris(trimethylsiloxy)silylethyl Dimethicone	Emulsifier	**2.80**	**2.80**	**2.80**	**2.80**	-
8	PEG/PPG-18/18 Dimethicone	Emulsifier	**-**	**-**	-	-	**2.80**
Phase C							
8	PPG-14 Butyl Ether	Silicone	5.00	5.00	5.00	5.00	5.00
9	Caprylyl Methicone		5.00	5.00	5.00	5.00	5.00
10	Cyclopentasiloxane (and) Dimethicone Crosspolymer		4.00	4.00	4.00	4.00	4.00
11	Dimethicone		**0.00**	**1.53**	**6.19**	**6.19**	**6.19**
	Phase D						
12	Dimethicone		**1.86**	**5.00**	**5.00**	5.00	5.00
Phase E							
13	Iron oxide (Red)		0.10	0.10	0.10	0.20	0.10
14	Iron oxide (Yellow)		0.25	0.25	0.25	0.15	0.25
15	Iron oxide (Black)		0.04	0.04	0.04	0.04	0.04
16	Titan dioxide (White)		5.00	5.00	5.00	5.00	5.00
Phase F							
17	Phenoxyethanol		0.80	0.80	0.80	0.80	0.80
18	Fragrance		0.50	0.50	0.50	0.50	0.50

Table S4: The viscosity of B3 and B5 formulations after four weeks month.

Formulation	Temperature	Initial	Two week	Four weeks
B3	25°C	20,645	20,875	20,464
	45°C	-	20,737	20,586
B5	25°C	13,847	13,662	13,002
	45°C	-	13,212	12,467

Table S5: Sensory Evaluation between W/Si BB cream (formulation B3) vs a commercial product (Control)

First name:…… Last name:……..
Gender:…….
Occupation:…….
Phone number:……..

	W/SI BB Cream (on a scale of ten)	Commercial product (Control) (on a scale of ten)
Velvety effect	/10	/10
Soft effect	/10	/10
Water-repellent	/10	/10
Non-greasiness	/10	/10
Uniformity	/10	/10
Spreadability	/10	/10
Hydrating feeling	/10	/10

Signature

Table S6: List of ingredients from the market product

List of ingredients
Water, Cyclopentasiloxane, Hydrogenated, polyisobutene, Sorbitan isostearate, Glycerin, Propylene glycol, Titanium dioxide, Cera microcristallina, Phenoxyethanol, Magnesium sulfate, Disodium stearoyl glutamate, Disteardimonium hectorite, Methyl paraben, Acrylonitrite/ methyl methacrylate/ vinylene chloride polymer, Aluminum hydroxide, Paraffin, Alumina , Stearic acid, Butyl paraben, Tocopherol, Isobutene, Polyethylene, Tin oxide.

Figure S1: Lauryl PEG-10 Tris (Trimethylsiloxy)silylethyl Dimethicone W/Si BB Cream with two different colors: Natural Skin Color and Pinky Skin Color (Formulation B3 and B4)

Figure S2: W/Si BB Cream from formulation B3.

Figure S3: W/Si BB Cream from formulation B5

A

B

C

D

Figure S4: Physical appearance of the two prepared BB Creams after one month storing at 45°C

A/ Formulation B3 on glass slide
B/ Formulation B5 on glass slide
C/ The surface of formulation B3
D/ The surface of formulation B5

SUMMARY

- Silicone is a widely-used cosmetic ingredient, whose advantages are perceived as detackification, soft and non-greasy feeling and excellent spreading quality. However, due to its special structures and properties, conventional emulsions fail to incorporate.[10,11] In this work, a formulation model of making BB Cream based on W/Si emulsion is developed with the aim of overcoming this hindrance. Furthermore, for flexible choice of makeup colors, uncoated pigments were used, which were dispersed into the formulation by silicone oil.
- We carried out tests on two different emulsifiers namely PEG/PPG-18/18 Dimethicone – a common silicone emulsifier and Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone – a new silicone emulsifier. Upon the completion, the properties and stabilities of two samples were investigated to compare their emulsifying ability.
- At the concentration of 3%, both emulsifiers are able to prepare stable emulsions with a high water volume fraction of up to 70%. Nevertheless, their stability states over time drives us to a different conclusion. After storage at 45°C for one month, BB Cream made from Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone appear to be more stable compared to its counterpart, which were proven explicitly by both quantitative and qualitative assessments. The destabilization of BB Cream made by PEG/PPG-18/18 Dimethicone was then analyzed under optical microscope (x40), followed by SEM micrographs. It is concluded that this sample was collided and coalesced to form larger droplets, and thus unstable at higher temperature. Therefore, the superior sample is Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone, which maintains long-term stability with droplet size ranging from 1µm to 2µm and is able to incorporate a large amount of untreated color pigments into the emulsion. This superior sample is continued to go through a sensory evaluation to compared the efficacy with a commercial BB Cream (a W/O emulsion). After using the product for a week as instructions, the survey showed that our prepared BB cream was superior in all aspects, especially in after-feel effects.
- With good properties testifying for Lauryl PEG-10 Tris(Trimethylsiloxy)silylethyl Dimethicone from our studies, we have the confidence that the developed composition is expected to represent a real asset in future make-up formulations.

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Cite this article: Huynh NT, Cuong QN, Tran TM, Nguyen TT, Bui TBH, Tran QD. Water-in-Silicone Emulsion – The Approach to an Ideal BB Cream. Indian J of Pharmaceutical Education and Research. 2022;56(2):372-86.