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ENHANCING EMOLLIENT PROPERTIES OF NATURAL AND STRUCTURED VIRGIN COCONUT OIL CREAMS ON SKIN CONDITIONS USING NON-INVASIVE SKIN BIOPHYSICAL METHODS

SALIZATUL ILYANA IBRAHIM[1,2*], JUAN MATMIN[3], NURIANA MUNIRAH HAIRUL[2] and ABU BAKAR ABDUL MAJEED[2]

[1]*Centre of Foundation Studies, Universiti Teknologi MARA, Cawangan Selangor, Kampus Dengkil, 43800 Dengkil, Selangor, Malaysia*
[2]*Faculty of Pharmacy, Universiti Teknologi MARA, Cawangan Selangor, Kampus Puncak Alam, Puncak Alam, Selangor, Malaysia*
[3]*Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia*
[*]*E-mail: saliza2910@uitm.edu.my*

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ABSTRACT

This study aims to evaluate the emollient properties of natural-based oil creams on skin conditions. The focus is primarily on natural virgin coconut oil (VCO) and structured VCO (SVCO) which contain medium-chain triglycerides (MCTs) that have been reported to have a permeation enhancement effect on the lipophilic active ingredient. SVCO, which contains a higher amount of MCTs than VCO, was produced by lipase-catalyzed acidolysis of caprylic/octanoic acid (eight-carbon chain) and VCO. The emollient cream was prepared using the oil in water (o/w) formulation cream and it consisted of 30% (w/w) of oils, emulsifying wax, and deionized water. While in the oil phase, 5% (w/w) α-tocopherol, the model lipophilic active ingredient was added to the cream. Significant effects (p<0.05) were statistically produced in the skin moisture content, transepidermal water loss (TEWL), and skin elasticity values for all formulations as compared to the skin at T0 (before application) after the short- and long-term study periods. The skin smoothness (SEsm) and skin roughness (SEr) values, which are indicators of the skin condition, also showed significant improvement. The results indicated that VCO and SVCO creams exerted an emollient effect when applied topically and also acted as skin permeation enhancers in the formulation.

Key words: Emollient, permeation enhancer, skin biophysical, structured virgin coconut oil

INTRODUCTION

An emollient is an ingredient used in skin care formulations that helps in maintaining the softness and smoothness of the skin and contributes to the moisturizing, lubricating, and conditioning effects which formed semi-occlusive films on the skin (Lodén & Maibach, 2012; Purnamawati *et al*., 2017; Chao *et al*., 2018; Pham *et al*., 2022). In clinical practice, it helps to reduce the itching sensation often present in dry skin while improving the appearance of the stratum corneum (Perrett & Peters, 2020). An emollient is also described as an oily substance that enhances the after-feel properties when topically applied onto the skin as it may soften and lubricate the skin. The sensory perceptions or skin-feel effects of these emollients such as gliding, sliding, moisturizing, conditioning, softening, and smoothing are complicated and very subjective and can be determined during and/or after application on the skin. These are related to the physicochemical properties of the emollient used (Kim *et al*., 2007). Emollients may decrease the friction coefficient due to their lubricant properties and modify the spreading performance of the product (Savary *et al*., 2013). Emolliency is the softening ability that is one of the most important parameters in skin moisturization as emollient helps to balance the skin moisture (Lodén & Maibach, 2012; Pham *et al*., 2022).

In a skincare formulation, the concentration of emollients normally is used between 3 to 30% w/w. Their concentrations can become higher in anhydrous systems and water-in-oil emulsions (Savary *et al*., 2013). Since an emollient is the second major ingredient after water, it plays a major role as a functional ingredient group in influencing the feel of

* To whom correspondence should be addressed

the skin when included in the formulations (Ahmad & Ahsan, 2020). The functionality of the emollient when it penetrates the skin and the cost involved in the formulation should be taken into consideration so that the desired stipulation could be met. The formulator should be very familiar with the chemical and physical behaviors of the emollient used especially when optimizing the properties of the emollient in the formulation. The emollient is a substance that actively affects the normal functions of the skin. If the chemical structure of the emollient is acceptable, an interaction between the emollient and the skin's natural fats may occur and chemical reactions may take place in the vital processes of the skin (Gore *et al*., 2020).

Vegetable oils have been used widely as emollients in skincare or pharmaceutical products as consumers are more concerned about using natural and organic ingredients (Łopaciuk & Łoboda, 2013). Purnamawati *et al*. (2017) have reported that vegetable oil may enhance skin hydration levels which may lead to a moisturizing effect. The oil which acts as an emollient will form an occlusive layer on the skin while preventing the water loss kinetics of the skin. Most vegetable oils primarily consist of triglycerides, which possess glycerol molecules with three carbon chain fatty acids attached to the hydroxy groups via ester linkages (Sarkar *et al*., 2017). Some vegetable oils consist of long fatty acids with varying lengths of the carbon chain (between 14 to 20) and unsaturation levels. Among other oils exist; medium chain triglycerides (MCTs) that consist of medium-length fatty acids have much potential application. Several studies have reported that MCTs act as a skin penetration enhancer that enhances and help the delivery of active ingredients into the skin when formulated into cosmetic products (Lusiana & Müller-Goymann, 2011; Hasanah & Warnasih, 2020; Ibrahim *et al*., 2020). However, the use of MCTs as skin emollients has not yet been investigated. Therefore, there is a need to investigate whether fast-absorbing ingredients have an emollient effect when formulated into creams.

In this study, the performances of related properties of emollients from MCTs were measured. The primary focus of the study was on natural virgin coconut oil (VCO) and structured VCO (SVCO). VCO fatty acids are predominantly medium-chain fatty acids with saturated carbon six to twelve carbon chain lengths primary the dodecanoic/lauric acid, C12:0 (48.21%) and myristic acid, C14:0 (21.07%) (Ibrahim *et al*., 2020). To produce SVCO, octanoic acid and VCO were mixed and reacted by lipase-catalyzed acidolysis. In the process, n-hexane was used as a solvent because it is highly soluble, has low evaporation loss and its residue is greasy (Mohd-Setapar *et al*., 2014). The SVCO contains 60.10% of octanoic/caprylic acid, C8:0, 18.94% of dodecanoic acid, C12:0, and tetradecanoic acid, 9.19% of C14:0. In the previous work, SVCO has been reported of having a better enhancement effect than the natural VCO (Ibrahim *et al*., 2020). The emollient properties of the oils in the formulation were investigated by using skin biophysical studies to look at skin hydration, skin elasticity, and skin microrelief using non-invasive methods.

MATERIALS AND METHODS

Materials

In this study, two types of oils namely VCO and SVCO were used. VCO was extracted using the wet extraction method while the SVCO containing 60% of caprylic/octanoic acid (a fatty acid $C_8H_{16}O_2$) was produced by enzymatic acidolysis using *1,3* immobilized *Rhizomucor meihei* as the biocatalyst. The method to produce the SVCO was adapted from the previously published work (Ibrahim *et al*., 2020). The acidolysis of octanoic acid and VCO was performed using the optimized parameters from the Central Composite Design (CCD) results with octanoic acid incorporated as the response. To incorporate as much octanoic acid in the formulation, octanoic acid to VCO ratio of 1.70 (w/w) was used together with 22.60% of an enzyme load at a temperature of 63.4 °C and 3.53% of water content at 96 h. The mixture was incubated at 63.4 °C in an orbital shaking water bath at 200 rpm. The octanoic acid composition in the oil was quantified using gas chromatography (Ibrahim *et al*., 2020).

The solvents and chemicals used in the study were of analytical or HPLC grade. The α-Tocopherol (Covitol F-1370), the model lipophilic active ingredient was purchased from Cognis Corporation, USA and butylated hydroxyanisole (BHA) was supplied by Sigma Chemical Co. Methanol, hexane, and tetrahydrofuran were purchased from Merck, GaA, Darmstadt, Germany while Zulat Pharmacy Sdn. Bhd., a Malaysia-based company provided emulsifying wax. Deionized water was obtained from Water Reservoir® (Elga Water System, UK).

Production of creams

The basic oil in water (o/w) cream formulation was applied to prepare the emollient cream. About 30% (w/w) of oils, emulsifying wax, and deionized water were added to the formulation. Regarding preparations that included the active ingredient, 5% (w/w) of α-tocopherol was added to the oil phase. First, the emulsifying wax was melted at a temperature of 70 to 75 °C using low heat. The oil was then added once the wax was completely melted with a continuous stirring. Butylated hydroxyl anisole (0.05% w/v) was also added to the oil phase to avoid oxidation of the active ingredient. The water phase was heated simultaneously until it reached a temperature

of 70 °C. Finally, the oil phase was slowly added to the water phase while continuously stirring using a homogenizer that began from a low rpm to 2000 rpm, until it became homogeneous. It was then left to cool and stored in an airtight cream jar at room temperature (25 °C).

Skin biophysical studies

This study was first assigned for human ethics and approved by the Research Ethics Committee (REC) of Universiti Teknologi MARA (UiTM). Twelve female volunteers, aged between 20 and 35 years, were involved and they signed the Informed Consent after being oriented to the research objectives and methods. Female participants in this age group (young-adult group) were chosen in this study as estrogenic hormones in different gender and age play a major role in the skin emollient efficacy (Hita *et al*., 2017). Subjects who were allergic to any of the cream's ingredients and ones who had topically applied any cream on the test site (dorsum of both arms) during the study were excluded. The use of any other cream products on the subject's test site was not allowed. Those who were also kept out of the study were subjects who were on regular medical therapy advised by a certified doctor, to avoid the untoward antagonistic effect of medications, subjects who develop hypersensitive skin reactions (unusual itchiness, urticarial rashes, skin ulceration, etc.) and systemic reaction (shortness of breath, stridor, vasovagal syncope, loss of consciousness, etc.) towards the product and subjects who were pregnant and breastfeeding.

To further the goal of achieving results that were dependable and could be reproduced, standardized methods were used for all measurements involved (De Paepe *et al*., 2000; Berardesca, 2002). All the test subjects were given these instructions: first, they were not allowed to clean their forearms with any products, including cleansers or surfactants. Second, they were not permitted to apply beauty care products on the skin of their inner arms. These instructions were to be carried out while the experiment was going on, starting one week before it began. Only purified water could be used to wash the forearm. The purified water was obtained from the Water Reservoir® (Elga Water System, UK). Environmental influences were avoided, by the subject being placed in a conditioned room (22 ± 2 °C, 45 ± 5% relative humidity) for at least 15 min with their arms exposed. This was so that their skin could be acclimated to the room's temperature and humidity.

Formulations containing or not 5% α-tocopherol in VCO and SVCO (containing 60% of caprylic acid) were applied to both the right and left forearm of each volunteer similarly. An amount of the product was placed in the center of the identified test area. The sample was circularly rotated with one finger 20 times within the circle, at a rate of two times per sec. Subjects were placed in a room where the temperature and humidity were administered (25 ± 2 °C and 45-55%, respectively) before the measurements began, for them to be acclimatized.

The four test skin products were listed as follows:

i. Cream 1 (C1, SVCO) without the active ingredient
ii. Cream 2 (C2, VCO) without the active ingredient
iii. Cream 3 (C3, SVCO) with the active ingredient
iv. Cream 4 (C4, VCO) with the active ingredient

Below were the four test areas identified over the dorsum of both forearms (Figure 1):

i. Area 1 (left forearm; from wrist joint up to the left mid forearm): Area treated with C1.
ii. Area 2 (left forearm; from left mid forearm up to the antecubital area): Area treated with C2.
iii. Area 3 (right forearm; from wrist joint up to the right mid forearm): Area treated with C3.
iv. Area 4 (right forearm; left forearm; from right mid forearm up to the antecubital area): Area treated with C4.

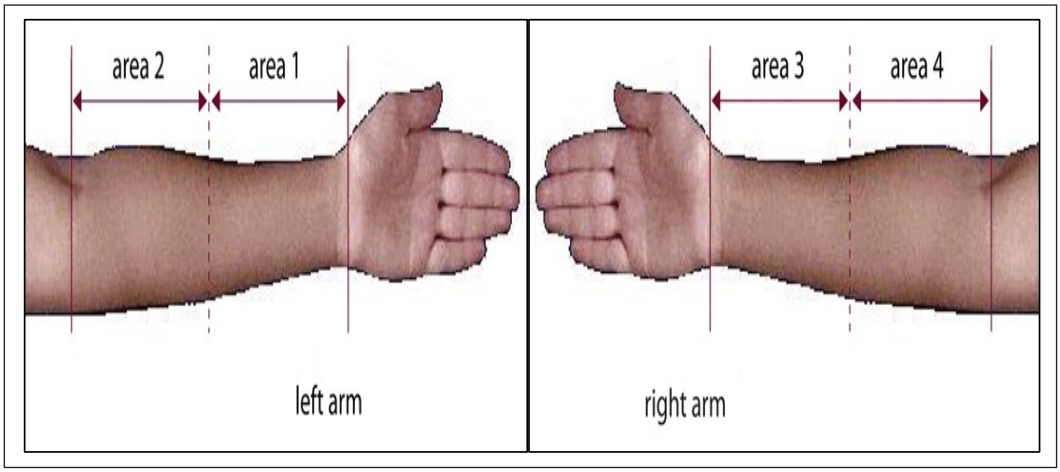


Fig. 1. Four test areas were identified over the dorsum of both forearms.

Using the same scheme of application, subjects repeated the application daily. Efficacy measurements were carried out before (T_0) and after the application of the sample (short-term test; 3h after a single application). This procedure was followed by a long-term test of 2 weeks when samples were applied twice daily for 14 consecutive days (Hussain *et al*., 2016; Simon *et al*., 2017). Measurements of stratum corneum (SC) hydration or skin moisture content, transepidermal water loss (TEWL) or epidermal barrier function, viscoelasticity, and skin topography were made by non-invasive methods using the Corneometer 825, Tewameter TM 210, Cutometer SEM 575 and Visioscan VC 98 ® (Courage & Khazaka Electronic GmbH., Cologne, Germany), respectively.

For the skin viscoelasticity, the parameters evaluated were as follows: skin fatigue resistance (F2), skin firmness (F4) which is the area below the approximated envelope function of maximum extensions where a decrease in F4 corresponds to an increase in skin firmness, and skin elasticity (F3/F4). The larger the F3 in comparison to the F4, the larger the restoring forces and the smaller the remaining residual deformation, the closer the resulting value is to 1, and the more elastic the skin. The calculation of the parameters was conducted by WinCT software (Courage & Khazaka GmbH, Cologne, Germany). The calculation of the parameters was conducted by WinCT software (Courage & Khazaka GmbH, Cologne, Germany). While the measurement items in Visioscan VC 98 were skin smoothness (SEsm) and skin roughness (SEr). A lower numerical value indicates more smoothness and fewer wrinkles.

Statistical analyses

The percentages of changes concerning initial values/zero h of volunteers for different parameters, taken at 3 h and 2nd week were calculated. The measured values were presented as mean values ± standard deviation (s.d.). Analysis of variance (ANOVA) and Student's t-test for paired samples was performed. Differences were considered statistically significant at $p<0.05$. Statistical analyses were assessed by SPSS 20.0.

RESULTS AND DISCUSSIONS

Skin moisture content, TransEpidermal Water Loss (TEWL), and skin elasticity

The skin moisture content or stratum corneum hydration, TEWL, and skin elasticity were measured before the application of creams (T_0), 3 h after the application, and on the second week of the study period. An increase in the skin moisture content value corresponded to an increase in skin hydration, while a decrease in TEWL value reflects the evaporation of the water incorporated in the cosmetic products themselves. The measuring skin moisture content and TEWL values of the 12 volunteers were calculated and summarised in Table 1 while changes in the values were given in Figure 2. Following a 2-week treatment, an increase in the skin moisture content value (30-40%) and changes in the mean of skin moisture content after the application of base and active creams were observed. There was a significant difference in the delta value (changes value) of skin elasticity (F3/F4) of the skin (Figure 3). Stratum corneum hydration, TEWL, and skin elasticity play an important role in skin function such as regulation of epidermal proliferation, differentiation, and inflammation (Mehta *et al*., 2017). All these parameters were found to improve after long-term application, especially for the creams with active ingredients. α-tocopherol is the most potent antioxidant, supports skin levels of tocopherols, allows it to permeate to the deepest layers of the stratum corneum via sebaceous gland secretions, to reside within cell membranes and protect them from oxidative stress (Goon *et al*., 2019; Rattanawiwatpong *et al*., 2020). The incorporation of α-tocopherol into the formulation corresponds to an increase in skin hydration and an improvement in the skin barrier or emollient properties (Vergou *et al*., 2012).

A decrease in TEWL value reflects the evaporation of the water incorporated in the cosmetic products. A combination of TEWL measurement with another non-invasive method such as skin moisture content is recommended as a more reliable and accurate approach (Chaikul *et al*., 2021).

Using paired sample t-test, it was evident that there was a significant difference in the skin moisture content and TEWL values for all formulations after the short- and long-term study period as compared to the skin at T_0 (before application). By applying ANOVA two-way analysis, no significant changes were observed on TEWL among creams tested but there was a significant effect (p=0.000) on the skin moisture content of VCO and SVCO creams with the active compared to creams without the active after two weeks of application.

It is important to know how the physicochemical properties of the ingredients will affect the emollient properties of the product. The findings showed that SVCO cream which contains a higher amount of MCTs with octanoic acids (carbon-8), the medium chain carbon-chain length as a major fatty acid, and lesser amount of carbon-10, 12, 14, and 16, gave less greasy characteristics when applied topically. It is correlated with the findings reported by Ibrahim *et al*., (2020) that a decrease in the saturated fatty acids composition (carbon-10, 12, 14, & 16) in SVCO cream decreased the elasticity of the cream. However, both the SVCO and VCO creams showed a significant improvement in the skin moisture content

Table 1. Skin moisture content and transepidermal water loss (TEWL) values of VCO and SVCO base and with active creams determined by a skin capacitance meter (Corneometer® MPA 5) and evaporimeter (Tewameter® MPA 5, Courage and Khazaka, Germany)

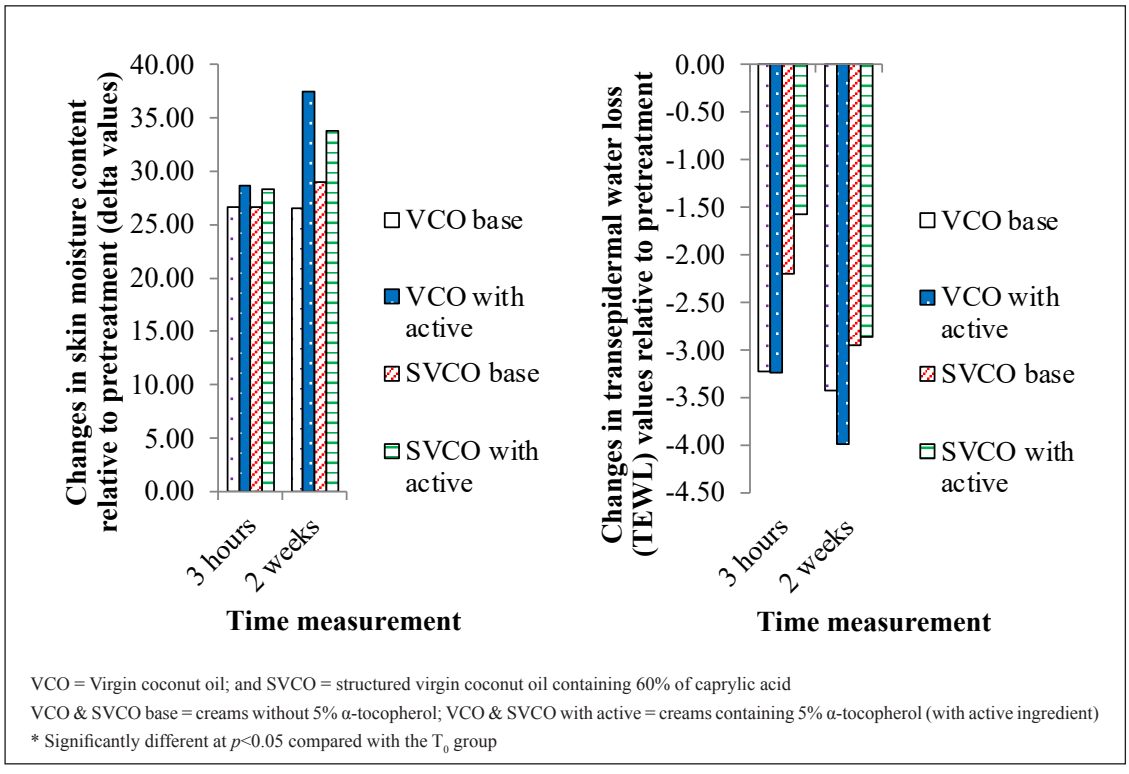
Parameter	Cream	Before application (T_0)	3 h after the application (3 h)	2 weeks after the application (2 weeks)
Skin moisture content (microsiemens)	VCO base	37.12 ± 4.35	63.78 ± 13.27*	63.62 ± 8.47*
	VCO with active	35.27 ± 2.63	63.89 ± 12.01*	72.77 ± 14.16*
	SVCO base	35.67 ± 4.09	62.31 ± 13.53*	64.69 ± 8.69*
	SVCO with active	33.20 ± 4.62	61.50 ± 12.86*	67.01 ± 6.85*
Transepidermal water loss (TEWL) (g/cm/h)	VCO base	9.13 ± 2.60	5.91 ± 0.89*	5.70 ± 0.72*
	VCO with active	9.23 ± 1.84	5.99 ± 0.95*	5.24 ± 1.67*
	SVCO base	9.00 ± 1.80	6.79 ± 1.79*	6.04 ± 1.88*
	SVCO with active	8.09 ± 1.42	6.51 ± 1.39*	5.23 ± 2.05*

Data presented as mean values ± standard deviation

VCO = Virgin coconut oil; and SVCO = structured virgin coconut oil containing 60% of caprylic acid

VCO & SVCO base = creams without 5% α-tocopherol; VCO & SVCO with active = creams containing 5% α-tocopherol (with active ingredient)

* Significantly different at $p<0.05$ compared with the T_0 group



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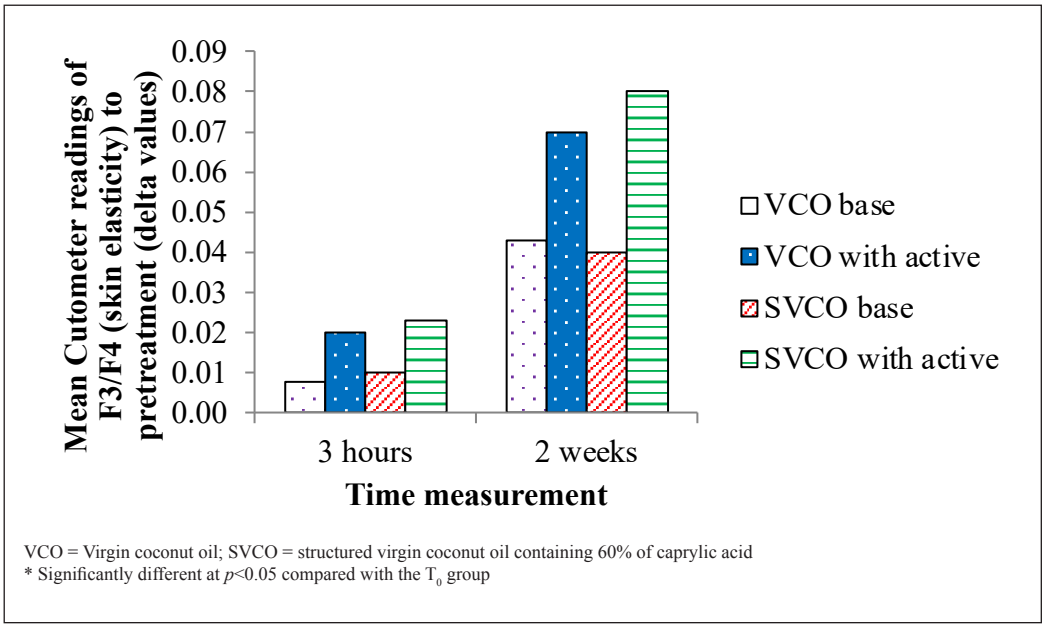
* Significantly different at $p<0.05$ compared with the T_0 group

Fig. 2. Changes in the mean of skin moisture content and transepidermal water loss after application of base and active creams determined by a skin capacitance meter. (Corneometer® MPA 5, Courage & Khazaka, Germany)



VCO = Virgin coconut oil; SVCO = structured virgin coconut oil containing 60% of caprylic acid
* Significantly different at $p<0.05$ compared with the T_0 group

Fig. 3. Mean of cutometer reading of F3/F4 (skin elasticity) determined by cutometer. (MPA 580, Courage & Khazaka, Germany)

and TEWL. It was suggested that even though SVCO and VCO creams are proven to act as skin permeation enhancers, these emollients also gave an emollient effect when applied topically.

Skin topography/microrelief

Values for skin smoothness (SEsm) and skin roughness (SEr) from the Visioscan image analysis and Visioscan images of treated and untreated areas before and after short-term (3h) and long-term (2 weeks) topical application are shown in Table 2 and Figure 4, respectively. These values, which are indicators of the skin condition, significant improvement (paired t-test: p=0.000) in terms of the value, and significant changes (ANOVA, p = 0.000) were observed for all test areas after 3 h of application and on the second week of application. After two weeks of application, significant changes were observed for creams with active compared to the untreated creams.

Natural oils with long-chain fatty acids such as coconut oil, palm oil, olive oil, and sunflower seed oil are commonly used as emollient and moisturizer ingredients in cosmetic formulations or topical pharmaceuticals to treat and prevent skin diseases such as atopic dermatitis (Purnamawati *et al*., 2017; Simon, *et al*., 2018; Danby *et al*., 2020). According to Danby *et al*. 2020, the oleic acid to the linoleic acid ratio in olive oil and sunflower seed oil oils improved skin hydration by accelerating skin barrier repair and development. Emollients affect the skin physiology and histopathology by utilizing many effects on skin barrier function, such as enhancing the eicosanoid level, membrane fluidity, and cell signaling, improving skin repair, and permeability, which act as the skin barrier function that plays a major role for therapeutic benefits.

Emollients mimic the intracellular bilayers of the stratum corneum and can remain on the skin surface or in the SC to act as a lubricant, reduce flaking, and improve skin appearance (Mehta *et al*., 2017; Danby *et al*., 2020; Barnes *et al*., 2021). They help to maintain the desired smooth, soft, and pliable texture of the human skin. The application of emollient to the skin reduces water loss by covering it with a protective film to trap moisture (Purnamawati *et al*., 2017). Some common emollients include essential fatty acids such as linoleic acid, stearic acid, oleic acid, and fatty alcohols and are found in several natural oils or triglycerides including coconut oil. These fatty acids and triglycerides may also influence skin physiology (Kim *et al*., 2007; Lodén & Maibach, 2012; Ahmad & Ahsan, 2020).

CONCLUSION

To summarise, SVCO and natural VCO, are MCTs that exhibited emollient characteristics and skin permeation enhancers when formulated in the formulation. In this study, the performances of related properties of emollients from these MCTs were measured accurately using non-invasive methods. The values measured were skin hydration or skin moisture content, TEWL, skin elasticity, and skin microrelief or skin topography. Although these emollients are fast absorbed in the skin when topically applied on the skin, there was a significant improvement in all evaluated parameters after short-term and long-term topical applications.

Table 2. SELS parameters values of VCO and SVCO base and with active creams determined by Visio Scan® VC98 (Courage & Khazaka, Germany)

Parameter	Cream	Before application (T_0)	3 h after the application (3 h)	2 weeks after the application (2 weeks)
SEsm (µm)	VCO base	59.94 ± 5.69[a]	53.61 ± 2.27[b]	56.30 ± 4.71[c]
	VCO with active	62.24 ± 4.61[a]	56.93 ± 6.59[b]	55.22 ± 6.82[b]
	SVCO base	61.63 ± 5.39[a]	55.22 ± 3.91[b]	57.22 ± 4.87[c]
	SVCO with active	58.00 ± 4.46[a]	54.24 ± 6.55[b]	54.05 ± 4.49[b]
SEr (Skin roughness) (µm)	VCO base	2.18 ± 0.20	1.83 ± 0.26	1.71 ± 0.22
	VCO with active	2.03 ± 0.23	1.57 ± 0.12	1.20 ± 0.50
	SVCO base	2.24 ± 0.31	2.16 ± 0.29	1.60 ± 0.54
	SVCO with active	2.42 ± 0.28	1.98 ± 0.67	1.66 ± 0.29

Data presented as mean values ± standard deviation

VCO = Virgin coconut oil; and SVCO = structured virgin coconut oil containing 60% of caprylic acid

VCO & SVCO base = creams without 5% α-tocopherol; VCO & SVCO with active = creams containing 5% α-tocopherol (with active ingredient)

[a to c] Mean values ± standard deviation, within a column followed by different superscripts are significantly different (p<0.05)

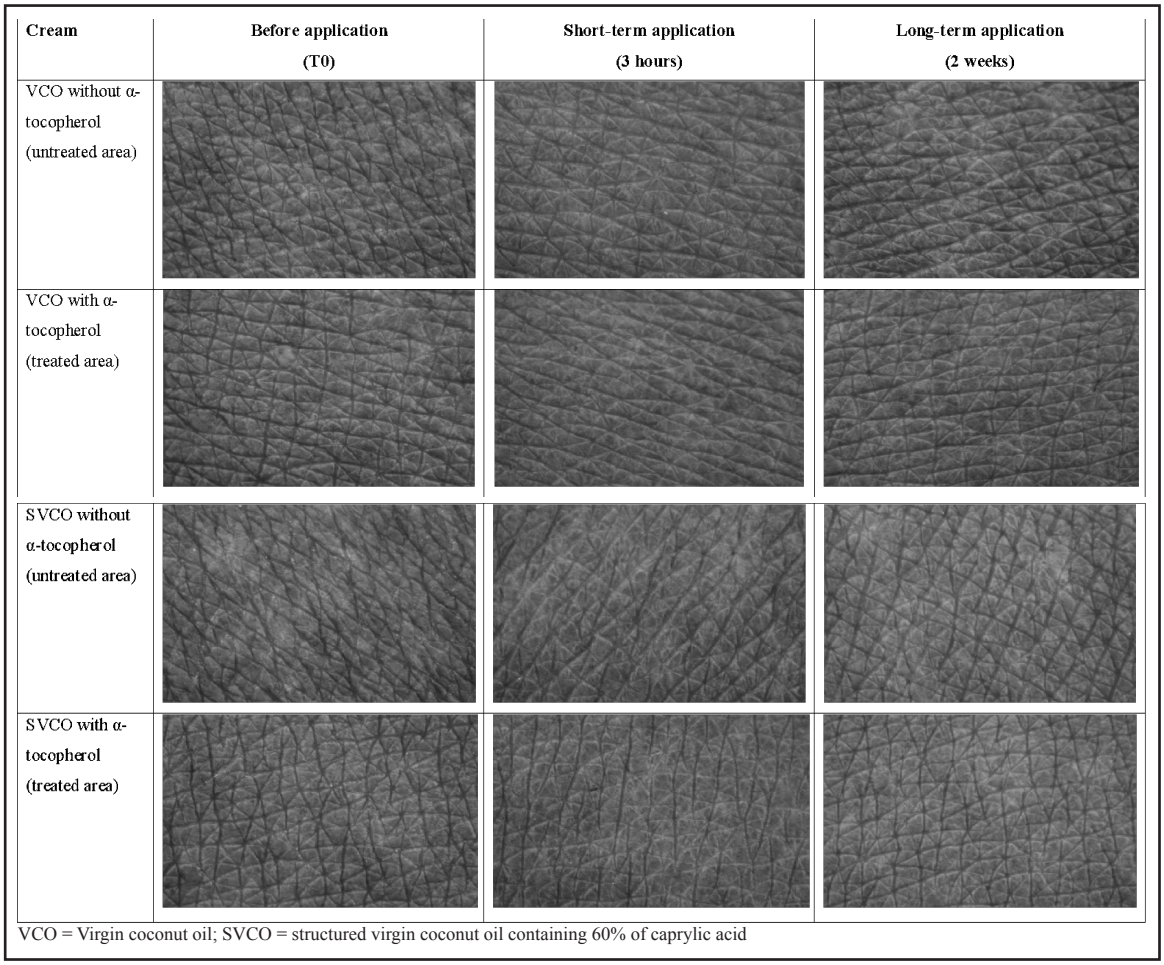


Fig. 4. Visioscan images of treated and untreated areas before and after short term (3 h) and long-term (2 weeks) topical application.

Although the non-invasive skin biophysical measurement methods that involve human subjects are tedious, it gives accurate data. The results of this study provide a better understanding of emollients' role in human skin conditions. These measurements are suited for analyzing the efficacy of topically applied cosmetic or pharmaceutical products on the cellular level. The results will be more reliable when correlated with the instrumental measurements to differentiate the textural properties and especially the actual usage of cream products. Comparison between age groups and gender will also be considered in the future.

In conclusion, VCO and SVCO creams incorporating α-tocopherol that has the potential of improving topical delivery of the lipophilic model antioxidant. These creams also work as good emollients in cosmetic applications.

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ETHICAL STATEMENT

This study was approved by UiTM Research Ethics Committee – Evaluation of Structured Lipids from Virgin Coconut Oil as Emollients in Cosmetics. Reference: 600-RMI (5/1/6/01).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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