NOTE

Moisturizing Effects of Diglycerol Combined with Glycerol on Human Stratum Corneum

Ai Tomiie*, Masami Shinozaki, Takeshi Yamada and Juhei Kuriyama

Sakamoto Yakuhin Kogyo Co., Ltd. Laboratory (3-1-62 Ayumino, Izumi, Osaka 594-1157, JAPAN)

Abstract: The water content of the stratum corneum was measured to investigate the skin-moisturizing property of diglycerol in water and in a lotion. The water content of the stratum corneum, to which the diglycerol solution was applied, was lower than that of the glycerol solution for 8 h. However, skin treated with diglycerol in combination with glycerol solution maintained a higher capacitance level compared with that of glycerol solution alone after 8 h. Moreover, the long-term moisturizing effect of the stratum corneum prominently appeared when diglycerol was formulated to the lotion containing glycerol and 1,3-butylene glycol. These studies suggest that diglycerol in combination with glycerol has a long-term moisturizing effect on human skin.

Key words: diglycerol, glycerol, moisturizing effect, humectant, stratum corneum, capacitance

1 INTRODUCTION

Cosmetic lotions are used to hydrate the skin and demonstrate long-term moisturizing effects. Glycerol and 1,3-butylene glycol, classified as polyols, are widely used in cosmetic lotions. Glycerol has been used as a humectant because it has a high hygroscopicity^{1,2)}. It is known that 1,3-butylene glycol has less moisturizing effects than glycerol, but it is used as a preservative in cosmetic materials^{3,4)}.

In cosmetic formulations, glycerol has been observed to improve skin smoothness^{5,6)} and flexibility⁷⁻⁹⁾ and to show anti-irritant^{10,11)} and desquamation repair effects¹²⁾. These effects result from the increased water content of the stratum corneum.

Bettinger *et al.* reported that 10% glycerol in oil-in-water emulsions significantly increased stratum corneum hydration compared with 10% urea and 10% propylene glycol, as measured by electrical capacitance¹³⁾.

Positive effects of glycerol on the stratum corneum were also revealed using *in vivo* Raman microspectroscopy. Zhang *et al.* reported that glycerol penetrated into the stratum corneum¹⁴⁾. Chrit *et al.* demonstrated that the water content of the stratum corneum increased after the application of a 3% glycerol-containing cream, compared with that of placebo-treated sites¹⁵⁾.

Batt *et al.* showed that glycerol reduced the transepidermal water loss (TEWL) under high humidity conditions^{5,6)}.

These previous studies have considered that glycerol diffuses into and retains water in the stratum corneum^{5,6,16)}. Thus, glycerol is able to reduce the TEWL and increase the water content of the stratum corneum.

Diglycerol, which has a high moisturizing effect on the skin, consists of two molecules of glycerol attached by an ether link¹⁷⁾. It is known that cosmetic lotions containing diglycerol have a reduced rate of water loss compared with cosmetic lotions containing glycerol¹⁸⁾, which suggests that cosmetic lotions containing diglycerol may also retain water in the human stratum corneum.

In this study, using a capacitance meter, we compared diglycerol, glycerol, and 1,3-butylene glycol with respect to the water content of the stratum corneum. In addition, we investigated moisturizing effects of diglycerol in combination with glycerol and 1,3-butylene glycol on the stratum corneum.

2 EXPERIMENTAL

2.1 Materials

Glycerol, diglycerol, and 1,3-butylene glycol (Sakamoto Yakuhin Kogyo Co., Ltd., Osaka, Japan), as well as methyl 4-hydroxybenzoate (Kishida Chemical Co., Ltd., Osaka, Japan) were obtained from commercial sources. All the ma-

*Correspondence to: Ai Tomiie, Sakamoto Yakuhin Kogyo Co., Ltd. Laboratory, 3-1-62 Ayumino, Izumi, Osaka 594-1157, JAPAN
E-mail: tomiie@sy-kogyo.co.jp

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terials were of cosmetic grade with no further purification.

2.2 Preparation of test samples

2.2.1 Polyol solutions

The polyol solutions contained the following components (wt%): a polyol, 10.00; methyl 4-hydroxybenzoate, 0.18; and ion-exchanged water, 89.82. The polyols were diglycerol, glycerol, and 1,3-butylene glycol.

2.2.2 Lotion models

Lotion A contained the following components (wt%): 1,3-butylene glycol, 5.00; glycerol, 13.00; methyl 4-hydroxybenzoate, 0.16; and ion-exchanged water, 81.84. Lotion B contained the following components (wt%): 1,3-butylene glycol, 5.00; glycerol, 10.00; diglycerol, 3.00; methyl 4-hydroxybenzoate, 0.16; and ion-exchanged water, 81.84.

2.3 Methods

The water content of the stratum corneum was measured using a Corneometer CM825 (Courage + Khazaka Electronic GmbH, Cologne, Germany). The Corneometer was used to register the electrical capacitance of the skin surface, which depends on the water content in the stratum corneum. The results of measurements are given in arbitrary units (a.u.), ranging from 0 to 120 a.u. A higher capacitance value indicates a higher moisturizing effect on the skin^{19, 20}.

One healthy Japanese woman (aged 25 years) participated in this double-blind randomized study. Informed consent was obtained from the participant prior to the experiments. We conducted a double-blind randomized study. To perform measurements, both forearms of a participant were washed with soap, rinsed with water, and wiped with a paper towel. Then, the participant acclimated their skin in an environmentally controlled room at 23°C and 50% relative humidity (RH) for 10 min. On each inner forearm two or three areas of 4 × 4 cm were marked, giving a total of five marked areas. Untreated test sites were measured to serve as baseline values.

Test samples were applied to a test site at 0.03 g/area for 40 s. Capacitance of the test sites was measured at 3 min, 10 min, 30 min, 1 h, 2 h, and 8 h after the application of test samples. The degree of skin hydration was defined as a change in capacitance values (Δ capacitance) measured at test sites before and after the application of test formulations. The site of application was rotated so that each test sample is equally applied on all test sites. Moreover, measurements were conducted five times in each area, making it a total of 25 measurements for each test sample.

2.4 Statistical Analysis

All results are expressed as the mean $\pm$ standard deviation ($n = 25$). Statistical significance between different samples was determined using the Student's *t*-test for un-

paired observations and was set at $p < 0.05$ at each time point.

3 RESULTS

3.1 Water content of the stratum corneum treated with polyol solutions

Figure 1 shows the water content of the stratum corneum treated with water or the 10% aqueous solution of each polyol sample over an 8-h period. At 3 min after the application, the Δ capacitance value of the skin treated with water was 11.4 a.u. The Δ capacitance values of the skin treated with the glycerol, diglycerol, and 1,3-butylene glycol solutions were 40, 35.3, and 39 a.u., respectively. Skin treated with the polyol solutions showed a higher water content of the stratum corneum compared with skin treated with water after 3 min. At 8 h after the application, the Δ capacitance value of the skin treated with water decreased to 5.2 a.u., which was almost equal to the pretreatment value. The Δ capacitance value of the skin treated with 1,3-butylene glycol solution was 5.7 a.u. and was comparable to that of the skin treated with water. The Δ capacitance values of the skin treated with the glycerol and diglycerol solutions were 24.9 and 20.8 a.u., respectively. The treatments with the glycerol and diglycerol solutions resulted in significantly higher water contents as compared to the treatment with water after 8 h. The water content of the stratum corneum treated with the diglycerol solution was lower than that of the stratum corneum treated with the glycerol solution at all time points.

Fig. 1 Changes in the water content of the stratum corneum with time after treatment with 10% polyol solutions. The data points and error bars correspond to the mean and standard deviation ($n = 25$), respectively. Different letters show the statistical significant differences ($p < 0.05$) using the Student's *t*-test.

Fig. 2 Changes in the water content of the stratum corneum with time after the treatment with glycerol and diglycerol solutions. ◆, Test area was treated with a 10% glycerol solution; ○, Test area was treated with 7% glycerol and 3% diglycerol solution. The data points and error bars correspond to the mean and standard deviation ($n=25$), respectively. *Statistical difference ($p<0.05$) as compared to 10% glycerol solution using the Student's t -test.

Figure 2 shows the efficacy over an 8-h period of 3% diglycerol in combination with 7% glycerol for preserving the water content of the stratum corneum. On skin treated during the initial 2-h period, the Δ capacitance values were similar for both samples. However, after 8 h, skin treated with diglycerol in combination with glycerol solution showed significantly higher Δ capacitance values than that treated with glycerol solution alone.

3.2 Water content of the stratum corneum treated with lotion models

Figure 3 shows the water content of the stratum corneum treated with lotions A and B over an 8-h period. There were no significant differences in the water content of the stratum corneum at 3 min after the application of either lotion. A significant difference was observed at 1 h after the application. The Δ capacitance values of the skin treated with lotion A, which were obtained after 1, 2, and 8 h, were 30.5, 27.1, and 21 a.u., respectively. In contrast, the Δ capacitance values of the skin treated with lotion B, which were obtained after 1, 2, and 8 h, were 34.1, 30.8, and 25 a.u., respectively.

4 DISCUSSION

Skin treated for 8 h with the diglycerol solution showed lower Δ capacitance values than skin treated with the gly-

Fig. 3 Changes in the water content of the stratum corneum after treatment with two lotions. ◆, Test area was treated with lotion A containing 13% glycerol and 5% 1,3-butylene glycol; ○, Test area was treated with lotion B containing 10% glycerol, 5% 1,3-butylene glycol, and 3% diglycerol. The data points and error bar correspond to the mean and standard deviation ($n=25$), respectively. *Statistical difference ($p<0.05$) as compared to lotion A using the Student's t -test.

erol solution. It is known that the moisturizing effect of a humectant is associated with its hygroscopicity. A previous study compared the hygroscopicities of glycerol and diglycerol, measured as the percentage of water at equilibrium at 20°C and 40%–80% RH. The amount of sorbed water in diglycerol was shown to be two-thirds of that in glycerol²¹. It has been suggested that diglycerol provides less water to the stratum corneum than glycerol. Thus, the skin treated with the diglycerol solution had a lower Δ capacitance value than that of the skin treated with the glycerol solution due to the lower hygroscopicity of diglycerol in the stratum corneum. However, the use of diglycerol in combination with the glycerol solution maintained a higher moisturizing effect. In a previous study, the moisturizing effect of diglycerol and glycerol mixtures was confirmed *in vitro*²². Moreover, diglycerol in cosmetic lotions has a reduced rate of water loss compared with that in cosmetic lotions containing glycerol¹⁸. These facts suggest that glycerol provides water to the stratum corneum, whereas diglycerol causes water retention in the stratum corneum. Thus, the concomitant use of glycerol with diglycerol appears to enhance long-term moisturizing effect.

The skin treated with the 1,3-butylene glycol solution initially showed a high Δ capacitance value. However, the Δ capacitance values decreased rapidly. This observation suggests that the lotion containing glycerol and 1,3-butylene glycol is easy to release water from the stratum corneum. The lotion with diglycerol left a higher water

content in the stratum corneum than the lotion without diglycerol. This result suggested that the lotion containing diglycerol showed a synergistic moisturizing effect with glycerol to retain water in the stratum corneum despite the existence of 1,3-butylene glycol.

5 CONCLUSION

We evaluated the effect of diglycerol on human stratum corneum. As shown in this study, diglycerol is effective for water retention on the human stratum corneum when combined with glycerol. Glycerol has been widely used in cosmetic products. Thus, it is expected that diglycerol can be widely used for a wide range of cosmetic products.

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