Development of Novel Multifunctional Cosmetic Raw Materials and Their Applications. I. Characterization of a Random Copolymer of Polyoxyethylene / Polyoxypropylene Dimethyl Ether†

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Abstract: In this study, we developed novel multifunctional raw materials, polyoxyethylene/polyoxypropylene dimethyl ether (EPDME). EPDME is a random copolymer of ethylene oxide and propylene oxide. The structure of the obtained EPDME was confirmed by Infrared (IR) absorption and NMR spectra. EPDME, which dissolves in water and oil. The compound has the following effects: [1] a high moisture-retaining effect without sticky feeling, [2] a preventing effect on dry skin, and [3] an improving effect on dry skin by daily application. It was also found that the application of EPDME in combination with glycerol resulted in a synergistic effect on the dry skin. When EPDME was formulated to lipsticks (oily bases), a high moisture-retaining effect was found. EPDME is a useful cosmetic ingredient that can give a good skin care effect in both water-based formula and oil-based formula. As the polarity of EPDME can easily be controlled, it is expected to be applicable for various cosmetics in the near future.

Key words: cosmetic raw material, EPDME, high moisture-retaining effect skin, prevention of dry skin, improvement of dry skin

1 Introduction

Moisturizing is closely related to the preservation of good skin condition. And NMF (natural moisturizing factor) has an important role in the healthy skin (1-3). For this reason, moisturizing skin is one of the major expected functions of cosmetics.

Humectants usually used in cosmetics are polyols (glycerol and 1,3-butane diol), water-soluble polymers (hyaluronic acid, etc.) and botanical extracts (4, 5). However, when polyols (the most frequently used in aqueous-base component in lotions) is added to cosmet-
moisture-retaining effects (10) and highly water-hold-
ing emollient (11-13) have been launched on the mar-
et. Despite these products available on the market, there are still many people who suffer from lip drying. Since lipsticks are oily bases, it is difficult to add hydrophilic moisture-retaining components in large amounts due to their low compatibility with oily com-
ponents, etc. Furthermore, since many humectants have their specific taste, the taste becomes a problem when such agents are added in large amounts to lipsticks. Therefore, it has been desired to develop lipstick bases, which have an excellent moisture-retaining effect.

We recently found that dimethyl ether of random copolymer of ethylene oxide and propylene oxide (EPDME) can solve the problems described above.

This paper presents the characteristics of EPDME, which can exert excellent skin-caring effects (moisture retention, prevention and improvement of dry skin, etc.) when added to not only aqueous but also oily bases.

2 Experimental

2.1 Materials

EPDME used in this study was synthesized as fol-
1ows. Propylene glycol and potassium hydroxide as a
catalyst were placed in an autoclave. After the air in the
autoclave was replaced with dry nitrogen, the catalyst
was completely dissolved at 140°C while stirring. Then,
a mixture of ethylene oxide and propylene oxide was
added drop wise thereto by a dropping apparatus and
stirred for 2 h. Thereafter, potassium hydroxide was
placed therein. After the atmosphere in the system
was replaced with dry nitrogen, methyl chloride was poured
thereto under a pressure at a temperature of 80-130°C to
react for 5 h. The reaction mixture was taken out from
the autoclave, neutralized with hydrochloric acid to pH
6-7, and treated at 100°C for 1 h under a reduced pres-
sure-0.095 Mpa (50 mmHg) in order to remove the con-
tained moisture. Further, in order to remove the salt
produced after treatment, filtration was performed to
obtain the alkylene oxide derivative of Fig. 1.

The structure of the obtained EPDME described
above was analyzed by Infrared (IR) absorption and
NMR spectra. IR spectrum was measured on a Magna
560 spectrometer (Thermo Electron, Yokohama, Japan).
NMR experiments were performed on a JEOL JNM
ECP-400 spectrometer (JEOL, Tokyo) operating at
395.88MHz for 1H and 99.00 MHz for 13C, equipped
with a 5 mm diameter probe. Dueterium oxide (99.9
atom % D) and Chloroform-d (minimum 99.96 atom %
D) were purchased from Sigma-Aldrich Japan co.,
LTD., Tokyo, Japan. The chemical shifts were expres-
sed with respect to 3-(Trimethylsilyl) propionic
2, 2, 3, 3-d4 acid, sodium salt (TSP, (δ = 0.00) as an
internal reference for 1H NMR and 1,4-Dioxane (δ =
67.40) as an external reference for 13C NMR.

The molecular weight of EPDME (14/7) was calcu-
lated using the hydroxyl value of the intermediate
which was obtained after the additional reaction with
ethylene and propylene oxide before methyl ethyl reac-
tion. The molecular weight was calculated by the fol-
lowing equation.

Molecular weight = 56.1 × 2/(hydroxyl value) ×
1000

The hydroxyl value of the intermediate EPDME
(14/7) before methyl ether reaction was 106.6, and then,
the molecular weight was calculated to be 1053. The
intermediate obtained dimethyl ether (MW:28), and
eventually the molecular weight of EPDME (14/7) was
calculated to be 1081.

Figure 1 shows the basic structure of EPDME used
in this study. The m/n ratio is variable. EPDME (14/7),
shown as (a) of Fig. 1, was used for aqueous bases.
EPDME (36/41), shown as (b), was used for oily bases.
Both were synthesized and purified before added to
base.

\[
\text{CH}_3\text{O-(CH}_2\text{CH}_2\text{O)}_m/(\text{CHCH}_2\text{O)}_n-\text{CH}_3
\]

\[
\text{CH}_3\text{O-(CH}_2\text{CH}_2\text{O)}_m/(\text{CHCH}_2\text{O)}_n-\text{CH}_3
\]

\[
\text{CH}_3\text{O-(CH}_2\text{CH}_2\text{O)}_m/(\text{CHCH}_2\text{O)}_n-\text{CH}_3
\]

Fig. 1 Molecular Structure of Polyoxyethylene/Polyoxy-
propylene Dimethyl Ether (EPDME). Two different
kind of EPDME were used in this study, (a) polyoxy-
ethylene (the number of molecules : 14)/polyoxy-
propylene (7) dimethyl ether (EPDME (14/7))
and (b) polyoxyethylene (36)/polyoxypropylene (41)
dimethyl ether (EPDME (36/41)). EPDME (m/n),
where m and n represent the average molecular ratio
of ethylene oxide and propylene oxide. EPDME is a
random copolymer of ethylene and propylene oxide.
In addition, a commercially available glycerol (Sakamoto Yakuhin Kogyo, Osaka, Japan), 1,3-butane diol (Daicel Chemical Industries, Osaka), and 2-cetyl ethylhexanoate (Nikko Chemicals, Tokyo) were used without further purification.

2.2 The Solubility of EPDME

The solubility of EPDME (14/7) and EPDME (36/41) in various solvents was examined and compared with glycerol. At 24°C, each sample was added in concentrations of 1%, 30%, and 50% to various solvents, and the solubility was evaluated 1 h later by naked eye.

2.3 The Equilibrium Moisture Content of EPDME

At 24°C and a relative humidity (RH) of 92%, EPDME (14/7), EPDME (36/41), glycerol (a humectant), and 2-cetyl ethylhexanoate (an oily component) were left standing until equilibrium (192 h). The moisture absorption of each sample (weight of water contained in 1 mol of each sample) was evaluated.

2.4 The Surface Tension of EPDME

Surface tension of EPDME (14/7) and EPDME (36/41) were measured by Wilhelmy method using a Dynamic Contact Angle Meter and Tensiometer 21 (DataPhysics Instrument, Filderstadt, Germany). All aqueous solutions were immersed in a constant temperature water bath of 25°C for 2 h before measuring the surface tensiometer. Critical micellization concentration (CMC) was determined from the break points of the surface tension curves.

2.5 The Sticky Feeling by Rolling Friction Measurement

The adhesive property of EPDME (14/7), glycerol, and 1,3-butane diol were evaluated by a modified friction tester equipped with a roller probe (14). At 25°C and 50% RH, each sample (10 μL) was dropped onto the tester, and the 5-min mean friction was measured.

2.6 The Moisture Retention Property of EPDME

The moisture retention property of sample was evaluated by 8 healthy volunteers. The inner forearm of panels was washed with soap, followed by the application of 10% aqueous solution of each sample (the final dose: 2 μL/cm²) at 24°C and 46%RH. Two hours later, the moisture content in the stratum corneum of the sample-applied area was measured by a stratum corneum hydrometer, Corneometer CM825 (C+K Electric, Koln, Germany) (15).

2.7 Efficacy of EPDME for Experimental Dry Skin

For evaluating the effect of the test substance on the dry skin induced artificially with sodium dodecyl sulfate (SDS), 100 μL of 5% SDS was applied to the inner forearm of healthy volunteer (n = 9) for 10 min (16-20). The applied site was washed with water, and then the sample was applied in appropriate amounts. This treatment was repeated for 5 days. On the 6th day, the sample-applied area was washed with soap, and the physiological parameters of skin were evaluated 20 min later. The water content of stratum corneum was measured by Corneometer CM825. The trans-epidermal water loss (TEWL) was measured by a special instrument for TEWL, Tewameter TM210 (C+K Electronic) (21).

2.8 The Glycerol Permeation through the Stratum Corneum

The inner forearm of healthy volunteer (n = 4) was washed with soap. Then, either 10% glycerol or 10% glycerol with 5% EPDME (14/7) was applied to the skin (the final dose: 1 mL/cm²). Four hours later, the solution-applied area was washed, and the stratum corneum was collected by tape stripping procedure. Glycerol was extracted with 10 mL water, and the amount of the glycerol was measured by HPLC with a pulse type electrochemical detector, Nanospace Pulsed Amperometric Detector 3016 (Shiseido, Tokyo).

2.9 Confirmation of the Efficacy of Lotion Contain EPDME in Winter

Males with dry skin (n = 20) in winter (March to April 2002 in Yokohama) used a lotion containing 3% EPDME (14/7) with 7% glycerol or a lotion containing 7% glycerol once or more times a day (in morning and/or evening) for 4 weeks. Each panel applied one of these two cosmetics to the half of his face and the other cosmetic to the other half of his face. Four weeks later, the water content in the stratum corneum and TEWL were measured at 24°C and 46% RH by Corneometer CM825 and Tewameter TM210, respectively. The skin surface morphology was evaluated by two-dimensional image analysis of the skin replica prepared with sili-
cone rubber. As parameters of skin texture, the anisotropy of skin furrows (VC1) and the average of skin roughness (KSD) were evaluated (22-25). During the test period, panels were forbidden to use any other cosmetics to their face.

2.10 The Lip Moisture Retention of EPDME

At 25°C with 50% RH, the lip of healthy volunteers (n = 8) was washed with water, and then lipsticks containing with and without 5% EPDME (36/41) were applied to the left and the right half of the lip, respectively. Two hours later, the lipstick was wiped off by tissue papers from the lip, and the conductance was measured with a stratum corneum hydrometer, SKICON-200 (IBS, Shizuoka, Japan) (26, 27).

2.11 Confirmation of the Efficacy of EPDME for Lip

Twenty females with dry lip skin were divided into two groups (10 each). The former and the latter groups used a lipstick containing with and without 5% EPDME (36/41) lipstick three times a day for 2 weeks (June 2002 in Yokohama), respectively. Then, the improvement of dryness of the lips was evaluated through measuring the moisture content in a stratum corneum by SKICON-200 and photographs.

3 Result

3.1 Characterization and Estimation of the Molar Ratio (N_{EO}/N_{PO}) of EPDME

The result of the structural analysis of EPDME (14/7) was shown below. IR, ¹H NMR, and ¹³C NMR spectra of EPDME (14/7) are used to calculate the ratio of ethylene oxide (EO) and propylene oxide (PO) random copolymer of EPDME (14/7) (Fig. 2, 3, and 4). These spectra data of EPDME (14/7) are as follows.

EPDME (14/7): IR (neat, cm⁻¹): 2970 (v C-CH₃), 2870 (v-CH₂), 1113 (v C-O-C ether). ¹H NMR (D₂O, TSP) δ: 1.13-1.16 (22.39H, -CH(CH₃)C₂H₅O-, PO), 3.37 (6.00H, s, -OCH₃, terminal methyl), 3.40-4.07 (82.15H, -CH₂CH₂O-, EO and -CH(CH₃)CH₂O-, PO). ¹³C NMR (D₂O, Dioxane) δ: 15.8 (-OCH₂CH(CH₃)-OCH₃, PO), 16.4-16.8 (-OCH₂CH(CH₃)-OCH₃, PO), 56.5 (-OCH₂CH(CH₃)-OCH₃, terminal methyl), 58.9 (-OCH₂CH₂-OCH₃, terminal methyl), 59.2 (-OCH₂CH₂(OH)-OCH₃, terminal methyl), 68.2 (-OCH₂CH₂(OH)-OCH₃, terminal methyl), 70.3-73.0 (-CH₂CH₂O-, EO), 74.9 (-OCH(CH₃)CH₂-, PO), 75.5-76.2 (-OCH₂CH₂-PO), 76.3 (-OCH₂CH₂-OCH₃, PO), 76.7-77.0 (-OCH₂CH₂OCH₃).

![Fig. 2 Infrared Spectrum of EPDME (14/7).](image)

![Fig. 3 ¹H NMR Spectrum (400 MHz, D₂O) of EPDME (14/7).](image)

![Fig. 4 ¹³C NMR Spectrum (100 MHz, D₂O) of EPDME (14/7). (a) complete decoupling. (b) DEPT (θ = 135 degree).](image)
The molar ratio \((N_{EO}/N_{PO})\) of EPDME (14/7) was estimated based on the relative intensities of the \(^1\)H NMR signals [the total number of methylene protons in ethylene oxide moiety (4 protons) and the total number of methyn and methylene protons in propylene oxide moiety (3 protons)]. It is calculated on formulae shown in below.

\[
N_{PO} = I_1/3 = 22.39/3 = 7.46
\]
\[
N_{EO} = (I_2-N_{PO} \times 3)/4 = (82.15-7.46 \times 3)/4 = 14.94
\]
\[
(N_{EO}/N_{PO}) = 14.94/7.46 = 2.00
\]

where \(N_{EO}\) is the total number of ethylene oxide moiety per EPDME (14/7) molecule and \(N_{PO}\) is the total number of propylene oxide moiety per EPDME (14/7) molecule.

Consequently, as the conclusion concerning molar ratio \((N_{EO}/N_{PO})\), it was confirmed assumed that EPDME (14/7) has been synthesized according to its designed structure.

3.2 The Solubility of EPDME

Glycerol, which serves as a standard humectant, is soluble in water and insoluble in oil.

On the other hand, EPDME was found to be soluble in both water and oil (Table 1).

3.3 The Equilibrium Moisture Content of EPDME

Figure 5 shows the moisture absorption (g/mol) of EPDME compared with glycerol or emollient oil. The higher value indicates that the capacity to retain moisture becomes greater. The oily component 2-cetyl ethylhexanoate showed hardly any moisture-retaining capacity, while EPDME (14/7) and EPDME (36/41) showed a higher moisture-retaining capacity than that of glycerol.

3.4 The Surface Tension of EPDME

Figure 6 shows the surface tension data of EPDME (14/7) and EPDME (36/41). Although EPDME showed a surface tension reducing ability, no break point corresponding to CMC were found with increasing in concentration. The result indicated that EPDME (14/7) and EPDME (36/41) have a little surface activity.

3.5 The Sticky Feeling by Rolling Friction Measurement

Figure 7 shows the rolling friction data of EPDME compared with the other humectants. It is known that, if the rolling friction of a cosmetic becomes lower, the cosmetic gives less sticky feeling. EPDME (14/7) was significantly less adhesive than glycerol. The adhesion property of EPDME (14/7) was comparable to that of 1,3-butane diol which is one of the widely used humectants with good texture.

3.6 The Moisture Retention Property of EPDME

Figure 8 shows the moisture content of the stratum corneum after 2 h application of 10% aqueous solution of each sample. Higher moisture content of the stratum corneum shows higher moisture-retaining effects to the skin. Moisture-retaining effects of aqueous EPDME (14/7) solution were significantly higher.

<table>
<thead>
<tr>
<th>Solvent</th>
<th>EPDME (14/7) (%)</th>
<th>EPDME (36/41) (%)</th>
<th>Glycerol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Methylphenyl polysiloxane</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Macadamia nut oil</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Glyceryl trioctanoate</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Water</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

S : soluble I : insoluble EPDME (14/7), EPDME (36/41), and glycerol were solubilized at 24°C, then each stood for 1 h at 24°C. a) polyoxyethylene (the number of molecules : 14)/polyoxypropylene (7) dimethyl polyoxyethylene (36)/polyoxypropylene (41) dimethyl ether.
than that of aqueous 1,3-butane diol solution, and was comparable to that of aqueous glycerol solution (known to have high moisture-retaining effects of the skin).

3.7 Efficacy of EPDME for Experimental Dry Skin

Figure 9 (A) shows the evaluation of efficacy of EPDME for experimentally induced dry skin based on the moisture contents of the stratum corneum. Greater moisture contents show more effective prevention of skin drying. Comparing with the SDS-treated skin areas (the control), the skin areas treated with EPDME (14/7) showed significantly higher moisture contents in the stratum corneum, indicating that EPDME (14/7) prevented the SDS-induced skin drying. It was also demonstrated that the effect on preventing skin drying

Fig. 5 The Moisture Absorption (g/mol) of Glycerol, 2-Cetyl Ethylhexanoate, EPDME (14/7), and EPDME (36/41). The y-axis shows the moisture absorption which indicates the weight of water held by 1 mol of each compound.

Fig. 6 Surface Tension vs. Concentration Curves of EPDME (14/7) and EPDME (36/41). The closed diamond mark (●) and square (■) represent EPDME (14/7) and EPDME (36/41), respectively.

Fig. 7 Adhesive Property of Glycerol, 1,3-Butane Diol, and EPDME (14/7) by Rolling Friction Measurement. The column and bar show the mean and the standard deviation (n = 5), respectively. The y-axis shows the friction force that indicates the stickness of the sample. * : p<0.05, n.s. : not significant (Tukey-Kramer test).

Fig. 8 Electrical Capacitance of Glycerol, 1,3-Butane Diol and EPDME (14/7) as a Measure of Moisture Retention Property. The column and bar show the mean and the standard deviation (n = 8), respectively. The y-axis shows the electrical capacitance which indicates the moisture contents in stratum corneum. * : p<0.05, n.s. : not significant (Tukey-Kramer test).
3.8 The Glycerol Permeation through the Stratum Corneum

Figure 10 shows the quantity of glycerol permeation across the stratum corneum. The use of EPDME (14/7) in combination with glycerol resulted in approximately 40% increase in glycerol contents in the stratum corneum, as compared to the only glycerol applied group. This result indicates that EPDME (14/7) allows more facilitate the permeation of glycerol across the stratum corneum.

3.9 Confirmation of the Efficacy of a Lotion Containing EPDME

Higher moisture contents in the stratum corneum indicate higher improvement of skin drying. Lower TEWL indicates higher barrier function. Lower VC1 or higher KSD indicates better improvement in the facial skin surface texture.

As shown in Table 2, the use of the lotion composed of EPDME (14/7) and glycerol for 4 weeks resulted in significant improvements in the moisture contents of the stratum corneum and TEWL, as compared to their baseline levels before use. The skin surface morphology was also improved significantly. These results suggest that the daily use of the lotion composed of EPDME (14/7) and glycerol can significantly improve dry skin.

Table 3 compares the results of the lotion containing EPDME (14/7) with the lotion containing only glycerol. The lotion composed of EPDME (14/7) and glycerol was found to improve moisture contents in the stratum corneum and TEWL significantly. Although the change in the facial skin texture was very similar in both...
Table 2  Effect of Daily Use of the Lotion EPDME (14/7) with Glycerol on Improvement of Dry Skin.

<table>
<thead>
<tr>
<th>Examination item</th>
<th>Before treatment Mean ± S.D.</th>
<th>After treatment Mean ± S.D.</th>
<th>paired t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical capacitance</td>
<td>33.76 ± 11.83</td>
<td>44.88 ± 13.27</td>
<td>*</td>
</tr>
<tr>
<td>TEWL</td>
<td>0.508 ± 0.154</td>
<td>18.24 ± 4.80</td>
<td>*</td>
</tr>
<tr>
<td>VC1</td>
<td>0.508 ± 0.154</td>
<td>0.412 ± 0.106</td>
<td>*</td>
</tr>
<tr>
<td>KSD</td>
<td>29.95 ± 6.53</td>
<td>33.94 ± 4.47</td>
<td>*</td>
</tr>
</tbody>
</table>

VC1 : Variation coefficient of number of black dots in each of 13 × 13 meshes composing binary image.  KSD : Standard deviation of gray level value at each pixel TV image.  * : p < 0.05.

Table 3  Effect of the Lotion EPDME (14/7) with Glycerol on Improvement of Dry Skin.

<table>
<thead>
<tr>
<th>Examination item</th>
<th>Glycerol only group Mean ± S.D.</th>
<th>Containing EPDME (14/7) and glycerol group Mean ± S.D.</th>
<th>paired t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Electrical capacitance</td>
<td>3.25 ± 10.05</td>
<td>9.86 ± 11.12</td>
<td>*</td>
</tr>
<tr>
<td>Δ TEWL</td>
<td>2.64 ± 5.23</td>
<td>−5.54 ± 4.90</td>
<td>*</td>
</tr>
<tr>
<td>Δ VC1</td>
<td>−0.0495 ± 0.228</td>
<td>−0.0965 ± 0.146</td>
<td>n.s.</td>
</tr>
<tr>
<td>Δ KS</td>
<td>0.463 ± 8.15</td>
<td>3.988 ± 6.98</td>
<td>+</td>
</tr>
</tbody>
</table>

VC1 : Variation coefficient of number of black dots in each of 13 × 13 meshes composing binary image.  KSD : Standard deviation of gray level value at each pixel TV image.  Mean value of each parameter indicates the difference between the post-treatment and pre-treatment periods.  * : p < 0.05  + : p ≥ 0.1  n.s. : not significant.

Fig. 11  Effect of EPDME (36/41) on Lip Moisturizing. The column and bar show the mean and the standard deviation (n = 8), respectively. The y-axis shows the conductance difference between the values before and after the treatment.  * : p<0.05 (paired t-test).

Fig. 12  Result of Panel Test Using a Lipsticks Containing EPDME (36/41) for 2 Weeks. The number of panels was 10. The closed diamond mark (◆) and the bar show the mean and the standard deviation of the conductance of lips.  * : p<0.05 (Dunnett’s test).
Development of Novel Multifunctional Cosmetic Raw Materials and Their Applications. I.

lotions, the average of skin roughness (KSD) tended to increase in the EPDME (14/7) with glycerol applied group.

3.10 The Lip Moisture Retention of EPDME

Figure 11 shows the moisture contents in the stratum corneum of lips. Higher values indicate higher moisture-retaining effects. Lipsticks containing EPDME (36/41) showed to have significantly greater moisture-retaining effects than lipsticks without EPDME (36/41).

3.11 Confirmation of the Efficacy of EPDME for Lip

Figure 12 shows the effect of EPDME (36/41) on the change of the moisture contents in the stratum corneum of the lip after two-week daily application. Figure 13 shows the actual photographs of the lip before and after use of the lipstick. The use of the lipstick containing EPDME (36/41) resulted in significantly higher moisture contents in the stratum corneum than that of the lipstick without EPDME (36/41). This relation resembled to the relationship shown in Fig. 11. The pictures shown in Fig. 13 also indicate that the dry skin was improved by daily use of this lipstick.

4 Discussion

It is difficult to develop cosmetic raw materials that can be used in products including both aqueous and oily bases without troubles. When EPDME was formulated in lotions, it gives less sticky feeling, while it exerted high efficacy to skin (e.g., high moisture-retaining effect, prevention of dry skin, and significant improvement of dry skin by daily application). Furthermore, since EPDME is well soluble in oil, it can be used in lipsticks, which are composed of oily bases. Lipsticks containing EPDME showed high moisture-retaining effects and allowed dry lips to obtain healthy condition markedly by daily application. Furthermore, unlike conventional humectants, EPDME caused no problem related to taste even when it was added in large amounts. EPDME is composed of random copolymer of ethylene oxide and propylene oxide. Both EPDME (14/7) with a molecular weight of approximately 1,000 and EPDME (36/41) with a molecular weight of approximately 4,000 keep a liquid form even at a temperature of -5°C, and are thus easy to handle. Regarding the solubility in various solvents, Table 1 shows that hydrophilic humectants such as glycerol are insoluble in oil, but EPDME is highly soluble in both water and oils, since it possesses both hydrophilic and lipophilic groups in its molecular structure. When the solubility in water was compared between EPDME (14/7) and EPDME (36/41), it was possible to prepare a 50% aqueous solution of EPDME (14/7) but impossible to prepare a 50% aqueous solution of EPDME (36/41). This is probably because the lipophilicity of EPDME (36/41) is higher than EPDME (14/7) due to the high ratio of propylene oxide to ethylene oxide.

Regarding the effects of EPDME, the data on equilibrium moisture content shown in Fig. 5 suggest that EPDME exerts a high skin moisture-retaining effect comparable to that of glycerol. As shown in Fig. 10, the use of glycerol in combination with EPDME (14/7) resulted in approximately 40% increase of glycerol permeation through the stratum corneum, probably leading to high moisture-retaining effects to the skin (28). This mechanism seems to explain the significant prevention and improvement of dry skin demonstrated in Fig. 5, Table 2, and Table 3.

Because glycerol is insoluble in the oily components of lipsticks, it is impossible to add it to directly lipsticks. Therefore, glycerol has been added in the form of W/O emulsion by using low HLB emulsifier (10). Since EPDME (36/41) is highly soluble in the oily
components of lipsticks, it can be added directly to lipsticks (oily bases). EPDME (36/41) thus added to lipsticks showed excellent effects to the lip.

5 Conclusion

EPDME has shown the following effects: [1] a high moisture-retaining effect without sticky feeling, [2] a preventing effect on dry skin, and [3] an improving effect on dry skin by daily application. It was also found that the application of EPDME in combination with glycerol resulted in a synergistic effect to the dry skin.

When EPDME was formulated to lipsticks (oily bases), a high moisture-retaining effect was found, and daily application of this lipstick improved the lip. These results indicate that the moisture-retaining effects of EPDME can be exerted even when it is added to oily bases such as lipsticks.

As shown in this study, EPDME is easy to handle and shows the skin-care effects either in aqueous base or oily base. This is, therefore, a very useful raw material of cosmetics.

With controlling its polarity and physical properties, this material will be applicable to a wide range of cosmetic formulation.

References