Study on the occlusivity of oil films

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Synopsis

The OCCLUSIVITY of oils was determined in vivo by measuring the suppression of transepidermal water loss (TEWL) of the skin. Various emollients were applied to human skin in various forms, including powder, solution and emulsion of different types having different size distributions, and the residual states of the OIL FILMS on the skin surface were examined with time. In order to discuss the occlusivity in relation to the individual skin conditions, the surface temperature of the skin and casual lipid level were also determined in each subject. The following are the results obtained from these experiments: 1) the occlusivity of the oil films varied with time, type of oils, their coating amount, physical forms, emulsion type and droplet diameter of the emulsion; and 2) the occlusive effect of oils also depended upon the characteristics of the skin such as casual lipid level and TEWL. These results could be explained by the differences in uniformity, spreadability and porosity of the oil films on the skin surface in the residual state. It is believed that the emolliency of the oil can be influenced by these differences.

INTRODUCTION

It has been always the aim of cosmetic chemists to maintain the skin's softness and freshness and it is considered important to retain moisture in the stratum corneum (1). Emollients, serving not only as lubricants but also forming occlusive films on the skin which retard the water loss from the stratum corneum, render the skin supple and flexible. In this respect, therefore, the emollients have been often termed "occlusive moisturizers" (2). A large number of works have been reported on the theory and measurement of the resistance to water vapor loss of the layer of emollients (3-7). Although their experimental conditions and interpretation of the results differ, it is generally observed that hydrocarbons such as petrolatum strongly inhibit water loss whereas synthetic esters with branched chain tend to transmit water through because of their porosity (8).

Unfortunately, there have not been many previous published reports on the effect of the differences in the states of occlusive films on emolliency. Since the occlusivity of the oil is believed to depend greatly on its state on the skin surface, the present study was undertaken to investigate the relation between the residual state of the oil on the skin surface and its occlusive effect. In order to vary the adhering state of oil films, oils
were applied to the skin directly in their neat form and also in the form of their chloroform solution or emulsion. Various emulsions were examined by changing the types of emulsion and particle size distributions. The occlusivity was then examined with these different types of oil samples. The present paper discusses the desirable state of oil films and suitable physical forms of oils for the application from the standpoint of skin care.

**EXPERIMENTAL**

**MATERIALS**

Solid paraffin with a melting point of 48°C, petrolatum, and liquid paraffin obtained from Wako Pure Chemical Industries, Ltd., were used as oil ingredients; they were of pure grade. Various forms of samples including neat, solution, and emulsion of these oils were prepared. Liquid paraffin with or without 5% of polyoxyethylene stearyl ether was used as neat samples. Solid paraffin with or without 5% of polyoxyethylene stearyl ether was ground into a powder form and employed as neat samples of solid paraffin. The solutions of these oils were prepared by dissolving them in chloroform of extra-pure grade. Oil-in-water emulsions of liquid paraffin and solid paraffin were prepared and stabilized with 5% of polyoxyethylene stearyl ether. O/W type emulsions of these oils having a different particle size distribution were also prepared using a different ratio of emulsifier mixtures of polyoxyethylene (20) sorbitan monooleate and sorbitan monooleate. Using 5% of sorbitan sesqui-oleate, a w/o type emulsion of liquid paraffin was prepared and used. All of the emulsifiers used were commercial materials of Kao Atlas Co. A Coulter Counter (Model TA-II, Coulter Electronics Inc.) was used to determine the particle size distribution of o/w type emulsions and their mean droplet diameter was calculated.

The subjects used for this experiment were 32 healthy human males and females ranging in age between 18 and 31.

**PROCEDURE**

*Measurement of TEWL*

Samples containing 4.5 to 5.4 mg of oil ingredient to be examined were applied with a microsyringe to a 1.5 cm × 1.5 cm area of the inner surface of the forearm in each subject. Each sample was spread to form its film with the microsyringe in a certain manner without rubbing. TEWL of the treated skin of the individual subjects was measured intermittently for 2 hr after the application of the samples using an electronic hygrometer, Evaporimeter EP-I (Servo Med in Sweden) equipped with a sensor having a diameter of 10 mm, at 21 to 23°C and 35 to 48%RH. TEWL of untreated skin adjacent to the treated skin was also measured as control at the same time. In order to discuss the occlusivity in relation with the individual skin conditions, the skin surface temperature and casual lipid level were also determined on the forearm in each subject using a usual method (9).

*Observation of Oil Film*

The residual state of oils on the skin surface was observed with time using a stereomicroscope (Wild, M-8) after the application of the samples. An additional
observation of the skin was made by preparing a replica of the skin and examining it with a scanning electron microscope (Nihon Denshi Co., JSM-II).

**CALCULATION OF OCCLUSIVITY:**

In order to express the occlusivity of oil films as a measure of a resistance to water loss, the occlusivity was defined by the following equation:

\[
\text{Occlusivity} (\%) = \left[ 1 - \left( \frac{\text{TEWL}(1)}{\text{TEWL}(2)} \times \frac{\text{TEWL}(C)}{\text{TEWL}(3)} \right) \right] \times 100
\]  \hspace{1cm} (1)

where;

\(\text{TEWL}(1)\) = TEWL of the treated skin at \(t\) minutes after sample application  
\(\text{TEWL}(2)\) = TEWL of the treated skin before sample application  
\(\text{TEWL}(3)\) = TEWL of the untreated skin at \(t\) minutes after sample application  
\(\text{TEWL}(C)\) = TEWL of the untreated skin before sample application

Since the occlusivity is generally expressed as a suppression of TEWL, it can be given by an equation of \([1 - \text{TEWL}(1)/\text{TEWL}(2)] \times 100\). When the oil layer is a strong barrier to water loss, \(\text{TEWL}(1)\) is zero and the occlusivity becomes 100%. On the other hand, the occlusivity becomes 0% when the oil layer shows no resistance to water loss because \(\text{TEWL}(1)\) and \(\text{TEWL}(2)\) take the same value. However, since \(\text{TEWL}\) of the skin changes with time even though the skin is untreated, it is necessary to correct this change of \(\text{TEWL}\) with time in determining the occlusivity of oil films. A correction term, \(\text{TEWL}(C)/\text{TEWL}(3)\), was therefore added to the equation, as seen in eq. 1.

**RESULTS AND DISCUSSION**

The average value of the casual TEWL level of untreated skin at given test period in 32 subjects ranged between 0.51 and 0.59 mg/cm²/hr. This value was rather higher than that reported by Baker (10). The average skin temperature during the test period was between 31.1 and 32.8°C. Although the \(\text{TEWL}(C)\) value differed largely between subjects, there was no large difference that was observed in the \(\text{TEWL}(C)\) value for individual subjects with time. A correlation between \(\text{TEWL}(C)\) and skin surface temperature was also observed and it generally agreed with the correlation reported by Grice (11). Since a constant value of \(\text{TEWL}(C)\) was observed for individual subjects, it is believed that the evaluation of occlusivity can be done by eq 1 as long as the experimental conditions such as laboratory temperature and site of oil application are kept the same.

Figure 1 shows the effect of coating amount of oils on their occlusivity observed after 15 min and 60 min of the application of their chloroform solutions. As seen from the figure, petrolatum was most effective in inhibiting water loss. The occlusivity of petrolatum and solid paraffin reached to a constant value beyond the coating amount greater than 3 mg/cm², which implied that the calculated minimum thickness of film whose occlusivity is not susceptible to the coating amount was 30 microns for both oils. The occlusivity of liquid paraffin at 15 min after the application increased with the coating amount of the oil; however, the occlusivity at 60 min after the application was shown to be constant beyond the coating amount larger than 2 mg/cm². This was because the liquid paraffin, due to its fluidity, continued its spreading on the skin surface over a period of time and the thickness of the resulting film was nearly the
same beyond 60 min after the application even if the coating amount of the oil increased.

It was found that the physical forms of oils strongly influenced the extent of the occlusivity as shown in Figures 2 and 3. The occlusive effect was most evident immediately after the application and it decreased with time for both liquid paraffin and solid paraffin when applied to the skin in their solution form. Different occlusive patterns attributable to the difference in the nature of oils were observed in the neat and emulsion forms. Solid paraffin in the neat form had no significant occlusive effect at any time, but liquid paraffin in the neat form occluded water as efficiently as liquid paraffin in the solution form. In the case of the emulsion form, the occlusivity immediately after the application of the samples could not be determined because of the evaporation of water contained in the emulsion. It required more than 30 min to
Figure 2. Effect of physical forms of solid paraffin on occlusivity.

Figure 3. Effect of physical forms of liquid paraffin on occlusivity.
evaporate the water completely from the emulsion samples coated on the skin. The occlusivity of solid paraffin in the emulsion form increased markedly with time and exceeded that in the solution form at around 80 to 90 min after the application. On the other hand, the occlusivity of liquid paraffin in the emulsion form initially increased with time but peaked out at around 100 min after the application and then decreased gradually. Since it is possible that the variation of the occlusivity of oil films is caused by the difference in the states of the oil films on the skin surface, the state of oil films was examined. The results of this examination are schematically shown in Figure 4.

When solid paraffin was applied to the skin surface in the neat form, non-continuous oil film was formed as shown in Figure 4. Solid paraffin in the neat form was not, therefore, a barrier to water loss. When solid paraffin was applied in the solution form, however, crystalline solid paraffin was precipitated and a tight solid film was formed upon the evaporation of the solvent. This solid film was an effective barrier to water loss; however, it was so fragile that cracks in the film occurred with skin movement. This is the reason why solid paraffin in the solution form showed a high occlusivity at beginning which then decreased with time. Because the emulsion particles were of solid state, their coalescence did not occur even if the emulsion was broken by the evaporation of water when solid paraffin was applied in the emulsion form. But creaming of the emulsion advanced and the particles tended to pack themselves closely, resulting in a gradual formation of a continuous, aggregated flexible film. This is the reason for the observation that the occlusivity of solid paraffin in the emulsion form increased with time. In the case of liquid paraffin, no appreciable differences were observed in the residual states of the oil films formed by the neat form and solution form. A liquid film with a weak occlusive effect was formed on the skin surface in both cases of the application forms. In spite of the formation of this occlusive film, the occlusive effect decreased with time. This could be due to the thinning of the liquid film that was observed with time. Partial destruction of the liquid film by increased vapor pressure of water and the migration of water through the liquid layer (12) could also account for the observation of this phenomenon. The occlusivity of liquid paraffin in the solution form was slightly higher than that in the neat form, which was caused by the difference in the wettability in both forms. Liquid paraffin in the solution form was easy to spread over the skin surface due to its low surface tension.

When liquid paraffin was applied to the skin in the form of emulsion, both coalescence and creaming were observed with time, forming a continuous oil film. Thus, the occlusivity of liquid paraffin in the emulsion form increased until the formation of the continuous oil film was completed and it then decreased with time because of the same reasons described above.

The effect of the emulsion types on the occlusive effect was also studied using o/w and w/o type liquid paraffin emulsions. Table 1 summarizes the results. Since the evaporation rate of water was faster in the o/w emulsion than w/o emulsion, the o/w emulsion began to show its occlusivity earlier than the w/o emulsion and it also reached to the maximum occlusivity earlier than the w/o emulsion. The pattern of the occlusivity-time curve observed was similar for both types of the emulsions, although there existed a time lag. The maximum occlusivity obtained with the w/o emulsion was slightly higher than that obtained with the o/w emulsion.

There were no appreciable differences that were observed in the residual states of both types of the emulsions on the skin surface. As mentioned previously, a continuous oil
Figure 4. Schematic illustration of residual states of solid paraffin and liquid paraffin on skin surface in different physical forms.
film was formed in the case of the o/w emulsion due to the coalescence of the droplets. A similar oil film was also formed by the w/o emulsion upon the evaporation of water and the occlusive effect of both types of the emulsions observed was almost the same in spite of the opposite emulsion type. An occlusive film formed from o/w emulsions tends to re-emulsify by the skin moisture because the oil film contains a small amount of hydrophilic emulsifier. However, those oil films formed from w/o emulsions containing a hydrophobic emulsifier seldom re-emulsify. The HLB number of the emulsifier may affect the destruction of oil films by re-emulsification. Our data in Table I indicated the possibility that the occlusive effect of w/o type emulsion would last for a long period of time.

The effect of the droplet diameter of emulsions on the occlusivity was determined and Figure 5 shows the results. As seen from the figure, the occlusivity of solid paraffin in the emulsion form decreased markedly with the increase in the particle size, while that of liquid paraffin in the emulsion form did not depend on the droplet diameter. It was observed that the particles of solid paraffin in a fine emulsion packed closely, forming

![Figure 5. Effect of droplet diameter of emulsions composed of oils on occlusivity.](image-url)
a firm and flexible film, whereas the film formed by solid paraffin in a coarse emulsion had a high porosity. The changes of the states of oil films on the skin surface respecting time are schematically shown in Figure 6. The formation of a continuous oil film was also observed with liquid paraffin in both fine and coarse emulsions. Although there existed a time lag until the continuous film was formed because the rate of coalescence depended on the droplet size, the final state of the oil films was the same both for fine and coarse emulsions. This is also illustrated in Figure 6.

Since rubbing is the general technique used to apply cosmetic creams to the skin, the effect of rubbing on the occlusive effect was also investigated. Table II summarizes the
results of the occlusive effect of solid paraffin and liquid paraffin in the emulsion form when they were applied by an ordinary rubbing technique and simple spreading technique. The effect of rubbing on the occlusivity was small in the case of solid paraffin and the trend of the occlusivity change with time was similar in both techniques. The rubbing only increased the rate of the evaporation of water from the emulsion of solid paraffin. On the other hand, when the emulsion of liquid paraffin was applied by rubbing, the value of the maximum occlusivity became smaller and the time required to begin showing the occlusivity was shortened. The rubbing in this case increased not only the evaporation rate of water from the emulsion but also the coalescence rate of the droplets of the emulsion, which reduced the time required to form a continuous oil film and resulted in thinning of the film.

The effect of rubbing on the occlusivity of petrolatum in the neat form is shown in Table III. In this experiment, the film of petrolatum applied by a simple spreading technique was rubbed 90 minutes after the application. It was found that the occlusivity of petrolatum decreased with time but that it recovered to a great extent by rubbing, as seen in the table. This observation suggested that the continuous oil film property can be restored when partially destructed continuous oil films are rubbed.

It is considered that the surface lipid film on the skin acts as a natural occlusive film to

### Table II
Effect of Rubbing on Occlusive Effect of Emollients in Emulsion Form

<table>
<thead>
<tr>
<th>Method of Application</th>
<th>Occlusivity of Solid Paraffin Emulsion</th>
<th>Occlusivity of Liquid Paraffin Emulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rubbing</td>
<td>Simple Spreading</td>
</tr>
<tr>
<td>Time required to begin showing occlusivity after application (min)</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Time required to reach to the maximum occlusivity after application (min)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Maximum occlusivity (%)</td>
<td>54</td>
<td>66</td>
</tr>
<tr>
<td>Occlusivity at 60 minutes after application (%)</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>Occlusivity at 90 minutes after application (%)</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td>Occlusivity at 120 minutes after application (%)</td>
<td>54</td>
<td>66</td>
</tr>
</tbody>
</table>

### Table III
Effect of Rubbing on Occlusivity of Petrolatum in Neat Form

<table>
<thead>
<tr>
<th>Time After Application</th>
<th>Method of Application</th>
<th>Occlusivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Applied by Simple Spreading</td>
<td>Rubbing</td>
</tr>
<tr>
<td>30 minutes</td>
<td>89%</td>
<td>—</td>
</tr>
<tr>
<td>60 minutes</td>
<td>75%</td>
<td>—</td>
</tr>
<tr>
<td>90 minutes</td>
<td>58%</td>
<td>84%</td>
</tr>
<tr>
<td>120 minutes</td>
<td>—</td>
<td>72%</td>
</tr>
</tbody>
</table>

*The film of the petrolatum applied to the skin by a simple spreading technique was rubbed after 90 min of the application.*
Table IV
Relationship of Casual Lipid Level with TEWL(C), Skin Surface Temperature, and Occlusivity of Solid Paraffin in Emulsion Form

<table>
<thead>
<tr>
<th>Range of Casual Lipid Level (mg/cm²)</th>
<th>Number of Persons</th>
<th>Average TEWL(C) (mg/cm²/h)</th>
<th>Average Skin Temperature (°C)</th>
<th>Average Occlusivity of Solid Paraffin Emulsion After 120 minutes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-40</td>
<td>2</td>
<td>0.92</td>
<td>33.7</td>
<td>32</td>
</tr>
<tr>
<td>40-50</td>
<td>6</td>
<td>0.59</td>
<td>32.8</td>
<td>57</td>
</tr>
<tr>
<td>50-60</td>
<td>5</td>
<td>0.36</td>
<td>31.4</td>
<td>72</td>
</tr>
<tr>
<td>60-70</td>
<td>2</td>
<td>0.53</td>
<td>32.7</td>
<td>59</td>
</tr>
</tbody>
</table>

prevent the skin from drying (13). Therefore, it is possible that the occlusive effect of oil films in those subjects having a high lipid level may be rather higher than in the subjects having a low lipid level even if the application method is the same. In order to verify this, the experimental results obtained in the above experiments were examined in relation with the surface lipid level. The results are summarized in Table IV. Although the number of the subjects examined were not large enough for statistical analysis, it was observed a tendency of smaller value of TEWL(C) and higher occlusive effect of oil films in the subjects with a higher lipid level. This implied that the occlusive effect of emollients was smaller on dry skin than oily skin by the same application method, which presented an interesting aspect from a standpoint of skin care.

CONCLUSION

It has been known that the occlusive effect of oils depends on the type of oils and their coating amount. However, it was further found in the present work that the occlusive effect also depended on other factors such as physical form of the oils, emulsion type, and droplet diameter of the emulsions. It was found that differences in the adhering states of the oil films on the skin were responsible for the observed changes in the occlusive effect.

Although emulsions are generally used for cosmetic creams because of their sensory advantages, it was also found that they played an important role from a standpoint of skin care. Namely, solid paraffin showed a remarkable occlusive effect when applied uniformly on the skin surface, but it showed no occlusive effect when applied nonuniformly. In order to apply solid paraffin uniformly, the use of its emulsion was found to be the most suitable technique. In other words, it is possible to obtain a liquid state of solid paraffin at room temperature when emulsified, thus solid paraffin can be applied uniformly on the skin surface, forming a flexible and occlusive film.

It was shown that the occlusive effect was low for persons having a low lipid level. This implied that the use of a cream with a high occlusive effect is important for dry skin. Therefore, for dry skin, it is suitable to apply those creams having fine emulsion droplets of solid oils since the occlusive effect of solid oils increases with the decrease in their emulsion droplets.
REFERENCES


