Evaluation of Certain Factors Influencing Oil Deposition on Skin After Immersion in an Oil Bath

M. E. STOLAR, Ph.D.*

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Synopsis—Previously developed methods for determining quantitatively the amount of oil and recording the oil film deposited on the skin after immersion in oil baths were utilized to evaluate various oils of potential use in bath oil formulations. The effect of the presence of various surfactants in mineral oil on the amount and skin coverage of the deposited oil film was determined. The existence of a relationship between spreading coefficient values and the amount or skin coverage of the deposited oil film was investigated.

The use of bath oils in the treatment of dry scaly skin has gained favor in the last few years. Originally, dry skin was explained on the assumption that the surface lubricating lipid film was qualitatively or quantitatively modified or even missing (1). Blank (2) and Borota (3) demonstrated that cornified material obtained from callus remained soft and pliable as long as it retained moisture. To extend the duration of moisture retention, as indicated by softness and pliability, the tissues were coated with oil and placed on a wet surface.

Normal baths are frequently contraindicated due to their degreasing and drying effects on the skin (4). Pillsbury *et al.* (5) claimed that immersion of the skin in water followed by topical application of grease demonstrated beneficial effects. These may be attributed to hydration of the stratum corneum due to a decrease in the rate of moisture loss

* Dome Laboratories, Div. Miles Chemicals, Inc., 125 West End Ave., New York, N. Y. 10023.

Table I

Effect of Grade of Mineral Oil (0.02%) Dispersed in Water (40°C) on Oil Deposition on Skin after 15 Minutes of Immersion

Grade of Oil	Composition in %[a]		Specific Gravity at 60°F	Saybolt Viscosity at 100°F	Amount of Oil Added to Bath (g)	Amount of Oil Eluted from Skin (g)	% of Oil Deposited on Skin
	Naph-thenic	Paraf-finic					
Mineral oil USP[a]	40.0	60.0	0.885	350	0.200	0.044[b]	22.2
Mineral oil NF[a]	37.0	63.0	0.852	83	0.200	0.062[b]	31.0
Mineral oil technical[a]	30.0	70.0	0.832	55	0.200	0.080[b]	40.0

[a] Supplied by Sonnenborn Chemical and Refining Company, New York, N. Y.
[b] Average of six determinations.

Table II

Spreading Coefficient Values for Various Grades of Mineral Oil

Grade of Oil[a]	Specific Gravity at 60°F	Surface Tension at 25°C (dynes/cm)	Interfacial Tension at 25°C	Spreading Coefficient at 25°C
Mineral oil USP	0.885	32.2	44.6	−4.8
Mineral oil NF	0.852	33.4	41.9	−3.3
Mineral oil technical	0.832	31.4	41.5	0

[a] Supplied by Sonnenborn Chemical and Refining Company, New York, N. Y.

from the skin without affecting the rate of moisture diffusion from the underlying tissues (1). Clinical studies attesting to the beneficial effects of bath oils have been reported in medical literature (6–9).

Commercially available bath oils may be classified as either spreading or dispersible types. The spreading type tends to form a surface film of oil on the water, while the dispersible type forms a dispersion of fine droplets of oil throughout the water. Both types are claimed to deposit an oil film on the immersed skin.

Knox (10) described the development of a water dispersible oil bath which is deposited on skin surfaces. Taylor (11) reported that about twice as much oil is deposited from aqueous dispersions of mineral oil as from vegetable oil. Similar conclusions were reached by Knox (12). Taylor's results are based on the difference between the initial amount of oil present in an immersion cylinder and the residual amount after immersion for a specified period of time. This difference is indicative of the amount of oil deposited on the treated skin surface.

Stolar (13) recently developed a method for determining the actual amount of oil deposited on the skin after immersion in an oil bath and

Figure 1a. Mineral oil U.S.P.

Figure 1b. Mineral oil N.F.

Figure 1c. Mineral oil technical

Figures 1a—1c. Effect of grade of mineral oil (0.02%) dispersed in water (40°C) on skin coverage of the deposited oil films

visually defined the area covered by the deposited film. This method was used to compare the affinity to skin of four commercial bath oils and to record the area covered by the deposited oil film.

This report is concerned with the evaluation of various oils of potential use in bath oil formulation for their affinity to skin and the determination of the coverage or continuity of the deposited films. Furthermore, it investigates the effect of some nonionic surfactants on the amount and continuity of the oil film deposited from aqueous dispersions of mineral oil.

Table III

Effect of Type of Oil (0.02%) in Aqueous Dispersion (40°C) on Oil Deposition on Skin after 15 Minutes Immersion (Average of Six Determinations)

Type of Oil	Amount of Oil Added to Bath (g)	Amount of Oil Eluted from Skin (g)	% Oil Deposited
Isopropyl esters of fatty acids			
Isopropyl myristate	0.200	0.078	39.0
Isopropyl laurate	0.200	0.079	39.5
Isopropyl palmitate	0.200	0.066	33.2
Isopropyl linoleate	0.200	0.074	37.2
Sebacic acid esters of alcohols			
Di-isopropyl sebacate	0.200	0.062	30.7
Di-butyl sebacate	0.200	0.072	36.2
Di-octyl sebacate	0.200	0.071	35.7
Triglyceride esters[a]			
Triglyceride of short chain fatty acids	0.200	0.073	36.5
Triglyceride of modified coconut oil	0.200	0.0612	30.6
Polyol esters[a]			
Polyol esters of fatty acids	0.200	0.011	5.7
Polyol diester of short chain fatty acids	0.200	0.087	40.0
Alcohol			
Hexadecyl alcohol	0.200	0.080	40.0
Lanolin derivatives			
A[b]	0.200	0.079	39.5
B[b]	0.200	0.095	47.5
C[c]	0.200	0.025	12.5
Vegetable oils			
Almond oil	0.200	0.018	9.0
Cottonseed oil	0.200	0.057	28.5
Corn oil	0.200	0.063	31.5

[a] Supplied by Drew Chemical Corporation, Boonton, N. J.
[b] Supplied by American Cholesterol Products, Inc., Edison, N. J.
[c] Supplied by Malmstrom Chemical Corporation, Newark, N. J.

Table IV
Spreading Coefficient Values for Various Oils

Type of Oil	Surface Tension of Oil (dynes/cm)	Interfacial Tension at 25°C	Spreading Coefficient
Isopropyl esters of fatty acids			
Isopropyl myristate	31.3	16.7	20.3
Isopropyl laurate	29.8	23.8	19.5
Isopropyl palmitate	27.8	25.9	17.1
Isopropyl linoleate	31.6	19.8	18.7
Sebacic acid esters of alcohol			
Di-isopropyl sebacate	31.1	12.9	29.7
Di-butyl sebacate	33.0	22.1	19.5
Di-octyl sebacate	33.4	15.1	26.1
Triglyceride esters[a]			
Triglyceride of short chain fatty acids	32.3	12.7	28.9
Triglyceride of modified coconut oil	32.0	20.6	19.8
Polyol esters[a]			
Polyol esters of fatty acids	33.5	31.1	7.8
Polyol diesters of short chain fatty acids	31.0	21.2	22.4
Alcohols			
Hexadecyl alcohol	28.8	24.1	19.1
Lanolin derivatives			
A[b]	32.0	16.5	23.0
B[b]	31.8	11.2	36.0
C[c]	31.3	11.5	31.2
Vegetable oils			
Almond oil	31.0	45.8	−5.1
Cottonseed oil	34.9	48.0	−8.1
Corn oil	31.9	51.6	−10.6

[a] Supplied by Drew Chemical Corporation, Boonton, N. J.
[b] Supplied by American Cholesterol Products, Inc., Edison, N. J.
[c] Supplied by Malmstrom Chemical Corporation, Newark, N. J.

EXPERIMENTAL

The experimental procedure and methods for determining the amount and continuity of the deposited oil film were previously described (13). Briefly, the procedure consisted of dispersing, by stirring for five minutes with a Lightenin mixer, 0.200 g of oil containing 4000 USP units of Vitamin A palmitate in one liter of tap water. The oil bath was maintained

Table V

Effect of Concentration of Various Surface Active Agents on Deposition of Mineral Oil on Skin After 15 Minutes Immersion (Average of Six Determinations)

Type and Concentration (%) of Surfactant in Mineral Oil (Technical)	Amount of Oil Added to Bath (g)	Amount of Oil Eluted from Skin (g)	% Oil Deposited
Polyethylene Glycol 400 Dilaurate			
0	0.200	0.080	40.0
4	0.200	0.082	40.0
6	0.200	0.056	28.0
8	0.200	0.039	19.7
Polyethylene Glycol 400 Dioleate			
0	0.200	0.081	40.0
4	0.200	0.080	40.0
6	0.200	0.065	32.5
8	0.200	0.040	20.0
Polyoxyethylene (5) Tallow Amine			
0	0.200	0.080	40.0
4	0.200	0.046	23.2
8	0.200	0.033	16.7
Polyoxyethylene (5) Soybean Amine			
0	0.200	0.080	40.0
4	0.200	0.081	40.5
8	0.200	0.035	17.8

at 40 °C in a water bath. The subject immersed his hand so that the water level reached his wrist, exposing the same surface area at each immersion. At the end of 15 minutes, the hand was removed and allowed to air dry. The back of the hand was exposed to a source of ultraviolet irradiation in a dark room and the fluorescence photographed using Ektachrome-X film.

The deposited oil film was then eluted with mineral oil, filtered through a #1 Whatman filter paper, and the volume adjusted with mineral oil to 100 ml. The eluate was then assayed spectrophotometrically at 325 mμ.
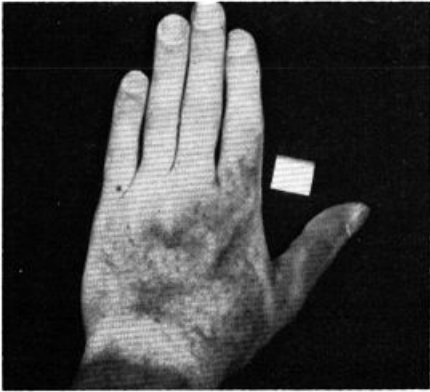
Figure 2a.   Isopropyl myristate

Figure 2b.   Isopropyl palmitate
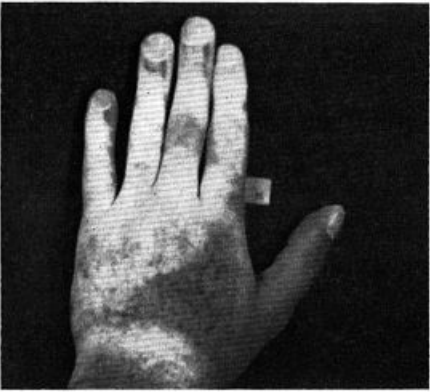

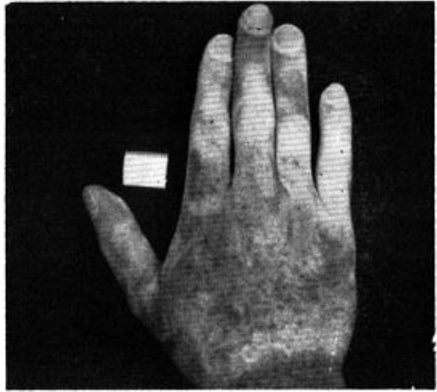*Figure 2c.*   Isopropyl linoleate

Figure 2d.   Di-isopropyl sebacate

Figure 2e.   Di-butyl sebacate

Figure 2f.   Di-octyl sebacate

Figure 2g.   Triglyceride of short chain fatty acids

Figure 2h.   Triglyceride of modified coconut oil
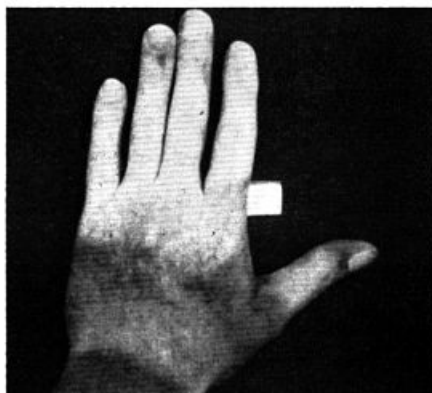

Figure 2i.   Polyol esters of fatty acids

Figure 2j.   Polyol di-esters of short chain fatty acids
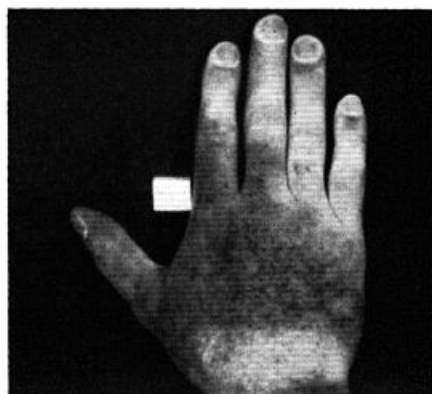

Figure 2k.   Hexadecyl alcohol

Figure 2l.   Lanolin derivative "A"

Figure 2m.   Lanolin derivative "B"   *Figure 2n.*   Lanolin derivative "C"

Figure 2o.   Cottonseed oil   *Figure 2p.*   Corn oil

Figures 2a–2p.   Effect of various oily liquids in aqueous dispersions, maintained at 40°C, on skin coverage of deposited oil films

The spreading coefficient has been used as an indication of spreadability of one immiscible liquid over another (14).   Spreading coefficient values were calculated from the relation:

Spreading coefficient = ST (water) − ST (oil) − IFT (water-oil)

The surface tension (ST) and interfacial tensions (IFT) were obtained with the DuNuoy tensiometer. The procedure consisted of measuring the surface tension of the aqueous phase which was then layered gently with the oil phase; the interfacial tension was then determined.   The surface tension of the oil was determined separately and the spreading coefficient calculated from these values after corrections were made for density and ring size.

Results and Discussion

The most extensively used ingredient in topical and cosmetic formulations is mineral oil. The affinity of mineral oil to hair from a shampoo formulation was demonstrated by Goldemberg (15). Taylor (11) reported that bath oils formulated with mineral oil were superior to bath oils prepared with vegetable oil. Neither researchers stated the type of grade of the mineral oil used in their investigation.

Mineral oils in given viscosity ranges may appear to be quite similar, yet can be significantly different in composition, physical properties, and behavior on the skin (16). These oils contain paraffinic (20–47%) and naphthenic (53–83%) fractions, and significant variations in relative percentages of these two fractions of hydrocarbons may exist in oils having similar viscosities.

Table I demonstrates the effect of the grade or composition of mineral oil in aqueous dispersion, maintained at 40 °C, on oil deposition on the skin after immersion for 15 minutes. From these results it would appear that the amount of oil deposited is affected by the grade of mineral oil. With increasing viscosities there appears to be a decrease in the amount of oil deposited. Furthermore, the viscosities appear to be directly related to the naphthenic content. An increase in the naphthenic content of the mineral oil results in an increase in viscosity and an apparent decrease in affinity to skin. This is exhibited in Figs. 1a–1c.

No correlation appears to exist between spreading coefficient values obtained for the various grades of mineral oil and the amount or coverage of the deposited oil film (Table II).

Table III illustrates the effect of various oily liquids dispersed in water maintained at 40 °C on oil deposition on skin after immersion for 15 minutes. Figures 2a–2p record the coverage of skin achieved by the deposited oil films from aqueous dispersions of the various oily liquids.

A direct correlation may be noted between the spreading coefficient values obtained for the isopropyl ester series and the amount of oil deposited on the skin (Table IV). With increasing spreading coefficient an increase may be noted in the amount and coverage of the skin by the deposited oil film.

In the sebacic acid esters series, significantly different spreading coefficient values were recorded for di-butyl and di-octyl esters. However, the amount of oil deposited appears to be the same. Figures 2e and 2f exhibit better coverage of skin from aqueous dispersions of di-butyl sebacate than from di-octyl sebacate. The best skin coverage was re-

corded from aqueous dispersions of di-isopropyl sebacate (Fig. 2d). However, the amount of di-isopropyl sebacate deposited on skin appears to be the least with the highest spreading coefficient value obtained in this series.

A relationship between spreading coefficient and the amount of oil deposited on the skin was recorded for triglyceride and the polyol

Table VI

Effect of Concentration of Various Surfactants on Spreading Coefficient of Mineral Oil (Technical)

Type and Concentration (%) of Surfactant in Mineral Oil	Surface Tension of Oil (dynes/ cm) at 25°C	Interfacial Tension at 25°C	Spreading Coefficient
Polyethylene Glycol 400 Dilaurate			
0	31.4	41.5	0
4	31.4	0.8	42.9
8	30.9	1.2	42.8
Polyethylene Glycol 400 Dioleate			
0	31.4	41.5	0
4	30.1	1.8	42.0
8	28.8	1.0	42.3
Polyoxyethylene (5) Tallow Amine			
0	31.4	41.5	0
4	30.9	1.0	42.9
8	31.8	0.8	42.4
Polyoxyethylene (5) Soybean Amine			
0	31.4	41.5	0
4	31.2	1.3	42.5
8	30.9	1.0	42.8

esters of fatty acids. In both series, with increasing spreading coefficient values there appears to be an increase in the amount and coverage of the oil film deposited after immersion in an oil bath.

Hexadecyl alcohol demonstrates good deposition on skin after immersion in aqueous dispersion and a substantial spreading coefficient value. However, the coverage of the deposited film on the skin appears to be inadequate when compared to the film deposited by esters of similar spreading coefficient values.

The affinity to skin of three lanolin derivatives in aqueous dispersions is recorded in Table III. A relationship appears to exist between the spreading coefficient values obtained for two lanolin derivatives (A and B) and the amount of oil deposited on the skin. However, lanolin
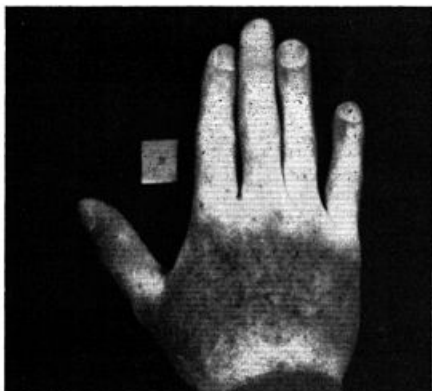
Figure 3a. 4% Polyethylene glycol 400 dilaurate in mineral oil

Figure 3b. 8% Polyethylene glycol 400 dilaurate in mineral oil

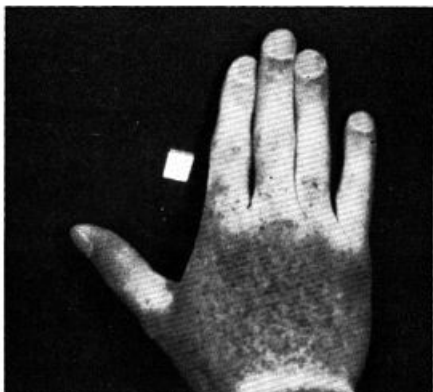*Figure 3c.* 4% Polyethylene glycol 400 dioleate in mineral oil

Figure 3d. 8% Polyethylene glycol 400 dioleate in mineral oil

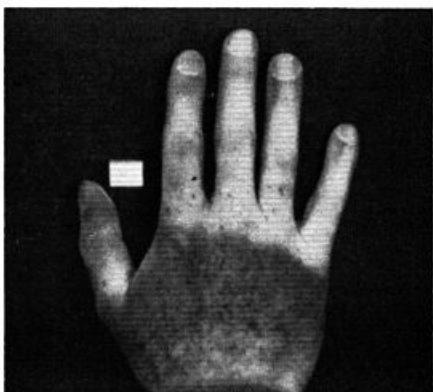*Figure 3e.* 4% Polyoxyethylene (5) tallow amine in mineral oil

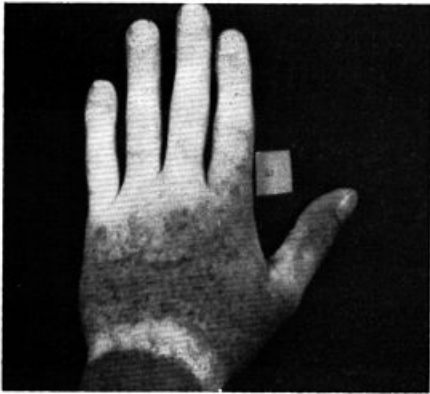*Figure 3f.* 8% Polyoxyethylene (5) tallow amine in mineral oil

Figure 3g. 4% Polyoxyethylene (5) soybean amine in mineral oil

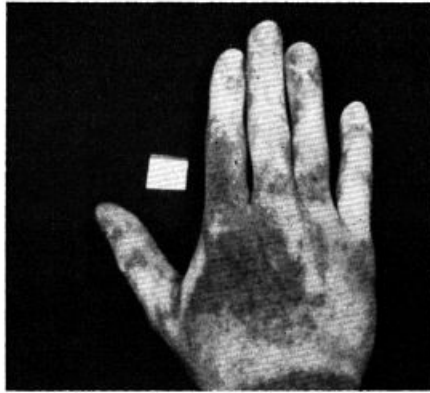Figure 3h. 8% Polyoxyethylene (5) soybean amine in mineral oil

Figure 3i. Mineral oil (technical)

Figures 3a–3i. Effect of presence and concentration of various surfactants in mineral oil (technical) dispersed in water, maintained at 40°C, on skin coverage of deposited oil films

derivative A, with the lower spreading coefficient value, appears to achieve superior coverage of the skin than lanolin derivative B. A significantly higher spreading coefficient value was obtained for lanolin derivative C, which exhibited poor deposition and coverage of the skin (Table IV).

The deposition of oil on the skin from aqueous dispersions of various vegetable oils appears to be unsatisfactory, due to their spotty nature (Figs. 2o and 2p). Significant differences in the amount of oil deposited on the skin were recorded in order of decreasing affinity: corn oil > cottonseed oil > almond oil.

Table V illustrates the effect of the presence of various surfactants at different levels in mineral oil (technical grade) on oil deposition on the skin after immersion in aqueous dispersions.   From the results, it would appear that increasing the concentration of surfactants above about 4% results in a decrease in the amount of oil deposited.   The amount of oil deposited appears to be unaffected as long as the concentration of the surfactant remains below a certain level.   This level appears to be between 4–6% for polyethylene glycol 400 dilaurate, polyethylene glycol 400 dioleate and polyoxyethylene (5) soybean amine.   The critical concentration for polyoxyethylene (5) tallow amine appears to be between 0–4%.

The addition of 4% surfactant to mineral oil (technical grade) results in a dramatic increase in spreading coefficient values.   Additional increases in surfactant concentration to mineral oil does not appear to affect significantly the spreading coefficient values (Table VI). Similar results were observed by Paruta et al. (17).

Figures 3a to 3i illustrate the effect of the presence of various surfactants at different levels in mineral oil (technical grade) on the skin coverage of the deposited oil film.   These photographs demonstrate that the area covered by the deposited oil film remains the same as that of the original oil, regardless of the concentration of surfactant. However, with increasing concentrations of surfactants, the amount of oil deposited is reduced, as may be seen by the decrease in the intensity of fluorescence.

From the data presented, it appears that a relationship may exist between spreading coefficient values and the amount of oil deposited on the skin after immersion in an oil bath.   No relationship could be observed between spreading coefficient values and the character of coverage achieved by the deposited oil film.   The surface area covered by the deposited oil film appears to be characteristic for the specific oil, and addition of various concentrations of surfactants does not appear to affect the area covered but rather the amount of oil deposited.

SUMMARY

The affinity to skin of various oils of potential use in bath oil formulations was investigated.

The effect of the presence of various surfactants in mineral oil (technical grade) on oil deposition after immersion in an oil bath was determined.

A possible relationship between spreading coefficient values and the amount or skin coverage of the deposited oil film was investigated.

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