J. Soc. Cosmet. Chem., 44, 239–247 (September/October 1993)

Emollient action of kukui nut oil

H. AKO, L. FUJIKAWA, and D. GRAY, *Department of Environmental Biochemistry, University of Hawaii, Honolulu, HI 96822 (H.A., L.F.), and Hawaiian Kukui Nut Company, P.O. Box 685, Waialua, HI 96791 (D.G.).*

Synopsis

Dry skin drives the search for effective emollients. This report searches for an explanation of the superb skin feel of this native Hawaiian oil. Using skin stripping technology and gas chromatography, we demonstrated kukui oil's ability to penetrate the stratum corneum, leaving a triglyceride barrier containing a mixture of saturated and unsaturated fatty acids. A kukui oil-based lotion was also very effective in laying down an emollient layer of lipids. However, skin penetration did not distinguish kukui oil from oils containing saturated fatty acids. It is speculated that the skin feel of kukui oil may be due to the fact that it lays down a mixture of saturated and unsaturated fatty acids, forming a semipermeable barrier that would protect the skin from further drying and would allow dry skin to heal naturally. It was found that kukui oil is quite stable as judged functionally by the degradation of linolenate (C18:3n-3).

INTRODUCTION

Kukui oil is produced in Hawaii by cold pressing the oil from the nut of the kukui tree (*Alleurites moluccana*). Hundreds of years ago, Hawaiians used it to protect the skin of babies. It is used as a body oil by modern-day Pacific Islanders. Cosmetic chemists report that kukui oil has an excellent skin feel. They say the kukui oil seems to be readily absorbed into the skin (it does not leave a greasy film). It seems to make chapped or rough dry skin feel smooth, silky, and soft. It seems to prevent scarring when applied to abrasions. A major purpose of the present work is to explain these reported properties. A number of hypotheses were entertained.

We do not prefer the metabolic explanation of dry skin. Based on the work of Burr and Burr (1), nutritional essential fatty acid deficiency (EFAD) has been cited as a cause of dry skin. They maintained weaned rats on a totally fat-free diet for months before signs of scaly feet, dandruff, and slow growth were seen. These symptoms were cured with small amounts of dietary essential fatty acids. The extreme conditions required to induce dry skin and the ease of curing dry skin nutritionally suggest to us that dry skin normally seen in the population may not be due to EFAD.

Goodgame, Lowry, and Brennan (2) studied a 13-year-old in a coma with signs of EFAD due to absence of essential fatty acids in intravenous feedings. Cutaneous application of essential fatty acids showed a slight decrease in his triene:tetraene ratio, a biochemical test for EFAD. However, cutaneous application did not bring the ratio within normal range. Essential fatty acid infusion three times per week with a product called "Intra-

lipid" at 5% of total caloric intake brought his triene:tetraene ratio into normal range in one week. This case contrasted topical application of EFAs with infusion of small amounts of EFAs. With an average intake of Americans at >30% kcal from fat, EFAD is not something one would expect to see in Americans except under very unusual circumstances.

In this work we exclude the possibility that kukui oil's superior skin feel is due to its penetrating ability. We demonstrate that coconut oil, a saturated fat, penetrates the skin as well as kukui oil. Thus we will be left with the hypothesis that kukui oil forms a semipermeable barrier that protects dry skin from further damage and permits dry skin to heal naturally.

While the definition of dry skin is beyond the scope of this paper, it may be assumed that dry skin is characterized by apparent dryness, scaling, cracking, etc. These conditions may be induced by the loss of natural lipids in the stratum corneum. Such could occur by swabbing with acetone (3). This treatment decreases the barrier function of the skin, as may be seen by the increase in transepidermal water loss (TEWL). There is a linear relationship between lipid removal and the increase in TEWL. It follows that use of household chemicals such as soaps, or extreme exposure to the wind, sun, and sea such as occurs commonly in Hawaii, may also cause dry skin. The same condition is often reported by people who live in very cold environments (where barrier lipid fluidity may be inappropriate to prevent TEWL) or very dry environments (where TEWL would be extremely high).

We also note that dry skin heals naturally. Unless further damage occurs, barrier function is restored to dry skin within 48 hours (3). Intervention in the healing process is not straightforward. On the one hand, some TEWL must occur because no lipid biosynthesis or recovery of the normal rate of TEWL occurs if the skin is protected occlusively with films such as latex. On the other hand, unprotected skin may be damaged further. We propose that lipids composed of a mixture of saturated and unsaturated fatty acids could provide a protective barrier against excessive TEWL and yet promote healing. Perhaps this explains the emollient properties of kukui oil. Kukui oil contains 8.1% saturated fatty acids, 15.3% monounsaturated fatty acids, 43% linoleate (C18:2n-6, a diunsaturated fatty acid), and 33% linolenate (C18:3n-3, a triunsaturated fatty acid).

Another purpose of the present study is to determine the stability of kukui oil. Kukui oil has the reputation of being highly susceptible to rancidity. It normally leaves the factory with a peroxide value of 2. Sometimes batches are rejected because peroxide values have risen to 10 or more.

METHODS

SAMPLES

Coconut oil was purchased commercially. Kukui oil samples with and without antioxidants were obtained from the production line of the Hawaiian Kukui Nut Company. Kukui lotion was obtained similarly. It contained water, 10% kukui oil, 3% macadamia nut oil, and an unextraordinary mixture of buffers and emulsifying agents.

FATTY ACID ANALYSIS

Lipid saponification, methylation, and gas chromatographic quantification of fatty acid methyl esters were done as described previously (4), except for skin stripping samples, which were concentrated with a nitrogen stream just before running on the gas chromatograph. AOAC methods were used to determine peroxide values.

STABILITY

In room temperature stability studies, kukui oil was held in glass vials on the windowsill (approx. 28°C). Some samples were flushed with nitrogen and sealed, and others were left open to the atmosphere with glass wool plugs keeping debris out of the vials. Some samples contained antioxidants (a mixture of vitamins C, E, and A), and others did not. In these stability studies, each data point represents an average of triplicate analyses. Accelerated rancidity tests were done with samples held in vials in a dry incubator at 60°C on the laboratory bench.

SKIN PENETRATION

Skin strippings were done following the approach of Brod *et al.* (5). Samples (none, 20 μl coconut oil, 20 μl kukui oil, or 50 mg of kukui lotion) were applied to 25-cm^2 sections of skin on the shins of test subjects. Samples were rubbed into the skin gently with a test tube. After one and a half hours, Blenderm® tapes were applied to each of the sections with a light touch and removed after about one minute. A total of five consecutive strippings were done for each sample.

No measurements were taken of the depths of skin removed with each stripping. However, we were conscious of possible inconsistency and attempted to remove equal amounts of skin in each stripping. There were no apparent differences in stripped skin to which different treatments were applied. In no case did the skin seem "tender" or "raw," as was the case in a preliminary study when tapes were applied vigorously.

Oils were extracted from individual tapes with hexane as described by Brod *et al.* (5) and were analyzed for fatty acids as described above. A follow-up test was done at half-loading rates (10 μl coconut oil and 10 μl kukui oil per 25-cm^2 section of skin).

STATISTICS

The Student's t-test was used.

RESULTS

STABILITY

The linolenate levels in kukui oil were taken as indicative of rancidity because linolenate is the most unstable fatty acid in kukui oil. Figure 1 is a room-temperature stability test. The closed triangles represent a control reaction with kukui oil containing no antioxidants and exposed to air. The data show that kukui oil rapidly became rancid

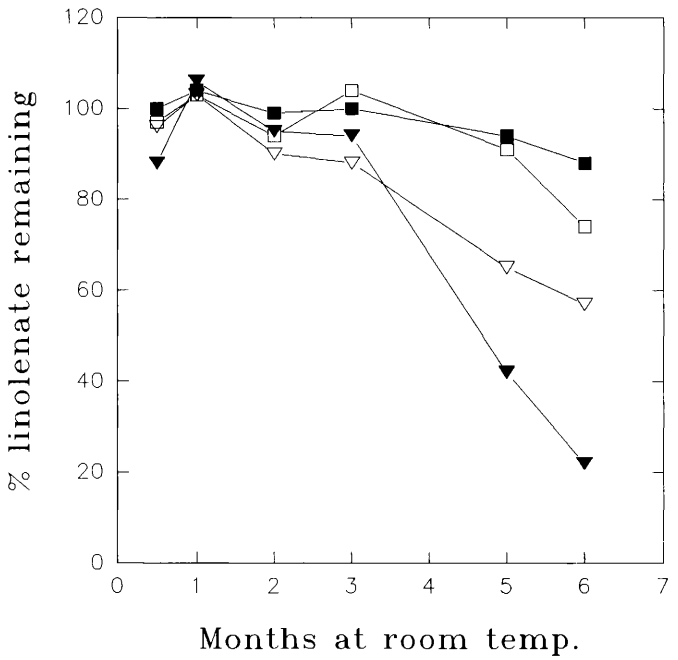

Figure 1. Stability of kukui nut oil at room temperature. Percentages of linolenate (C18:3n-3) remaining in kukui oil after incubation. Closed triangles, in air, no antioxidants; open triangles, in air; open squares, under N_2; closed squares, under N_2, no antioxidants.

after three months. Antioxidants protected against rancidity induced by exposure to air (open triangles). Stability tests done under a nitrogen atmosphere were considered to be models for kukui oil stability during shipping to a potential customer. The data (open squares) suggest that kukui oil remained stable for three to five months.

Figure 2 is an elevated-temperature stability test. The data in Figure 2 suggest that 90% of the kukui oil remained non-rancid for about 17 days at 60°C. This contrasts with the results of the peroxide value test. Kukui oil without antioxidants exposed to air had peroxide values of 44 ± 2.3 after 2¾ days exposure to 60°C and 133 ± 63 after 17 days. With antioxidants and exposure to air, kukui oil had peroxide values of 7.0 ± 0.3 and 41 ± 6.3 at 2¾ and 17 days, respectively. Under a nitrogen atmosphere in the presence of antioxidants, peroxide values were 4.3 ± 0.9 and 31 ± 4.6 at the same incubation times.

A repeat of the elevated-temperature test with the same batch of oil yielded indistinguishable results using the linolenate test, while another repeat of the elevated-temperature test with a different batch of oil yielded similar but statistically different results.

SKIN PENETRATION

Table I is an example of a typical stripping. In the control region of the skin (no oil applied), lipid is concentrated in the top layers of skin. There was less and less oil as one

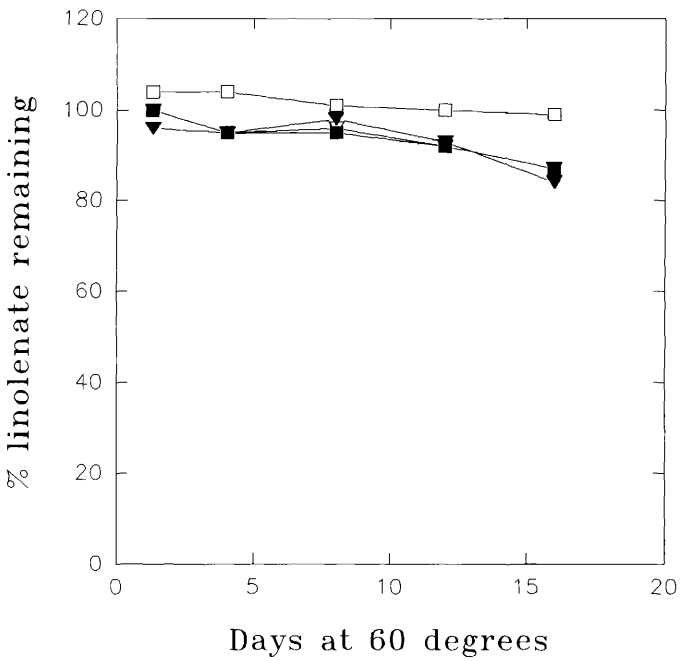

Figure 2. Stability of kukui nut oil measured at 60°C. Percentages of linolenate (C18:3n-3) remaining in kukui oil after incubation. Closed triangles, in air, no antioxidants; open triangles, in air; open squares, under N_2; closed squares, under N_2, no antioxidants.

went down into the skin via the strippings. For this sample, total fatty acids were 251 μg/strip in the fifth stripping.

Table I also shows the penetration of kukui oil into the skin. As with the control, there was less and less oil as one went down through the layers of the stratum corneum. The level of fatty acids in the fifth stripping (1037 μg/strip) was significantly higher than

Table I
Strippings of Control (no oil applied) and Kukui Oil Patches[a]

		Control					Kukui oil			
Stripping no.		1	2	3	4	5	2	3	4	5
C12	Laurate	73	70	42	18	26	123	22	91	80
C14	Myristate	64	53	32	24	21	65	18	43	37
	Unknown	133	16	8	0	8	0	0	0	0
C16	Palmitate	380	123	81	54	44	393	105	99	79
C16:1n-7	Palmitoleate	65	23	18	9	8	14	6	5	6
C18	Stearate	119	66	51	22	30	86	52	46	36
C18:1n-9	Oleate	356	132	181	42	84	458	215	179	125
C18:2n-6	Linoleate	421	49	46	21	17	3234	529	415	264
C18:3n-3	Linolenate	307	30	31	74	10	1849	473	392	405
C20:1n-9	Eicosenoate	0	0	0	0	0	17	0	0	0
Total fatty acids		1922	564	495	266	251	6243	1424	1275	1037

[a] Example is from subject A. Units are μg fatty acid/stripping.

it was in the control, demonstrating the penetration of kukui oil through the skin. In addition, it may be seen that the fifth stripping on the patch of skin to which kukui oil had been applied had a fatty acid profile roughly characteristic of kukui oil with high levels of linoleate (C18:2n-6) and linolenate (C18:3n-3).

Data averaged from all three volunteers suggested that total fatty acid levels were 234 ± 67 μg/strip at the fifth stripping for control (no oil applied), 824 ± 616 μg/strip at the fifth stripping for kukui oil, and 834 ± 311 μg/strip at the fifth stripping for coconut oil.

Much the same effects were seen when oil was applied at half dose (data not shown). Oils penetrated the stratum corneum but were deposited at lower levels than when applied at the full doses described above. Averaged values for fifth strippings for two subjects were 430 μg/strip and 480 μg/strip for kukui and coconut oils, respectively.

While coconut oil penetrated the skin, the nature of the oils left in the skin was very different than when using kukui oil. Figure 3 shows that coconut oil left lipids composed largely of saturated fatty acids while kukui oil left lipids composed of a mixture of saturated, monounsaturated, and polyunsaturated fatty acids.

Lotion left a disproportionate percentage of oil in the skin. Lotion contained only 13% oil, which is much less than the neat oils. However, as indicated in METHODS, lotion was applied at higher rates (50 mg = 50 μl) as compared with 20 μl of full doses of the neat oils. Hence, oil application rates of the lotion compared with full doses of the neat oils were 50/20 × 0.13 = 32.5%. About 65% as much oil was applied with the

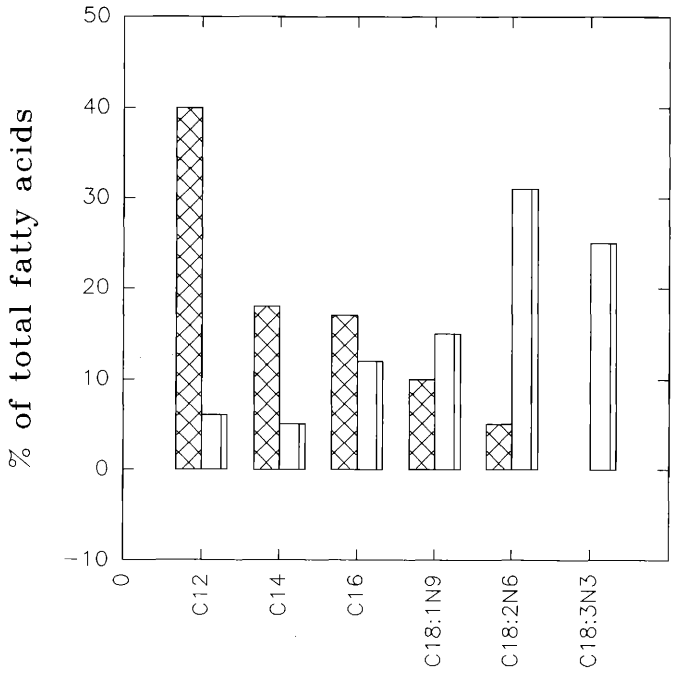

Figure 3. Fatty acid profiles of skin strippings treated with coconut oil (cross-hatched) or kukui nut oil (open bars with line).

lotion as compared with half doses of the neat oils. In spite of the lower oil application rate with the lotion, by the fifth stripping among the three subjects, 735 ± 161 μg/strip of oil was left after kukui lotion application. This was not significantly less than with full-dose neat oil application but was significantly more than the half dose of neat oil.

This point may be seen in another way in Figure 4. Compared with the oils, a larger percentage of the applied oil remained in the stratum corneum from the second through the fifth stripping with the lotion. Oil appeared to spread more evenly through the layers of skin with kukui lotion.

Table II is a side bar showing fatty acids extracted from untreated skin of the three volunteers. It may be seen that there was variation in fatty acid profiles. The variations were consistent with the accepted notion that with fatty acids, one is what one eats. The strippings were consistent with self-reported dietary habits of the three individuals. In the mixed cultural milieu that is Hawaii, subject A reported eating a typical American diet except that fish was eaten twice a week on recommendation of the American Heart Association. The profile therefore contained traces of EPA (C20:5n-3) and DHA (C22:6n-3), which are marine fatty acids, in a background containing high levels of oleate (C18:1n-9), linoleate (C18:2n-6), and linolenate (C18:3n-3), which may have come from plant oils in the subject's foods. Subject B reported having fish on the table every evening. Her profile contained substantial levels of marine fatty acids. Subject C's skin fatty acid profile contained high levels of saturated fatty acids. Subject C reported eating large amounts of beef and pork at a University of Hawaii dormitory.

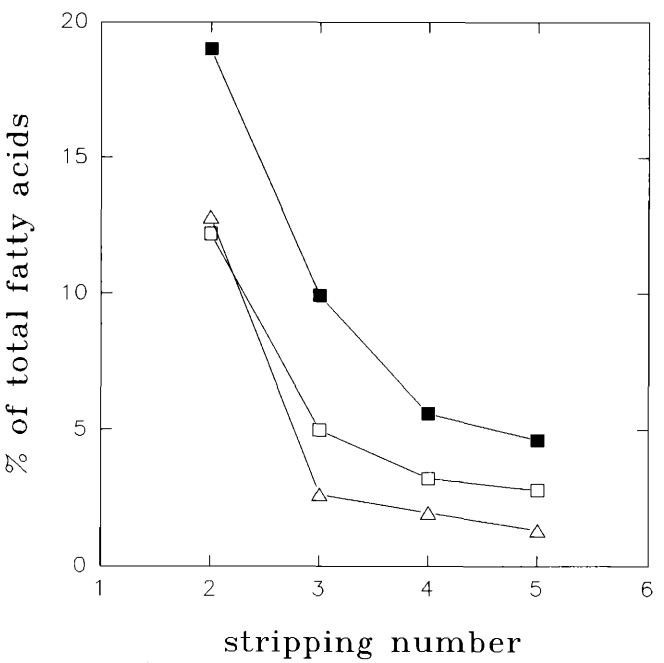

Figure 4. Penetration of oils into the stratum corneum for kukui lotion (closed squares), coconut oil (open squares), and kukui oil (open triangles).

Table II
Fatty Acids in Strippings From Three Individuals[a]

		Subject A	Subject B	Subject C
C12	Laurate	7	1	16
C14	Myristate	6	10	10
	Unknown	5	—	—
C16	Palmitate	20	24	35
C16:1n-7	Palmitoleate	4	10	4
C18	Stearate	8	5	21
C18:1n-9	Oleate	23	14	7
C18:2n-6	Linoleate	16	2	6
C18:3n-3	Linolenate	13	—[b]	2
C18:4n-3	Octadecatetraenoate	—	3	—
C20:1n-9	Eicosenoate	—	5	—
C20:4n-6	Arachidonate	—	3	—
C20:5n-3	Eicosapentaenoate	Trace	11	—
C22:6n-3	Docosahexaenoate	Trace	9	—
Total fatty acids		100	100	100

[a] For each individual, all five strippings were summed. Data are expressed as percentages of total fatty acids.
[b] Not detected.

DISCUSSION

Kukui oil has a reputation for going rancid quickly. We chose to focus our efforts on linolenate (C18:3n-3) because it is the most unstable of the fatty acids in kukui oil. Disappearance of linolenate would be a worst-case scenario. The sensitivity of linolenate was confirmed by the fact that of the samples that did go rancid, linolenate with three double bonds disappeared far faster than linoleate with two double bonds (C18:2n-6) or oleate with one double bond (C18:1n-9). Saturated fatty acids were stable. This said, kukui oil has an undeserved reputation for turning rancid quickly. Kukui oil is stable for three to five months, and work is in progress to stabilize it further.

Brod *et al.* (6) noted the non-equivalence of one day at 60°C and 22 days at room temperature. We also observed this non-equivalence. In our 60°C tests, we found little if any linolenate degradation in 17 days, which is equivalent to about one year at room temperature. This was not consistent with the room temperature tests.

Also, our 60°C test samples, which were approximately 90% intact based on fatty acid analyses, had very high peroxide values. This points out the problematic nature of molecular-level interpretations of peroxide value tests with kukui oil.

The skin stripping method of Brod *et al.* (5) worked well for us. The data seemed quantitative and internally consistent. Control strippings showing the effect of diet on the skin fatty acid profile may be worth further investigation. They raise a question of whether non-clinical variations in skin fatty acid profiles affect skin properties.

We began this paper by wondering why kukui oil has its reputedly excellent emollient properties. On nutritional grounds, we decided to be lukewarm about metabolic explanations. We are lukewarm about dry skin being caused primarily by a localized essential fatty acid deficiency in omega 6 fatty acids. This being the case, we are lukewarm about the superiority of gamma linolenate (C18:3n-6), such as found in blackcurrant oil, over the alpha form.

Our data also exclude skin penetration as an explanation. Oils made of lipids containing saturated fatty acids are reputed to have a greasy feel because they are reputed to remain on top of the skin. We used coconut oil as such an example. Our skin stripping data did not confirm this reputation because coconut oil penetrated the stratum corneum essentially as well as kukui oil. We therefore conclude that skin penetration is not the reason kukui oil has a different skin feel compared with oils containing primarily saturated fatty acids.

We can speculate as to why kukui oil either neat or as a lotion feels like an excellent emollient, taking into account reviews by Rieger (7) and Idson (8). We know that kukui oil penetrates deeply into the stratum corneum. It would lay down a triglyceride blanket of lipids containing both saturated and unsaturated fatty acids. Such blankets should be semipermeable (9) with regard to TEWL. This blanket would protect the skin from further drying yet would allow some water to escape, inducing the skin to heal naturally.

We can speculate further as to the use of kukui oil by the ancient Hawaiians on newborns. The skin senses the rate of TEWL and biosynthesizes a protective lipid layer that is responsive to the humidity of the environment. A child *in utero* would tend to have skin that is adapted to 100% humidity. After birth, the baby's skin would therefore be extremely susceptible to chapping as the relative humidity would probably be considerably less than 100%. Kukui oil would have provided a semipermeable barrier that would have protected the skin of newborns from further chapping and would have allowed their skin to adjust to the new environment.

ACKNOWLEDGMENTS

We wish to thank Mathew Pania for determining peroxide values and Christopher Ako for helping to develop skin stripping fatty acid analyses. This work was supported by the Governor's Agriculture Coordinating Committee Contract #91-34 and is Journal Series #3773 of the Hawaii Institute of Tropical Agriculture and Human Resources.

REFERENCES

(1) G. O. Burr and M. M. Burr, On the nature and role of the fatty acids essential in nutrition, *J. Biol. Chem.*, **86**, 587–621 (1930).
(2) J. T. Goodgame, S. F. Lowry, and M. F. Brennan, Essential fatty acid deficiency in total parenteral nutrition: Time course of development and suggestions for therapy, *Surgery*, **84**, 271–277 (1978).
(3) G. Grubauer, P. M. Elias, and K. R. Feingold, Transepidermal water loss: The signal for recovery of barrier structure and function, *J. Lip. Res.*, **30**, 323–333 (1989).
(4) C. S. Tamaru, H. Ako, and C.-S. Lee, Fatty acid and amino acid profiles of spawned eggs of striped mullet, *Mugil cephalus* L, *Aquaculture*, **105**, 83–94 (1992).
(5) J. Brod, H. Traitler, A. Studer, and O. De Lacharriere, Evolution of lipid composition in skin treated with blackcurrant seed oil, *Int. J. Cosmet. Sci.*, **10**, 149–159 (1988).
(6) G. R. Goss, D. D. Brooks, S. K. Brophy, and B. L. Hayden, A comparative study of soybean oil oxidation methodology, Presentation at the 1989 AOCS Convention, Cincinnati, Ohio.
(7) M. Rieger, Skin care: New concepts vs established practices, *Cosmet. Toiletr.*, **106**, 55–68 (1991).
(8) B. Idson, Dry skin, moisturizing and emolliency, *Cosmet. Toiletr.*, **107**, 69–78 (1992).
(9) V. K. LaMer, Ed., *Retardation of Evaporation by Monolayers: Transport Processes* (Academic Press, New York, 1962).