J. Cosmet. Sci., 69, 269–278 (July/August 2018)

Skin Tolerance of Three Types of Dead Sea Mud on Healthy Skin: A Short-Term Study

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Accepted for publication July 10, 2018.

Synopsis

Dead Sea mud (DSM) is commonly used by patients with various skin conditions because of its contents of healing elements. No study was published to show whether DSM application weakens or strengthens skin barrier function. In this study, we investigated the impact of 30-minute single application of various types of DSM ("As Is" mud, mud with extra Dead Sea salt, and over-the-shelf mud) on the barrier function of normal skin. The influence of 30-minute application of various types of DSM was investigated noninvasively on skin barrier properties of healthy female adult volunteers ($n = 75$) on predetermined circular areas. Skin hydration, transepidermal water loss (TEWL), erythema and melanin levels, and skin pH were measured directly, 30 minutes, and 60 minutes after mud removal. Thirty-minute single application of DSM was well tolerated with short-lived moisturizing effects, which was enhanced by the presence of humectant ingredients, and with no negative impact on barrier integrity, pH, and erythema and melanin levels.

INTRODUCTION

In Jordan, numerous pharmaceutical and cosmetic manufacturers produce and distribute cosmetic and skin-care products worldwide based on minerals and mud from the Dead Sea. For thousands of years, the extraordinary water and mud of the Dead Sea were recognized as a natural treatment for patients with various cutaneous and rheumatic diseases. Balenotherapy is a well-known treatment modality in dermatology that involves immersion of the patient in mineral water baths with a high salt concentration for healing and recovery from a number of inflammatory skin diseases such as psoriasis and atopic dermatitis (1). It has been documented that Dead Sea water and mud are effective treatments for patients with psoriasis, with excellent improvement exceeding 85% after 4 weeks of treatment (2). A significant increase in the levels of serum Br, Rb, Ca, and Zn was noticed in psoriatic patients after daily bathing in the Dead Sea for 4 weeks, which may be partly responsible for the improvement of psoriatic condition (3). The mechanisms by which salty water alleviates these diseases have not been fully elucidated. However, natural Dead

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Sea products use the power of Dead Sea minerals, specifically magnesium ion, which has been shown to play a key role in the anti-inflammatory effect of Dead Sea water in both *in vitro* and *in vivo* studies (4,5).

Dead Sea mud (DSM) masks are also popular at spa body sessions at Dead Sea spa centers and are a well-known component of a number of facial and body mask products manufactured by the cosmetic industry in Jordan. Dead Sea black mud is a blend of Dead Sea minerals and organic matters naturally formed over thousands of years on the bed of the Dead Sea (6). This unique product is rich in various minerals including magnesium, potassium, calcium, and chloride.

DSM, whether from the Dead Sea shore or as an over-the-shelf product, is applied directly on skin for a designated period of time. To our knowledge, there is no published work regarding the effect of DSM on skin barrier properties. This fact, coupled with the widespread use of DMS, prompted us to initiate this study to evaluate, noninvasively, the short-term effects of various types of DMS on various skin properties (barrier integrity, hydration, pH, and erythema and melanin levels).

MATERIALS AND METHODS

MATERIALS

Native DSM was generously provided by Numeira Mixed Salts & Mud Company Ltd. (Amman, Jordan); it was treated at our laboratory by removing stones. Three types of DMS were used in the study:

1. "As Is" mud was prepared by mixing 15 kg of the native mud (after removing stones) with 1,500 ml of distilled water to improve its spreadability. The mud was then autoclaved for 15 min at 121°C.
2. Salted DSM was prepared by mixing 30 kg of the native mud (after removing stones) with 2,000 ml of Dead Sea water, followed by autoclaving the mud for 15 min at 121°C.
3. Over-the-shelf mud was bought from a well-known shopping mall in Jordan. The list of its ingredients is presented in Table I.

Natrosol® 250 HHX (hydroxyethyl cellulose) was provided by Ashland, Inc. (Covington, KY) and used to prepare a gel at 2% w/w concentration in distilled water to serve as control in this study to account for the occlusion effect of the mud on skin barrier properties.

STUDY DESIGN

Healthy female adult volunteers ($n = 75$), aged 18–45 years (22.1 ± 5.8 years), participated in this short-term study after giving their informed consent. The study was approved by the Institutional Review Board (IRB) of the Hashemite University. The participants were divided randomly into three groups of 20 subjects and one group of 15 subjects. Each group ($n = 20$)

Table I
Ingredient List for Over-the-Shelf Mud

DSM, water, aluminum silicate, glycerin, monopropylene glycol, ethanol, PEG-40 hydrogenated castor oil, preservatives, and fragrance.

was used to test one type of the aforementioned DSM types and the fourth group ($n = 15$) was used as a control group to test the occlusion effect of the prepared Natrosol® gel.

The exclusion criteria were as follows: subjects with dermatitis, erythema, psoriasis, skin cracking, or any lesions on their forearms; subjects receiving any local or systemic treatments; and subjects who were pregnant or lactating. Before baseline measurements, subjects were asked to refrain from using moisturizers on their volar forearms 1 week before the study and to wash their forearms during this week in a prescribed manner twice daily (morning and evening) with a regular soap supplied by the researcher to start with dry skin on both forearms. On the measurement day, subjects were asked to relax for 20 min in a controlled ambient temperature (22°C ± 2°C) and controlled relative humidity (45% ± 5%). Three circles were marked on the ventral aspect of each forearm. Circles on both forearms were used to measure the following skin barrier properties using the Multi Probe Adapter System from CK Electronics GmbH (Koln, Germany):

(a) Skin hydration level using the Corneometer® CM 825 (CK Electronics GmbH)
(b) Skin melanin and erythema levels using the Mexameter® MX 18 (CK Electronics GmbH)
(c) Transepidermal water loss (TEWL) as an indicator of barrier integrity using the Tewameter® TM 300 (CK Electronics GmbH)
(d) Skin pH using the Skin pH-Meter® PH 905 (CK Electronics GmbH)

Each volunteer served as her own control, and mud treated and untreated forearms were randomized among subjects in each group. On the study day, following the washout period, baseline values of the aforementioned skin barrier properties were measured. Then, 10 ml of the mud was applied using a feeding syringe and spread gently using a tongue depressor on the ventral aspect of the assigned forearm and left for 30 min. The amount of DSM applied in the study was found to be satisfactory to achieve good distribution and a thick layer over the whole ventral aspect of the forearm on trials by the authors during study protocol development.

The mud was then removed by gently washing the forearm with warm water and drying by gentle tapping with medical gauze. The same washing procedure and tapping with gauze were carried out for the untreated control forearm. The skin barrier properties on the predetermined circular areas were then measured directly, 30 min, and 60 min after mud removal.

DATA ANALYSIS

The measurements made for each parameter in each group were summarized as mean ± SEM. The data were subjected to statistical analysis in SigmaPlot version 11.0 (Systat Software GmbH, Erkrath, Germany) using repeated measures ANOVA to determine if there were differences among mud-treated versus untreated forearms; then, multiple comparison procedures were used to isolate these differences. Values of $p < 0.05$ were considered statistically significant.

RESULTS AND DISCUSSION

All volunteers reported that they had refrained from using topical products on both forearms 1 week before baseline measurements and washed them twice daily with the given regular soap according to the instructions.

All types of DSM ("As Is" mud, salted mud, and over-the-shelf mud) caused a significant increase in skin hydration values directly after mud removal compared with baseline values, as shown in Figure 1.

The improvements in skin hydration values in the mud-treated forearm measured directly after removal of "As Is" DSM and over-the-shelf mud were significant ($p = 0.002$ and $p < 0.001$, respectively) compared with the untreated forearms at the same time points (Figure 1A and C).

However, the improvement in skin hydration level observed directly after removal of the salted mud was not significant compared with untreated forearms at the same time point, as shown in Figure 1B.

The gel-treated group also showed a significant increase in skin hydration level directly after gel removal compared with the baseline value ($p < 0.001$) and compared with the untreated forearm ($p < 0.001$) at the same time point, as shown in Figure 1D.

The positive increase in skin hydration from baseline values was in descending orders as follows: Gel (Δ18.45) > over-the-shelf mud (16.41) > salted mud (11.88) ~ "As Is" mud (11.11), whereas the positive increase in skin hydration from baseline values for the untreated forearms that were just washed with tap water did not exceed Δ8.71.

Thirty minutes post the mud application, the skin hydration level retuned to the baseline level for "As Is" mud, salted mud, and gel-treated forearms. It is noteworthy to mention

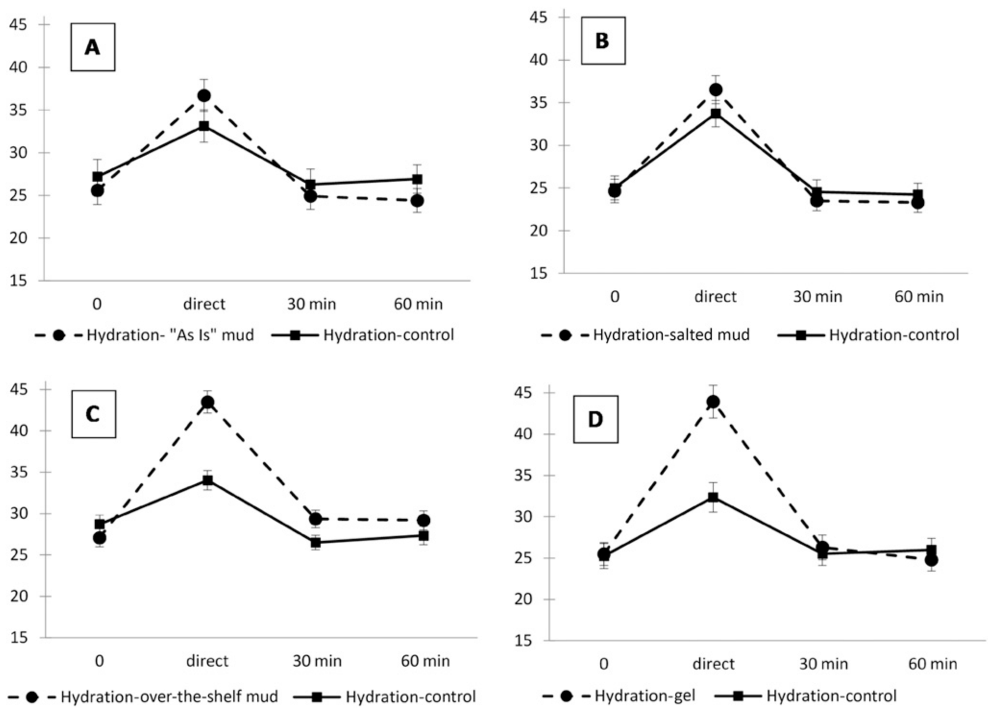

Figure 1. Skin hydration levels for forearms treated with "As Is" mud ($n = 20$) (A), salted mud ($n = 20$) (B), over-the-shelf mud ($n = 20$) (C), and gel ($n = 15$) (D) at the baseline, directly, 30 min, and 60 min after mud removal, compared with untreated forearms. Values represented as mean ± SEM.

that although insignificant, the hydration values at 30 and 60 min post-application were slightly lower for the forearms treated with "As Is" and salted muds compared with the untreated forearms at the same time points (Figure 1A and B). However, the hydration level remained significantly higher for over-the-shelf mud–treated forearms ($p < 0.001$) as compared with the untreated one 30 min post-application (Figure 1C).

Apparently, all types of the mud caused a temporary increase in skin hydration shortly after mud removal. Skin hydration values measured by the Corneometer® directly after mud removal were highest for over-the-shelf mud and gel-treated forearms (~44) and were lowest (~37) for "As Is" and salted mud–treated forearms. It is also noteworthy to mention that the direct short-lived increase in skin hydration value for "As Is" and salted mud (~37)–treated forearms was just slightly higher than the values measured for the untreated forearms that were just washed with tap water (~33).

It is highly probable that the Natrosol® gel caused higher measured skin hydration value compared with "As Is" and salted mud because of its high water content that was absorbed by the skin during the 30-min application. As for over-the-shelf mud that caused a similar high skin hydration level, apparently the presence of humectant (i.e., glycerin) in the mud influenced its short-term hydration effect as shown by both the high skin hydration value directly after mud removal and the enhanced skin hydration level 30 min after mud removal compared with the untreated forearm at the mentioned time points (Figure 1C).

"As Is" salted and over-the-shelf mud did not cause a considerable change in melanin levels for the treated forearms at all tested time points, as shown in Table II, as compared with both baseline values and the untreated forearm values at each time points.

Interestingly, all types of DSM showed no noticeable increase in erythema levels at all tested time points. The erythema levels were comparable to untreated forearms at all tested time points for all types of the mud. On the contrary, a slight decrease in skin erythema was noticed 60 min after mud removal as compared with baseline values for all types of the mud and gel-treated forearms (Figure 2).

The permeability of the skin barrier was determined with the Tewameter® TM 300 by measuring the passive diffusion of water through the skin surface. TEWL is an important indicator of stratum corneum functioning as a protective barrier for water loss and for the passage of allergens and irritants into the lower epidermis and dermis (7). Thus, TEWL is a useful technique to study various physical and chemical skin irritants as well as to assess the mildness of skin care products (8).

All types of DSM and Natrosol® gel caused a significant increase in TEWL directly after removal as compared with their baseline values (Figure 3). The positive increase in TEWL that occurred directly after removal compared with baseline values in a descending order was as follows: Gel > "As Is" mud > over-the-shelf mud > salted mud (Δ15.18, Δ8.08, Δ7.25, and Δ6.37, respectively) with $p < 0.001$. The TEWL for the untreated forearms that were washed with tap water showed a slight increase directly after mud removal as compared with their baseline values for all tested groups: Gel, "As Is" mud, salted mud, and over-the-shelf mud (Δ2.16, Δ3.58, Δ2.99, and Δ1.83, respectively). The increase in TEWL in both treated and untreated forearms returned to normal values 30 min post-removal for all tested groups (Figure 3).

Water in the DSM and gel hydrates the stratum corneum through absorption into the skin as previously known for other skin care products (9). This amount of absorbed water

Table II

Melanin Content for Forearms Treated with "As Is" Mud (n = 20), Salted Mud (n = 20), Over-the-Shelf Mud (n = 20), and Gel (n = 15), at Baseline, Directly, 30 Min, and 60 Min after Mud Removal, Compared with Untreated Forearms

"As Is" mud		
Time	Melanin—"As Is" mud	Melanin—control
Baseline	168.35 ± 7.66	170.31 ± 8.48
Direct	172.21 ± 8.10	172.62 ± 8.41
30 min	176.81 ± 7.64	174.43 ± 8.32
60 min	179.21 ± 7.60	175.09 ± 8.09
Salted mud		
Time	Melanin—salted mud	Melanin—control
Baseline	173.91 ± 9.25	180.51 ± 9.70
Direct	178.48 ± 9.49	182.99 ± 9.67
30 min	180.74 ± 8.82	179.41 ± 9.11
60 min	182.63 ± 8.59	183.01 ± 8.82
Over-the-shelf mud		
Time	Melanin—over-the-shelf mud	Melanin—control
Baseline	202.39 ± 25.01	203.59 ± 25.64
Direct	201.49 ± 25.52	205.76 ± 24.79
30 min	205.91 ± 25.39	204.98 ± 24.71
60 min	207.34 ± 25.50	207.25 ± 25.44
Gel		
Time	Melanin—gel	Melanin—control
Baseline	188.02 ± 16.74	184.12 ± 15.19
Direct	178.88 ± 16.67	187.65 ± 14.70
30 min	191.88 ± 16.74	186.83 ± 14.89
60 min	192.38 ± 16.91	187.83 ± 14.82

Values represented as mean ± SEM.

was enhanced by the 30-min occlusion. Thirty-minute occlusion allows a buildup of water in the skin as can be seen by the slight increase in hydration and TEWL values for the untreated un-occluded control forearms that were just washed with warm tap water for all treated groups: "As Is" mud, salted mud, over-the-shelf mud, and gel from their baseline values (Figures 1 and 3).

The positive increases in skin hydration from baseline values for treated forearms were comparable for both "As Is" mud (Δ11.11) and salted mud (Δ11.88). The highest increases in skin hydration were observed for forearms treated with over-the-shelf mud and gel (Δ16.41 and Δ18.45, respectively). This direct increase in skin hydration resulted from absorbed water from applied mud and gel and the trapping of water by the 30-min occlusion, which is considered as one mechanism by which moisturizers can immediately increase the hydration of the skin. The effect of the absorbed water is observed as an increase in TEWL after mud and gel removal, as shown in Figure 4. Although "As Is" and salted mud caused comparable enhancement in skin hydration, forearms treated with salted

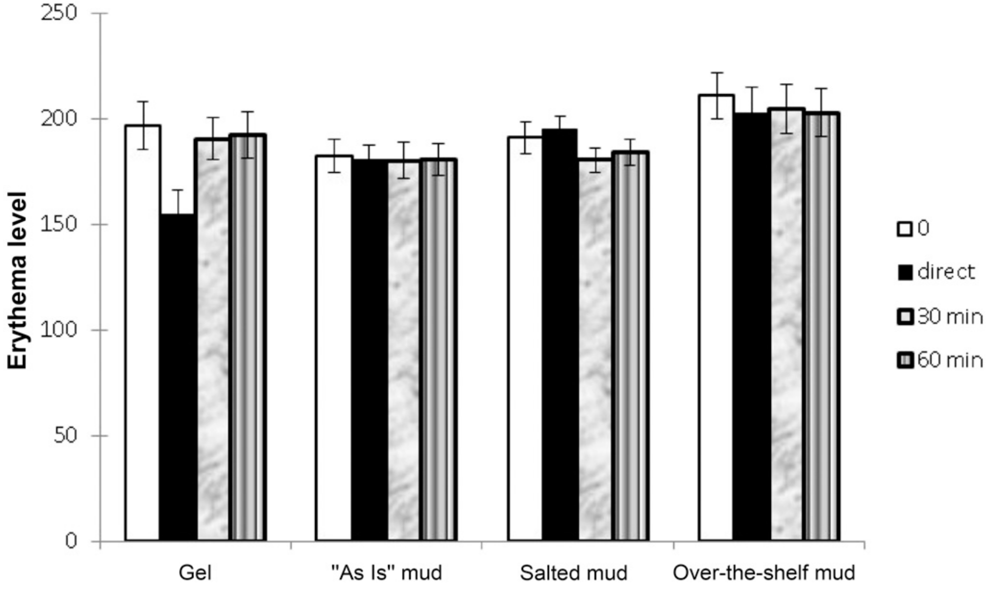

Figure 2. Erythema levels for forearms treated with "As Is" mud ($n = 20$), salted mud ($n = 20$), over-the-shelf mud ($n = 20$), and gel ($n = 15$) at baseline, directly, 30 min, and 60 min after mud removal. Values represented as mean ± SEM.

mud showed lower TEWL directly after mud removal. Dead Sea minerals are considered hygroscopic and may play a role in attracting and retaining the water content of the upper epidermis similar to the role played by natural moisturizing factors (NMF). NMF consist of lactate, amino acids, and pyrollidone carboxylic acid and are present inside the corneocytes. They are necessary to maintain proper hydration of the stratum corneum because of their water-loving characteristics (10).

In addition, although the gel and over-the-shelf mud caused a comparable increase in skin hydration directly after their removal, forearms treated with over-the-shelf mud showed lower TEWL directly after their removal (Figure 4). One factor that may retain absorbed water in the stratum corneum and slow its loss from skin is the humectants in the formulation that penetrated into the skin. The presence of glycerin as a humectant in moisturizers decreases TEWL with an increase in skin hydration by retaining applied water on or immediately below the surface of the stratum corneum (11). Apparently, water evaporation is slowed by the retention of water in the skin by added glycerin in the over-the-shelf mud.

The effect of humectants on skin care products is known to enhance the skin hydration capacity of the applied product. Thus, boosting DSM with other ingredients can enhance its effect on skin barrier properties.

"As Is" mud, salted mud, over-the-shelf mud, and gel did not cause dramatic changes in skin pH after application. Skin pH remained acidic up to 60 min post-removal and was comparable to the untreated forearm values at all tested time points, as shown in Table III.

CONCLUSION

Thirty-minute single application of various types of DSM did not cause any detectable damage to skin integrity. The mildness of the mud was confirmed by the lack of any

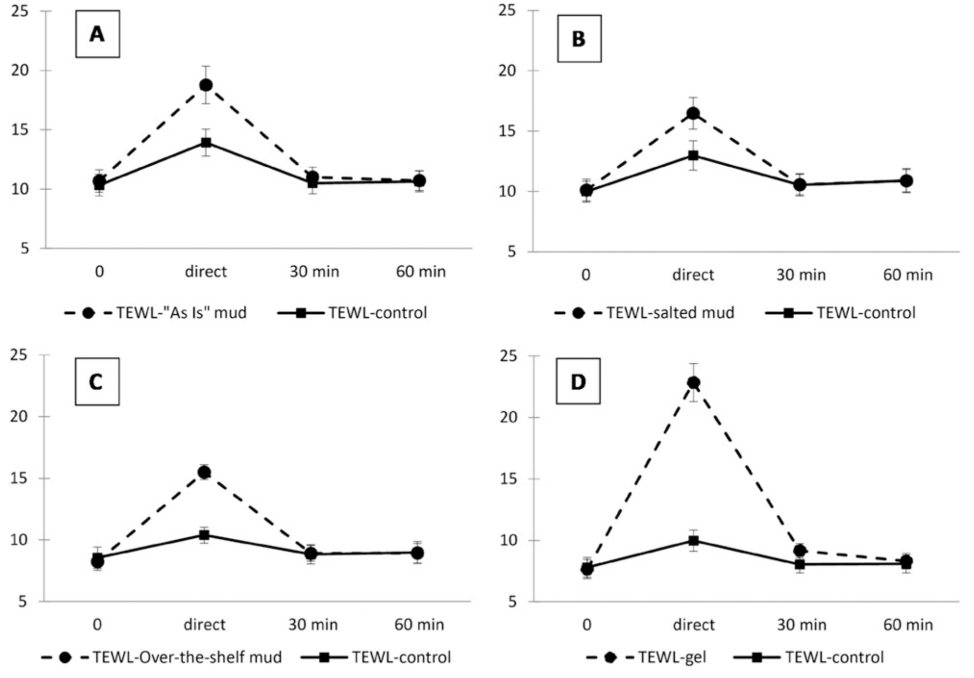

Figure 3. TEWL for forearms treated with "As Is" mud ($n = 20$) (A), salted mud ($n = 20$) (B), over-the-shelf mud ($n = 20$) (C), and gel ($n = 15$) (D) at baseline, directly, 30 min, and 60 min after mud removal, compared with untreated forearms. Values represented as mean ± SEM.

marked differences in skin erythema and pH in the treated forearm skin as compared with baseline values. In addition, the short-lived increase in TEWL directly after mud removal confirms no negative impact of mud on skin integrity. Furthermore, the results showed a short-lived hydration effect of DSM on skin and the importance of boosting the mud with other valuable additives to enhance its skin hydration benefits.

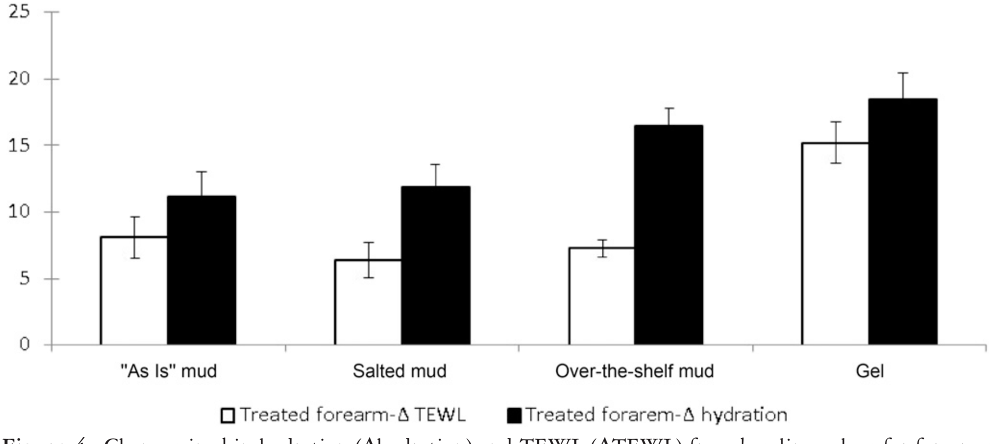

Figure 4. Changes in skin hydration (Δhydration) and TEWL (ΔTEWL) from baseline values for forearms treated with "As Is" mud ($n = 20$), salted mud ($n = 20$), over-the-shelf mud ($n = 20$), and gel ($n = 15$) directly after mud removal. Values represented as mean ± SEM.

Table III
pH Values for Forearms Treated with "As Is" Mud (n = 20), Salted Mud (n = 20), Over-the-Shelf Mud (n = 20), and Gel (n = 15), at Baseline, Directly, 30 Min, and 60 Min after Mud Removal, Compared with Untreated Forearms

Time	pH	pH—control
"As Is" mud		
Time	pH—"As Is" mud	pH—control
Baseline	5.47 ± 0.12	5.47 ± 0.13
Direct	6.23 ± 0.07	6.25 ± 0.07
30 min	6.27 ± 0.07	6.16 ± 0.07
60 min	6.24 ± 0.07	6.19 ± 0.09
Salted mud		
Time	pH—salted mud	pH—control
Baseline	5.72 ± 0.15	5.73 ± 0.15
Direct	6.27 ± 0.07	6.32 ± 0.06
30 min	6.29 ± 0.07	6.28 ± 0.06
60 min	6.29 ± 0.08	6.30 ± 0.06
Over-the-shelf mud		
Time	pH—over-the-shelf mud	pH—control
Baseline	5.98 ± 0.17	6.10 ± 0.21
Direct	6.57 ± 0.08	6.60 ± 0.08
30 min	6.49 ± 0.10	6.53 ± 0.10
60 min	6.52 ± 0.09	6.50 ± 0.09
Gel		
Time	pH—gel	pH—control
Baseline	6.02 ± 0.22	6.13 ± 0.22
Direct	6.53 ± 0.05	6.55 ± 0.11
30 min	6.53 ± 0.06	6.56 ± 0.07
60 min	6.52 ± 0.07	6.57 ± 0.08

Values represented as mean ± SEM.

ACKNOWLEDGMENTS

This project was funded by the Scientific Research Fund, Ministry of Higher Education and Scientific Research, Jordan (grant number: 2008/19/ ص ط/ 2) and was supported by the Hashemite University through the use of Skin Biophysical Measurements facilities at the Faculty of Pharmaceutical Sciences. The authors would like to acknowledge Dr. Hatim S. AlKhatib (Faculty of Pharmacy, University of Jordan) for his helpful suggestions and discussions.

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