A Comparison of Physicochemical Properties of a Selection of Modern Moisturizers: Hydrophilic Index and pH

Vivian Y. Shi BS, a Khiem Tran PhD, b and Peter A. Lio MD c

a University of Illinois, College of Medicine, Chicago, IL
b University of Illinois College of Medicine, Department of Pharmacology, Chicago, IL
c Northwestern University Feinberg School of Medicine, Department of Dermatology, Chicago, IL

Objective: To quantify and compare the physicochemical properties of various topical emollients and to correlate these findings with the products’ potential to maintain the stratum corneum (SC) acid milieu, while possessing the appropriate water content for skin rehydration, user adherence, and comfort.

Material and Methods: The pH and hydrophilic fraction of 31 skin moisturizers sold in the US were measured. Hydrophilic Index (HI) was calculated using the “HI equation.” The two parameters were charted using a scatter plot with quadrant divisions. Products with lower hydrophilicity were considered “more greasy” and assigned a lower HI as compared to their counterparts with a higher hydrophilicity.

Results: Our findings are in good accordance with common clinical impressions: lotions generally have higher HI, while ointments have lower HI. The majority of the products tested fall into low HI, suggesting that a large percentage of the products may be rich in overall lipid content. The pH values range widely, from 3.7 to 8.2, with the majority of the products close to the physiologic skin pH of 4 to 6.

Conclusion: This study introduces HI as a novel method of quantifying the aqueous content of topical emollients. When considered together with pH, the two indices can guide providers in choosing the most suitable emollients for patients with skin diseases involving altered acid mantle and barrier disruption, such as atopic dermatitis, irritant contact dermatitis, and ichthyosis vulgaris.


ABSTRACT

INTRODUCTION

A vast array of choices are available for skin moisturizers, making the selection process an overwhelming task for both consumers and health care practitioners. Despite this problem, few studies have compared the physicochemical properties between various brands in an independent fashion.

The Acid Mantle

Healthy human skin lies in the pH range of 4 to 6.1-4 An increase in stratum corneum (SC) pH can disrupt the activity of enzymes involved in keratinization, barrier restoration, and anti-microbial function.5-8 This phenomenon is seen in atopic dermatitis9-11 and other xerotic skin diseases12-13 and correlates with disease severity of dryness,14 pruritus,13 and total skin involvement.3,6,8 Chemicals applied to the skin are an important exogenous factor that may stabilize the skin’s acid mantle.3 Therefore, topical products with near-physiologic pH are considered best in prevention and treatment of these same skin abnormalities.3

Formulations of Moisturizers

Topical products are traditionally divided into very limited and general classes, namely ointment, cream, lotion, gel, and foam.13 There have been many modern additions and changes to these standard excipients. The “lotion” from one manufacturer may be significantly texturally more viscous than the “cream” of another manufacturer. This system creates obvious confusion in selecting an emollient with the desirable texture and reflects the need for a more precise and standardized classification. In an attempt to address this problem, we introduce Hydrophilic Index (HI) as a novel methodology to measure the aqueous content of a topical product, and utilize it as an indirect quantification of “greasiness.”

In this study, we assessed the pH and HI of 31 skin moisturizers sold in the US, and then combined these two parameters to determine which products have the most potential to restore SC acid milieu and provide sufficient hydration, yet possess the appropriate aqueous content to suit user preference.

METHODS AND MATERIALS

pH Measurement

A pea sized amount of moisturizer was placed on Parafilm® wrap. pH was measured using a glass flat tip electrode (Hanna® HI 99191) with accuracy: pH = ± 0.02 at 25°C. All measurements were performed 5 times to achieve their standard deviations.
Hydrophilicity Measurement

To measure, we placed 0.25 g of each product and 750 microliters of H₂O into a 1.7 mL microcentrifuge tube, producing a total weight of 1.0 g (density of H₂O = 1.0 g/cm³ = 1.0 g/ml). The tube was vortexed at maximum speed for 30 seconds to allow adequate emulsification of the two components. In our experience, a 1:3 product to water ratio allows for optimal mixing. Next, the mixture was centrifuged at 25°C for 15 minutes. This separated the denser, more hydrophilic layer on the bottom from the lighter, more hydrophobic layer on top (Figure 1). The most translucent layer was assumed to have the highest percentage of emulsified water, have the highest percentage of emulsified H₂O, and least amount of water extracted. All HI measurements were performed 5 times to achieve their standard deviations.

Calculation of Hydrophilic Index—The HI Equation

\[ HI = \frac{1.0 \text{ g} - \text{weight of aqueous layer in grams}}{1.0 \text{ g}} \times 100\% \]

We selected Shell® motor oil and de-ionized water as controls for HI measurement due to their absolute respective hydrophobicity and hydrophilicity.

RESULTS

Among the 31 products studied, pH values ranged from 3.73 (Vanicream® Light Moisturizing Lotion) to 8.19 (Eucerin® In- dicator Repair Body Lotion) with the majority falling within physiologic skin pH of 4 to 6 (Table 1). The HI also exhibited a wide range of values, from 26.84 (Triple Paste®) to 100.00 (Neosalus® Cream). Nearly 2/3 of the products fell below HI 50 (Table 1). This suggested that a large number of moisturizers are rich in lipid content. Our findings are in agreement with the common finding that centrifugation leads to its separation into multiple layers, a finding also seen in Dove® Day Lotion (Figure 1). Interestingly, CeraVe® Moisturizing Cream, though clearly “heavier” than CeraVe® Moisturizing Lotion when handled, was found have an HI of 92, whereas the lotion only has an HI of 66. Such counterintuitive results may be due to delivery technologies, which may alter the perception of both hydrophobic and hydrophilic components. This property may explain our finding that centrifugation leads to its separation into multiple layers, a finding also seen in Dove® Day Lotion (Figure 1). Neosalus® also defies easy categorization: though marketed as a cream, it has the highest HI of all the products, and remains completely emulsified despite centrifugation.

DISCUSSION

The two primary goals of a moisturizer are to introduce water directly into the SC and to prevent transepidermal water loss (TEWL). These two tasks are accomplished by the hydrophilic and hydrophobic components of a moisturizer, respectively. Increased SC pH results in barrier dysfunction and decreased antimicrobial capability, both of which play important roles in the pathogenesis of skin diseases such as atopic dermatitis, irritant contact dermatitis, and ichthyosis vulgaris. Application of moisturizers with appropriate pH and HI can potentially prevent and improve these skin diseases. When choosing a suitable moisturizer for such patients, providers could consider products in Quadrants I and II because their low pHs may allow for better repair of the acid mantle and antimicrobial defense capability. Additionally, dermatologists could recommend products with an HI that matches user comfort and cosmetic tolerability, while considering how effective they are at rehydrating and protecting the skin. More importantly, however, if a patient does not like an aspect of a moisturizer (eg, “It's too greasy”), recommending another agent with a different HI may provide a more suitable choice.
Quadrant II products are more hydrophobic, and can retain water in both the upper and deeper SC. Upon application, a fraction of the product is retained on the skin surface, which can decrease water permeability by acting as a physical occlusant. They may also penetrate into deeper SC and change the packing and lamellar organization of the intercellular lipid matrix, further making it impermeable to water evaporation.\textsuperscript{19-22} Unfortunately, their texture may increase the risk of occlusive folliculitis\textsuperscript{12} and may also diminish patient acceptance and

Quadrant I products are hydrophilic, and can quickly hydrate upper layers of SC.\textsuperscript{19} These products may require more frequent application because the extent of their moisturization relies on the concentration of the product applied. Furthermore, most of their water content is retained largely in the upper layers of the SC, and does not benefit the lipid metabolism in the deeper SC.\textsuperscript{20} However, their aqueous texture makes them easier to apply, and these may be more cosmetically elegant and acceptable and therefore more suitable for patients who cannot tolerate greasier products.

### TABLE 1.

<table>
<thead>
<tr>
<th>#</th>
<th>Brand and Product Name</th>
<th>HI</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CeraVe® moisturizing cream</td>
<td>92.29 ± 0.58</td>
<td>5.49 ± 0.02</td>
</tr>
<tr>
<td>2</td>
<td>Aquanil® lotion</td>
<td>74.52 ± 0.03</td>
<td>5.19 ± 0.04</td>
</tr>
<tr>
<td>3</td>
<td>Acid Mantle®</td>
<td>68.21 ± 7.40</td>
<td>4.71 ± 0.01</td>
</tr>
<tr>
<td>4</td>
<td>CeraVe® moisturizing lotion</td>
<td>66.27 ± 2.51</td>
<td>5.68 ± 0.02</td>
</tr>
<tr>
<td>5</td>
<td>Vaseline® intensive rescue skin protectant body lotion</td>
<td>62.10 ± 1.62</td>
<td>4.30 ± 0.02</td>
</tr>
<tr>
<td>6</td>
<td>Aveeno® daily moisturizing lotion</td>
<td>54.34 ± 4.20</td>
<td>5.62 ± 0.01</td>
</tr>
<tr>
<td>7</td>
<td>CeraVe® facial moisturizing lotion PM</td>
<td>56.53 ± 4.66</td>
<td>5.95 ± 0.01</td>
</tr>
</tbody>
</table>

Within each quadrant, the emollients are listed from highest to lowest HI. pH and HI values were measured five times to achieve the standard deviation values shown.
compliance by leaving greasy stains on clothing or causing a physical sensation of “greasiness.”

Products in Quadrants III and IV have a more alkaline pH and therefore may be less desirable in restoring skin pH, but may have other characteristics that supersede this single measure. The Quadrant IV products may provide better hydration than the more hydrophilic agents in Quadrant III.

HI provides an objective, in vitro assessment of the aqueous content of the products, without reliance on human subjects or perception, thus allowing straightforward and consistent measurements. Future studies should be done to correlate HI with user perception of emollient texture and to assess how products with different HI and pH may actually influence SC in TEWL and corneometry, and perhaps even in disease outcome. Additionally, topical products and medications may be divided into more precise vehicle categories with respect to both the HI and the pH, and be selected to tailor user preference and clinical goals.

REFERENCES


DISCLOSURES

Dr. Lio has served as an advisory board member for Aveeno, Galderma, and Onset Therapeutics. Dr. Tran and Ms. Shi have no conflicts of interest to declare.

ADDRESS FOR CORRESPONDENCE

Peter A. Lio MD
1455 N. Milwaukee Ave, 2nd Floor
Chicago, IL 60622
Phone: ..................................................(773) 276-1100
E-mail: ..................................................p-lio@northwestern.edu

© 2012-Journal of Drugs in Dermatology. All Rights Reserved.
This document contains proprietary information, images and marks of Journal of Drugs in Dermatology (JDD).
No reproduction or use of any portion of the contents of these materials may be made without the express written consent of JDD.
If you feel you have obtained this copy illegally, please contact JDD immediately.