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The Concept of the Acid Mantle of the Skin: Its Relevance for the Choice of Skin Cleansers

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Abstract
Whereas soap has long been the only cleansing agent, a new generation of cleansers, the so-called synthetic detergents or syndets, has been developed during the last decades. They offer a wide variety of formulations and are therefore becoming more and more important for cleansing of diseased and healthy skin. Among the syndets, especially those with a pH of about 5.5 seem to be relevant. In contrast to alkaline soap, they do not interfere with the cutaneous microflora, whose composition is linked to the skin surface pH. As their irritancy potential might be even lower than that of soap, the benefit-to-risk ratio of syndets appears favorable.

Introduction

The pH of normal skin has been a matter of debate since the end of the last century. In 1892, Heuss [1] was the first to claim that the entire body surface is acidic, which – in principle – has remained unchallenged until today. But it was not until the end of the twenties that Schade and Marchionini [2] published their experiments performed with more exact electrometric methods; using a 'gas chain bell electrode' adapted for the skin, they found a skin pH between 3.0 and 5.0. This acidic reaction was interpreted as being due to impregnation of the horny layer with acidic constituents of eccrine sweat. In intertriginous areas and in regions supplied by apocrine glands the reaction was found to be less acidic or even neutral. Precise and reliable potentiometric measurements carried out later by Blank [3] showed a higher skin pH between 4.2 and 5.6. Since the beginning of the 1950s, the flat glass electrode introduced by Ingold has been used for pH measurements as an alternative to the gas chain bell electrode [4]. Schirren [4] found the same pH values on the skin surface using the glass electrode or the quinhydrone electrode, which showed the equivalence of both methods.

Most of the publications so far available suggest a skin pH between 5.4 and 5.9 [5]. Zlotogorski's [6] results based on recent experiments range between pH 4.0 and 4.9, which confirms our own findings [7]. Tronnier [8] mentions average pH values between pH 6.4 and 6.5. However, these results are not sufficiently supported by experiments.

All recent data confirm the acidity of the skin surface, except for some areas, in which physiologically higher pH values prevail, the axilla, the genitoanal and interdigital regions termed 'physiologische Lücken des Säuremantels' (physiologic holes of the acid mantle) [9]. Due to less acidity, the normal bacterial flora in these areas is considered different. The relationship between skin pH and resident flora deserves some interest.

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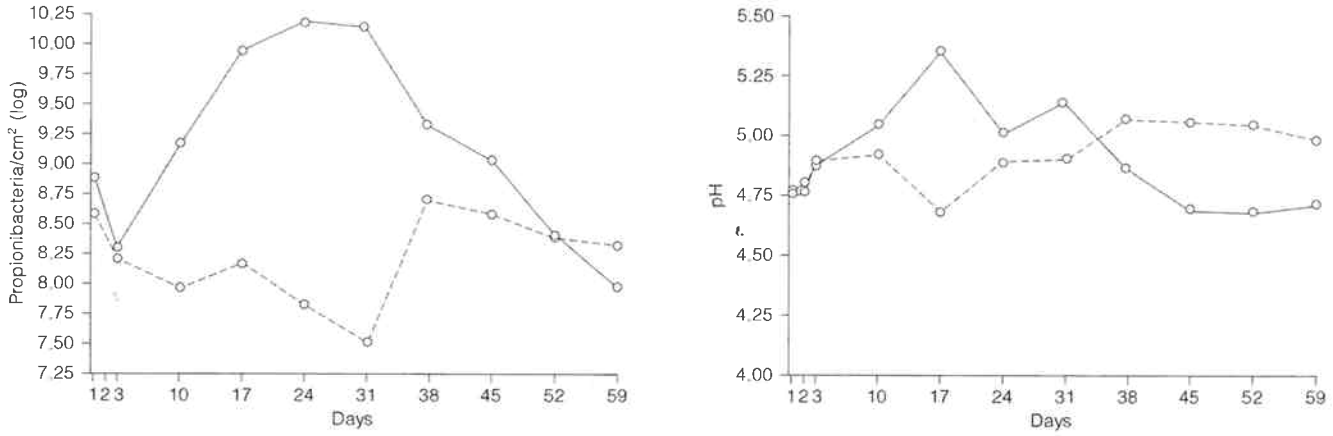

Fig. 1, 2. Evolution of the propionibacterium counts per square centimeter (**1**) and of the mean pH values (**2**) on the subjects' foreheads during repeat applications of alkaline soap and acidic syndet in the frame of a comparative cross-over trial. —= Soap first for 4 weeks, then syndet for 4 weeks; – – – = syndet first for 4 weeks, then soap for 4 weeks. From Korting et al. [14].

Skin pH and Bacterial Flora

The concept of defense against micro-organisms due to skin surface acidity was first elaborated in some detail in the twenties and thirties by Marchionini and Hausknecht [9] and Schade and Marchionini [10]. This concept, termed the 'acid mantle concept', has long been a subject of controversy.

Hartmann et al. [11] examined the effect of repeated washing on the bacterial flora of the skin, in particular staphylococci and propionibacteria addressing bathing in particular. They concluded that the ecosystem of the resident human skin flora is largely resistant to outside factors: bathing once a day for 3 weeks or avoidance of washing of the forearms for the same length of time did not lead to either an overgrowth of transient, or a major shift in the composition of resident micro-organisms [10]. Yet these studies have been performed without looking at the pH value.

It therefore appeared interesting to investigate the interrelationship between skin surface pH and the resident flora. For this reason, we performed studies involving the repeated use of (alkaline) soap and (acidic) syndet over an extended period of time under well-defined conditions and looked at changes of both skin surface pH and resident flora [7].

Each of two parallel groups comprising 5 healthy volunteers each had to wash their foreheads and forearms twice a day with alkaline soap or acidic syndets for 4 weeks [7]. Thereafter the alternative skin cleanser was used for another 4 weeks. Before the start of the trial proper and at the end of each week, skin pH was measured using the flat glass electrode as described by Schirren [4], and the bacterial flora was determined using the detergent scrub method introduced by Williamson and Kligman [12]. Examinations were always performed in the middle of the application interval to avoid short-term effects. In addition, skin pH and bacterial flora were determined once within the hours following one single washing procedure.

In the subjects who were initially using soap the skin pH rose and fell when the acidic syndet was used. In those volunteers who started washing with the syndet, the skin surface pH remained stable or slightly declined; after the cross-over to soap, the pH rose above the baseline values. The skin surface pH was lower by 0.3 units when the acidic syndet had been used for at least 2 weeks. Yet both with syndet and soap a rise in skin pH was found as a short-term effect of washing. These effects, however, where reversible within 2 h. No definite change in the counts of coagulase-negative staphylococci could be established. The behavior of propionibacteria, however, was different: repeated washings with soap led to increased bacterial counts, after changing to the acidic syndet, counts decreased again (fig. 1). Moreover, there was a correlation between skin pH and density of both bacterial species at the forehead. These observations indicate that (i) repeated washings with either soap or acidic syndet produce long-term changes in skin pH (fig. 2); (ii) different bacterial species forming the resident

flora can be influenced differently in the long run by the type of skin cleanser [7]. Further evidence for the causal relationship between pH and propionibacterial count changes comes from additional clinical trials.

To prove or disprove this hypothesis definitively, however, in vitro investigations are indispensable. Thus the growth of cutaneous isolates of staphylococci and propionibacteria was investigated at different pH values in discontinuous or overnight culture [13]. Cutaneous *Staphylococcus aureus* strains showed an optimum growth at pH 7.5, whereas with *Propionibacterium acnes,* the optimum growth was found at pH 6.0 and 6.5. At a pH of 5.5, however, the specific growth rate was much lower. This led to the conclusion that minor shifts in skin surface pH from its normal value (pH 5.5) towards more alkaline values (e.g. pH 6.0) may enhance the growth of *P. acnes* but not that of *S. aureus*. This is of particular interest as slightly higher pH values can result from washings with soap. Yet a similar enhancement of growth for *S. aureus* could only be expected from major pH shifts [13]. These findings from batch culture experiments could be confirmed by later experiments in cutaneous culture using a chemostat with cutaneous isolates of *Staphylococcus epidermidis, S. aureus* and *P. acnes* in continuous culture at varying pH values ranging from 5.0 to 8.5 [14]. Growth rates as well as bacterial density during the plateau phase were measured. *P. acnes* showed highest growth rates in the pH 6.0 to 7.0 range while *S. epidermidis* and *S. aureus* did not show any major differences at pH 5.5 and 7.0. These findings substantiate the above hypothesis that minor pH changes in the pH 5.5 to 6.0 range, e.g. induced by alkaline skin cleansers, can markedly increase the number of propionibacteria but not of staphylococci. In more recent experiments, *Brevibacterium epidermidis* – a major component of the bacterial flora of certain skin surface biotopes such as the axilla – was grown in vitro in continuous culture. While *B. epidermidis* grew readily from pH 5.5 to 8.5, this was not the case with a pH of 5.0. Thus the growth of *B. epidermidis,* which seems to be linked to unpleasant body odor, may only be prevented if the pH value is decreased to 5.0 or less [15].

Skin pH and Skin Cleansing

While soap was used for skin cleansing for over thousands of years, synthetic cleansers of the liquid or the bar type have started to become an alternative only fairly recently. In 1959, Keining [16] was the first to describe the advantages of syndets. In his historical paper, he mentioned a decreased irritancy potential, lack of sensitization and capability to maintain or even to restore the acid mantle of the skin. Although experimental evidence is still lacking, the value of acidic syndets in the therapy of various skin diseases, including acne vulgaris, is widely accepted on clinical grounds [17]. Yet there is currently a debate on whether syndets should be used for cleansing healthy skin, and if so at what pH.

To get more insight into this problem, we performed a cross-over trial using syndets that were chemically identical except for the pH, which was either of 8.5 or 5.5 [18]. Skin pH and bacterial counts were determined. Foreheads and forearms of the volunteers showed markedly higher skin surface pH values after the use of the alkaline preparation. While the counts of coagulase-negative staphylococci were not influenced, the opposite was true for propionibacteria: their count on the skin of the forehead and forearm was increased at the end of the 4th week in the presence of the alkaline preparation. Moreover, a positive correlation was seen between propionibacterial counts and pH [18]. These findings were supported by a similar cross-over trial performed later [19] using chemically almost identical syndets of pH 5.5 and 7.0. Once more, the results suggested that even minor differences – of the order of a single pH unit – in skin surface pH markedly influence the resident flora, in particular propionibacteria [19]. Moreover, it is now undebatable that the pH itself and not the constituents of the cleanser have major implications for the cutaneous microecology.

In this context it might be of particular interest to know whether not only healthy volunteers but also acne-prone patients may benefit from washing with acidic syndets. For this reason we evaluated the influence of a soap and an acidic syndet on the development of acne lesions in subjects with a tendency to develop acne vulgaris ('pre-acne') [20]: in an open, confirmatory, comparative trial the volunteers either used an acidic syndet bar or conventional soap over a period of 12 weeks. Application time was 1 min each in the morning and in the evening. The number of inflammatory and noninflammatory acne lesions was counted as well as side effects such as itch, redness and scaling. In the group using soap, the mean number of papulopustules on the face increased from 14.6 to 15.3 while it decreased from 13.4 to 10.4 ($p < 0.0001$) in the group using syndet. In fact, the acidic syndet not only reduced the manifestation of lesions of inflammatory acne but it was also better tolerated. This might further improve the benefit-to-risk ratio of syndets [20].

Safety

In 1930, Stauffer [21] wrote: 'However, individuals prone to the development of eczema should best avoid soap because of the enormous risk of an eczematous reaction. For this reason I now forbid the use of soap in almost all my patients with occupational eczema'. This piece of advice which in German-speaking countries is known as 'Seifenverbot' (prohibition of soap), indeed found many proponents as cleansing agents of the soap type available at that time showed many unwanted effects. Yet with the introduction of synthetic detergents, the situation has changed. Today, judgements on skin cleansers should take into account both their wanted effects which by convention means cleansing activity in particular and unwanted effects such as: (i) impairment of the acid mantle, recently corroborated as a relevant aspect of skin physiology, and (ii) impairment of the epidermal permeability barrier resulting in dry skin and increased skin roughness.

In general, chemical composition (i.e. nature and concentration of the various surfactants), duration of application and temperature seem to be important as far as the unwanted effects of washing are concerned. Irritation can be reduced by modifying the chemical composition which, in some cases, unfortunately compromises the cleansing activity. The adjustment of the pH value of the cleansing preparation is another and perhaps more promising possibility to improve the benefit-to-risk ratio of syndets. This is suggested by Osborne and Friberg [22] and Friberg [23] who reported that the key to the bilayer formation and water-retaining capacity of the epidermal lipids is the pH of the system. Only if the pH is adjusted to that of normal skin (pH 5.5) are bilayers of these lipids formed which are essential for the prevention of skin dryness and roughness. The validity of this hypothesis has been corroborated by clinical investigations. In 1989, Antoine et al. [24] concluded from investigations based on the assessment of cutaneous blood flow values that the 'pH cannot be considered as a major contributive factor of irritancy', at least with respect to the well-known model irritant sodium lauryl sulfate applied under occlusion over 48 h. This is in accordance with our findings comparing synthetic cleansers, as described with pH 5.5, 7.0 and 8.5, a judgment based on the parameters transepidermal water loss and skin roughness expressed as mean peak-to-valley height or R_{ZDIN} values [25]. Using infrared spectroscopy and corneometry, i.e., skin capacitance measurements, Gehring et al. [26] even described 'a greater dehydrative effect at alkaline pH (7.5) than at neutral or acidic pH (4.5)'. On the basis of these data, it may be suggested that individuals with sensitive skin such as atopics should preferably not use alkaline soaps [27].

Outlook

In summary, synthetic detergent cleansers of the acidic type are more than just another type of skin cleansing agents. They have become a real alternative to soap not only in patients with proven or suspected soap intolerance. Today acidic syndets are an established management principle in dermatology for the cleansing of diseased and healthy skin. Some subjects seem to profit most from acidic syndets: individuals with seborrhea or even a clear-cut predisposition to seborrheic dermatoses such as acne vulgaris. There is good reason to believe that the same might apply for persons suffering from atopic dry skin or even atopic eczema. Individuals with so-called mixed type skin, however, still can choose their favored cleansers on the basis of other parameters ranging from aesthetic to economic aspects.

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