ELSEVIER

The Effect of Detergents on Skin pH and Its Consequences

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Interest in skin surface pH is already of long standing. More than a century ago, in 1892, Heuss claimed that the entire surface of the body is acidic.[1] This early finding, based on the use of hardly adequate technology, was corroborated by the investigations of Schade and Marchionini.[2] With the help of a so-called gas chain bell electrode, adapted for cutaneous use, they determined skin surface pH between 3.0 and 5.0. Schade and Marchionini had already addressed differences according to the region of the body area; in particular, they found that occluded skin was less acidic than skin exposed only to the atmosphere. Later Blank considered the skin surface pH to lie in the range of 4.2 to 5.6,[3] which described the range considered relevant ever since.

In fact, Marchionini and his group focused not only on skin surface pH by itself but also on its presumable biologic meaning. As early as the 1930s, they formulated the hypothesis that the potential of differing bacterial species to grow on human skin differed according to its dependence on its surface pH. This was established mainly by comparing the capability of certain bacterial species, including *Serratia marcescens*, to survive on unoccluded and occluded human skin with their known difference in skin surface pH.[4] The concept has remained popular ever since, although it did not remain unchallenged. This might be due to the suggestive term "acid mantle," coined by Marchionini.

The Normal Surface Skin pH

In the 1950s, the flat glass electrode became available; it is still the device of choice for the determination of skin surface pH. This electrode, devised by Ingold, was introduced into the scientific literature by Schirren, who demonstrated that this easy-to-use device essentially gives the same results as the previously used quinhydrone electrode.[5] Virtually all modern investigations use the flat glass electrode, and in most cases the pH range for normal human skin is said to be between 5.4 and 5.9—as was demonstrated in detail in a specialized review.[6] A study on the subject was performed by Zlotogorski; investigating facial skin, he found values between 4.0 and 4.9.[7] This is roughly in accordance with our findings. At the forehead the pH in Munich volunteers ranged from 4.5 to 5.6 and at the forearm from 4.2 to 5.4, with mean values reading 4.8 and 4.7 respectively.[8]

Influence of Repeated Washings on Skin Surface pH

It has been known for a long time that cleansing the skin can lead to changes in its surface pH and that there is a relationship between the pH of the cleanser and the degree of influence on the skin surface under the aspect of its pH.[9] This held true as initial data from the 1940s were confirmed in the 1960s. Yet, the effect was considered to be short-lasting: about 2 hours after an individual washing procedure.[10] Given that there are two or three such procedures a day, it seems obvious that there should be no profound effect on related parameters. Against this background it has come as a surprise to many that there are also long-lasting effects with as few as two washing procedures of 1 minute each a day, as we demonstrated at the end of the 1980s.[8] According to a randomized open crossover trial, skin surface pH increases on the regular use of a conventional soap and decreases again after the change to an acidic cleanser (of pH 5.5) and vice versa. Yet, it was not clear at first whether it was the pH of the cleanser by itself that influenced the skin surface pH or perhaps related factors. Hence, similar investigations were performed using an alkaline cleanser of identical pH (8.5) yet chemically corresponding to the acidic one—that is, a corresponding syndet. In fact, such was the case even when a so-called neutral cleanser was used instead of the alkaline one (ie, a chemically corresponding syndet of pH 7.0).[11] The data found in this case at the forearm are represented in Fig 1[12]. As could be expected, a short-term effect was demonstrated in one of these trials.[8] Hence there is ample evidence that there is both a short-term and a long-term effect on skin surface pH if a cleanser is used whose pH deviates from the pH of the skin surface to which it is applied. In keeping with this hypothesis, so-called neutral cleansers are by no means neutral in a biologic sense.

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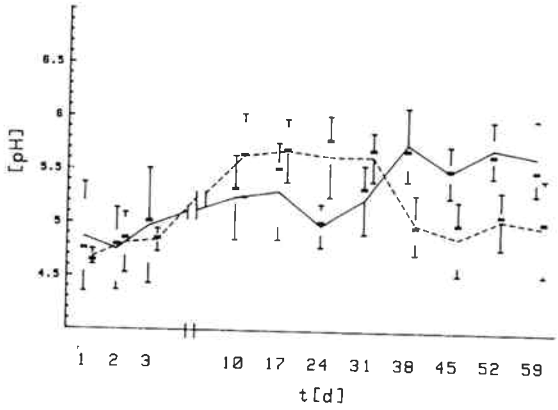


Figure 1. *pH values at the forearm at various times during the repeated application of an acidic and a neutral liquid syndet. (Continuous line: volunteers starting with the acidic cleanser and changing to the neutral one after 28 days' application; dotted line: volunteers starting with neutral cleanser and changing to the acidic one after 28 days' application.) (Reprinted, with permission, from Korting et al.[12])*

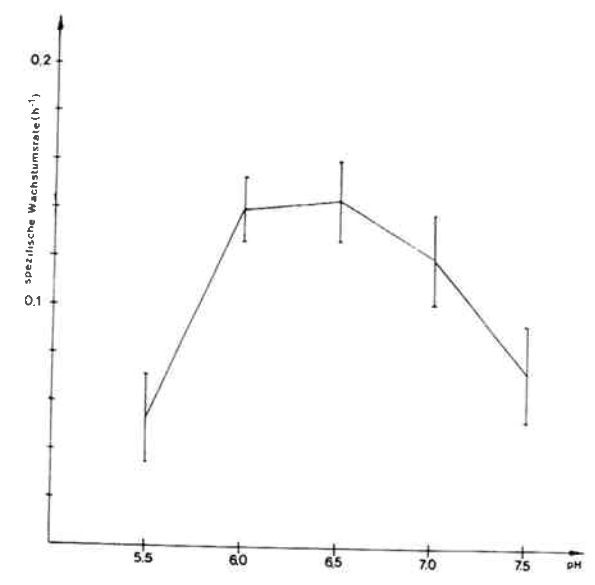
Skin Surface pH and Bacterial Flora

The notion has long existed that there is a close relationship between skin surface pH and its bacterial flora. This integral part of the acid mantle concept of Marchionini is backed by both in vitro and in vivo evidence. To understand this evidence in full requires some knowledge of the nature of the bacterial microflora of the skin. According to current doctrine, three types of flora have to be distinguished: transient, temporary resident, and, in particular, resident flora.[13] The resident flora comprises several species belonging to the Micrococcaceae, which under technical or diagnostic aspects can be designated coagulase-negative Staphylococci, and Propionibacteria comprising the species *P. acnes*, *P. avidum*, and *P. granulosum*, of which the first is most prominent. Other components of the cutaneous microflora are corynebacteria, such as *C. xerosis*, also termed lipophilic diphtheroids or small-colony diphtheroids and yeasts, *Pityrosporum ovale* and *P. orbiculare*. While these are the components of the microflora of glabrous skin in general, their relative importance depends on the habitat. Three have been distinguished: the dry habitat at the forearm flexor aspect, the damp habitat at the axilla, and the sebaceous habitat at the forehead. In a dry habitat, coagulase-negative Staphylococci clearly prevail; the Propionibacteria predominate in a sebaceous habitat. On the forehead, for example, Propionibacterium species account for up to 90% of the bacteria forming the resident flora.[13] The actual composition of the skin flora at a given location depends on a variety of factors, which can be divided into biotic and abiotic. Biotic factors comprise phenomena such as neutralism, commensalism, mutualism, and antagonism; abiotic factors include physical and chemical factors, among which pH is prominent.[14]

In Vitro Situation

The influence of pH on the growth of components of the cutaneous microflora can be most easily investigated in vitro using overnight or "batch" cultures. Pertinent investigations allow determination of the specific growth rate, defined as the number of doublings of colony-forming units per microliter of liquid medium. Figure 2 depicts the pH range at the surface of human skin and the changes that can be induced by washing procedures. According to our investigations, these changes amount to up to 0.3 unit.[8] While *P. acnes* grows very well at pH values such as 6.0 and 6.5, this is not the case at a pH of 5.5. With Staphylococci the situation is different. *S. aureus*, one of the main representatives of the Micrococcaceae, grows best at a pH of 7.5, yet there is not much difference in the pH range of 5.0 to 5.5. to 6.0.[15] Overnight cultures allow only limited insight. In contrast, continuous culture, which can be performed in a chemostat, allows simulation of in vivo conditions. Even in this crucial assay, the clear-cut difference between pH values 5.0, 5.5, and 6.0 could be demonstrated as is depicted in Fig 3: a pH of 6.0 clearly promotes Propionibacterial growth, while the opposite applies to pH values of 5.5 and 5.0.[16]

Figure 2. *Specific growth rates of* P. acnes *at various pH values in batch culture. (Reprinted, with permission, from Korting et al.[15])*



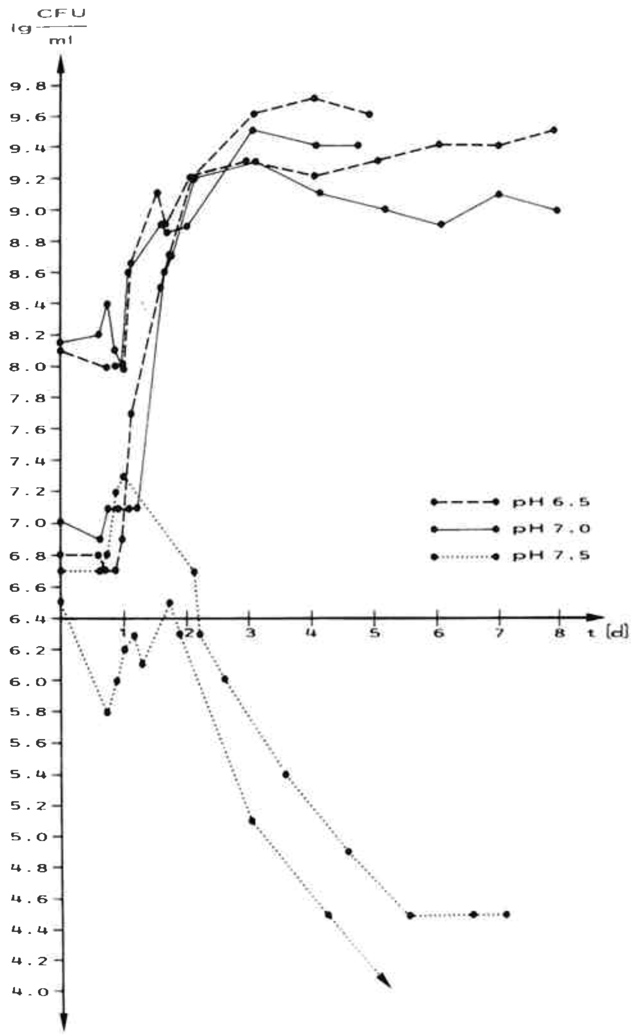


Figure 3. *Density of* P. acnes *(colony-forming units per ml) at different pH values in continuous culture. (Reprinted, with permission, from Korting et al.[16])*

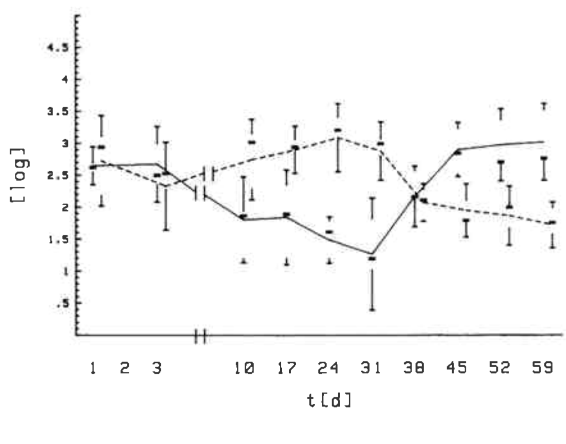
In Vivo Situation

If the hypothesis to be derived from the in vitro findings were right, Propionibacterial but not Staphylococcal counts on the skin should arise when an alkaline cleanser is applied due to the shift in pH toward alkaline values, while there should be virtually no change if an acidic cleanser were applied respecting the original skin surface pH. In fact, such was demonstrated in three individual trials.[8,11,12] Whatever the nature of the cleanser and irrespective of its pH, given that it is lying in the neutral or alkaline range, Propionibacterial density on the skin on repeated application of the cleanser increases other than Staphylococcal density, while the opposite happens if this type of cleanser is replaced by an acidic one, or vice versa. Fig 4 demonstrates the increase of colony-forming units of Propionibacteria per square centimeter on the use of a neutral cleanser (of pH 7.0) and its decrease on the switch to a corresponding acidic one as well as the opposite phenomenon when both preparations are applied in reverse order.

Clinical Relevance of pH Changes of the Skin Surface

The role of Propionibacteria in the development of manifest acne in disease-prone patients is not fully understood. There is reason to believe that Propionibacterial counts are linked to manifestations of acne or that high counts are correlated with manifest or acne vulgaris at least in adolescents.[17] This theory has not remained unchallenged, yet even those who question the concept admit that the pH might be a central ecologic factor moderating the acne-inducing potential of propionibacteria.[18] If the findings on cutaneous surface pH, bacterial microflora, and the influence of skin cleansing were relevant, acne vulgaris and in particular its inflammatory component would be more marked if alkaline cleansers were applied for a longer period than acidic ones. Recently this evidence was advanced on the basis of a confirmatory comparative trial in acne-prone patients comparing the number of inflammatory lesions on the face.[19] About 30 patients per group used either a conventional alkaline soap or a frequently used acidic syndet bar over a 12-week period in a confirmatory trial. While the number of inflammatory lesions increased in the former group from 14.6 ± 5.3 to 15.3 ± 6.0, it decreased in the latter from 13.4 (±5.2) to 10.4 (±5.8). Statistically, there were clear-cut differences from the 4th week of application onward ($p < .0001$). Fig 5 depicts the number of facial inflammatory acne lesions in both groups over time. As acne vulgaris is a common disorder in adolescence and early adulthood—

Figure 4. *Number of propionibacteria per square centimeter on the forearm at various times during the repeated application of an acidic and a neutral liquid syndet. (Continuous line: volunteers starting with the acidic cleanser and changing to the neutral one after 28 days' application; dotted line: volunteers starting with the neutral cleanser and changing to the acidic one after 28 days' application.) (Reprinted, with permission, from Korting et al.[12])*



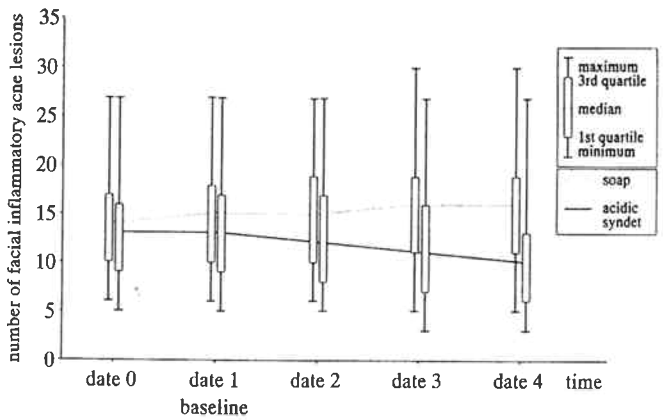


Figure 5. *Number of inflammatory acne lesions at the face in acne-prone patients on regular application of (alkaline) soap and (acidic) syndet over time (weeks 0, 2, 4, 8, 12). (Reprinted, with permission, from Korting, et al.*[19]*)*

particularly on the face—adolescents and young adults should prefer an acidic cleanser for skin cleansing if there is no reason to decide otherwise.[20–22]

Safety Aspects

For centuries it has been known that skin cleansing might be not only beneficial to human skin. In the 1930s, the idea was propagated that the use of soap could damage the skin in patients prone to develop eczema. Stauffer went so far as to disallow soap for such patients, using the frequently cited German term *Seifenverbot*, or prohibition of soap.[23] On these grounds, the introduction of acidic cleansers in the 1950s was initially welcomed. Later, however, it was postulated that acidic syndets might be more irritant than chemically neutral ones,[24] and this notion was at first supported by experimental evidence.[25] Our own investigations, however, did not support this hypothesis. In fact, we could not find any difference in terms of skin surface roughness or transepidermal water loss to be measured objectively by bioengineering procedures investigating corresponding syndet preparations of pH 5.5, 7.0, and 8.5.[26] Using the subtle method of infrared spectroscopy, Gehring et al were able to demonstrate that an acidic skin cleanser can be less irritant than a neutral or alkaline one, the pH being respectively 4.5 and 7.5.[27] These findings are backed by our current knowledge on the dependence of the bi-layer formation and thus water-retaining capacity of epidermal lipids in dependence on the pH of the milieu.[28,29] Hence, persons prone to develop atopic dry skin can be advised to use acidic cleansers. Indeed, a large proportion of the general population—those with a polar constitution of the skin surface that is either seborrheic or sebostatic skin—might profit from the regular use of an acidic cleanser, and there is no reason to believe that it might be disadvantageous in the rest.

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