Acid mantle: What we need to know

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Introduction

The pH of the viable epidermis is near neutral, but the skin surface pH is acidic, with a value of 5.4–5.9 (range 4–6) in healthy adult white males and slightly higher in age-matched females. However, the difference is small and its implications are unknown.[1–3] In the stratum corneum, pH changes follow a sigmoid curve- a slight decrease of pH in the outermost layers of the stratum corneum, followed by a gradual increase of pH in deeper layers of the stratum corneum. Schade and Marchionini, in 1928, coined the term "*Säuremantel*" (acid mantle) to describe this inherent acidic nature of stratum corneum. Initially, the acid mantle was considered to be important in antimicrobial defence only, but with the developments in the understanding of skin biology, it became apparent that skin pH plays a key role in the biological processes that are crucial in the maintenance of the epidermal barrier [Figure 1]. The importance of acid mantle is increasingly being recognized in both physiological and pathological states. The practical application of the concept of skin pH lies in the formulation of topical preparations with an aim to preserve acid mantle and epidermal barrier functions.[1,4]

Biological role

Acidic pH influences many biological processes responsible for epidermal barrier function. On the skin surface, one of the major roles of the acid mantle is to prevent colonisation and multiplication of pathogenic organisms (antimicrobial barrier). In the outermost layers of the stratum corneum, acidic pH plays a key role in maintaining the permeability barrier by preventing desquamation and by promoting the maturation of the hydrophobic lipid barrier. In the deeper layers of stratum corneum, acidic pH is required for the proper action of enzymes involved in the processing of lipids programmed to reinforce corneocytes to form a permeability barrier. The biological functions of the acid mantle are described as under:

Acid mantle and permeability barrier

Homoeostasis: Lipids secreted by lamellar bodies are processed by enzymes, namely β-glucocerebrosidase and acidic sphingomyelinase, to generate ceramides and other lipophilic components. These molecules are then arranged into a lamellar bilayer structure around the corneocytes,and are responsible for the permeability barrier function of the stratum corneum. The lipid processing enzymes are active at acidic pH and are inhibited at higher pH. Thus, the acid mantle helps in the formation and maintenance of the permeability barrier. At higher pH, this barrier function is compromised making the skin susceptible to various allergens.[5,6]

Desquamation: Physiological desquamation is an essential component of homeostasis of the stratum corneum and is brought about by the activities of serine proteases (kallikrein 5 and kallikrein 7) which cleave desmoglein 1 and alkaline ceramidase. These enzymes are active at neutral or higher pH and their continued activity inhibits the secretion of lamellar bodies. When the acid mantle is disturbed, persistent and appreciable exfoliation is noted, as seen in a variety of skin conditions.[5,6]

Acid mantle as an antimicrobial barrier

Acidic pH favours the growth of normal flora and inhibits the pathogenic bacteria. Thus, the acid mantle helps in the formation of a non-specific antimicrobial barrier. Additionally, certain antimicrobial peptides like dermcidin are best effective at acidic pH. In a study, it was shown that dermcidin offered greater than 90% bactericidal effect against *Staphylococcus aureus* at pH 5.5; however, at pH 6.5 the bactericidal effect was reduced to 60 percent. Besides, an acidic pH favours the conversion of nitrate (secreted in sweat) to nitrite (a non-specific antimicrobial compound) by bacteria; which re-emphasises the antimicrobial role of the acid mantle.[1]

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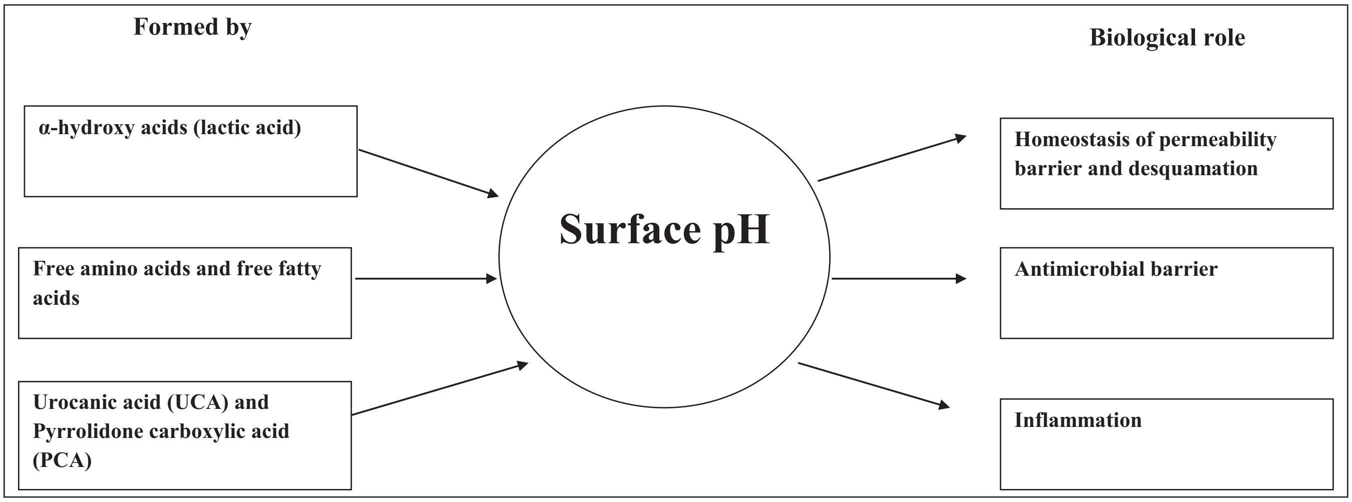

Figure 1: Physiology of skin surface pH

Table 1: Agents contributing towards the formation of acid mantle[1,4,5]

Agent	Origin	Topographical location	Known function
α-hydroxy acids (lactic acid) and free amino acids	Sweat glands.	Skin surface.	Antimicrobial barrier.
Free fatty acids and amino acids from sebum	Sebaceous glands.	Skin surface.	Antimicrobial barrier.
Urocanic acid (UCA)	Proteolysis of filaggrin.	Outer stratum corneum.	Maintaining hydrophobic lipid layer around corneocytes, preventing desquamtion, Photoprotection.
Pyrrolidone carboxylic acid (PCA)	Proteolysis of filaggrin.	Outer stratum corneum.	Maintaining hydrophobic lipid layer around corneocytes, preventing desquamtion, Photoprotection.
Hydrogen ions	Na+/H+ antiporter 1 (NHEA1) located on the membrane of lamellar (Odland) bodies.	Stratum corneum- stratum granulosum interface.	Enzymes mediated maturation of barrier lipids.
Melanin	Melanosomes in stratum granulosum.	Stratum corneum- stratum granulosum interface.	Imparting pigment to keratinocytes, Photoprotection.
Cholesterol sulphate	*Stratum basale* (cholesterol is acted upon by cholesterol sulfotransferase).	Stratum granulosum.	Maintenance of consistency of barrier lipids.

Acid mantle and inflammation

Corneocytes have pools of precursor forms of inflammatory cytokines (pro-IL-1α and pro-IL-1β). With the disturbance of barrier function and rise of pH, kallikreins are activated which in turn causes a release of active cytokines IL-1α and IL-1β. These cytokines through a cytokine cascade restores the stratum corneum barrier. While a transient increase in skin pH helps in the restoration of the stratum corneum barrier, a persistent change in pH contributes to epidermal inflammation mediated by IL-1α and IL-1β.[5]

Formation and maintenance of skin pH

The acidic pH at the skin surface is mainly maintained by α-hydroxy acids (lactic acid) and free amino acids excreted from sweat glands; free fatty acids and amino acids from sebum; and urocanic acid and pyrrolidone carboxylic acid produced after proteolysis of filaggrin in the outermost layers of stratum corneum. In the outer layers of the stratum corneum, acidic pH is mainly maintained by amino acids urocanic acid and pyrrolidone carboxylic acid. In the deeper compartments of stratum corneum, other players including Na+/H+ antiporter 1, melanin and cholesterol sulphate play a role. The agents responsible for acidic pH are summarised in Table 1.[1,4,5] The factors influencing skin pH are summarised in Table 2.[1,7,8]

Measurement of skin pH

Skin surface pH can be measured by a skin pH meter using a planar glass electrode connected to a voltmeter. Some of the important precautions while measuring skin pH are listed in box 1. The standard international guidelines provide more detail information on this topic .[9,10]

Clinical implication of skin pH

Skin pH and dermatoses

Increased skin pH leads to impaired barrier function (as measured by increased trans-epidermal water loss and increased sensitivity to sodium lauryl sulphate), defective exfoliation and increased susceptibility to infections by pathogens including *Staphylococcus aureus* and *Candida albicans*. These altered biological functions are central to the pathogenesis of several

Box 1 : Precautions while measuring skin pH

- Skin pH meter should be calibrated before the assessment.
- As a standard practice, the mid-volar forearm is chosen as the preferred site.
- The person needs to be acclimated for at least 20 min at a temperature of 20–22°C and relative humidity of 40–60%.
- Exogenous agents can influence the skin pH evaluation. So, it is recommended that skin surface pH measurements be made 2–3 hours after washing with tap water, 5 hours after washing with synthetic detergents, and 10 hours after washing with alkaline soaps.
- Care should be taken to remove cosmetics or excess sebum with dry, oil or lotion-free tissue paper or filter paper. Water should not be used for this purpose as even washing with water raises the skin pH.

Table 2: Factors influencing skin pH[1,7,8]

Factor	Comment
Physiological factors	
Age	Neonates at birth have neutral or slightly alkaline pH and achieve pH similar to adults by infancy. The elderly have higher skin pH.
Site	Intertriginous areas such as interdigital spaces, axillae, groin, and inframammary zone have higher pH.
Pigmented skin	Skin pH is slightly more acidic in people with skin of colour (Fitzpatrick IV–V).
Genetic predisposition	Genetic variations may influence the various components responsible for the formation and maintenance of skin pH.
Sebum	The composition of sebum may vary from individual to individual and thus, may influence skin pH.
Sweat	The composition of sweat may vary from individual to individual and thus, may influence skin pH.
Skin moisture	Both reduced and increased hydration is associated with increased skin pH.
Exogenous factors	
Skin cleansing	Cleansing with water raises the pH transiently. Cleansing with soaps and detergents may produce a significant rise in pH value.
Occlusion	Occlusion increases skin pH.

dermatoses. Understanding the role of altered skin pH in the development of different dermatoses is helpful in designing novel treatment strategies as summarised in Table 3. For example, defective barrier function is the pathophysiological hallmark of both atopic dermatitis (because of endogenous filaggrin deficiency) and irritant contact dermatitis (because of exposure to irritants). Attempts at restoring the acid mantle and thereby facilitating repair of stratum corneum barrier functions by topical acidic preparations have led to significant clinical improvements. In a study, twice daily application of 4% l-lactic acid formulations (pH 3.7–4.0) led to significant improvement in the stratum corneum ceramides concentration, barrier function and reduced sensitivity to sodium lauryl sulphate after four weeks of application.[1,4–6] Another instance, where the defective stratum corneum barrier function due to altered skin pH might play a role, is women complaining of increased pruritus in the genital area during menstruation. Blood with a pH of 7.4 raises the vaginal pH (3.5–4.5) and leads to a transient defect in the stratum corneum barrier. As a result, women complain of dryness and pruritus. To tackle this issue, tampons with micro–ribbons™ containing citric acid and l–lactide have been developed and are commercially available in certain countries.[1]

Skincare products and cosmetics

As the role of skin pH in health and disease is being studied, it is imperative to apply the concepts in formulating various topical formulations like soaps, cleansers, moisturisers, other skin care products and cosmetics. Such products are meant for daily use and hence, they can influence the skin pH to a great extent.[11,12] It has been demonstrated that hand washing with alkaline soaps can increase the skin pH (mean of three units) for a time period of up to 90 minutes after washing. Homeostatic mechanisms discussed earlier continue to work to restore skin pH. However, frequent use of alkaline soaps ultimately causes sustained increase in surface pH leading to impaired barrier repair functions.[1] Hence, daily hand washing with soaps has an etiological role in the initiation, maintenance, aggravation and progression of hand eczema. The widespread recognition of the skin pH-altering potential of soaps led to the development of syndets with a neutral or acidic

Table 3: The connecting link between acid mantle and different dermatological conditions[1,4–6]

Disease	Skin pH alteration in pathogenesis	Clinical impact of pH restoring measures
Atopic dermatitis	• Reduced filaggrin → less acidic skin pH → impaired organisation of surface lipids (& *Staphylococcus aureus* colonisation) → impaired barrier function • Eczematous skin has higher pH compared to uninvolved skin.	Application of topical acidic preparations improved eczema scores in murine model.[11]
Ichthyosis	• Reduced filaggrin in ichthyosis vulgaris → higher skin pH→ defective enzyme-mediated exfoliation • Ichthyosis vulgaris has higher mean skin pH than X-linked ichthyosis.	Lactic acid preparations promote keratolysis and are useful.
Diaper dermatitis	• Alkaline pH in diaper area →activation of faecal proteases and lipases →loss of epidermal barrier • Alkaline pH in diaper area → increased susceptibility to *Candida albicans*.	Avoidance of occlusion and prolonged exposure to urine and faeces (rich in ammonia which raises pH) has a protective role.
Irritant contact dermatitis	Frequent use of water and soaps → increased skin pH → defective barrier function → skin lesions.	Avoiding soaps and frequent washing will have a beneficial effect.
Acne vulgaris	Increased skin pH is favourable to the growth of *Propionibacterium acnes.*	In a study, the number of inflammatory lesions increased in the group using alkaline soap and decreased in the group using the acidic syndet cleansers by the 4th week of application.[12]
Candidal intertrigo	Occlusion →higher pH →susceptibility to *Candida* infection.	Avoidance of occlusion has a protective role.

pH. In addition, cleansers may have active acidic ingredients like lactic and citric acid, sodium acetate, sodium lactate, sodium citrate, diammonium citrate, etc., to match the physiological skin pH. Cleansers with acidic pH alter the acid mantle to a lesser extent and for a lesser time, and hence, are considered suitable for daily use, frequent use, patients with sensitive skin syndrome and other conditions related to an increased skin pH.[1,4,13]

Unfortunately, there is a dearth of pH-balanced skin care products and cosmetics. Also, information about pH-balanced products is not readily available. Scientists, pharmaceutical industries, physicians, patients, general population and legislators need to recognise the importance of pH-balanced skin care products and cosmetics in skin health and disease.

Conclusion

The origin of the acid mantle and its functional importance in skin health and diseases are not yet completely understood. The role of skin pH in various stratum corneum functions is increasingly being recognised. It is now clear that an increase in skin pH impairs stratum corneum homeostasis and stratum corneum barrier functions, leading to compromised skin health and contributing to the development of various dermatoses. Considering the cardinal role of the acid mantle in skin health, there is a growing need to have pH-balanced skin care products and cosmetics which protect and restore the physiological skin pH. Also, awareness of the importance of pH-balanced topical formulations in skin health and disease needs to be increased among physicians, patients with skin diseases and general population. Scientists and industry people need to come forward to bridge the gap between the need and availability of different pH-balanced products.

Declaration of patient consent

Patient's consent not required as there are no patients in this study.

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Conflict of interest

There are no conflicts of interest.

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