STUDIES ON THE CHEMISTRY OF HUMAN PERSPIRATION WITH ESPECIAL REFERENCE TO ITS LACTIC ACID CONTENT*

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Using a Howard Cabinet† heated with infra-red light and maintaining a thermal bath temperature of 58°C. at 65 to 70 per cent humidity, human perspiration from 46 subjects was collected in small glass flasks from the axillae, trunk, and forehead. Thirteen had acne vulgaris, but other than this all were free from systemic disease.

The apocrine and eccrine sweat thus collected was examined for: 1) hydrogen ion concentration in 46 people; 2) quantitative lactic acid content in 22; and 3) ammonia nitrogen in 2.

During the heat bath there was an average body weight loss of 250 grams, and a drop in blood pressure of 5 to 10 millimeters of mercury. After 15 minutes exposure to the thermal bath the body temperature rose from 37 to 37.8°C., and returned to normal within 15 minutes' rest outside the cabinet. An average 1.5 to 2.5 cc. of perspiration was collected from the body, and 0.5 to 1.5 cc. from the axillae. Usually the forehead, being outside the heat chamber, yielded only a few drops of collectable perspiration. In these experiments 0.1 cc. each of apocrine and eccrine sweat were used for the analyses. The perspiration was collected between March 4 and June 13, before the onset of intense summer heat.

Of the 46 volunteers, 34 were women and 12 were men. Five women with ages 18 to 22 years, and 6 men aged 14 to 20 years had acne vulgaris.

HYDROGEN ION CONCENTRATION

The pH determinations of body and axillary perspiration were carried out with the Beckman's glass electrode, but for the forehead pH indicator paper was used.

In general the results confirmed those previously reported by Talbert (1, 2), Marchionini (3), Herrmann and Furst (4), and others (5, 8, 9). The axillary perspiration, preponderantly apocrine, tended more toward the neutral point than did the values for eccrine perspiration. There is a noteworthy difference in pH values of heat induced perspiration in men as contrasted with women, the average masculine pH values tended more deeply toward acidity. In acne vulgaris the respective pH values in both sexes are lower or more acid than are the

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values in subjects free of acne. For example, the average pH of axillary perspiration in women without acne was 6.4 while in those with acne the average value was 5.7. Similarly the males without acne averaged axillary values of 6.5, while in those with acne the average was 4.6. These average pH values for the axillary, body, and forehead perspiration are charted in Table 1.

LACTIC ACID

Lactic acid, because of its quantity in sweat and its buffering qualities at pH of 5.0, probably is chiefly responsible for the acidity of sweat. The studies of Pemberton (6), Fishberg and Bierman (7, 8), Bergeim and Cornbleet (9, 10) and others, indicate the lactic acid in sweat contributes more to its acidity than the total amounts of fatty acids, carbonic acid, and phosphoric acid combined. The concentration of lactic acid in sweat is given as 250 to 350 mg. per cent by Fishberg and Bierman, while Schwarz and Peck (13) cite 100 mg. per cent as the

TABLE 1

pH values in sweat of 46 persons

SEX	NUMBER	AGE	pH VALUES		
			Axillae	Body	Forehead
Female	29	30 to 60	6.4 ± 0.7	6.0 ± 0.9	7.0 ± 0.5
Male	6	19 to 33	6.5 ± 1.6	4.7 ± 0.7	5.9 ± 1.2
Female with acne	5	16 to 22	5.7 ± 1.2	5.2 ± 0.6	6.6 ± 0.9
Male with acne	6	14 to 20	4.6 ± 0.2	4.2 ± 0.1	5.0 ± 0.5

average figure. This means that the lactic acid concentration in sweat is 10 to 20 times greater than in blood, where the average concentration is 15 mg. per cent.

That this high concentration of lactic acid in sweat may be a factor in health and in disease is amply illustrated. Bergeim and Cornbleet (9, 10) observed the acidity of the scalp to vary between pH 4.5 and 5.5, and stated this acidity is due chiefly to the lactic acid secreted in sweat, and to a lesser degree, to volatile fatty acids believed formed from the lactic acid by micro-organisms on the scalp. These results are similar to those they obtained on sweat from other parts of the body (10). They attribute to these acidities or range of pH from 4.5 to 5.5 definite antibacterial action which affords at least a partial protection against infection with certain bacteria and fungi. They aver the accumulation of acids on the scalp may be associated with pruritus of the scalp.

Peck and his co-workers (11, 12) ascribed fungicidal and fungistatic properties in sweat to be due to its content of acetic, propionic, caproic, caprylic, lactic, and ascorbic acids, and used topical applications of higher fatty acids in the treatment of certain fungus infections.

Herrmann, Behrentd, and Karp (14), using a buffered solution of propionic acid and citric acid at pH 4, incorporated a new fungicide, trimethyl cetyl ammonium pentachlorphenate, and an acid shampoo as a detergent, successfully treated established cases of tinea capitis due to Microsporon audouini.

Butcher and Parnell (15) further contributed data on this acidity of the per-

spiration. Analyzing the sebaceous secretion of the head they determined an average of fat ranging from 0.168 mg. to 0.219 mg. of fat, and 0.0119 mg. to 0.0171 mg. cholesterol per sq. cm. of surface, the cholesterol amounting to from 6.3 per cent to 9.4 per cent of the total sebum.

As judged from these observations it would seem that the maintenance of skin surface acidity is of some importance and that the role of lactic acid as secreted in the perspiration is significant.

In the experiments herein reported, lactic acid was determined by the method of Barker and Summerson (21) on 0.1 cc. amounts of sweat collected during the thermal baths. This method, developed for biological material, depends on the oxidation of lactic acid to acetaldehyde by treating it with concentrated sulfuric acid. The acetaldehyde is determined by its color reaction with P-hydroxydiphenyl in the presence of copper ion. The color is measured in a photoelectric colorimeter with a filter of maximal transmission at 560 mμ. After deproteiniza-

TABLE 2

Lactic acid content in the sweat of 22 subjects

SEX	NUMBER	AGE	LACTIC ACID IN MG. %	
			Axillae	Body
Female	8	30 to 60	247 ± 36	285 ± 24
Male	4	19 to 33	328 ± 57	336 ± 85
Female with acne	6	16 to 22	348 ± 139	452 ± 90
Male with acne	4	14 to 20	424 ± 50	455 ± 85

tion by any standard method, the above technic is applicable to a number of biological fluids and tissues. It is specific for lactic acid. The range of error is approximately 1 to 2 per cent.

The average values for the lactic acid in the sweat of 22 people from the axillae (apocrine) and body (eccrine) are summarized in Table 2.

The average normal values of 247 to 336 mg. per cent of lactic acid in perspiration agree with those of Fishberg and Bierman (8).

One woman with acne perspired excessively, and in this instance, due to the larger quantity of sweat produced, the lactic acid concentration dropped, thus accounting for the wide scattering (±139) noted in that column.

Of physiological interest is the fact that the lactic acid concentration in the perspiration of men consistenly is higher than in women. This finding is in agreement with the lower pH values found in men.

In acne vulgaris the lactic acid concentration increases above the average normal figure in both sexes.

AMMONIA NITROGEN

Lobitz, et al., (16, 17, 18), using a special collecting technic, determined ammonia nitrogen as well as urea, uric acid, chlorides, and reducing substances in palmar sweat. They found 7.7 mg. per cent ammonia nitrogen in profuse palmar sweat, and 28.9 mg. for the so-called intermittent type. Since the blood normally

contains only 0.1 mg. per cc. of ammonia nitrogen, the authors ascribe to the sweat glands the ability to form ammonia.

In connection with the buffering of sweat, we have been interested in ion exchange resins and the characteristics of the cation and anion exchange groups (19). In two instances, using the method of Conway (20), ammonia nitrogen determinations in axillary and body perspiration are cited as examples of several similar evaluations. The results, tabulated in Table 3, show the axillary sweat to contain more ammonia nitrogen than body sweat. Perhaps the less acid reaction of apocrine sweat may be explained by its large content of additional base in the form of ammonia.

TABLE 3

Ammonia nitrogen in sweat

	AXILLAE	BODY
Case 1.....	78.0 mg.%	5.1 mg.%
Case 2.....	21.2 mg.%	8.5 mg.%

ION EXCHANGE RESINS

The fundamental purpose of this study was: first, to acquaint ourselves with experienced knowledge of the complex chemistry of human perspiration in health, and in some instances in disease; and second, to observe the effects of Amberlite Ion Exchange Resins* in their cationic and anionic phases of exchange with certain component elements of human perspiration. It was surmised that perhaps with the use of suitable ion exchangers, the objectionable odoriferous portions of apocrine sweat could be rendered innocuous, and further, it was hoped to be able quickly to restore a disturbed skin pH to a more nearly normal level and to maintain that level for prolonged periods.

Ion exchange resins now are of a high capacity, durable, complex type. They are synthetically produced and, when desired, can be made so finely as to go through 300 mesh. These exchange resins may be adjusted to eliminate or change acids, bases, toxins, biotics, and other substances, provided their field of activity is restricted to an electrolytic medium. They can be adjusted to permit the exchange of cations and anions in the same medium, and to maintain a desired pH within reasonable limits. They are used chemically to purify solutions. In fact, their fields of application are so divergent as to include industry, agriculture, biology, medicine and chemistry. From the dermatological standpoint, they can be used as suspensions in solutions, as powders and as ointments.

Experiments 1, 2, and 3 are charted, and they clearly illustrate that the amberlite ion exchange resins XE-64, and XE-87 eliminate lactic acid in amounts greater than 50 per cent, urea in amounts of 27 per cent or greater, and ammonia in amounts greater than 25 per cent.

Experiment 4 indicates that the exchange resins XE-64, and XE-87 quickly restore to acidity the alkalinity of the skin following the use of soap.

* The Amberlite Ion Exchange Resins used in this study were those manufactured by the Rohm and Haas Company of Philadelphia, Pa.

EXPERIMENT 1

Quantitative Determination of Lactic Acid and Ammonia by Column Filtration, using Amberlite Ion Exchange XE-64.

Artificial sweat was filtered through a column filled with Amberlite XE-64 in the H form and Na form in a mixture of 1:1. The pH of lactic acid and of ammonia was determined before and after column filtration.

This was done with artificial sweat made up of 300 mg. per cent lactic acid, with 100 mg. per cent ammonia salt, and determined quantitatively.

Result: The lactic acid was taken up 50%, and the ammonia compound was taken up approximately 25%.

EXPERIMENT 2

Lactic Acid and Urea Elimination in Sweat with Amberlite XE-87

5.5 cc. pooled perspiration was mixed with 1.3 gms. XE-87 Wet., and stirred ½ hour
Lactic acid before = 310 mg. %
Lactic acid after 30 minutes stirring = 130 mg. %

Taken up = 58.1%

Urea before = 43.9 mg. %
Urea after 30 minutes stirring = 32.2 mg. %

Taken up = 27 mg. %
(No NH_3 in this sample of sweat)

EXPERIMENT 3

Quantitative tests of lactic acid, ammonia, and urea

1.4 cc. pooled perspiration were mixed with 0.5 gm. wetted XE-87

pH before = 8.0	Lactic acid before = 438 mg. %	NH_3 before = 37 mg. %	Urea before = 48 mg. %
pH after = 7.0	Lactic acid after = 58 mg. %	NH_3 after = 0	Urea after = 29.3 mg. %

EXPERIMENT 4

*The action of Amerlite XE-64, and XE-87, in various ointment bases applied to adult male palm**

(Normal measured pH of the palm 4.7)
(Tests with Yardley Shaving Bowl Soap)

AMBERLITE	BASE	CONCENTRATION OF AMBERLITE RESIN (%)	TIME APPLIED IN MINUTES	pH BEFORE APPLICATION	pH AFTER APPLICATION	pH DIFFERENCE
XE-64	Hydrophilic U.S.P. XIV	25	10	10.0	6.3	3.7
XE-64	Beeler Base	25	10	8.5	4.9	3.6
XE-87	Hydrophilic U.S.P. XIV	25	10	8.3	6.8	2.5
XE-64	Beeler Base	25	5	8.8	5.3	3.5
XE-64	Hydrophilic U.S.P. XIV	25	1	8.4	5.2	3.2
XE-64	Glycerol Methocel	25	1	8.6	4.8	3.8
XE-64	Polyethylene	25	1	8.7	5.0	3.7

* The alkalinity from the soap is quickly removed and the skin returned to acidity.

These single experiments indicate that Amberlite Ion Exchange Resins are capable of taking up lactic acid, urea, and ammonia in substantial amounts.

Projecting these *in vitro* findings to *in vivo* evaluations, it would seem, theoretically at least, that ion exchange resins could be used to bind or clear the sweat of products normally excreted and with offensive odor, and similarly of products which are decomposed by bacteria and fungi and capable of causing disease.

SUMMARY

1. To obtain sufficient quantities of sweat from stated areas in short periods of time moist heat baths were used.

2. The hydrogen ion concentration of eccrine sweat shows characteristic differences between the sexes, there being greater acidity in men than in women.

3. The apocrine and eccrine sweat of normal people contains from 247 to 336 mg. per cent lactic acid.

4. At a pH of 5, in the range of dissociation of lactic acid, human sweat has a good buffering capacity as a result of its lactic acid content.

5. The lactic acid content in male sweat is greater than that of females.

6. In patients with acne vulgaris, the lactic acid content and the acidity of sweat is greater than in people without acne.

7. Apocrine sweat contains a markedly higher concentration of ammonia than eccrine sweat.

8. In vitro experiments with certain Amberlite Ion Exchange Resins are cited. They indicate that these resins are capable of eliminating or changing lactic acid, urea, and ammonia, and of quickly returning an alkaline pH of the skin following the use of soap to an acidity near normal for that particular area of skin.

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