A Study of Athlete's Foot and Its Control*

J. B. Vaughan† *and H. G. DeKay*‡

During the last decade or so there have come to the fore an interest in and a need for effective means of controlling certain ringworm infections. That an effective cure is yet forthcoming, there seems to be no doubt. Probably the outstanding ringworm infection, especially with respect to incidence, is the disease known popularly as athlete's foot.

Although ringworm may infect many parts of the body, statistics show the most frequent site of the infection is on the feet. The disease is almost as widespread as the common cold and as yet comparably as incurable. Nor is it confined to any particular part of the world. However, it possibly had its origin in the Eastern Archipelago (1). It seems to have been prevalent early in many of the South Sea Islands. The fact that the organisms thrive in moist, warm environment such as found on the islands mentioned, as well as sweaty shod feet of the healthy average citizen of many of the more temperate climes is a step toward explaining the whyfore of existence of this troublesome world-wide invader.

Among the reasons advanced for the spread of athlete's foot, the following seem to have special merit. First, we have to deal with the negative claim that there has been no increase in the disease. This is possible on the ground that a superior means of diagnosis exists to-day. Second, the public has been made more conscious of it through the extensive advertising of many so-called cures Third, the major and most commonly accepted reason advanced for the increased incidence of athlete's foot is the increased participation in all forms of sports which necessitates the use of common locker rooms, runways and shower baths where organisms find a ready substrate upon bare feet.

According to Osborne and Hitchcock (2), "The estimated frequency ranges from 90 per cent in male college students indulging in athletics to 50 per cent in the general adult population. In children of high school age the incidence has been estimated at about 25 to 50 per cent."

"In a recent survey of the toes of all students at the University of Pennsylvania, over 60 per cent showed ringworm infection. This was confirmed by bacteriologic methods of examination." (Goodman (3).)

The results of an investigation by Shaffer and Cary (4) in the public schools of Detroit show the incidence of epidermophytosis in school children. The general incidence of infection for girls ranged from 3 per cent of the first grade with rather regular ascendancy from grade to grade to 72 per cent of the twelfth grade girls. Among the boys, the general incidence of infection averaged 8 per cent higher than for the girls, beginning with 12 per cent and ending with 79 per cent of the twelfth grade boys.

At Purdue University the cases of athlete's foot were quite prevalent and of the 500 cases treated by the Student Health Service the first semester of 1938–1939, it was found that the majority had frequented the gymnasiums and pools of the university physical health department. In an effort to attempt to curtail the spread of this infection and with the intention of adopting the most effective means of control, this investigation was undertaken. The primary aim of this work was to make a thorough examination of sodium hypochlorite solution when used as a prophylactic measure because a careful check of the literature (2, 5, 6) revealed a number of recommendations for the use of this solution.

EXPERIMENTAL

In order to ascertain the concentration of sodium hypochlorite solution which is adequate for prophylaxis it would be necessary to determine the actual change of the chemical content with time, the number of students using the solution and the fungicidal power at various dilutions. The task, then, was threefold:

1. Chemical analysis at intervals of time.
2. Determinations of fungicidal properties with regard to attending percentages of chemical present.
3. Count of students who used the solution.

* An abstract of a thesis presented to the faculty of Purdue University in partial fulfilment of the requirements for the degree of Master of Science by J. B. Vaughan.

† Assistant in Pharmaceutical Chemistry, Purdue University.

‡ Associate Professor of Pharmacy, Purdue University.

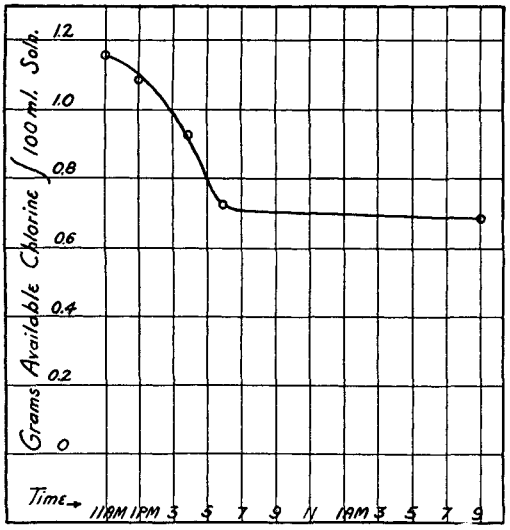

Fig. 1.—Curve No. I Showing Changes in Content of Available Chlorine in Sodium Hypochlorite Foot Bath.

With the coöperation of the athletic department, foot baths were placed in doorways leading to the general and varsity shower-rooms in the Fieldhouse. The containers were three feet square, with a capacity of about twenty-five gallons. Thirteen gallons of sodium hypochlorite solution calculated to be approximately one per cent of available chlorine were placed in these pans daily. Samples were collected at hourly intervals and analyzed for available chlorine. This was repeated several times a week over a three-month period.

The method of analysis used is that found in the U. S. P. XI Solution of Sodium Hypochlorite; ten-ml. samples instead of weighed samples were determined.

Graphs were made in which Gm. available chlorine per 100-ml. sample is plotted against time in hours. Figure 1 and Figure 2, Curves III, IV and V are typical examples of the changes in chlorine content which took place during the day. In general there resulted a loss of chlorine content with the lapse of time. This loss is not to be attributed to the escape of chlorine gas from the solution. During the hours when more students made use of the foot baths, loss of chlorine content was greater. This is due, then, either to the bodily removal of the chemical or possibly to dilution. The latter contention is not plausible in view of the fact that observation showed the baths decreased in volume.

As contrasted with the decrease in chlorine content between the hours of four and seven (time when large numbers of students made use of the showers), the loss during the entire night (when no students used the showers) shows very little change; therefore it seems evident that the diminution in available chlorine by evaporation is more or less unimportant. See Fig. 1.

As shown in Fig. 2, Curve II, the foot bath was made to contain approximately 0.5 per cent available chlorine. The percentage of chlorine, after the day's use, dropped to 0.23. Although it was not possible to keep a complete record of the number of students using the foot baths daily, observation at specific times showed the percentage decrease was proportional to the number of users.

A slight rise in some of the curves shortly after introduction of the bath and other slight deviations may be attributed to failure in securing representative samples.

These foot baths accommodated an average of 400 students per day; during that period, the available chlorine decreased from one per cent to four-tenths of one per cent. As will be shown later, even this lower concentration possesses high fungicidal power.

Figure 2, Curve III, shows 0.97 per cent available chlorine at 9:00 A.M., 0.90 per cent at 11:00 A.M., 0.86 per cent at 2:00 P.M. Then the curve begins a rather steep descent until at 6:00 P.M. it approaches the 0.5 per cent mark. At the close of the day, at 9:00 P.M., the chlorine content has fallen to 0.45 per cent, or a loss during the twelve hours of 0.52 per cent.

In order to carry on the work of examination of chemical substances for fungicidal properties, the successful culturing of representative fungi, or at least a representative fungus, is obviously necessary. In this study *Trichophyton rosaceum* (common in athlete's foot) is the organism employed in all cases. The fact that *Trichophyton rosaceum* has conspicuous macroscopic characteristics makes it the organism of selection. It has also a reasonably high resistance to action of fungicides.

Of course it is recognized that although a substance proves completely fungicidal toward the organism, *T. rosaceum*, other fungi of athlete's foot

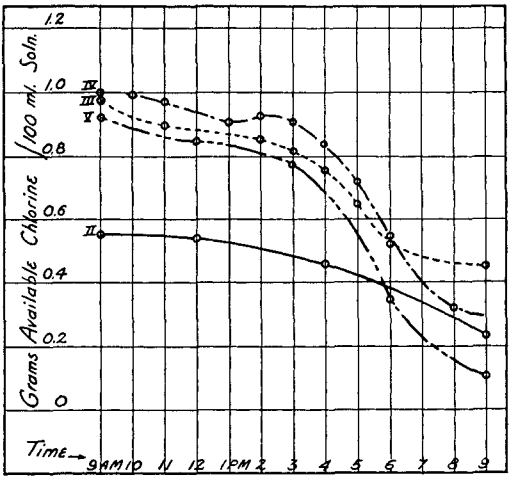

Fig. 2.—Curves Nos. II–V Showing Changes in Content of Available Chlorine in Sodium Hypochlorite Foot Bath.

Table I.—Fungicidal Action of Sodium Hypochlorite

Tube No.	Seconds Exposed	Growth After 18 Hrs.	1 Day	2 Days	5 Days	10 Days
A. 0.1123 Gm. Cl/100 ml.						
77	10	−	−	+	+	+
78	20	−	−	−	−	−
79	30	−	−	−	−	−
80	60	−	−	−	−	−
Control		+	+	+	+	+
B. 0.2154 Gm. Cl/100 ml.						
97	10	−	−	−	+	+
98	20	−	−	−	−	−
99	30	−	−	−	−	−
100	60	−	−	−	−	−
Control		+	+	+	+	+
C. 0.2951 Gm. Cl/100 ml.						
89	10	−	−	−	−	−
90	20	−	−	−	−	−
91	30	−	−	−	−	−
92	60	−	−	−	−	−
Control		+	+	+	+	+
D. 0.4127 Gm. Cl/100 ml.						
81	10	−	−	−	−	−
82	20	−	−	−	−	−
83	30	−	−	−	−	−
84	60	−	−	−	−	−
Control		+	+	+	+	+
E. 0.5038 Gm. Cl/100 ml.						
65	10	−	−	−	−	−
66	20	−	−	−	−	−
67	30	−	−	−	−	−
68	60	−	−	−	−	−
Control		+	+	+	+	+
F. 0.6197 Gm. Cl/100 ml.						
73	10	−	−	−	−	−
74	20	−	−	−	−	−
75	30	−	−	−	−	−
76	60	−	−	−	−	−
Control		+	+	+	+	+
G. 0.7163 Gm. Cl/100 ml.						
93	10	−	−	−	−	−
94	20	−	−	−	−	−
95	30	−	−	−	−	−
96	60	−	−	−	−	−
Control		+	+	+	+	+
H. 0.8756 Gm. Cl/100 ml.						
61	10	−	−	−	−	−
62	20	−	−	−	±	±
63	30	−	−	−	−	−
64	60	−	−	−	−	−
Control		+	+	+	+	+
I. 0.9512 Gm. Cl/100 ml.						
69	10	−	−	−	−	−
70	20	−	−	−	−	−
71	30	−	−	−	−	−
72	60	−	−	−	−	−
Control		+	+	+	+	+

may react contrariwise. However, *T. rosaceum* is typical and certainly worthy of giving indicative results.

Sabouraud culture medium (7) was prepared and used as the culture medium. A stock culture of the organism was transferred to a Petri dish containing the medium and allowed to incubate at room temperature for three weeks. After this period, growth covered the agar plates. An inoculum consisting of the organisms from the culture plate in normal saline was next prepared.

Samples of the foot bath collected previously were redetermined and the prepared inoculum subjected to whatever fungicidal action there might be with various concentrations of sodium hypochlorite. The accompanying table shows different strength solutions of sodium hypochlorite selected. In each case the organisms were exposed for 10, 20, 30 and 60 seconds. Growth positive or negative is indicated after 18 hours, 1 day, 2, 5 and 10 days incubation at room temperature. Negative tubes were observed for two-week periods. Divisions A, B, C, etc., indicate ascending concentrations of chlorine content beginning with 0.1123 Gm. available chlorine per 100 ml. sample and ending with 0.9512 Gm. available chlorine per 100 ml. sample.

In A and B, Tubes Nos. 77 and 97 show positive growth with 10 seconds exposure. With longer periods of exposure even these low concentrations (0.1123% and 0.2154%) show no growth.

In D, Tube No. 81 shows a slight growth after 5 days incubation as indicated by the symbol, ±.

In H, Tube No. 62 shows a slight positive growth. This is undoubtedly due to contamination through some mishap in technique, as Tube No. 61, which is the 10-second-exposed tube of the series, is negative.

C, E, F, G and I all show negative growth with 10, 20, 30 and 60 seconds exposure.

An examination of Table I, then, reveals that in all strengths of sodium hypochlorite tried (0.1123% to 0.9512%) positive growth is inhibited after the organisms are exposed for twenty seconds.

Other chemicals examined mycologically included: mercuric chloride, copper sulfate, zinc chloride, alum, sulfosalicylic acid, sodium chloride, sodium thiosulfate and formaldehyde.

Mercuric chloride, copper sulfate, zinc chloride and ammonium alum in 1:1000 dilutions were found to be non-fungicidal to *T. rosaceum*.

Sodium chloride in ten per cent solution, sodium thiosulfate in ten per cent solution and sulfosalicylic acid in one per cent solution proved to be non-fungicidal to *T. rosaceum* with as long as sixty seconds exposure.

Five per cent solution of formaldehyde inhibits growth of *T. rosaceum* with twenty seconds exposure.

SUMMARY

In summarizing, it may be said that a foot bath containing thirteen gallons of one per cent (available chlorine) sodium hypochlorite solution is very satisfactory as a prophylactic to athlete's foot for daily use of four hundred persons. This conclusion is further supported by the clinical finding of Dr. S. J. Miller, Director of the Student Health Service at Purdue University, who reports a decrease in the number of new cases of athlete's foot since the installation of sodium hypochlorite foot baths in the Fieldhouse.

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A Method for the Determination of Peptic Activity*

By C. J. Klemme† and Lee Worrell‡

INTRODUCTION

This study is the result of an attempt to find in the literature a relatively short, convenient, accurate method of assay for preparations containing pepsin, which could be used for routine assays in a study of the stability of such preparations.

Although numerous assay methods for pepsin have been proposed, original references to many of which may be found in publications by Sherman and Neun (1), Vahlteich and Glover (2), Northrop (3), Greenberg (4), Jenkins and Hoshall (5) and Waksman and Davison (6), none have proved entirely satisfactory. The variability of the substrate and correlation between the actual measurement of the amount of digestion and the concentration of enzyme causing the digestion have been outstanding difficulties involved.

EXPERIMENTAL

Preliminary experiments, in which several of the above-mentioned methods were tested, indicated that the method of Jenkins and Hoshall (5) offered the most convenient means of determining the amount of digestion. It was necessary to make several important changes, however, before accurate results could be obtained.

Method.—Using a solution 10 cc. of which contain 0.05 Gm. of reference pepsin, determine the K value of the lot of casein to be used in the assays by the method described below. The reference pepsin is preferably a sample of the pepsin used in the preparations to be assayed; if this is not available, the "Reference Pepsin" of the U. S. P. XI may be used.

To about 200 cc. of 0.0800N hydrochloric acid contained in a one-liter Erlenmeyer flask, add 17.2 Gm. of casein (according to Hammarsten). Shake the flask until the casein is thoroughly moistened and evenly dispersed. Add enough 0.0800N hydrochloric acid to make the total volume of acid exactly 400 cc. Stopper the flask loosely and place in a bath of boiling water for exactly 30 minutes.[1] Remove and quickly cool (under the tap) to room temperature. The product should contain no undissolved particles of casein. Pipette 70 cc. of this substrate into a 125-cc. Erlenmeyer flask. Stopper the flask loosely and place it in a constant temperature bath, previously regulated to maintain a temperature of 55° C., in such a position that the neck of the flask is above the water in the bath. After the flask has remained in the bath exactly 10 minutes, and without removing it from the bath, add by means of a pipette 10 cc. of a dilution of the preparation to be assayed and mix by gently shaking. The preparation is diluted with distilled water so that 10 cc. of the dilution contain 0.02 Gm. to 0.08 Gm. of pepsin. Preliminary trial assays may be necessary in order to determine the proper dilution. Allow the flask, loosely stoppered, to remain in the bath exactly 30 minutes after the sample is added. Remove from the bath and immediately add exactly 20 cc. of a solution of sodium sulfate (20 Gm. of the anhydrous salt in 100 cc. of distilled water), mix well and cool under the tap to 25° C. Filter through hardened filter paper. Titrate a 25-cc. aliquot portion of the clear filtrate with $N/10$ sodium hydroxide, using phenolphthalein as the indicator. Run a blank, using 10 cc. of distilled water instead of the pepsin solution, in exactly the same manner. At the end-point of the blank titration, add 2.50 cc. of the dilution used in the determination, and complete the titration. The difference in acidity between the determination and blank, expressed as cc. of $N/10$ acid, is an index of the relative proteolytic activity and is designated in the calculations as X.

Calculations: To determine the K value of the casein, substitute the value obtained for X in the reference determination into the equation

$$K = X/2.24$$

To determine the amount of active pepsin in the preparation assayed, substitute the value obtained for X in the assay into the equation

$$\sqrt{E} = X/K$$

* An abstract of a thesis submitted to the faculty of Purdue University in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

† Professor of Pharmaceutical Chemistry, Purdue University, School of Pharmacy.

‡ Eli Lilly & Co. Fellow, Purdue University, School of Pharmacy.

[1] In high altitudes where the boiling point of water is appreciably below 100° C., the time required for solution may be longer. This time would have to be determined experimentally.