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Use of a laboratory model to evaluate the factors influencing the performance of depilatories

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Synopsis—The use of laboratory MODELS to evaluate the performance of COSMETIC and TOILETRY products is full of pitfalls, and subjective assessments nearly always give more accurate results.

However, the investigation of the comparatively large number of variables which influence the speed of action of DEPILATORIES cannot conveniently be carried out on a subjective assessment basis and requires the use of a suitable laboratory model.

The particular model developed (referred to as a DEPILOMETER) was designed to simulate practical use conditions as closely as possible and it enabled the more important formulation variables to be studied quickly. In-use tests on final depilatory formulations gave good correlation with the DEPILOMETER findings.

INTRODUCTION

The main problem of testing depilatories with a users panel on a day-to-day basis is the practical difficulty of the necessary time required to re-grow the hair in between tests.

Another problem is the known variability of hair coarseness between individuals so that in extreme cases this can be a more significant factor in speed of depilation than changes in formulation.

There have been several attempts in the past to develop an *in vitro* test for measuring the effectiveness of depilatories and these have mostly been

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based on measuring the breaking time for mechanically stressed hair in contact with the depilatory preparations.

Yablonsky and Williams (1) criticized these methods and developed their own test based upon the measurement of time of maximum hair swelling of individual hairs suspended in the depilatory preparations.

The essential criteria for our own laboratory test model was that the the instrument should simulate as closely as possible the conditions under which the depilatory would normally be used and the important factors in this context were seen as follows: (a) use of leg hair and under-arm hair; (b) application of product for predetermined time without use of mechanical force; (c) use of moderate force after this time to produce breakage (simulating the use of a spatula).

Procedure

The development of the instrument or 'depilometer' was handed over to Beecham Special Services laboratory, and I am indebted to Mr J. D. Cheshire and Mr H. Ashmore for developing this piece of equipment.

Mode of action

Ten similar hairs are tested together. After the application of the depilatory product to the hairs, a suitable time interval elapses before a mechanical force (load) is applied for 10 s at each successive minute until the hairs break. The procedure is automatically timed, requiring attention only to fit new hairs and apply the depilatory. The key observation made is the number of minutes taken to break the hairs.

Apparatus and operations

The instrument is in two parts—the load applicator and the control box and timer—joined by a cable.

(1) *Load applicator*. The mechanism consists of a load bar which falls transversely across the mounted hair sample.

The load bar is mounted on the plunger assembly which consists of a circular table for carrying ring weights, an axial support rod which slides freely in a sleeve and a guide rod to prevent rotation. The axial support normally rests on a platform which drops away when the solenoid is energized.

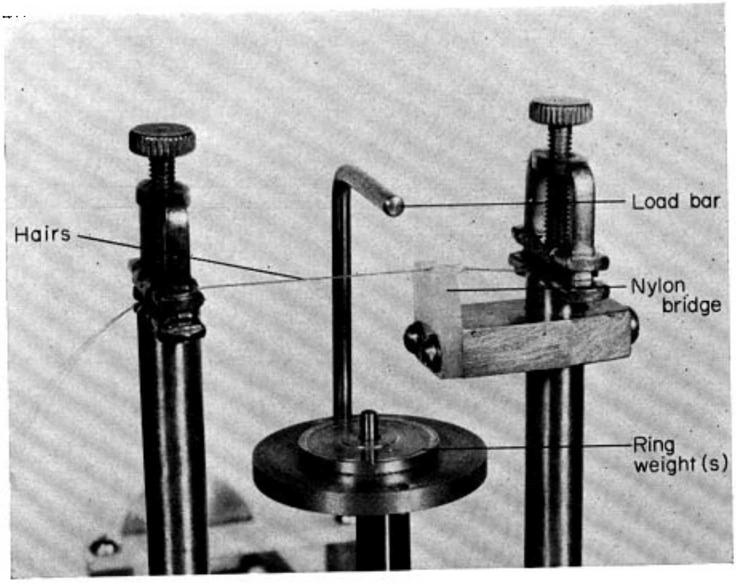

Figure 1. Hairs in position on load applicator.

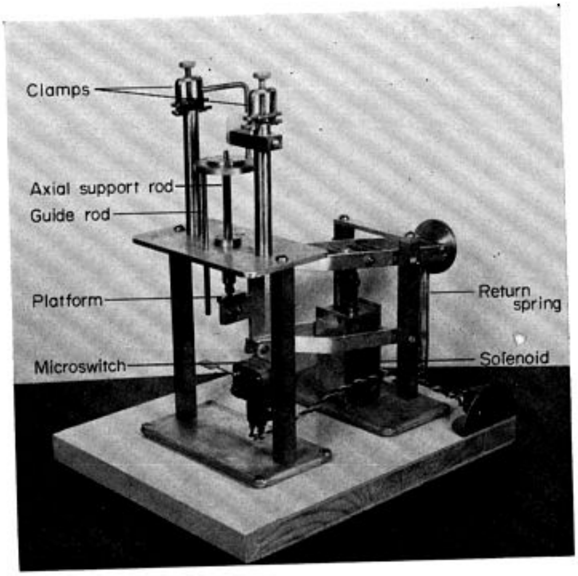

Figure 2. Load applicator.

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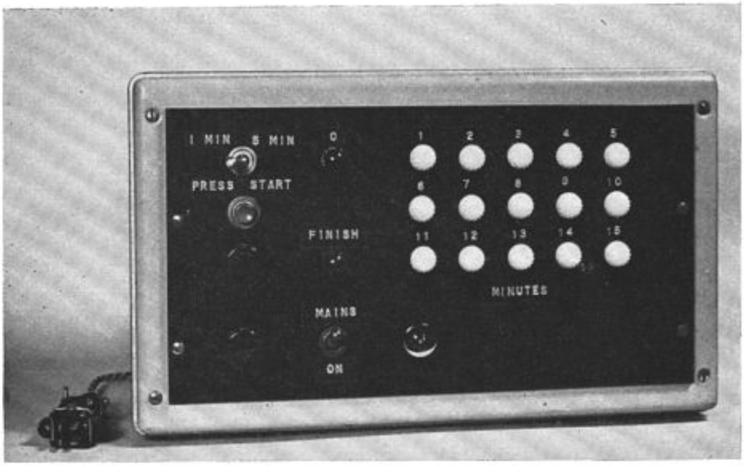

Figure 3. Control box and timer.

Hairs are laid with minimal tension between the two rubber-lined clamps, and the depilatory preparation is applied where the hair rests on the nylon bridge.

At the programmed time intervals after depilatory application, the solenoid is energized rapidly, removing the platform from the plunger assembly which drops onto the hair under its own weight and rests there for the load duration. When the solenoid is de-energized, the return spring lifts the load off the hair. When the hair breaks under load, the guide rod actuates the micro-switch and arrests the timing indicator.

(2) *Control box and timer*. Immediately after application of the depilatory preparation, a START button is depressed to zero the timer and start the test sequence. A cam driven by a synchronous motor causes a stepping relay to move forward at regular intervals, indicating the time elapsed and applying a short duration loading to the hair via the solenoid.

An initial delay to the application of hair loading may be introduced if required.

Test conditions

Simple alterations to the timing mechanism enable the intervals between and duration of hair loading to be changed. Similarly, alterations in the load applicator can be made to enable different loads to be applied. We have adopted the following conditions for all testing:

Number of hairs	10
Length of hairs between clamps	55 mm
Length of hair treated	3–5 mm
Width of nylon bridge	3 mm
Diameter of load bar	3 mm
Distance between load bar and nylon bridge	8 mm
Height of load bar above hair	13 mm
Total weight of plunger assembly	50 g
Time of first load application	1–5 min
Frequency of load application	1 per min
Duration of load application	5 s

Although we would have preferred to use axillary hair and leg hair for the tests, we found that this was not easily available in the quantities we required, so of necessity we had to use standard untreated European head hair.

However, we carried out tests to evaluate the differences in time of depilation between samples of head, leg and axillary hair, using a controlled depilatory application.

Men (10 subjects)

Depilation time (Meter)	Leg hair	Axillary hair	Head hair
Range of times	6–10	7–12	10–15
Average time	7	9.5	12.5

Women (10 subjects)

Depilation time (Meter)	Leg hair	Axillary hair	Head hair
Range of times	4–7	6–13	8–15
Average time	6	10	10

These results show that, although there was considerable variation in depilation times between individuals, in general leg hair is easier to depilate than axillary hair (which is confirmed by practical experience); and that head hair is similar to axillary hair in depilation time.

Formulation factors

The factors which we were interested in evaluating with regard to their effect on speed of depilation were as follows.

Nature of thio-compound.
Choice of neutralizing base.
Concentration of thio-compound.
Effect of pH.

The thio-compounds selected were as follows: (a) thioglycerol, (b) thioglycollic acid, (c) thiomalic acid, (d) 2-mercapto propionic acid, (e) 3-mercapto propionic acid, (f) thiodiglycol, (g) 2-mercapto ethanol.

The neutralizing bases were as follows: (a) lithium hydroxide, (b) sodium hydroxide, (c) potassium hydroxide, (d) calcium hydroxide, (e) strontium hydroxide, (f) barium hydroxide.

In order to measure the speed of depilation of the various combinations of thio-compounds and neutralizing bases, a basic cream depilatory formula was used:

Cetyl alcohol	6.00 % w/w
Lanbritol Wax	10.00 % w/w
Thio-compound	5.00 % w/w
Neutralizing base	q.s.
Water to	100

In most cases this formula gave a satisfactory cream, but even where separation of the product took place, for the purposes of the test it was not considered that this had any significance.

All determinations were carried out in duplicate at room temperature at 25°C. The depilation times shown below are the mean of two readings.

Results

Type of thio compound and neutralizing base
Thioglycerol.

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	2.0	11.6	6.0
Sodium hydroxide	1.9	11.2	4.5
Potassium hydroxide	2.6	11.5	6.5
Calcium hydroxide	1.7	11.9	6.0
Strontium hydroxide	6.2	11.0	8.0
Barium hydroxide	7.3	11.0	8.0

Thioglycollic acid.

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	4.6	11.8	5.0
Sodium hydroxide	4.5	11.4	5.5
Potassium hydroxide	6.1	11.7	7.0
Calcium hydroxide	4.0	12.1	7.0
Strontium hydroxide	14.5	12.0	7.5
Barium hydroxide	17.2	12.0	13.0

Thiomalic acid.

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	4.2	11.6	>15.0
Barium hydroxide	15.8	12.1	>15.0

2-*mercaptopropionic acid.*

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	4.0	11.8	8.0
Sodium hydroxide	3.9	11.3	7.5
Potassium hydroxide	5.3	11.4	14.0
Calcium hydroxide	3.5	12.2	13.5
Strontium hydroxide	12.5	11.0	13.0
Barium hydroxide	14.9	11.2	10.0

3-*mercaptopropionic acid.*

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	4.0	11.5	6.0
Sodium hydroxide	3.9	11.9	7.0
Potassium hydroxide	5.3	11.5	8.0
Calcium hydroxide	3.5	11.3	14.0
Strontium hydroxide	12.5	12.7	6.5
Barium hydroxide	14.9	12.7	6.5

Thiodiglycol.

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	3·1	11.5	>15.0
Sodium hydroxide	2.9	11.0	>15.0
Potassium hydroxide	3.6	12.2	12.5
Calcium hydroxide	2.7	12.2	>15.0
Strontium hydroxide	9.7	12.6	>15.0
Barium hydroxide	11.5	12.2	>15.5

2-mercapto ethanol.

Neutralizing base	% w/w of commercial material	pH	Depilation time (min)
Lithium hydroxide	2.7	11.6	3.5
Sodium hydroxide	2.6	11.2	4.0
Potassium hydroxide	3.2	11.1	4.0
Calcium hydroxide	2.4	11.8	5.0
Strontium hydroxide	6.4	11.9	6.0
Barium hydroxide	10.2	11.6	5.0

[Note: No attempt was made to bring these products to a constant pH but only to approximately the right range of pH.]

Conclusions. Of the two factors investigated, the most significant one influencing the speed of depilation is the choice of thio compound. In order of effectiveness based on depilation times averaged for all the neutralizing bases the results show the following.

Thio-compound	Average depilation time (min)
2-mercapto ethanol	4.0
Thioglycerol	6.5
Thioglycollic acid	7.5
3-mercapto propionic acid	8.0
2-mercapto propionic acid	11.0
Thiodiglycol	15.0
Thiomalic acid	15.0

The influence of neutralizing base is not so significant as the choice of thio compound, but there is a relationship between speed of depilation and choice of base as follows.

Base	Average depilation time (min)
Sodium	5.7
Lithium	5.7
Potassium	6.5
Barium	6.5
Calcium	7.1
Strontium	8.3

In general monovalent bases would seem to give faster acting depilation than di-valent bases.

Based upon these experiments, and on considerations of odour, it was decided to eliminate at this stage certain thio compounds as follows.

Thiomalic acid—slow acting, very bad odour.
Thiodiglycol—slow acting, poor odour.
2-mercapto propionic acid—slow acting, poor odour.
3-mercapto propionic acid—moderate speed action, good odour.

The choice for retention of thioglycerol and thioglycollic acid was obvious as they were both fast-acting and with reasonable odour 2-mercapto ethanol was also retained because it gave the fastest acting depilation, although it has a very poor odour.

From the monovalent bases, sodium hydroxide was selected as the best overall; and from the divalent bases calcium hydroxide was selected.

Effect of pH

Using the basic depilatory cream formula previously described, depilatory creams were made up containing 5% w/w of each of the following thio compounds: (a) 2-mercapto ethanol; (b) thioglycerol; (c) thioglycollic acid. Each cream was neutralized to a range of pH values with (a) sodium hydroxide, and (b) calcium hydroxide; the depilation times were determined for each formulation.

2-mercapto ethanol.

Neutralizing base	pH	Depilation time (min)
Sodium hydroxide	9	14.0
Sodium hydroxide	10	5.0
Sodium hydroxide	11	<3.0
Calcium hydroxide	9	8.0
Calcium hydroxide	10	3.0
Calcium hydroxide	11	3.0
Calcium hydroxide	12	6.0

Thioglycerol.

Neutralizing base	pH	Depilation time (min)
Sodium hydroxide	9	>15.0
Sodium hydroxide	10	7.0
Sodium hydroxide	11	5.0
Calcium hydroxide	9	10.0
Calcium hydroxide	10	10.0
Calcium hydroxide	11	8.0
Calcium hydroxide	12	6.0

Thioglycollic acid.

Neutralizing base	pH	Depilation time (min)
Sodium hydroxidc	9	>15.0
Sodium hydroxide	10	12.0
Sodium hydroxide	11	5.0
Calcium hydroxide	9	>15.0
Calcium hydroxide	10	15.0
Calcium hydroxide	11	11.0
Calcium hydroxide	12	7.0

Conclusions. Depilation time is decreased as pH is increased as would be expected. In practical terms a pH of 9 would be too low to give a reasonably fast-acting depilatory.

In the range of pH of 10–12 the choice of thio compound and neutralizing base can have more effect on speed of depilation than the pH.

Effect of concentration of thio compound

Using the basic depilatory cream formula previously described, depilatory creams were made up containing (a) 2.5% w/w, (b) 5.0% w/w and (c) 7.5% w/w of each of the following thio compounds: (a) 2-mercapto ethanol; (b) thioglycerol; (c) thioglycollic acid. Each cream was neutralized to a pH of 11 with (a) sodium hydroxide and (b) calcium hydroxide, and the depilation times were determined for each formulation.

2-*mercapto-ethanol.*

Neutralizing base	% w/w of thio compound	Depilation time (min)
Sodium hydroxide	2.5	8.0
Sodium hydroxide	5.0	<3.0
Sodium hydroxide	7.5	<3.0
Calcium hydroxide	2.5	8.0
Calcium hydroxide	5.0	3.0
Calcium hydroxide	7.5	4.0

Thioglycerol.

Neutralizing base	% w/w of thio compound	Depilation time (min)
Sodium hydroxide	2.5	14.0
Sodium hydroxide	5.0	5.0
Sodium hydroxide	7.5	5.0
Calcium hydroxide	2.5	10.0
Calcium hydroxide	5.0	8.0
Calcium hydroxide	7.5	6.0

Thioglycollic acid.

Neutralizing base	% w/w of thio compound	Depilation time (min)
Sodium hydroxide	2.5	10.0
Sodium hydroxide	5.0	5.0
Sodium hydroxide	7.5	6.0
Calcium hydroxide	2.5	12.0
Calcium hydroxide	5.0	11.0
Calcium hydroxide	7.5	15.0

Conclusions. Whilst an increase in concentration from 2.5% to 5.0% with all three thio compounds gives a decrease in depilation times, a further increase to 7.5% does not have any further effect (probably due to solubility limits having been reached).

An optimum concentration of thio compound of approximately 5% would seem to be indicated for practical purposes.

Discussion

This series of results enabled us to formulate a range of practical depilatories which could then be compared with competitive products to give a measure of relative performance.

Although speed of depilation is probably the most important factor in the development of a commercial depilatory, other characteristics (particularly potential irritation) have to be considered.

When skin irritation studies were carried out using the most rapid acting depilatories, it was found in general that speed of action and depilation were inversely proportional.

However, the factors which were most significant for speed of depilation did not necessarily have the same order of importance for irritation. Using the results obtained from the Depilometer studies together with the results of irritation studies a number of practical depilatory creams were formulated which represented different degrees of compromise between speed of action and irritation.

User tests with these depilatory creams then enabled the best overall compromise to be selected.

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REFERENCE

(1) Yablonsky, H. A. and Williams, R. A qualitative study of the effect of depilatory solutions upon hair. *J. Soc. Cosmet. Chem.* **19** 699 (1968).

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Society of Cosmetic Chemists of Great Britain 1974 Medal Lecture

Professor J. Ebling was the recipient of the 1974 Medal of the Society of Cosmetic Chemists of Great Britain. The Society's Medal was presented to Professor Ebling at a meeting held at the Royal Society of Arts on Thursday, 7th March 1974. In making the presentation, the President of the Society, Mr G. A. C. Pitt, expressed the great pleasure it gave the Society to honour one of its own members for the first time, in this way. Professor Ebling, who holds the chair of Zoology in the University of Sheffield, was a regular contributor to the scientific activities of the Society as well as being a major contributor to the science of dermatology. His lecture, 'Sex Hormones and the Skin', was then delivered to the meeting, and Miss Anne Young, the Vice-President of the Society, proposed a vote of thanks.

Professor F. J. G. Ebling (left) receiving the Silver Medal from the Society's President, Mr G. A. C. Pitt (right)