THE PHYSICAL PROPERTIES OF SEBUM IN ACNE VULGARIS

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SUMMARY

1. Methods are described for the collection of scalp sebum, and for the determination of the density, viscosity, surface tension, and freezing-point of sebum samples from individual subjects.

2. Data are presented from ten acne patients and seven normal subjects, of whom three previously had acne. No significant difference was demonstrated between the sebum from acne patients and controls. The sebum viscosity increased with fall in temperature, but sebum did not solidify at physiological skin temperatures, and it is concluded that sebum viscosity is unlikely to be important in the pathogenesis of acne.

3. There was no relationship between sebum excretion rate and viscosity in individual subjects and sebum viscosity is unlikely to play a major role in the normal regulation of sebum production.

Acne is accompanied by a seborrhoea which persists into middle age long after the acne lesions have become inactive (Cunliffe & Shuster, 1969a). This suggests that some factor in addition to seborrhoea is implicated in the pathogenesis of the acne lesion. Histological studies (Strauss & Pochi, 1965) have shown that the sebaceous gland may rupture in acne, liberating inflammatory materials into the dermis, and it is possible that obstruction of the sebaceous duct causes retention of sebum, with consequent distension and rupture of the gland wall. Such obstruction may be due either to changes in the duct wall, e.g. increased keratinization, or to changes in the physical properties of the sebum, e.g. increased viscosity or gel formation. The standard methods for measuring viscosity would require far greater quantities of sebum than could conveniently be obtained from individual subjects. I here describe a micromethod for the determination of sebum viscosity and present data obtained from acne patients and control subjects.

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Sebum collection

Scalp sebum samples were collected from ten patients with acne, aged 15–24 years, and from seven normal subjects, aged 14–31 years, of whom three had previously had acne, but the lesions had cleared some years ago. The subjects washed their scalps on the day prior to the collection and applied no topical therapy or cosmetic preparation to the face or scalp thereafter. The sebum was collected with the subject lying on a couch in the supine position with the head overhanging the edge of the couch. The hair and scalp were lowered gently backwards into a bowl of Analar ether, whilst more ether was poured over the anterior scalp and collected as it drained into the bowl. The ether was filtered to remove any hairs or squames, and then slowly evaporated to a small volume (about 5 ml) which was placed in an incubator at 35° for final evaporation. Approximately 0·2 ml of liquid sebum was thus obtained from each subject. Special precautions were taken to exclude sources of heat or sparks from the room during the collection procedure, and protective pads were placed over the patients’ eyes. Informed consent was obtained from each subject (and from parents in the case of minors); there was no morbidity from the procedure, though most subjects found the fumes unpleasant, and one subject felt giddy for about 2 min afterwards.

The sebum excretion rate from the forehead was measured immediately prior to this collection in five of the acne patients and in seven normal subjects, using the method of Strauss & Pochi (1961) as modified by Cunliffe & Shuster (1969b). A large sample of forehead skin sebum for comparison with scalp sebum was also obtained from one normal subject (the author) by this method, by applying the absorbent papers to a large area of forehead skin and changing them five times at convenient intervals over a period of 24 h. The sebum was extracted from the paper with Analar ether in the usual way.

Sebum viscosity determination

The method, which depends on the rate of rise of sebum in a vertical capillary tube, was a modification of that used by Levin (1937) to determine the viscosity of small oil samples. The apparatus consisted of a thin-walled capillary tube of uniform bore (radius 0·008 cm) and a small conical glass reservoir (volume 0·1 ml) which was stuck to a vertical wire with Araldite. These were arranged, as shown in Fig. 1, in a boiling tube suspended in a Perspex water bath fitted with an electrical thermostat and stirrer. The capillary tube was marked at distances of 25, 38 and 51 mm from its lower end. To determine the sebum viscosity the thermostat was set to the required temperature and after a suitable equilibration period (about 20 min) the cup was lifted until the sebum came into contact with the capillary tube. The sebum rose due to surface tension forces, and the time taken for the meniscus to reach the first, second and third marks was noted from a stop watch. It was found that the meniscus had reached its maximum height by 30 min, and this height was measured by a millimetre rule. The capillary tube was cleaned by sucking Analar ether through it, followed by air. Few difficulties were caused by dust or dirt blocking the capillary tube, but a check was provided in that when the tube was clean there was a constant relationship between the times taken to reach the three horizontal lines and partial blockage of the capillary produced a deviation from this relationship.

The sebum viscosity was measured at 35°, 30°, 25° and 20°. Several other liquids were tested in the micro-viscometer and it was found that ‘3 in l’ oil (E. R. Howard Ltd, Ipswich) and
arachis oil had viscosities similar to that of sebum. Since these were available in adequate quantities they were used as reference liquids, and in order to check the validity of the micro-method their viscosities were also determined by a standard U-tube viscometer.

![Microviscometer used to determine the viscosity of small samples of sebum.](image)

**Sebum density**

The calculation of viscosity by this micromethod requires that the density of the liquid be known. The density of sebum was obtained by filling a clean weighed capillary tube with sebum to a mark, reweighing and then repeating the procedure with glacial acetic acid of known density (1.049 ± 0.001 g/cm³ at 20°). The sebum density was then calculated using three observations for each sample. Temperature corrections were applied, taking the volume coefficient of expansion for organic liquids to be approximately 10⁻³ per °C, but their effect was small enough to be disregarded.

**Freezing-point**

An approximate estimate of the freezing-point of each sample was made by observing the temperature at which the sebum failed to rise up the capillary tube, each temperature decrement being 5°.

**Calculation of results**

The general equation governing the rise of a Newtonian liquid in a capillary tube under the
influence of surface tension has been given by Washburn (1921). For the present case, in which
the tube only just dips into the liquid in the reservoir, this becomes

\[
\frac{t}{8 \eta h_0} = \log_{10} \frac{1}{1 - h/h_0} - h/h_0
\]  

(1)

where \( t \) = time (s) to reach height \( h \) (cm)
\( \eta \) = viscosity (poise)
\( \rho \) = density (g/cm\(^3\))
\( g \) = acceleration due to gravity (981 cm/sec\(^2\))
\( h_0 \) = height (cm) reached when \( t = \infty \)
\( r \) = capillary tube radius (cm)

Under this equation we may calculate the values for \( t/8 \eta h_0/\rho gr^2 \) for arbitrary values of \( h/h_0 \) and draw the graph (Fig. 2). It may thus be shown that \( t_1 \) (the value of \( t \) when \( h = h_0/2 \)) is given by

\[
\frac{t_1}{8 \eta h_0} = 0.193,
\]

i.e.

\[
\eta = \frac{0.65 \rho gr^2}{h_0} \cdot t_1
\]  

(2)

\( \eta \) may be determined from the experimental observations by plotting \( h \) against \( t \) (Fig. 3), measuring the time \( t_1 \) taken to reach \( h_0/2 \) from the graph, and using equation (2).

The final height \( h_0 \) is related to the surface tension \( \gamma \) of the liquid and its angle of contact with
glass \( \alpha \) by the relation

\[
h_0 = \frac{2 \gamma \cos \alpha}{\rho gr}
\]  

(3)

RESULTS

The viscosities of the reference fluids (arachis oil and '3 in 1' oil) at 35° determined by the
capillary micromethod correlated well with the values obtained by a standard U-tube visco-
meter (Table I). The latter values were converted from stokes to poise by multiplying by the
density of the fluid.

The sebum density was measured in three normal subjects and in three acne patients and in
both groups the mean value was 0.90 ± 0.01 g/cm\(^3\). Since the quantity of sebum obtained from
most subjects was only just sufficient for the viscosity determinations, and since the effect of
small changes in density on the calculation of viscosity is negligible, the mean value was used
in all the sebum viscosity calculations.

The mean viscosity of the scalp sebum from control subjects at 35° was 0.32 ± 0.03 poise
(Fig. 4), but at 20° the mean viscosity had increased significantly to 1.71 ± 0.70 poise \((t = 3.28,\ d.f. = 8, P<0.02)\). The variance of the observations tended to increase with decreasing tempera-
ture, but at physiological skin temperatures there was relatively little difference between the
Fig. 2. Calculated rise of a Newtonian liquid in a capillary tube, where $t =$ time (s) to reach vertical height $h$ (cm), $\eta =$ viscosity of liquid (poise), $\rho =$ density of liquid (g/cm$^3$), $g =$ acceleration due to gravity (981 cm sec$^{-1}$ sec$^{-2}$), $r =$ capillary tube radius (cm), and $h_0 =$ final height reached when the liquid is stationary ($t = \infty$). Arbitrary values are assigned to $h/h_0$ and the graph is then obtained from the general equation, shown as equation (1) in text.

Fig. 3. An example of the experimental data obtained with the microviscometer, using scalp sebum from a subject with a previous history of acne. $h_0$ is the maximum height reached by the sebum meniscus at a given temperature.
TABLE 1. Comparison of viscosities of reference fluids determined by the capillary micromethod and a standard U-tube viscometer

<table>
<thead>
<tr>
<th>Sample</th>
<th>Temp (°C)</th>
<th>Microviscometer method (poise)</th>
<th>Standard U-tube viscometer (poise)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arachis oil</td>
<td>35</td>
<td>0.59</td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>1.12</td>
<td>1.17</td>
</tr>
<tr>
<td>'3 in 1' oil</td>
<td>35</td>
<td>0.22</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>0.46</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Fig. 4. The mean viscosity (± 1 SE) of the scalp sebum from seven normal subjects is plotted against the temperature of the sebum. The mean viscosity increased significantly with a fall in temperature from 35° to 20°.
Sebum viscosity

Sebum samples. None were solid at physiological temperatures, but two samples failed to rise up the capillary at 20°, and the other five were solid at 15°.

The mean viscosity of the scalp sebum from the acne patients was 0.35 ± 0.03 poise at 35° and 0.93 ± 0.14 at 20° (Fig. 5). Though the acne sebum tended to be less viscous than normal

![Diagram](image)

**Fig. 5.** The mean viscosity (± 1 SE) of the scalp sebum from ten acne patients is plotted against the temperature of the sebum. The values are not significantly different from those obtained from normal subjects.

Sebum at the lower temperatures the difference was not significant. Sebum from two patients failed to rise up the tube at 20°, and the other eight samples were solid at 15°.

Three of the ten acne patients were taking long-term tetracycline therapy (250 mg daily) at the time of the sebum collection. The mean viscosity of these samples at 35° was 0.44 ± 0.04
Fig. 6. The sebum excretion rates from forehead skin are plotted against the viscosities of scalp sebum of twelve subjects. • = No acne ever, ▲ = old acne, ○ = acne.

Fig. 7. Comparison of viscosities of sebum samples from the forehead and scalp of a normal subject. The mean viscosity (± 1 SE) of each sample is plotted against its temperature.
Sebum viscosity

poise compared with $0.31 \pm 0.03$ poise for the seven patients not taking tetracycline. This difference was just significant ($P < 0.05$).

There was no correlation between scalp sebum viscosity and forehead sebum excretion rates in the twelve subjects in whom both determinations were made (Fig. 6).

In the normal subject from whom both forehead skin and scalp sebum samples were collected the viscosity of the two samples was almost identical at all temperatures (Fig. 7).

The mean value of the product of surface tension and $\cos \alpha$ (calculated from equation 3) for the control sebum samples was $22.8 \pm 0.8$ dyne/cm at $35^\circ$ and $24.2 \pm 1.1$ dyne/cm in the acne patients, but this difference was not significant.

DISCUSSION

Several authors have suggested that the physical properties of sebum may be important either in the normal regulation of sebum production (Butcher & Parnell, 1948; Emanuel, 1936) or in the pathogenesis of acne (Cunliffe & Shuster, 1969a). Little experimental data on this subject is available in the literature, however, probably due to difficulty in obtaining sufficient quantities of sebum. Butcher & Coonin (1949) studied the physical properties of a pooled sebum sample obtained by the Emanuel ether cup method from a large number of (presumably normal) subjects, but as far as is known there are no reports with regard to sebum from individual subjects.

Butcher & Coonin (1949) determined the specific gravity of their pooled specimen by a pycnometer method and their value of $0.91 \text{ g/cm}^3$ is close to my mean value of $0.90 \pm 0.01 \text{ g/cm}^3$ for three normal subjects. The mean surface tension of their sebum specimen at temperatures ranging from $26.5$ to $31^\circ$ was $24.9$ dyne/cm, which is only slightly greater than my mean value of $22.9 \pm 0.9$ dyne/cm for six normal sebum specimens at $30^\circ$.

Butcher & Coonin (1949) used a capillary microviscometer which depended on the flow of liquid produced by a head of water. The mean viscosity of their sebum at $38^\circ$ (0.55 poise) was higher than my value of $0.32 \pm 0.03$ poise at $35^\circ$, but their value at $26.5^\circ$ (1.00 poise) was close to my value of $0.82 \pm 0.22$ poise for sebum at $25^\circ$. Their viscosity curve was discontinuous at $30^\circ$ due to the separation of a precipitate in the sebum. This discontinuity was not observed in my experiments and may have been due to the heterogeneous nature of their sample.

Miescher & Schoenberg (1944) have ascribed to Linser the value of $33-36^\circ$ for the freezing-point of sebum. My observations do not support this, since all my specimens flowed up the capillary tube at $25^\circ$, and the true value is probably closer to the $15-17^\circ$ suggested by Butcher & Coonin (1949).

Butcher & Parnell (1948) observed that the quantity of sebum on the forehead varied with temperature, and Butcher & Coonin (1949) suggested this could be explained by the effect of temperature on sebum viscosity. They concluded from this that the viscosity of sebum largely affords the resistance to further excretion of sebum from the gland orifice, and thus regulates the accumulation of sebum on the skin surface. The present observation that the sebum excretion rate is unrelated to the sebum viscosity does not preclude the possibility that viscosity changes may modify the rate of excretion to the skin surface, but it does suggest that viscosity is not the major factor which governs the quantity of sebum produced by the gland.

My finding of an increase in sebum viscosity in patients taking tetracycline may be related to the known effect of tetracyclines in reducing the free fatty acid content of sebum (Freinkel,
Strauss, Yiu Yip & Pochi, 1965). An increase in the proportion of unsplit triglycerides in the sebum might be expected to increase sebum viscosity, since simple triglycerides such as tristearin and tributyrin have a higher viscosity than their constituent fatty acids (Weast, 1969).

I have shown that the viscosity of scalp sebum from acne patients and control subjects is almost identical at physiological skin temperatures. It is difficult to exclude the possibility that the physical properties of the sebum have been altered by passage through ethereal solution, though the extraction ratio of sebum in ether is very high. A further source of error would arise if sebum from the scalp, an area which is not involved in acne vulgaris, differed in its physical properties from sebum from facial skin which does produce acne lesions. This possibility has not been completely eliminated though I have shown that in a normal subject the viscosity of scalp and forehead sebum is virtually identical. A less likely source of misinterpretation of the data is the possibility that acne patients secrete two types of sebum, some of normal viscosity which reaches the skin surface, and also a more viscous sebum which solidifies to block the ducts before it reaches the skin surface; this would not be collected by washing the skin in ether. Finally it is possible that sebum may not be a true Newtonian liquid, but rather a gel with a low yield stress. The presence of such a low yield stress would not necessarily have become apparent in the capillary tube measurements but could exert a controlling influence on the excretion of sebum.

With these caveats, I feel that the present observations strongly suggest that sebum viscosity changes play no significant role in the pathogenesis of acne.

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REFERENCES


Sebum viscosity


