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The Regulation of Sebum Excretion in Man

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Summary. The refatting curve of 21 test persons shows that the sebum excretion is highest during the first hour and decreases continously with every following refatting interval. Refatting after regular defatting every hour reveals a constant excretion rate over 7 hrs. Thus the conclusion can be drawn that sebum excretion is regulated by the excreted sebum itself.

Prints of the forehead on slides show that the sebum is excreted in the form of droplets. Sebum is an oily liquid. The water content of sebum is so low that the assumption of spontaneous formed water-sebum emulsions is not justified.

One of the physical properties of sebum, the viscosity or the surface tension, might regulate its excretion. We determined the pressure, needed to overcome the viscosity and surface tension in the sebaceous gland. The results indicate that the surface tension regulates sebum excretion.

Zusammenfassung. Die Rückfettungskurve von 21 Versuchspersonen zeigt, daß die Talgausscheidung in der ersten Stunde am größten ist und mit jedem weiteren Rückfettungsintervall abnimmt. Die Rückfettung nach stündlicher Entfettung ergibt dagegen eine konstante Ausscheidungsrate über 7 Std. Daraus kann geschlossen werden, daß die Talgausscheidung durch den ausgeschiedenen Talg reguliert wird.

Abdrücke der Stirn mit Glasplättchen zeigen, daß der Talg in Form von Tröpfchen ausgeschieden wird. Talg ist eine ölige Flüssigkeit, dessen Wassergehalt so gering ist, daß die Annahme einer spontanen Emulsionsbildung mit Schweiß nicht gerechtfertigt ist.

Eine der beiden physikalischen Eigenschaften des Talges, nämlich die Viscosität oder die Oberflächenspannung, sollte die Ausscheidung regulieren. Wir haben den Druck gemessen, der notwendig ist, die Viscosität und die Oberflächenspannung in der Talgdrüse zu überwinden. Die Resultate zeigen, daß die Oberflächenspannung die Talgausscheidung reguliert.

As a rule, the refatting of defatted human skin leads to the same level of sebum at the surface of the skin after several hours as prior to defatting. This level varies for each individual, as well as for every particular part of the body, symmetrical arranged areas revealing identical excretion. Without external interferences, e.g. cleaning of the skin, the sebum level remains constant. Slight interferences e.g. wiping off at unprotected areas are either of little importance or are compensated quickly: this is explaining the relative constancy of the "casual level". The constancy of surface fat levels suggests a decrease of the sebum excretion with increasing levels of excreted sebum. This is in agreement with the clinical pattern of skin fattening. The decrease means that the sebum excretion must be regulated. Such regulation has been claimed by Miescher and Schönberg and denied by Kligman and Shelley.

The Quantitative Determination of Sebum Excretion

During our experiments on the influence of substances inhibiting sebum excretion we found that controls always showed a flattening of the excretion-time

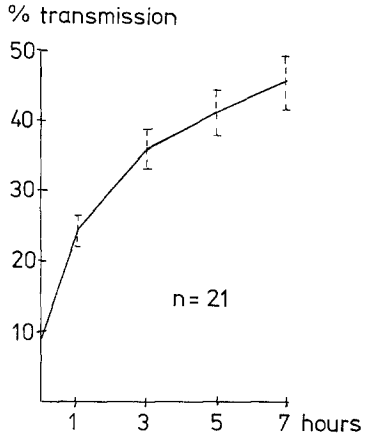

Fig. 1. Refatting curve of 21 test persons (Standard deviations, confidance limits 95% are given)

function. As this observation offered us a chance to collect valuable information on the physiology of sebum excretion, which was examined more closely using the following procedure.

The test person's forehead was defatted by ten successive applications of strips of clear plastic under pressure. The remaining sebum was determined by the ground glass method of Schaefer and Kuhn-Bussius. After refatting times of 1, 3, 5 and 7 hrs, the amount of excreted sebum was measured on consecutive days. Daily measuring was performed to avoid misleading results from the wiping-off-effect arising from the measuring method. Fig. 1 shows the refatting curve obtained from 21 test persons over a 7 hrs-period.

The excretion rate was highest during the first hour of the experiment and decreased continuously with every consecutive fatting interval.

From these data it can be concluded that either the sebaceous gland is rapidly exhausted or that the excreted sebum itself inhibits further excretion. Since the test persons were not immobilized a certain amount of wiping-off during the refatting time had, of course, to be taken into consideration. However, the constancy of the individual measurements shows that the natural loss of sebum cannot, by any means, explain the flattening of the curve.

The test persons were divided into four groups according to their sebum excretion. 1. very strong excretion (30—50% transmission after 1 hr), 2. strong excretion (20—30% transmission after 1 hr), 3. weak excretion (10—20% transmission after 1 hr) and 4. very weak excretion (below 10% transmission after 1 hr). Fig. 2 shows the four groups.

In the first group a considerable inhibition could already be noted; in the second group the inhibitory effect was still stronger and in the third group the excretion had completely stopped at the time of the last reading. Group four, as well, fits into this general picture, however exact quantitative data on the results could not be obtained, due to considerable scattering of the values.

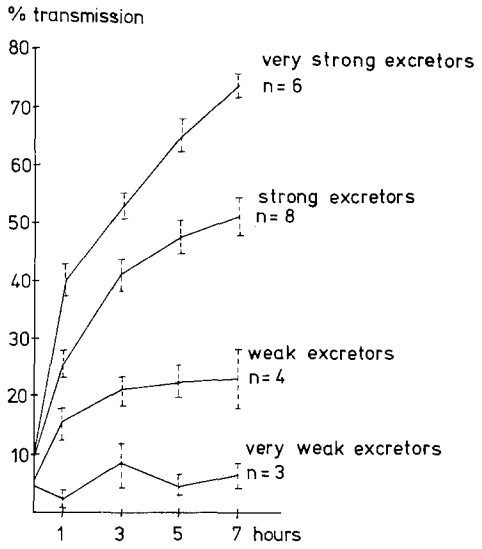

Fig. 2. Refatting curve of different excretors (Standard deviations, confidance limits 95% are given)

These data raised the question whether an exhaustion of the sebaceous gland plays an important role in sebum regulation. To clarify this point, further experiments were performed.

Exhaustion of Sebaceous Glands

The skin was defatted as described above and the residual sebum was determined by the ground glass method. After 1 hr the refatting was measured. Subsequently the skin was defatted again and allowed to refat for 1hr. Then the excretion was measured as previously. This procedure was repeated over 7 hrs. The results (Fig. 3) indicate that the excretion rate is constant during the whole experiment and equals the initial rate in Fig. 1.

These data prove that there is no exhaustion of the sebaceous gland, at least not during our reading period of 7 hrs. Subdividing the test persons into strong and weak excretors and plotting the respective results separately reveals the same general pattern (Fig. 4). Sebum excretion is constant in both groups, the excretion rate being equal to the respective initial rates in Fig. 1.

The rate of sebum excretion remains constant, if the sebum is removed continually, whereas it decreases when the sebum is not removed. There is only one possible explanation for this fact, that is that the sebum excretion is regulated by the excreted sebum itself, the regulation being more effective in weak excretors than in strong ones. The results presented here are not necessarily in disagreement with those of Kligman and Shelley. These authors used "sebaceous athlets", whose weak regulation probably escaped detection by the authors methods.

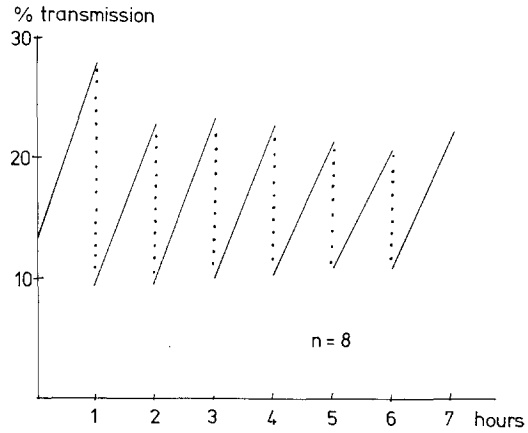

Fig. 3. Refatting curve by defatting each hour

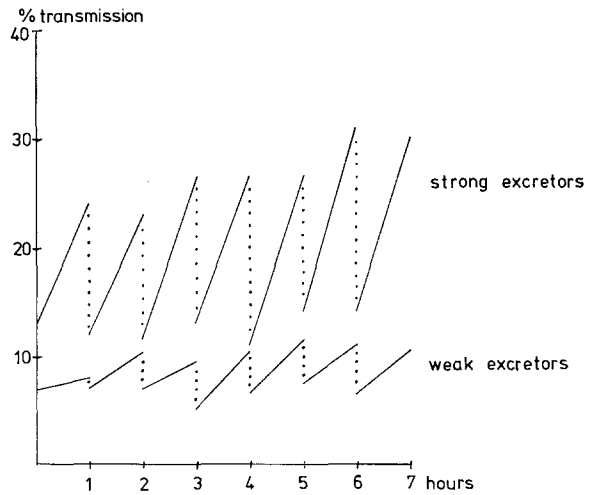

Fig. 4. Refatting curve by defatting each hour; different excretors

Sebum Excretion on the Forehead

In accordance with Kligman and Shelley we found a droplet shaped excretion of sebum on the forehead of our test persons. While Kligman and Shelley looked at the forehead directly with a stereoscopic microscope, we examined prints of the forehead on glass plates, e.g. slides, under the stereoscopic microscope, whereby we made the following observations (Fig. 5).

1. There is no coherent film, but rather a lot of little droplets to be seen; this is in agreement with Kligman and Shelley's results who used cigarette paper prints.

2. The excreted sebum is a clear and transparent oil which does not contain any emulgated droplets of water.

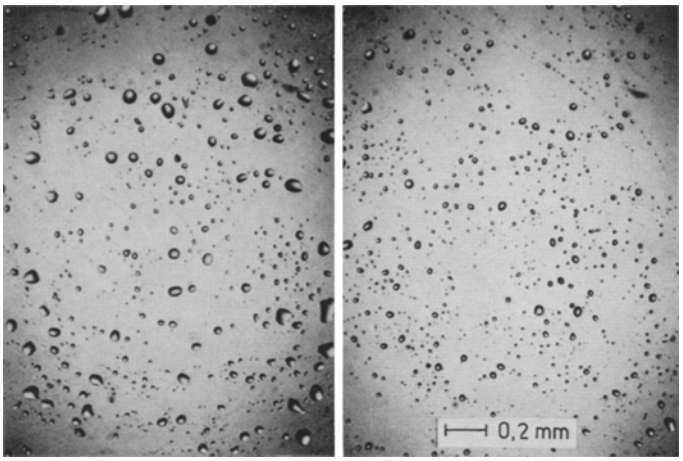

Fig. 5. Prints of the forehead on slides, strong excretor (left), weak excretor (right), taken 15 min after defatting of the forehead

3. In the sebum solid particles are visible, presumably remainders of cell walls from the sebaceous gland or horny cells of the infundibulum.

4. Strong and weak sebum excretors differ mainly in the size of the droplets; the number of droplets was about the same in both series.

In a second experiment, when we wiped off the forehead immediately before taking a print, again only droplets could be detected on the slides. This observation indicates that the droplets are located in funnel-like depressions of the skin surface, namely in the openings of the sebaceous gland follicles. If they would be located on the skin surface, the droplets would have been wiped off and would have disappeared.

From these experiments, sebum excretion on the forehead can be described as follows:

The available sebum is mainly located in the openings of the sebaceous gland follicles and constitutes an oily liquid. Under the stereoscopic microscope little droplets can be seen, which are located in the duct openings as shown in Kligman's and Shelley's paper. These droplets are partly removed with glass plates. According to these morphologic observations, the sebum does not spread over the surface of the skin. Moreover, the horny layer cannot act as an important reservoir for sebum, as no film-like, homogeneous print could be obtained. There is no film-like spreading of the sebum over the skin surface. Only with strong excretors can a overflow into the furrows of the skin occur. The measurement of the so called skin surface fat by various methods therefore amounts to a more or less complete extraction of the available sebum from the sebaceous gland follicles.

The Properties of Sebum

As shown in Figg. 1—3, sebum regulates its own excretion. It can be assumed that this regulation is effected by the physical properties of the oily liquid. The sebum needed for our studies was readily attained in the following way.

Table 1. Water content of sebum samples

Subject	mg Sebum	% water
As	0.87	3.2
Bl	1.05	0
Ga	1.34	1.2
Hb	0.65	1.4
Hz	0.90	1.8
Ja	0.70	0
Po	1.79	0
Si	1.12	1.1
St	1.55	0
Su	1.25	0

a) Collection of the Sebum

From the prints taken from the forehead the sebum droplets were collected by means of a bent razor blade.

From the razor blade the sebum was transferred into a narrow capillary, whereby the scales of horny layer remained on the razor blade. With normal excretors every print provides milligram quantities of fresh, unchanged sebum. The sebum obtained by this procedure still contains solid particles, which can be removed by centrifugation in a melting point tube at 3000 rpm. The supernatant consists of clear sebum.

b) Measurement of the Water Content of the Sebum

It has repeatedly been claimed that sebum and sweat form an emulsion. With our prints of sebum droplets, we were unable to detect any signs of such an emulsion, i.e. droplets of water in the sebum. However, it seemed worthwhile to gather some information on the water content of sebum, using a very sensitive method.

Sebum was collected from 10 test persons and its water content was determined by infrared (IR) spectroscopy according to Meeker *et al.* The samples of sebum were dissolved in 0.4 ml aceton and their IR absorption measured at 1910 nm and 1 mm path length. The results are summarized in Table 1[1].

The low water content found in a few samples does not justify the assumption that sebum forms emulsions spontaneously. It is even possible that the respective IR-bands stem from hydroxylic groups belonging to components other than water. Accordingly, it was not possible to remove the bands by evaporating the sample "As" of Table 1 in a vacuum, which means that there is no water present which could form an emulsion. These results do not encourage further belief in the formation of an emulsion from sebum and sweat.

[1] We wish to thank Mr. W. Huppertz of our Analytical Laboratories for measuring the IR spectra.

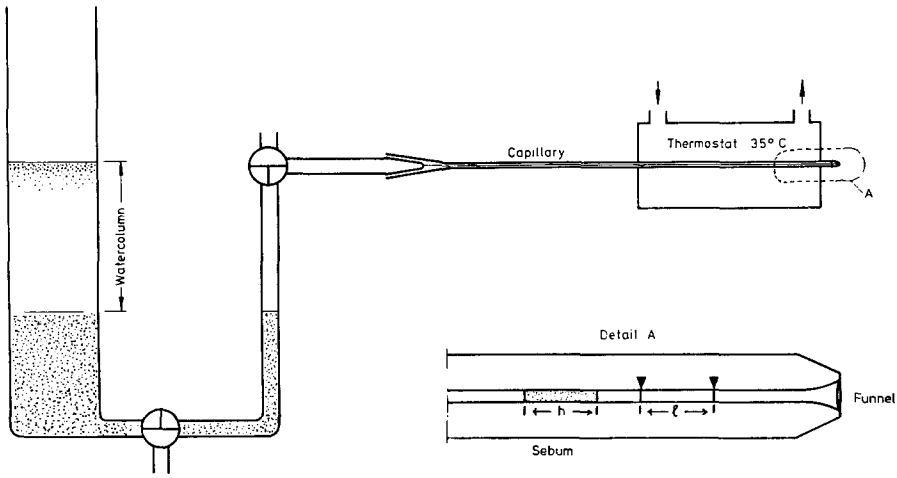

Fig. 6. Apparatus for measuring viscosity and surface tension

c) The Regulating Properties of the Sebum

In principle, two properties of the liquid sebum could be responsible for the regulation of excretion, i.e. viscosity and surface tension.

We have determined the pressure necessary to overcome the viscosity and the surface tension in a capillary, simulating a sebaceous gland follicle. Both measurements were made with the same apparatus using a normal thermometer capillary (Fig. 6). The temperature was held constant at 35°C.

Pressure and Viscosity

We determined the pressure-time function of the viscosity. The length of the sebum column as well as the distance over which it was moved in the capillary were kept constant.

The dimensions of the *in vitro* experiment:

Radius of the capillary (r)	0.12 mm
Length of the sebum column (h)	10.00 mm
Distance moved in the capillary (l)	10.00 mm

The experiment *in vitro*.

The experiment was carried out with sebum samples of ten different persons in the following way. After removal of the solid particles by centrifugation, sebum was transferred to the capillary where it formed a column of 1 cm length. Subsequently the column was moved over a distance of 1 cm by applying a certain pressure; the time necessary for this movement was registered. Fig. 7 shows the average pressure-time-function. From this curve the following pressure-time-function can be derived:

$$p = 282 \frac{1}{t} (\pm 13.9) + 16.3 (\pm 1.93)$$

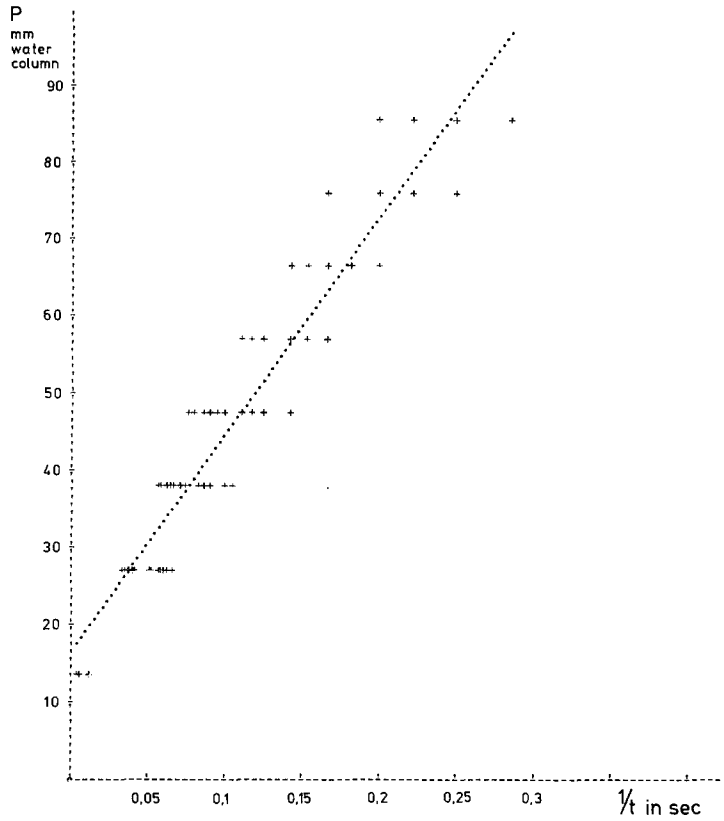

Fig. 7. Pressure-time function of sebum viscosity

The intercept in the plot of the experimental data is an integration constant and does not therefore influence the evaluation of the equation. Substituting h and l into it we obtain:

$$p = 2.82 \cdot h \cdot l \cdot \frac{1}{t}$$

This equation is a special form of the equation of Hagen-Poiseuille.

Assumed dimensions of the sebaceous gland:

In order to compare the above mentioned data with the physiological conditions of sebum excretion, the following dimensions were assumed:

Radius of the duct (r)	approx. 0.10 mm
Lenght of the sebum column in the duct (h)	approx. 1.00 mm
Distance (excessive value) moved by the column in the duct in 1 hr (3600 sec)	approx. 0.10 mm

Comparison of the *in vitro* data to the actual sebum secretion:

The results, obtained *in vitro*, shall now be applied to the sebaceous gland. Substitution of these values into the experimentally obtained equation, yields the pressure which is needed to overcome the viscosity in the sebaceous gland.

$$p = 2.82 \times 1 \times 0.1 \cdot \frac{1}{3600} = 7.8 \cdot 10^{-5} \text{ mm water column}$$

Table 2. Pressure needed to increase the surface of sebum samples from 0.05 mm^2 to 0.5 mm^2

Subject	Pressure in mm watercolumn
As	49
Bl	52
Es	51
Ja	48
Ma	46
Me	48
Po	55
Qu	49
Sw	57
Wa	53
average	51

It has to be taken into consideration, however, that the original sebum contains solid particles, which may increase its viscosity.

Pressure and Surface Tension

The pressure has been determined which was necessary to increase the surface of the sebum from 0.05 mm^2 in the capillary ($r = 0.12$ mm) to 0.5 mm^2 in its funnel-shaped opening ($r = 0.4$ mm). These results are shown in Table 2.

For the increase of the surface against the surface tension, an average pressure of a 51 mm water column is required. This means, that a similar pressure has to be generated by the sebaceous gland for sebum excretion, when the same dimensions are assumed, as applied in this *in vitro* experiment.

These results demonstrate that the outflow resistance, due to the viscosity is several orders of magnitude smaller ($7.8 \cdot 10^{-5}$ vs 51 mm water column), than that due to the surface tension. Therefore the surface tension must be the physical property, which regulates the sebum excretion.

The time for the increase in surface tension of the sebum in the widening duct openings corresponds to the decrease in sebum excretion (Fig. 1). The influence of the viscosity, which would be a linear one, could not account for the flattening of the excretion-time curve (Fig. 1).

Considering the surface tension, it is easy to explain why a weak sebum excretor exhibits a stronger regulatory effect, than a strong excretor. This effect manifests itself already a few hours after defatting (Fig. 2): the surface tension is more effective in the narrow sebaceous gland ducts of weak excretors, than in the wider ducts of the strong excretors.

The regulatory mechanism can be visualized as follows. The sebaceous gland delivers the sebum into the duct. Since the duct widens towards its opening, the surface tension increases with the filling of the duct. As soon as the surface tension reaches a critical level, the gland stops further excretion. This leads to the so called "casual level", which in fact is an uncasual level, as is demonstrated by its remarkable constancy.

This regulatory mechanism of sebum excretion might influence the sebum production by feed back. The amount of sebum present in the duct could regulate

the production in the gland via a chalon mechanism. This would correspond to the common view, that proliferating systems are regulated via an inhibition of the proliferation by chalons, produced in the differentiated part of these tissues.

I wish to thank Dr. W. G. Eberlein and Dr. H. Machleidt for discussing the physical part.

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