

THE CONTRIBUTION OF HAIR FOLLICLES AND SEBACEOUS GLANDS TO THE VOID SPACE OF HIDES*

1949

ABSTRACT

The void spaces produced by the removal of hair and sebaceous glands from a hide have been estimated by measurement of the proportional area occupied by these structures in serial stratigraphic layers. Fresh hide specimens were stained with picric acid to produce a contrast between the keratin and the collagen fibers. The layers were photographically enlarged so that the area of the hair follicles could be measured with a planimeter. The results demonstrate that the void space contributed by the hair follicles and the sebaceous glands is only a small fraction of the total hide volume.



INTRODUCTION

The void spaces in hides and leather play an important role in the processing and properties of leather. They could affect the penetration of materials into hides and leather and also affect the degree to which the fibrous components can be altered and rearranged to make leathers of different properties. Various techniques have been used for measuring the void space of hides (1,2,3). These have been able to approximate the size distribution of the void spaces for the microscopic-sized voids but are inadequate for measuring the distribution of large void spaces.

Stubbings and Theis (4) demonstrated through a stratigraphic study of swelling phenomena that the grain region was much less dense than the corium region. A similar difference in density between the grain and the center of the corium was shown by Mellon *et al.* (5) in stratigraphic studies of the dry matter and nitrogen in cattlehide. These studies aroused interest in the amount of large void spaces contributed by the hair follicles and sebaceous glands. This study employs planimeter measurements on photographic enlargements of stratigraphic layers to determine the relative area of the surface of each layer covered by the hair follicles and sebaceous glands.

*This paper was presented at the 58th Meeting of the American Leather Chemists Association, June 17-20, 1962, Mackinac Island, Michigan.

†Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

EXPERIMENTAL

A freshly flayed steerhide was washed with cold water for 15 minutes in a slotted drum to remove blood and debris, cut into blocks, then stored at -20°F . until used. One block from the bend area was thawed, shaved as closely as possible with a dry razor, and cut into pieces about 1.5" square. One of these pieces was stained by placing it in 100 ml. of saturated picric acid solution for 24 hours. Excess picric acid was removed by washing twice with water. A small piece, 0.90 x 1.00 cm., was cut from it, and one corner of this piece was cut off diagonally to provide an index position for orienting the serial layers. The grain side of this piece was held flat against a smooth aluminum plate with a small weight and frozen to produce a very smooth grain surface. The piece was removed from the aluminum plate while still frozen and was then frozen flesh side down onto the microtome stage. The stage was adjusted carefully so that the grain surface was parallel to the path of the knife edge. The surface of the piece was raised to the level of the knife edge. Then, 12 layers, each 0.120 mm. thick, were cut parallel to the grain surface. Each piece was placed on a glass slide and adjusted approximately to the shape of the original piece and photographed. The photographs were enlarged 20 diameters to produce a picture on which the follicles could be identified from layer to layer. A characteristic pattern produced by four large follicles was used to outline an area on these photographs in which the follicles would be studied.

The photographs were projected onto large sheets of white paper so that the area to be studied in each layer covered the same area. This area was 21,100 times the original skin area. The outlines of the follicles and sebaceous glands were traced. The traces for layer number 1 were numbered. These numbers were copied onto a sheet of polyethylene, and this sheet was placed over the tracings for layer number 2, and the corresponding traces were identified and numbered with the same number. This procedure was followed from layer to layer until all of the tracings were numbered. The outline of each follicle and sebaceous gland for each of the 12 layers was then traced with a planimeter to obtain the area. All the measurements were recorded on IBM cards, which were sorted to determine the relationships reported.

RESULTS AND DISCUSSION

The slices were cut and numbered consecutively from the grain surface toward the corium. The first slice, which was the grain surface, was difficult to study. The hair stubble projected slightly above the grain surface, and since the hair shafts are oblique to the surface, the areas shown in their photographs are considerably greater than the true cross section of the hair shafts. For this reason, the measurements made on the first slice are not reported. Slice number 2 is shown in Fig. 1a. The four large follicles used to outline the area studied have been connected with straight lines. All four of

these extra large follicles have been included in the measurements. This outlined area is shown in the photographic enlargement in Fig. 1*b*. Since all the follicles are not at the same angle to the grain surface, the pattern created by the follicles shifts slightly from layer to layer. This pattern was used to trace the follicles through succeeding layers, and the outline was used only as a guide for finding the follicles which were present in the area originally outlined on layer 2.

The corresponding area for layer 5 is shown in Fig. 1*c*. Here the sebaceous glands are seen as white areas surrounding the hair follicles. The corresponding area for layer 8 is shown in Fig. 1*d*. Only a few sebaceous glands are still visible, and many of the hair follicles are missing, having terminated in earlier layers. The number of follicles present in the ninth layer was so small

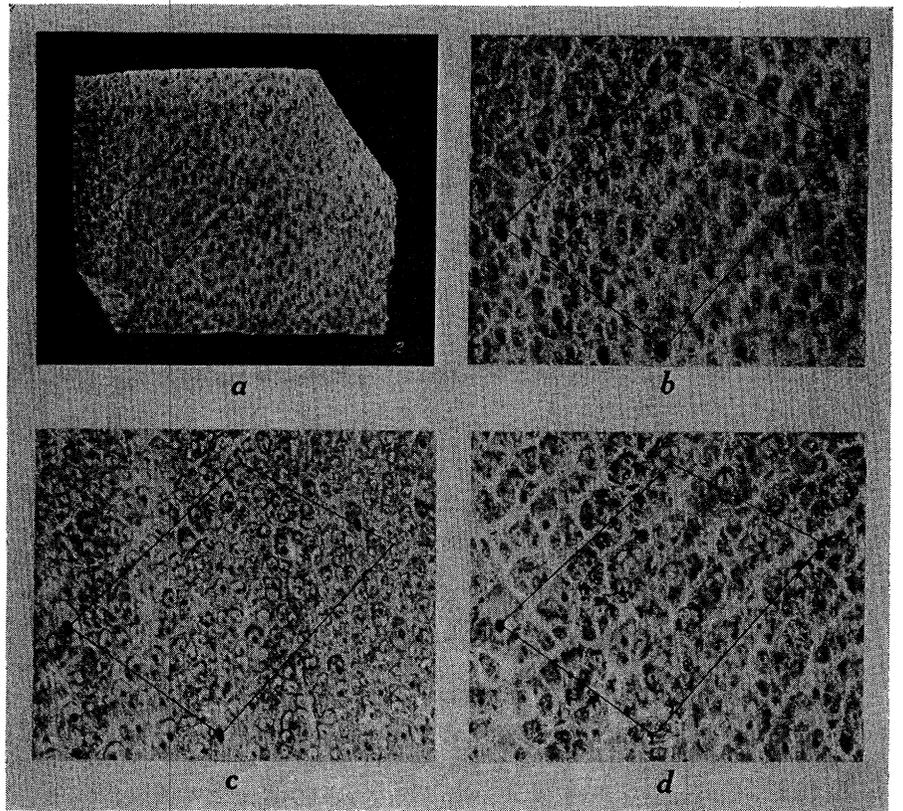


FIGURE 1.—*a*. Photograph of actual piece cut by microtome for layer 2. The base is 1 cm. long.
b. Layer 2 enlarged to show actual area studied.
c. The same area on layer 5.
d. The same area on layer 8.

that it was impossible to distinguish exactly the area under study. Therefore, no measurements were made beyond the eighth layer.

The number of hair follicles found in each layer is given in Fig. 2. The same number of hair follicles is found in the first three layers. From the fourth to the seventh layers there is a gradual decrease in the number of hair follicles present. Between the seventh and eighth layers about one-third of the remaining follicles disappear.

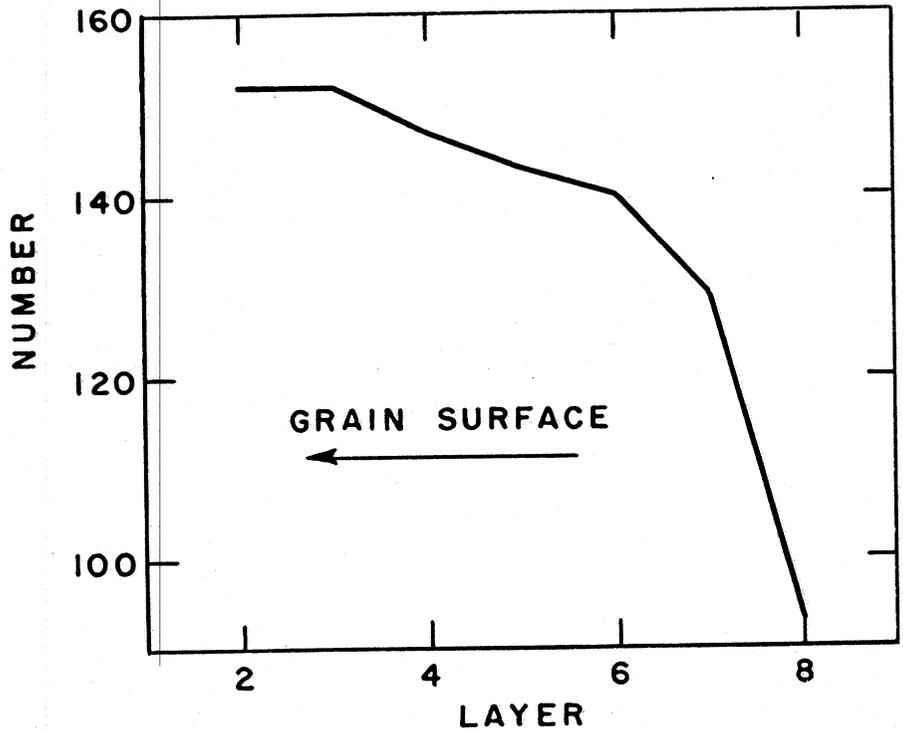


FIGURE 2.—The distribution of follicles within the thickness of the hide.

The sizes of the hair follicles vary over a considerable range. The smallest follicle which had a planimeter reading of 0.001 had a projected area of 0.039 sq. cm. The largest follicle had a planimeter reading of 0.089 which corresponded to a projected area of 3.5 sq. cm. Since the projections magnified the original areas 21,100 times, the actual cross-sectional area of the hair follicles in the hide ranged from 1.8×10^{-6} to 1.6×10^{-4} sq. cm. The size distribution of the follicles in each layer is given in Table I. There is a broad spectrum of sizes in which only a few size ranges show any preponderance. These are at planimeter readings of 2, 3, 4, 12, 14, 15, 20, and 22. There are

HAIR FOLLICLES AND SEBACEOUS GLANDS

only a few large follicles. The number of follicles of any one size varies from layer to layer for several reasons. Some follicles extend deeper into the hide than others. All follicles appear to be constricted in the region of the sebaceous gland and to expand in the region of the hair root. Since these

TABLE I
SIZE DISTRIBUTION OF FOLLICLES IN EACH LAYER

Planimeter reading × 1000	Projected area* cm ²	Number of Follicles in Layer Number							
		2	3	4	5	6	7	8	
1	0.039	1	1	1	0	0	0	0	
2	0.078	13	14	15	17	11	3	0	
3	0.117	14	11	14	10	11	6	2	
4	0.156	9	10	7	7	8	11	2	
5	0.195	6	5	8	11	9	6	2	
6	0.233	6	8	5	7	7	10	3	
7	0.272	7	9	7	6	10	6	3	
8	0.31	6	3	7	3	6	4	6	
9	0.35	9	10	5	6	3	4	6	
10	0.39	1	4	5	9	6	8	2	
11	0.43	6	7	6	3	6	3	5	
12	0.47	11	7	5	9	6	7	4	
14	0.55	7	8	13	13	12	10	12	
15	0.58	11	8	8	11	11	9	5	
16	0.62	1	3	2	3	1	3	1	
17	0.66	3	3	2	1	1	5	9	
18	0.70	5	6	8	4	5	3	3	
20	0.78	9	11	10	6	5	8	11	
21	0.82	0	0	0	0	1	0	0	
22	0.86	10	9	5	3	5	6	3	
25	0.97	4	2	3	4	4	4	5	
28	1.09	2	2	1	2	3	1	2	
31	1.21	0	0	0	0	0	1	0	
32	1.25	0	1	1	0	0	2	0	
34	1.32	0	0	0	1	0	0	0	
35	1.36	1	0	0	0	1	1	0	
36	1.40	0	0	1	0	1	1	1	
40	1.56	2	1	2	1	1	2	2	
45	1.75	1	4	2	3	3	2	1	
50	1.95	2	1	1	0	0	0	0	
56	2.18	2	1	0	0	1	1	1	
63	2.45	0	0	0	1	0	0	0	
71	2.76	0	0	0	0	0	1	2	
79	3.07	1	1	1	1	2	1	0	
89	3.46	2	2	2	1	0	0	0	
Total		152	152	147	143	140	129	93	

*21,100 times the actual area in the skin.

structures come at different layers for different follicles, they produce variations in the size distribution data.

The number of follicles multiplied by their area gives the total area of the follicles of that size. These have been summarized for groups of sizes in Table II. The number of follicles in the second layer for each group is given to establish the fact that although there are a large number of small-sized follicles, most of the area is contributed by the few large follicles. In general, the total area of the follicles for each layer decreases the further the layer is from the surface because the number of follicles present decreases. The

TABLE II
COMBINED PROJECTED AREA* OF FOLLICLES BY SIZE GROUPS

Size Group cm ² × 100	No. of Follicles†	Area (cm ²) for Layer Number						
		2	3	4	5	6	7	8
1-20	43	5	5	6	6	5	4	1
20-40	29	8	10	9	10	10	10	6
40-60	35	18	15	17	19	18	15	14
60-80	18	13	17	16	10	9	14	17
80-100	14	12	10	7	6	9	9	7
100-200	8	12	14	12	10	13	14	8
200-400	5	14	12	10	9	8	8	8
Total	152	82	83	77	70	72	74	61
Ratio to skin area, %		3.6	3.6	3.3	3.0	3.1	3.2	2.6

*21,100 times the actual area in the skin.

†In second layer. Subsequent layers have fewer follicles present.

slight increases in the sixth and seventh layers are due to the presence of the bulb at the hair root end. These increases would be greater were the number of follicles not decreasing in these layers. The low ratio of the combined area of the follicles to the total area of the hide piece shows that the area occupied by the follicles is very small, ranging from 2.6% to 3.6% of the total area.

The sebaceous gland which surrounds each follicle has a very irregular shape. The glands are also at different depths from the surface. This is shown by the data of Table III. A comparison of the figures for follicles with glands and the number of glands appearing for the first time leads to the conclusion that the glands extend over 0.12 mm. from the top to the bottom. Thus, when the layers are cut, the glands are cut at different parts of their structure, and a variety of cross sections are obtained. It is, therefore, meaningless to compare the areas of the glands from follicle to follicle or layer to layer as was done with the follicles themselves. However, the areas traced for the glands in each layer represent the area covered by the glands at this particular position. There may be regions on either side of the cut

TABLE III
SEBACEOUS GLAND DATA

	For Layer Number		
	5	6	7
Distance from grain surface, mm.	0.48	0.60	0.72
Follicles with glands, number	101	83	26
Percent of total follicles	71	59	20
Glands appearing 1st time, number	101	19	8
Gland area, percent of total area	11.5	8.6	4.6

where the area may be larger or smaller than the values obtained at point of measurement, but large variations from these values are not to be expected. Therefore, the sebaceous glands do not appear to occupy more than about 12% of the area of a cross section of hide cut through them.

The ratios of the follicle areas and sebaceous gland areas to the total area of the region they occupy are summarized in Table IV. These area measurements, when extended through a thickness of hide, become volume measurements. Therefore, the figures represent not only areas occupied, but also

TABLE IV
VOID SPACE DETERMINED

	For Layer Number						
	2	3	4	5	6	7	8
Follicle area, %	3.6	3.6	3.3	3.0	3.1	3.2	2.6
Sebaceous gland area, %	0.0	0.0	0.0	11.5	8.6	4.6	
Combined area, %	3.6	3.6	3.3	14.5	11.7	7.8	2.6

volumes occupied, by the follicles and sebaceous glands. It is apparent that the removal of these two hide structures produces void spaces of from 4% to 15% of the total volume in the various layers of the grain. Since it has been previously shown (5) that the grain layer has about half the density of the central portion of the hide, which also has void spaces, the void space in the grain layer must be greater than 50% of the total volume. Therefore, the void space produced by removal of the hair follicles and sebaceous glands contributes only a small part to the total void space found in the grain layer of cattlehides.

DISCUSSION

DR. KANAGY: The most important stratum of leather to the piece of leather itself is the grain layer. The grain, of course, is also the most sensitive and most prone to crack and scuff, and for this reason I think it is very important to make a study of the structure of the grain as Dr. Mellon has started to do in this work.

We have had quite a few misconceptions of the structure of the grain in leather. For instance, several years ago in our work on impregnation we were led to believe that the grain acted as a barrier to the penetration of materials into the center of the skin. Now I would like to ask Dr. Mellon whether, in the course of his work, there is any indication that, in spite of the void spaces in the grain, there may still be a barrier leading from the grain into the rest of the hide.

DR. MELLON: I don't have too much experimental data along this line. We do know that there is a barrier membrane between the epidermis and the dermis. This was shown by Dr. Cordon and Mr. Everett in their unairing studies. This membrane has to be broken or disrupted before the hair becomes loose. We have had the Lowell Technological Institute study the composition of this membrane, and those results should be reported in the literature within the next year.

Since the grain fibers are much smaller than those of the corium, I would suspect that they would, even after all of the other materials in the hide have been removed, act as a very fine filter compared with the coarse fibers which would act as a very coarse filter. This would cause a slower transfer of materials through the grain leather than through the corium part of the leather.

DR. KANAGY: I think for a number of years we have had the idea that in a young animal like a calf we have a certain amount of hair follicles and these hair follicles do not increase in number during the life of the animal but become larger as the animal matures. Do you have any ideas about that?

DR. MELLON: I think it is probably true. Most of the structures in the grain area of the hide are the same in the calf's skin as they are in the skin of the full grown animal, and I think most of the difference is that the hide is just growing larger in area, and possibly the hair shafts and the hair follicles are larger in area, and the number remains probably very closely the same.

WILLIAM T. RODDY (Tanners' Council Research Laboratory, University of Cincinnati): Dr. Mellon, The work that you presented here today has to do with the fresh hide or skin. Now, how was that related, as an example, to the void spaces which you would have in the same areas in, let us say, the finished

leather? Would you anticipate that you would have the same amount of void spaces or much less as a result of the tanning and finishing of leather?

DR. MELLON: Well, I think probably this question would be more easily explained after Dr. Kanagy's paper where he has actually measured more void spaces. I think the size of these hair shafts and hair follicles would be large enough that we would not be filling them up appreciably with tanning materials. The chromium tanning materials would probably not fill them at all; the vegetable tanning materials may partially fill them. Unless the hide were being put under fairly high pressures during the processing so that these structures would be pushed out of line, we would not do anything with the follicle void space. We may compact a hide by pressure in the region of the sebaceous glands because there appears to be quite an amount of free space there and probably a much weaker structure.

MR. RODDY: In your stratigraphic analysis you cite the various layers and the amount of space shown up by the oil glands. Isn't it really the lobes of the oil glands in any given layer rather than the total oil glands?

DR. MELLON: In the photographs (it doesn't show up too well on the screen) we get all shapes for the cross section of the sebaceous gland. When we look at the vertical sections, which you usually see for histological sections of the skin, the sebaceous gland comes out in two lobes on each side of the hair shaft, but there appears to be a region around the top of these lobes where the sebaceous gland is sort of like a horseshoe fitting around the hair shaft, and there are a number of the tracings which do have almost a horseshoe shape.

Other cross sections show just two little elliptical areas on each side, so that in some cases we are cutting across the upper part of the sebaceous gland and other times across the bottom part. That is one reason why we cannot place too much reliability upon the actual volume represented here, although there are indications of the region that the volume would correspond to.

DR. HAROLD G. TURLEY (Rohm & Haas Company, Philadelphia, Pennsylvania): I don't recollect, Dr. Mellon, that you said anything about the sweat glands. Do you consider them in this particular work?

DR. MELLON: We didn't notice the sweat glands on our photographs. I believe we would probably have to use a different staining technique to make them visible.

JOSEPH BASSETT (A. C. Lawrence Leather Company, Peabody, Massachusetts): Dr. Mellon, did you do anything as to the type of animal or age of the animal?

DR. MELLON: No; this was done only on the steerhide which we presume is roughly two years old. We have not done it on any other animals. Also, the area that we have studied is less than a postage stamp in size on the back of one animal.

REFERENCES

1. Kanagy, J. R., and Wallace, E. L. *JALCA*, **38**, 314 (1943).
2. Pomeroy, C. D., and Mitton, R. G. *J. Soc. Leather Trades Chemists*, **35**, 360 (1951).
3. Stromberg, R. B., and Swerdlow, M. *JALCA*, **50**, 336 (1955).
4. Stubbings, R. L., and Theis, E. R. *JALCA*, **45**, 138 (1950).
5. Mellon, E. F., Viola, S. J., Korn, A. H., and Naghski, J. *JALCA*, **54**, 182 (1959).

Received April 13, 1963.