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INFLUENCE OF ANIMAL FACTORS AND PROCESSING TREATMENTS ON GRAIN LAYER AND TOTAL THICKNESS OF CATTLEHIDES*

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ABSTRACT

Differences in physical structure between the grain (papillary) and corium (reticular) layers of cattlehides, and especially their final thickness ratio, have important effects on the physical properties of leather. Tanners need more data on the extent of variability of grain layer thickness in rawstock from different sources. The effects of cattle breed, sex, and age on 221 fresh hide biopsy samples from known sources and the effect of body location in seven identified hides were evaluated. While total thickness varied considerably with all factors, depth of grain layer increased very gradually with age and was essentially constant (1.5 to 2.0 mm) after one year. Breed and sex were also minor factors. Extensive data later found in the literature (summarized here) confirm and supplement our results and show that the grain is slightly deeper in colder climates and seasons.

Information was also obtained on the changes in depth of grain layer induced by upper leather processing. Measurements from 168 wet-blue sides and 148 crust sides from 13 different commercial suppliers indicate that grain depth decreases from about 1.7 mm in rawstock to about 1.0 mm at the blue stage, and then to about 0.7 mm in dry leather. Certain retannages and finishing procedures may further modify this value. Correlations between grain and total thickness were relatively weak in rawstock, but stronger and more useful in unsplit blue stock.

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INTRODUCTION

It is well known that animal hides and skins vary considerably in physical structure and chemical composition at different levels within the skin. Even after undergoing drastic chemical and mechanical processing in a tannery, the relatively pure dermal collagen matrix remaining is not homogeneous in physical structure but consists of two distinctly different layers in terms of fiber dimen-

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no correlation with sex. A comparison of six breeds raised in Britain *vs.* Australia, however, showed that habitat and season have significant effects, amounting to 0.1 to 0.4 mm deeper grain in the cooler climate and in winter.

As part of a worldwide survey, Jenkinson and Nay (13) studied samples from 1363 adult European cattle of all breeds and found that the average depth of follicles was 1.76 mm, and hair density ranged from 900 to 1,000 follicles/cm^2. Data for 16 common breed groups in this survey are shown in Appendix Table A. They extended the survey in 1973 (14) to Asian, African, and South American cattle. Average grain depths (mm) were as follows: for 471 Asian cattle, 1.29; for 281 African cattle, 1.35; for 186 South American cattle, 1.51. Data for the various breed types are shown in Appendix Table B. In general, the European breeds had the deepest grain layer, Asian and African breeds had the shallowest, and South American breeds were intermediate.

In a later study (15) of species of Bovidae other than cattle, it was reported that the water buffalo (*Bubalus bubalis*) hide, commonly used for leather in India, has a deep grain layer of about 2.36 mm but a low hair density of 237/cm^2. This difference from cattlehides, which have about 900–1,000 hairs/cm^2 (13), is useful in identifying the grain pattern of buffalo leather. The American buffalo (*Bison bison*) hide has an extremely deep grain layer of 4.31 mm, a total thickness of about 15 mm, and a high hair density of 1616/cm^2 (15). These characteristics should affect the properties of hides from an experimental cattle hybrid known as the "beefalo" (16).

No reference to grain thickness in wet-blue stock has been found. Bowes and Raistrick (17) reported a value of about 0.4 mm in finished side leather, whereas Haines (18) indicated a range of 0.6 to 0.7 mm in crust side leather produced from fresh and salted hides. Haines noted that the strength of a grain split depends approximately on the proportion of the original hide thickness retained. Haines and Barlow (19) stated that the depth of grain layer can vary with the cattle breed and is also influenced by tannery processing, a shallow grain being associated with minimum swelling action.

The present study was undertaken to provide quantitative data on the grain layer thickness and total thickness of cattlehides from known sources and cattlehide leather to aid in determining: (a) how these measurements in rawstock are influenced by animal factors such as breed, sex, and age, (b) to what extent grain thickness changes at the wet blue stage and then at the dry crust stage of processing for shoe upper leather, and (c) whether there is a significant correlation between grain and total thickness in unsplit stock.

EXPERIMENTAL

Rawstock Samples

A previous study of the vertical fiber defect in twin cattle (20) had provided hide biopsy samples (1 cm diameter) from the rump area of 30 Hereford (in-

cluding six ¾-Hereford) and 30 Holstein heifers at one year and again at two years of age. That study was extended to the reciprocal crossbred progeny of the cows (to be published), providing samples from 25 Hereford-Holstein crossbreds at six months of age and from 76 at 12 months. These collections amounted to 221 samples for analysis.

To evaluate the effect of body location, we obtained whole hides from six of the crossbred progeny when they were slaughtered at 18 months of age, and from one of the original Hereford cows at the age of 4½ years. These hides were received in the salted condition and were thoroughly soaked overnight and well washed before use. One half of each hide was then sampled at 12 locations by means of a ¾ in. circular die, and the plugs were processed and evaluated in the same manner as the fresh hide biopsy samples. For selection of sampling sites, the sides were marked in a rectangular pattern; within this pattern, three equally spaced rows and four equally spaced columns were marked, and the plugs were cut out of the center of each block and numbered in horizontal sequence starting at the tail. We have frequently used this pattern (21, Fig. 1) in detailed studies of physical properties.

Wet-Blue Samples

Butt panels from commercially processed, unsplit blue (immediately after chrome tanning) stock were available from two previous studies. The first was an interlaboratory study by the ALCA Rawstock Committee, reported by Tancous in 1974 (22). This provided 10 samples from each of 12 commercial suppliers who utilized a wide variety of beamhouse methods. The second source was a comparative study of leather made from uncured and pit-cured hides, reported by Feairheller *et al.* in 1975 (23). This provided 36 samples from unstored sides on which other data have been published (23) and 12 samples from sides stored for five months; all sides had been processed in the same tannery lot. These collections amounted to 168 samples for analysis.

Crust Leather Samples

All of the blue stock was further processed into grain-split upper leather. The 12 suppliers for the interlaboratory study (22) provided butt panels at the crust (just before surface finishing) stage from other sides in the same lots as represented by their blue samples; since two of them did not participate, there were 100 samples from this study. From the second source (23), adjacent panels were cut at the crust stage from the same 48 sides that supplied the blue samples. These collections amounted to 148 samples for analysis.

Histology

The rawstock biopsy samples had been freshly preserved in neutral formalin solution; frozen cross sections had beeen cut at 50 microns in the approximate plane of the hair follicles and the sections had been stained with hematoxylin-

eosin and mounted on slides for the previous study (20). Similar sections were prepared from the blue and crust samples but were stained with Oil Red 0 (20) for suitable contrast. The method of Nay and Hayman (24) as modified by Nay (25) was employed in the extensive studies summarized in the introduction. Their method utilized hand-cut cross sections at 400 to 500 microns to include a larger number of intact glands and follicles for measurement and to minimize their distortion; it was somewhat more refined than our method, which may explain the slight differences in results.

Measurements

The slides were examined by means of a stereomicroscope at about 20X magnification, and measurements were made with a metric rule graduated to increments of 0.1 mm. The depth of grain layer was defined as the average vertical distance from the top of the epidermis to the base of actively growing hair (Fig. 1a) as indicated diagrammatically by the broken line in Figure 1. The depth of deep hairs (Fig. 1b) was measured but not used as an index of the grain layer; resting "club" hairs (Fig. 1c) were ignored. Deep hairs were termed "giant follicles" by Hayman and Nay (8), who reported their incidence as four to six percent of all hairs in most cattlehides, but also disregarded them in measure-

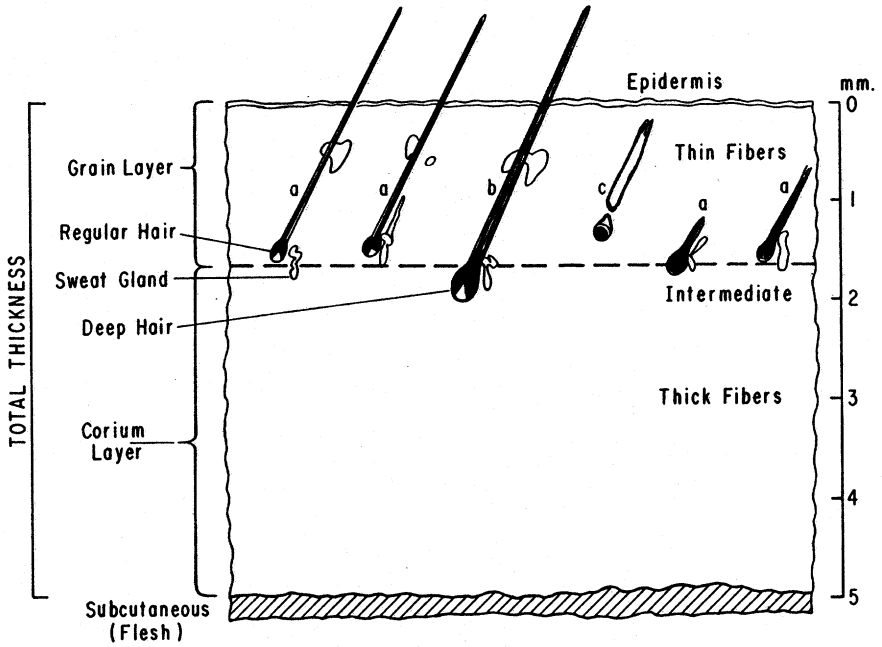

FIGURE 1.—Diagram representing cross section of cattlehide. Definition of grain and corium layers and total thickness indicated by brackets. Types of hair follicles: (a) actively growing; (b) deep or "giant" hair; (c) resting or "club" hair.

ments of follicle depth. Depth of sweat glands was measured to show its relationship to follicle depth. Total hide thickness was defined as the vertical distance to the junction of the corium and subcutaneous layers, as indicated by brackets in Figure 1.

RESULTS AND DISCUSSION

Rawstock Measurements

The measurements of total hide thickness and depth of grain layer from 221 biopsy samples are summarized in Table I according to the various breed and age groups. Values for grain ratio, or grain depth as percent of total thickness, varied only slightly from 26 to 32 percent. Average values for the three age

TABLE I

VARIATION IN FRESH HIDE THICKNESS WITH BREED AND AGE

Cattle Breed*	Age (mo)	Number	Average Depth Total (mm)	Average Depth Grain (mm)	Grain Ratio† (%)
Hereford	12	24	5.98	1.70	28
	24	24	6.24	1.71	27
Her. - Beef	12	6	6.40	1.68	26
	24	6	6.22	1.67	27
Her. - Hol.	6	12	5.35	1.67	31
	12	37	6.35	1.65	26
Hol. - Her.	6	13	4.86	1.56	32
	12	39	6.02	1.65	27
Holstein	12	30	5.14	1.54	30
	24	30	5.58	1.59	28
Averages:	6	25	5.11	1.62	32
	12	136	5.98	1.64	27
	24	60	6.01	1.66	28

*Hyphenated terms indicate crossbreds, with sire's breed on the left. Her. - Beef group, combined for convenience, includes: four cows (¾ Hereford + ¼ Shorthorn); two cows (¾ Hereford + ¼ Charolais).

†Grain depth as percent of total thickness.

groups indicate that total thickness increased the most between six and 12 months but not much thereafter. Among the breed groups surveyed, Herefords had thicker hides than Holsteins, and the crossbreds tended to have hides of intermediate thickness. Likewise, the grain layer tended to be deeper in Herefords and Hereford-sired crossbreds, but the differences were relatively small. Average grain depth increased very slightly with age: from 1.62 mm at six months to 1.64 at 12 months and to 1.66 at 24 months. The depth of deep hairs

(not shown) followed the same trends as the depth of regular hairs, averaging about 0.35 mm deeper than the latter. The depth of sweat glands (not shown) was usually slightly greater than the depth of regular hairs, but it tended to increase more with age: from 1.60 mm at six months to 1.72 at 12 months and to 1.81 at 24 months. Samples from one pair of identical twin Hereford cows (#236 and #237) were of special interest because their sweat glands were unusually deep. At two years of age, average total thickness was 6.3 mm, depth of sweat glands 3.8 mm, and depth of grain 1.7 mm. Samples from three crossbred progeny of one of these cows (other cow infertile) had normal measurements. This rare condition was not mentioned in Nay's publications.

Although most of the cattle sampled were females, the crossbred progeny included the usual distribution of sexes (heifers and steers). In Table II the data

TABLE II

VARIATION IN FRESH HIDE THICKNESS WITH SEX

		Total Depth (mm) by Age			Grain Depth (mm) by Age		
Cattle Breed*	Sex	6 mo	12 mo	24 mo	6 mo	12 mo	24 mo
Hereford	F	—	5.98	6.24	—	1.70	1.71
Her. - Beef	F	—	6.40	6.22	—	1.68	1.67
Her. - Hol.	F	5.20	5.95	—	1.65	1.63	—
	M	5.49	6.43	—	1.68	1.64	—
Holstein	F	—	5.14	5.58	—	1.54	1.59
Hol. - Her.	F	4.92	5.96	—	1.54	1.66	—
	M	4.79	5.96	—	1.58	1.65	—
Averages:	F	5.06	5.89	6.01	1.60	1.64	1.66
	M	5.14	6.20	—	1.63	1.65	—
Ranges:		4.3–6.0	4.5–7.3	4.9–7.0	1.4–1.8	1.2–1.9	1.4–2.0

*See Table I for explanations.

are rearranged according to sex, within the breed and age groups, to indicate any sex differences. Average values show only slight, inconsistent differences. Jenkinson and Nay (12) also found that, among adult cattle, the grain depth does not vary significantly with sex or age. They (13) reported an average value of 1.93 mm for the Hereford (Middlehorned) breed group and 1.67 mm for the Holstein (Friesian) group. We did not calculate the extent of variability among our observations, but the overall ranges are shown at the bottom of Table II. Standard deviations reported by Jenkinson and Nay (Appendix Tables A and B) usually ranged from 5 to 15 percent of the means.

Variation with Body Location

The seven experimental hides available from a previous study (to be pub-

lished) provided the opportunity to evaluate the variability of grain and total thickness over 12 evenly spaced body locations. Results are shown in Table III as average values for three Hereford-Holstein crossbreds, three Holstein-Hereford crossbreds, and one older Hereford cow. The crossbreds, which had been

TABLE III

VARIATION IN SALTED HIDE THICKNESS (mm) WITH BODY LOCATION

Loc.* Block	Her. - Hol.†		Hol. - Her.‡		Hereford**		Loc. Average	
	Total	Grain	Total	Grain	Total	Grain	Total	Grain
1	6.40	1.67	6.17	1.53	6.1	1.6	6.22	1.60
2	7.00	1.67	6.40	1.67	6.0	1.4	6.47	1.58
3	6.70	1.73	6.60	1.70	5.8	1.7	6.37	1.71
4	6.20	1.67	6.03	1.63	5.3	1.6	5.84	1.63
5	6.90	1.67	6.37	1.55	6.8	1.6	6.69	1.61
6	7.60	1.73	7.43	1.63	7.0	1.7	7.34	1.69
7	6.60	1.77	7.10	1.73	6.8	1.7	6.83	1.73
8	6.70	1.67	6.77	1.63	6.3	1.7	6.59	1.67
9	6.90	1.80	7.00	1.65	6.5	1.7	6.80	1.72
10	8.25	1.70	7.90	1.70	7.0	1.7	7.72	1.70
11	6.65	1.70	7.13	1.63	6.0	1.7	6.59	1.68
12	6.67	1.80	6.80	1.60	6.0	—	6.49	1.70
Average	6.88	1.72	6.81	1.63	6.30	1.65	6.66	1.67
Range	6.2–8.3	1.7–1.8	6.0–7.9	1.5–1.7	5.3–7.0	1.4–1.7		

*Body locations as described in Experimental section and (ref. 21, Fig. 1).
†Hereford - Holstein Crossbreds, 18 mo old; average for 2 males and 1 female.
‡Holstein - Hereford crossbreds, 18 mo old; average for 2 males and 1 female.
**Hereford cow 54 mo old.

fed for beef, had thicker hides in almost every location than the older cow, and this measurement varied considerably with location. However, the depth of grain varied only within the range of 1.4 to 1.8 mm.

Wet-Blue Measurements

Because the grain layer contains a number of cellular structures with a relatively high moisture content, it can be expected that this layer will collapse in thickness following the decomposing and dehydrating actions of chemical treatments in the tannery. The corium layer should change very little. Variations in the time and equipment used for beamhouse processing might also influence the depth of the grain. Since the commercial sources had supplied general information about their processes, these variables are incorporated into Table IV, along with the average measurements of total thickness, grain thickness, and grain ratio.

TABLE IV

VARIATION IN COMMERCIALLY PROCESSED SIDE THICKNESS WITH TYPE OF PROCESS

Source	Equipment*	Blue, Depth			Crust, Depth		
		Total (mm)	Grain (mm)	Grain Ratio (%	Total (mm)	Grain (mm)	Grain Ratio (%
			24-hour Processes				
1	M	4.6	0.84	18	2.6	0.72	28
2†	M	5.9	0.95	17	2.6	0.75	29
3†	D	5.1	0.90	18	—	—	—
4	D	7.6	1.31	17	—	—	—
Average		(40) 5.7	0.97	18	(20) 2.6	0,74	29
			35-hour Processes				
5†	M, D	6.4	0.95	15	2.9	0.73	26
6†	V, D	5.4	0.81	15	2.2	0.61	28
7	M	7.2	1.00	14	2.6	0.69	27
8†	D	5.8	0.94	16	2.8	0.78	29
Average		(40) 6.1	0.91	15	(40) 2.6	0.70	28
			48-hour Processes				
9†	D	7.2	1.02	15	3.1	0.91	30
10†	M	6.8	0.97	15	2.9	0.87	30
11†	V, D	5.3	0.89	17	2.1	0.68	32
12†	V, D	6.4	0.97	16	3.0	0.68	23
13‡	D	6.6	0.99	15	2.9	0.71	25
Average		(88) 6.5	0.98	16	(88) 2.8	0.75	27

*Equipment used in beamhouse: M — mixer; D — drum; V — vat.
†Five samples from each of two lots; others supplied ten from single lots.
‡24 pairs of matched sides, uncured compared with cured.

The values from samples of wrung, unsplit, wet-blue stock are shown in Table IV (left side). Total thickness, by lot averages, ranged‡ from 4.6 to 7.6 mm (sample range 3.5 to 9.5), grain thickness ranged from 0.79 to 1.31 mm (sample range 0.65 to 1.55), and grain ratio ranged from 14 to 20 percent. Average grain depth for all 168 sides was 0.96 mm, and there was no apparent trend for this to change with time of processing. The average grain-to-total ratio was 16 percent; this ratio tended to be slightly higher in the shortest processes. With respect to equipment used, the five suppliers using just drums produced the deepest average grain depth (1.03 mm), compared with the four using mixers (0.94) and the four using combinations of mixers or vats with drums (0.91).

‡Ranges indicated are based on values for individual lots, not all of which are shown in Table IV.

The apparent difference was due to the unusually high value (1.31) obtained for source #4 which also produced the thickest stock. The grain ratio was identical (16 percent) for all three groups.

Crust Measurements

As expected, processing the wet-blue stock to dry crust leather further reduced the depth of the grain. Measurements on crust samples corresponding to the blue stock are shown on the right side of Table IV. Total thickness, by lot averages, ranged from 1.9 to 3.2 mm (4½ to 8 oz), grain thickness from 0.55 to 0.95 mm, and grain ratio from 23 to 33 percent. The average grain depth for all 148 sides was 0.73 mm and, again, there was no apparent trend with time of processing. Unfortunately, source #4 did not provide crust stock for comparison with the deep grain found in its blue stock. The average grain ratio was 28 percent which, in this relatively heavy (average 6½ oz) leather, happened to match the value obtained for mature rawstock (Table I). Although samples from two sources were missing, those from the three others using drums again had the deepest grain (0.80 mm), compared with mixers (0.76) and combinations (0.68); grain ratios were closely similar.

The change, or shrinkage, in depth of grain layer from the wet-blue stage to the dry crust did not seem to vary with time of processing; the average change for each of the three groups was about 23 percent. However, values for individual sources ranged from about 10 to 31 percent. The two sources with the least change were of special interest: #9 (11 percent) and #10 (10 percent). Crust samples from these two sources had the deepest average grain depth, about 0.9 mm, and were known to have received a vegetable retannage. It is reasonable to expect that such filling effects would retain a deeper grain, but we have no explanation for any other differences found.

Succession of Changes

The progressive changes that occurred in the relative depth of the grain layer during leather processing are summarized diagrammatically in Figure 2. Average values derived from this study are drawn to scale in representative cross sections of raw, blue, and crust stock. The millimeter (mm) scale is shown on the left and corresponding ounces (oz) on the right. The width of the heavy lines separating the grain and corium layers indicates the approximate range of variability in the measurements. The samples of raw and blue stock came from entirely separate sources. Therefore, the difference in total thickness shown in Figure 2 occurred purely by chance and does not imply that total thickness increases at the blue stage. The focus here is on changes in the grain layer. The broken line across the corium of crust stock is included to illustrate that the grain ratio would have changed from 28 percent to 46 percent if this leather had been split to a thickness of 4 oz instead of 6½ oz. Serious impairment of strength may occur when the ratio exceeds 40 percent (26).

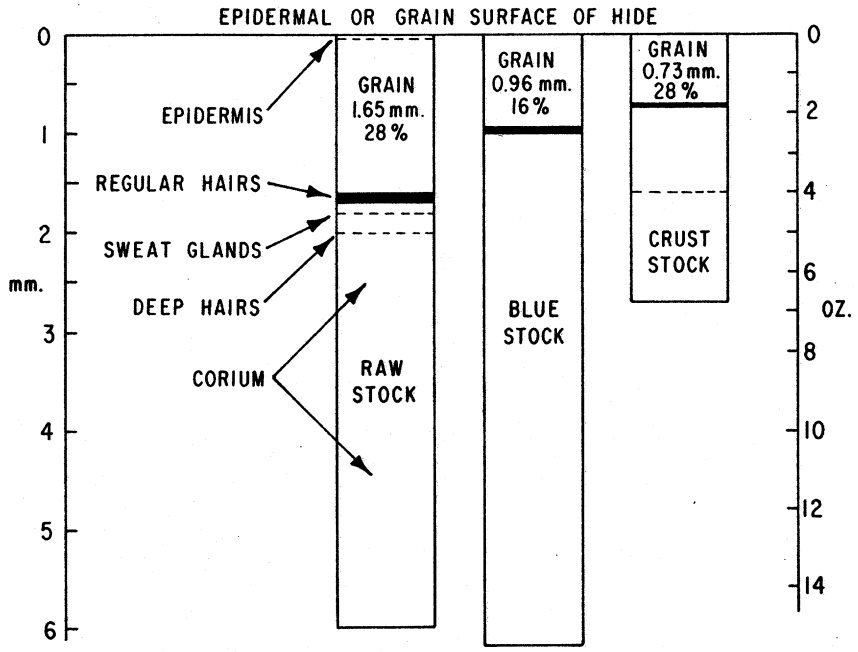

FIGURE 2.—Scale diagram showing average measurements obtained on three types of stock. Percentage values refer to ratio of grain to total thickness. See text for further details.

Correlation of Grain and Total Thickness

Although grain depth and total thickness were fairly constant in the raw hides, these dimensions varied over wide ranges in the blue stock. To clarify the degrees of correlation in the two kinds of stock, the data were subjected to standard linear regression analysis. Data from all of the raw samples were analyzed first, and then the separate data from the 12 month hides were analyzed for comparison, since these formed the largest age group. Data from the blue stock were analyzed as a single group since animal factors were unknown and process groups were too small.

Results of these analyses are shown in Table V. Significant correlations were found in each case, but, since the correlation coefficients for the hide biopsy samples were below 0.50, the practical importance of the relationship in rawstock is questionable. On the other hand, the coefficient of 0.63 for the blue stock indicates that this correlation should have practical utility. There is also a 95 percent statistical confidence that the lower limit of this coefficient will remain above 0.50 in repeated studies like the present one. Grain thickness (Y) can be computed from the equation for the regression line by substituting values for total thickness (X). These results appear to support the trade practice of selecting heavier sides in the blue for splitting into heavier grains and lighter sides for lighter grains.

TABLE V

REGRESSION OF GRAIN THICKNESS ON TOTAL THICKNESS

Regression Value	Fresh Hide Biopsy Samples		Blue Stock
	Ages 6 - 24 mo	Age 12 mo only	
No. of samples	220	136	164
Equation of line*	Y = 1.14 + 0.09(X)	Y = 1.13 + 0.09(X)	Y = 0.49 + 0.08(X)
Correlation coefficient	R = 0.455	R = 0.450	R = 0.632
Confidence limits (95%)	0.34 — 0.55	0.31 — 0.58	0.53 — 0.72

*Y — grain thickness; X — total thickness.

CONCLUSIONS

1. Hereford hides tend to be thicker and have a slightly deeper grain layer than comparable Holstein hides; crossbreds tend to have hides of intermediate thickness. Total thickness varies slightly with age and sex but considerably with body location. Depth of grain is essentially unaffected by these factors.

2. Grain depth decreases from about 1.7 mm in rawstock to about 1.0 mm at the wet-blue stage and finally to about 0.7 mm in the crust, with no apparent trend related to time for beamhouse processing. Filling retannages tend to increase the grain depth slightly.

3. There is a slight positive correlation between grain depth and total thickness in rawstock, but this relationship is stronger in blue stock and should have predictive value in blue sorting.

4. Based on other studies, Zebu breeds and crosses have a shallower grain than European types, but within the two species there is minimal variation. Cold climates and seasons have a significant deepening effect on the grain.

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APPENDIX TABLE A

SURVEY OF ADULT EUROPEAN CATTLE*
DEPTH OF GRAIN (mm ± STD. DEV.)

Breed Group	Grain Depth	Breed Group	Grain Depth
Scottish Highland	2.23 ± 0.24	Simmental	1.92 ± 0.29
Galloway, Angus	1.86 ± 0.26	Friesian	1.67 ± 0.29
Shorthorn	1.87 ± 0.20	Brown Swiss	1.70 ± 0.32
Hereford, Sussex	1.93 ± 0.24	Charolais	1.73 ± 0.17
Ayrshire	1.73 ± 0.29	Spanish	1.69 ± 0.29
Jersey, Guernsey	1.43 ± 0.16	Italian	1.64 ± 0.37
German Yellow	1.90 ± 0.33	Grey Steppe	1.83 ± 0.34
Normandy, Maine-Anjou	1.69 ± 0.19	Kazakh	1.45 ± 0.21

*Data excerpted from Jenkinson and Nay (ref. 13). Names of breed groups are sometimes altered and were selected as examples from the 32 groups listed. Further details (published and unpublished) are available from the Hides and Leather Laboratory, Eastern Regional Research Center.

APPENDIX TABLE B

SURVEY OF ASIAN, AFRICAN, AND SOUTH AMERICAN CATTLE*
DEPTH OF GRAIN (mm ± STD. DEV.)

Continent	Breed Type (No.)†	Range of Grain Depth
Asia	Humped Zebu (8)	1.15 ± 0.12 — 1.43 ± 0.24
	Humpless (3)	1.13 ± 0.17 — 1.54 ± 0.19
	Zeboid (4)	1.23 ± 0.17 — 1.35 ± 0.19
Africa	European (1)	1.59 ± 0.21
	Sanga (1)	1.43 ± 0.17
	Zebu (3)	1.26 ± 0.13 — 1.29 ± 0.05
	Egyptian (1)	1.43 ± 0.08
	Humpless (1)	1.26 ± 0.15
S. America	Zebu (1)	1.53 ± 0.11
	Zeboid (1)	1.43 ± 0.12
	Early Imports (1)	1.51 ± 0.19
	European (1)	1.48 ± 0.13

*Data excerpted from Jenkinson and Nay (ref. 14). Further details (published and unpublished) are available from the Hides and Leather Laboratory, Eastern Regional Research Center.

†Number of breed groups involved.

DISCUSSION

MR. EDWIN J. KAINE (John J. Riley Company): Thank you, Jerry, for a fine practical paper. A question did come up when I read this paper, and since it may not come from the floor, I will ask it. Do thicker hides tend to have a thicker grain layer in rawstock, or in blue stock so that we should be aware of it in sorting?

DR. HARLAN: We looked for correlations that would be useful to the tanner in the sorting process for selecting hides for different purposes. We looked at a number of correlations and evaluated them statistically with the aid of our now well publicized computer capabilities. We found that there were statistically significant correlations, but we felt that despite the fact that they were statistically significant, there was still considerable scatter. I do have a slide showing the correlation that we obtained between the blue stock thickness and the thickness of the grain layer in the blue stock. The correlation coefficient was 0.63 and the statistics told us that we did have a valid correlation. This graph gives a relationship that one could use to predict the grain layer thickness approximately by measuring the thickness of the blue stock. If you were sorting stock to get either thick or thin grain layer in the final leather you could use blue stock thickness as a criteria of selection with some reasonable reliability. Whether it is practical to use this type of correlation in tanneries is a question that we cannot answer. We are continuing to look for a useful relationship to predict grain thickness in crust and finished leather.

MR. KAINE: Do we have any questions from the floor?

MR. DEXTER J. RISEDORPH (E. Cummings Leather Co., Inc.): It is interesting to note that the average grain layer thickness was about 0.7 mm, which is about 1¾ ounces, which in the crust weight would be very common today for cowhide garment leathers. It points out the difficulty in making and lubricating a leather, when in fact you are working with a skiver as opposed to the other types of leathers where you have some corium fiber. I have a question: How do you explain that the ratio of the grain layer to the total thickness in the fleshed hide was 28 percent and dropped to 16 percent in the blue and went back to 28 percent in the crust?

DR. HARLAN: The percentage figure that we reported on the crust should not be compared to those of the fleshed hide or blue stock because the crust leathers had been split. Thus the percentage of the grain layer in the crust is dependent upon what the weight is in the split. Most of these samples were split to about 6 ounces. The current interest in very light weight leathers made us think this type of investigation was timely, because, as you pointed out, we are getting down in these light leathers to practically all grain and very little corium. If we had found large differences in the grain thickness due, for example, to one breed of catte, it might have been very useful. We found that the Holsteins had the thinnest total weight. If breed X had a significantly thinner grain layer, then presumably one might want to select breed X hides for making very light weight leathers and still have sufficient corium left to give the desired strength.

MR. CLINTON E. RETZSCH (Diamond Shamrock): Are you contemplating continuing this study in order to see what effect the environmental conditions have upon this ratio? When we compare hides, like Colorado's or Texas', where weather conditions are very severe, with hides from Florida, where weather conditions are very mild, we note there is a difference in the appearance and heft of the stock. What is the percentage ratio of the grain under such varying conditions? This might be of real interest in making light weight leathers.

DR. HARLAN: Yes, we do plan to do this. We are making arrangements for samples with several stations that ARS has contact with which do animal feeding and animal breeding experiments. This type of work is very slow because you have to factor into these programs and wait 6, 12, or 24 months to get the samples. There are many questions to be answered but to date we have only had a chance to look at two breeds, Hereford and Holstein, and some crosses. The cattle that are grown on the West Coast that have Brahman blood in them are an interesting subject and we hope to get samples from there. When I was out there this spring, they claimed that in California they had the best hides in the country because of the breed of cattle that they had. We are continuing these studies as we can get samples from cooperators in the field.