THE VERTICAL FIBER HIDE DEFECT: BIOPSY STUDY OF TWIN CATTLE FURNISHES FURTHER PROOF OF GENETIC ORIGIN, DISPROOF OF FEEDING INFLUENCE*

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ABSTRACT

Hide biopsy samples were obtained from the rump area of 58 living twin heifers, of two major breeds and at two ages, that were randomly fed high or low energy feeds. Previous studies had delineated two degrees of vertical fiber defect in hides leading to corresponding degrees of weakness in leather. Histological evaluation of the 28 Herefords (ten pairs identical, four fraternal) revealed five cases of extreme (vertical) defect and eight moderate (intermediate) ones. All 30 Holsteins were normal, confirming the apparent absence of the defect in this breed. All identical pairs had perfectly matching fiber structure but not all fraternals did, which constitutes strong evidence for genetic control. Furthermore, since more of the defective animals ate the low level feed and two defective, identical pairs were split-fed, the results contradict the hypothesis that intensive feeding is involved. It now appears that selective breeding could eventually eliminate the defect. Hide corium fat and hide thickness were also evaluated with respect to feed, breed, and age groups.

INTRODUCTION

The continuous prevalence of the hide defect known as vertical fiber ("pulpy butt") in Hereford hides has stirred anew the interest in identifying its basic cause. A previous publication from this laboratory (1), which briefly reviewed the research on this problem since its original description by Amos in 1958 (2), presented evidence based on hides obtained from a sire performance test suggesting that the defect is genetic in origin. However, Thorstensen (3, p. 23) speculates

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that growth alterations induced by feedlot use of high-energy diets may be responsible for development of vertical fiber, which also seems logical. Additional evidence on these two points is obviously needed.

Defective hides yield leather that is extremely weak in the butt (rump) area, owing to an inherent abnormality in the fiber orientation of the corium (reticular layer), wherein the collagen fiber bundles are loosely arranged perpendicular to the grain (papillary layer) rather than being well interwoven with a moderate angle of weave. A less extreme variation of the defect consists of a type of structure intermediate between these two, which is responsible for many cases of moderately weak leather. At present the defect cannot be accurately detected except by microscopic examination or other destructive physical tests. A common symptom of the condition is severe grain crack during staking in the tannery and especially during the lasting operation in the manufacture of shoe uppers. It is costly to the leather and shoe industries as well as to the consumer.

In 1933, Frey *et al.* (4) investigated the fat contents of hides from two different nutritional studies on Hereford cattle, to find an explanation for excessive "kidney grease" in heavy sole leather. Results from one group were especially interesting because they indicated a strong correlation between internal hide fat and animal weight gain. It was also shown that the fat that caused the grease stains in leather was inherently present in the corium in proportion to the feed energy level. Photomicrographs illustrated that the amount of histologically evident fat was in agreement with analytical values. The vertical fiber defect was probably prevalent at this time but, since the heavy Hereford hides went into sole leather without splitting, their frequent structural weakness was not evident.

This paper presents results from the histological evaluation of full-thickness hide biopsy plugs taken from the rump area of 28 Hereford and 30 Holstein twin heifers. The cattle are involved in a five-year nutritional study employing diets with high and low energy levels which was designed to evaluate the interaction of genetic and environmental effects on weight gain, feed efficiency, body conformation, reproductive performance, and other important traits of the two breeds and their crossbred offspring. The study is essentially an extension of a previous experiment involving the use of identical and fraternal twins devised to study the same performance traits (5–7).

Such a study is ideally suited to our needs because it provides evidence on both of the prevailing causative theories at the same time. Since identical twins have identical types of genes, all such pairs must be matched with respect to the defect if it is genetically controlled. On the other hand, if high-energy feeds induce the defect, there should be a strong correlation between these two factors, regardless of twin relationships. The results obtained in this study support the genetic origin of the defect and negate the effect of intensive feeding. Additional data of practical interest show the variation in corium fat and hide thickness among the breed, feed, and age groups.

EXPERIMENTAL

Test Design

The animal study is being conducted at the University of Wisconsin un direction of Professor E. R. Hauser and with the co-operation of the Agric Research Service (ARS), U.S.D.A. The cattle were classified as ident fraternal twins by the use of blood typing after close comparison of certai characteristics (5). The herd consists of 28 Hereford and 30 Holstein heifers, including ten sets of identical twins of each breed. All were pla randomly assigned high- or low-energy diets at 210 days of age. Table I the composition of the two types of diets fed to the twin cattle at variou

TABLE I

VARIATIONS IN COMPOSITION OF EXPERIMENTAL DIETS AND MAINTENANCE OF TWO DIFFERENT ENERGY LEVELS

Feed Ingredients*	210–365 Days		366–449 Days		450 Days U	
	High	Low	High	Low	High	L
Rolled Oats	600	—	400	—	400	—
Cracked Corn	400	—	500	—	—	—
Linseed Meal	200	100	100	150	100	—
Wheat Bran	200	100	—	—	—	—
Chopped Alfalfa Hay	600	1800	1000	—	1500	—
Chopped Hay	—	—	—	1850	—	20
Trace Minerals	10	10	10	—	—	—
Bone Meal	10	10	10	—	—	—
Antibiotic	5	5	—	—	—	—
Vit. A & D Conc.	2.8	2.8	5	5	—	—

*Quantities in pounds to make approximately one ton of feed. Data from perso communications from E. R. Hauser.

Note that there is no grain in the low diet; this quantity is substituted alfalfa or other hay. Although the two types of feeding formulas were modifie nutrients at 365 days and again at 449 days of age, a significant differenc energy content was maintained. Each animal was tied to an individual feeder approximately four hours each day and allowed to eat its fill of assigned rat The high-level diet, especially during the first 15 months, corresponds roug to the intensive feeding done in feedlots.

Table II describes the assignment by animal groups of the two types of f Twin sets for each assignment were randomly chosen. The next to last colu is of particular interest. These twin sets were split-fed; that is, one member the high-level diet while the other ate the low diet. Any difference found h between identical twins would be environmental and not genetic. Figure 1 sh

TABLE II

ASSIGNMENT OF FEED LEVELS TO TWIN HEIFER SETS

Breed	Twin Type	Both High	Both Low	One High One Low	Total Pairs
Hereford	Identical	4	4	2	10
	Fraternal	1	1	2	4
Holstein	Identical	3	3	4	10
	Fraternal	2	2	1	5

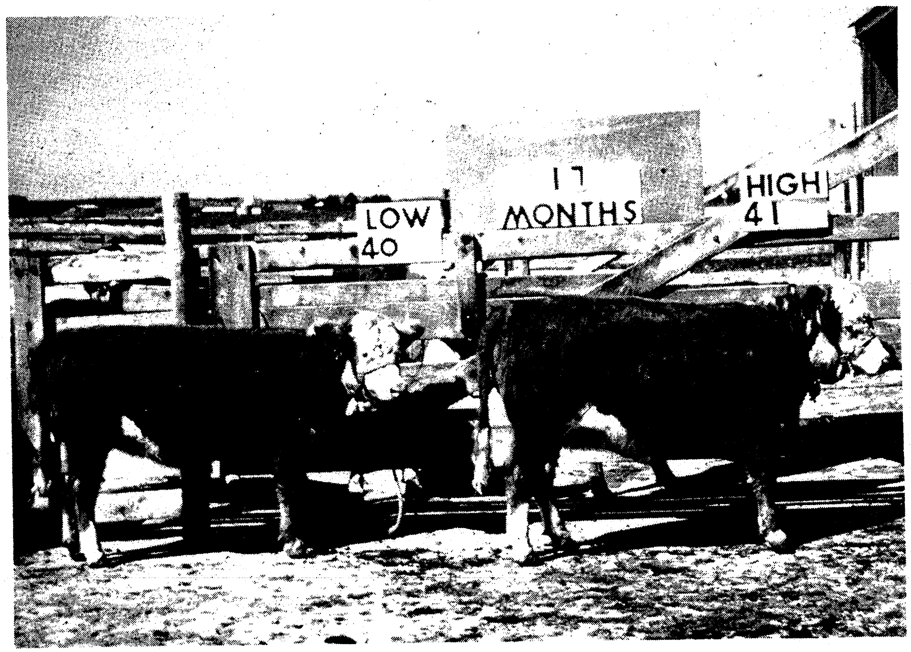

FIGURE 1.—Identical Hereford twin heifers #240 and #241 at 17 months of age. These were split-fed, one on the low-level diet and the other on the high, yet both exhibited the vertical fiber defect. Note the difference in size.

one of the pairs of identical twin Herefords at approximately 17 months of age (typical marketing age) that was split-fed. The difference in growth can readily be seen.

Biopsy Procedure

A biopsy specimen, hereafter designated as a sample, consisting of a small plug of full-thickness hide ⅜ inch in diameter, was taken by means of an automatic "biopsy gun" (8) from the rump area of each animal, approximately ten inches in from the tail root and ten inches down from the backbone line. Single samples were obtained at one year of age (within two weeks) and two additional samples at two years (within two months). The two-year samples were taken to confirm the one-year findings and to examine the effects of maturity. It was felt that the use of three samples would improve the accuracy of the final conclusions, in view of the small size of the samples. The samples were put into containers of ten percent neutral formalin solution‡ and forwarded to our laboratory, where they were cut in half in the plane of the hair follicles.

Histology

One half of each sample was cut into cross sections on the freezing microtome at 50 microns. The sections were stained by the Lillie-Mayer variant of hematoxylin and eosin (9, p. 174) for the study of general structure and with Oil Red O (9, p. 457) for the observation of fat content. The other half of the sample was either embedded in paraffin for sectioning or was stored in 70 percent alcohol.

The sections stained with hematoxylin and eosin were examined especially for the architectural structure of the fiber bundles, which was classified as normal, intermediate, or vertical. A normal designation means that the fiber structure is tight and well interwoven at the normal angle of weave. Intermediate is a variation of the defect, such that it cannot be called normal yet is not extreme enough to be called vertical. There is a variable looseness of weave and the fiber bundles, although not consistently perpendicular to the grain, are often rather upright in localized areas. Vertical is the typically extreme manifestation of the defect; the fiber bundles are loosely arranged and are perpendicular to the grain, although not necessarily throughout the entire thickness of the corium (reticular layer).

In the sections stained with Oil Red O the fat content of the corium was graded subjectively from zero to five, zero meaning none and five indicating the maximum amount ever found. The approximate thickness of each section, from epidermal surface to the junction of subcutaneous tissue, or flesh, was measured with a millimeter rule under low magnification.

RESULTS

Fiber Structure

Each of the samples was carefully evaluated in order to classify its fiber structure into one of the three types described in the experimental section. To illustrate this difference in orientation, the structure of a sample with vertical fiber is shown in Figure 2a. In contrast to this, Figure 2c shows a cross section of a sample with normal fiber orientation. Between the two extremes is the intermediate structure shown in Figure 2b.

‡A 1:10 dilution of commercial formaldehyde solution to which an excess of $CaCO_3$ is added, giving a formaldehyde concentration of 3.7 to 4.0 percent.

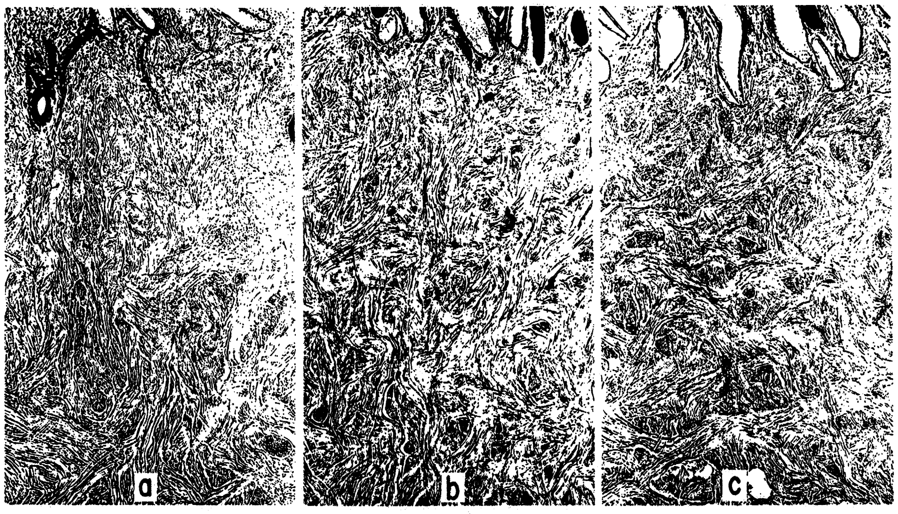

FIGURE 2.—Cross sections of corium portion (reticular layer) of three Hereford biopsy samples at one year of age to illustrate the three types of fiber structure: *a* — vertical; *b* — intermediate; *c* — normal. H. & E. stain, approximately 30 X.

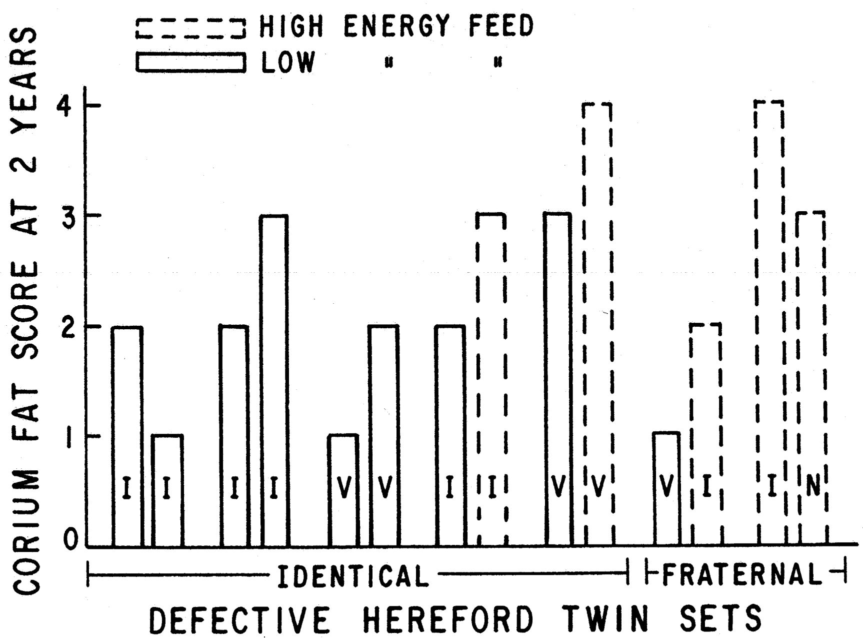

FIGURE 3.—Fiber structure and fat scores, in relation to feed energy level, in the seven sets of Hereford twins with abnormal structure at two years of age. Pairs of bars represent twin sets. Labels in the bars represent: V — vertical; I — intermediate; N — normal. Note that identical twins have identical fiber structure regardless of feed level.

Microscopic evaluation of the samples revealed the presence of abnorma structure in seven of the 14 Hereford twin sets but in none of the Ho Figure 3 illustrates the defect data in these seven sets according to types o involved and the corresponding feed energy level assigned to each anima convenience in plotting, the height of each bar represents the corium fat s two years of age, and each pair of bars represents a twin set of the type ind Vertical, intermediate, or normal structure is shown by labels in the bars a or N, respectively. Among the identical twins, three sets had intermedia two sets had vertical fiber structure. Among the fraternals, one set consi a vertical and an intermediate, while the other included an intermediate normal. The remaining seven sets of Hereford twins not shown (five id and two fraternal) had normal fiber structure.

In all instances in this study it is to be emphasized that the fiber structu identical within every set of identical twin heifers examined. The str associated with the fraternal twins, however, did not always match beca ordinary sisters, such twins consisted of a pair of genetically unique indiv These observations strongly support the theory that the architectural st of the hide is genetically controlled.

As to the influence of intensive feeding, Table III summarizes the in

TABLE III

INCIDENCE OF DEFECTIVE FIBER STRUCTURE IN HEREFORDS AS RELATED TO FEED ENERGY LEVEL

Feed	Twin Type	Number Normal	Number Defective		
			Inter.	Vert.	To
High	Identical	8	1	1	2
	Fraternal	2	2	0	2
	Total	10	3	1	4
Low	Identical	2	5	3	8
	Fraternal	3	0	1	1
	Total	5	5	4	9

of defective fiber structure in the 28 Herefords as it is related to feed level. It is apparent that nine of the 13 animals with defective structure w the low-level diet, while only four were on the high level. Therefore, ther direct correlation between the high dietary level and the defect. Furtherm can be seen from Figure 3 that there were two split-fed pairs of identical that had matched abnormal structure, one pair rated vertical and one mediate. This is even more convincing evidence against the implication of sive feeding.

Fat in Corium

The upper half of Table IV shows the average scores for fat storage in the corium of the samples at one and two years of age as related to feed and breed. The animals on the high-energy diet grew faster than those on the low diet but their hide fat scores increased only slightly from one to two years, the increases ranging from 3.3 to 7.4 percent. The animals on the low-energy diet showed lower scores for the first year, but their scores increased dramatically by 90 to

TABLE IV

CORIUM FAT AND TOTAL HIDE THICKNESS
BY BREED AND FEED GROUPS AT TWO AGES

Breed	Feed	Age in Years		Changes with Age	
		One	Two	Increase	% Increase
		Average Fat Score*			
Hereford	High	3.0	3.1	0.1	3.3
	Low	1.0	1.9	0.9	90.0
Holstein	High	2.7	2.9	0.2	7.4
	Low	0.5	1.2	0.7	140.0
		Average Thickness, mm.†			
Hereford	High	6.06	6.22	0.16	2.6
	Low	6.00	6.29	0.29	4.8
Holstein	High	5.23	5.57	0.34	6.5
	Low	5.00	5.53	0.53	10.6

*Subjective estimate from stained cross sections, ranging from 0 (none) to five (maximum).

†From epidermal surface to subcutaneous layer (flesh), measured with millimeter rule at 15 X magnification.

140 percent by the end of the second year. At corresponding ages and feed levels, the finding that the Holstein hides contained slightly less fat generally than the Herefords indicated a definite trend with breed. Fat storage also varied considerably between individual animals even within twin sets and feed sets, as can be seen in Figure 3. Figure 4 shows a pair of hide cross sections stained with Oil Red O from a one-year-old animal on high-energy feed *vs.* another on low. Fat deposits appear here as black spots of various sizes in the corium. A fat score of "4" was assigned to the section in Figure 4a which is still less than the maximum found in other tests, while Figure 4b was scored as "1." It can easily be understood how extremely fatty hides, such as that shown in Figure 4a, would produce greasy leather.

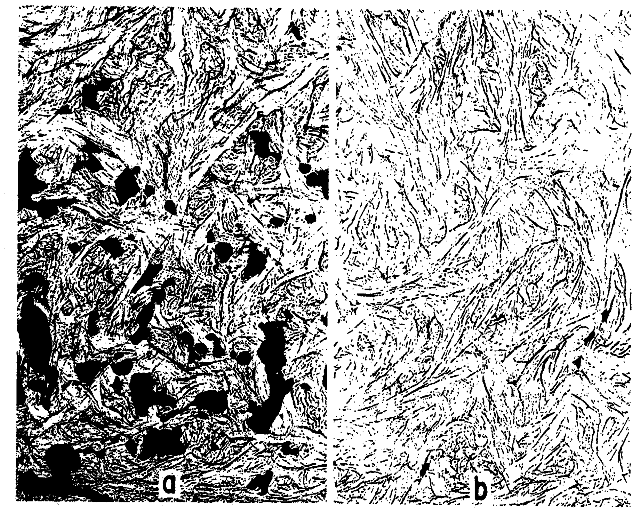

FIGURE 4.—Cross sections of corium portion (reticular layer) of two Herefor samples at one year of age to illustrate fat content in relation to fee level: *a* — high level feed, fat score = 4; *b* — low level, score = Red O stain, green filter, approximately 30 X.

Hide Thickness

The lower half of Table IV shows the average values for total hide th in the samples at one and two years of age in the different groups. The measured from the top, epidermal surface down to the subcutaneous layer. In general, they show little or no trend in relation to feed level, increases with age are relatively small. However, the breed difference i consistent here. At one year the Herefords are about one mm. thicker th Holsteins, and at two years they are still about 0.7 mm. thicker.

While hide thickness is not involved in the fiber defect, it is of inte gather such data from known material to add to our general informatic example, the thickness of the papillary or grain layer, disregarding the guard hairs, was found to be remarkably constant in all of the samples, reg of the differences in breed, age, and feed level. This grain layer thickness from about 1.5 to 1.9 mm.

Animal Growth

It is of interest to examine briefly the variations in nutritional response experimental heifers that resulted from consumption of the two types o Some of these measurements are shown in Table V, for the period betwe and 365 days of age. As expected, the high-level diet induced more rapid in in weight gain and body dimensions than the low diet. Figure 1 illustrat difference at 17 months of age. Also the feed was utilized more efficiently

TABLE V

NUTRITIONAL RESPONSE OF CATTLE AT ONE YEAR TO DIETS OF TWO DIFFERENT ENERGY LEVELS

Measurement, average*	Herefords		Holsteins	
	High	Low	High	Low
Body Weight, lbs.	632	501	741	607
Daily Gain, lbs.	1.8	0.8	2.1	1.3
Increases in				
Chest Circumference, cm.	31.8	13.5	32.4	19.7
Chest Depth, cm.	10.4	5.3	11.0	7.3
Wither Height, cm.	12.7	10.2	15.3	12.5
Lbs. Feed Consumed Daily	14.2	11.4	16.8	14.2
Lbs. Feed/lb. Gain	8.1	15.1	8.0	11.0
Lbs. TDN†/lb. Gain	5.4	8.1	5.3	5.9

*Average for breed and feed group from 210 to 365 days of age. Data from personal communications from E. R. Hauser.

†Total digestible nutrients. See Table I for composition of feeds.

high level and it was more palatable, resulting in a greater intake. Comparing the two breeds, it is apparent that the Holsteins ate more and grew faster on both diets and utilized the feed more efficiently at the low level. This is surprising in connection with the observations above that the Hereford hides contained more fat and had a greater total thickness than the Holsteins.

DISCUSSION

The genetic evidence from this study, based on perfect matching of abnormal fiber structure within ten sets of identical twins and some mismatching among four fraternals, is conclusive in nature but somewhat limited in number. Previous to this study, two other hide samples were obtained from a set of identical twin Hereford heifers in a U.S.D.A. experimental herd at Beltsville, Md. These two had normal fiber structure, so we now have data on 11 sets of identical twins. Statistical analysis of the data from two different approaches confirmed the genetic theory with probabilities of 95 percent and 98.2 percent.

Complementing this evidence is that from the previous study (1) of 130 hides from the progeny of 15 registered Hereford bulls. From the incidence of the defect in that group, an estimate of 30 percent heritability was calculated, suggesting that selective breeding would strongly influence the trait**. Again the number of progeny involved was too small for the desired level of significance. Taken together, the two lines of evidence are considered sufficient to establish the genetic origin of the defect for all practical purposes, although the exact mode of transmission has not been resolved.

**Personal communication from Dr. L. V. Cundiff, ARS, Lincoln, Nebraska.

While it appears that the defect is linked to the Hereford breed, there is very little accurate information on the incidence of the defect in other breeds. Tancous, Schmitt, and Windus (10) reported two comparative studies of commercial hides. In the first series they found ten weak (intermediate) sides but none pulpy (vertical) among 816 combined Angus and Holstein sides tested. In the second series they rated all 670 Angus sides as normal. Our data show 30 known Holsteins as normal. The problem with using commercial hides is the difficulty in judging the breed type from the hair color pattern of a trimmed hide. Hereford and Holstein patterns are probably distinctive enough to allow fairly accurate judgments, but black-haired hides can be very misleading because black hair is usually dominant in crossbreeding. Therefore the weak hides may have come from Angus or Holstein crosses with Hereford. At least there is now some additional support for the opinion that Holsteins, the major dairy breed, are free of the defect.

The biopsy approach has many unique advantages. Not only does it permit a quick decision from a small sample, but application to the live animal allows resampling to follow the effects of age or environmental treatments. As a leather research tool it overcomes the difficulty of procuring suitable hides for study at the time of slaughter. From the standpoint of leather damage, it does no more harm than a large grub hole. It might benefit animal science and meat research if hide fat can be correlated with body or muscle fat, since the hide is much more accessible for analysis. A point of some anatomical interest was also observed in the present study; it was found that one of the identical Hereford twin sets had very deep sweat glands extending through the entire thickness of the corium. Studies are being continued on selected crossbred offspring of these twins, and more work is needed to confirm the validity of the biopsy diagnoses.

For the future, the biopsy approach would provide the means for evaluating sire bulls for the presence of defective fiber structure, so that selective breeding could be applied on a commercial scale to eliminate the defect. For the present, however, there is not enough incentive for such a proposal. More information is needed on the real incidence of the defect in Herefords, and especially in other breeds and crosses, and on the possible association of the defect with pathological symptoms or with meat quality.

CONCLUSIONS

On the basis of this twin heifer study:

1. Cumulative evidence now indicates that the vertical fiber defect is a genetically controlled trait of Hereford cattle which first becomes manifest at about one year of age.

2. The defect was not induced by the consumption of high-energy feeds for prolonged periods.

. The defect was absent in 30 hides of known Holstein source.

Hide corium fat was strongly influenced by dietary energy level and by age, a trend towards higher amounts in Herefords than in Holsteins.

Hide thickness was appreciably greater in Hereford hides but was only tly influenced by dietary energy level and by age. Grain layer thickness was tant.

The biopsy technique is a valuable tool for hide and leather research.

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DISCUSSION

D. F. Holloway (Wisconsin Leather Co., Milwaukee, Wisconsin): Jean Tancous of the Tanners' Council Research Laboratory is the Discussion Leader for this paper.

. Jean J. Tancous (Tanners' Council Research Laboratory): Again the tanning industry thanks the U.S.D.A. for a fine contribution in determining the cause of pulpy butts in cattle hides. About seven years ago, a tanner approached me with the comment, "Jean, if something is not done about pulpy butts, they will run the tanner out of business." I bring this comment to your attention because it points out how a problem going unsolved as it had been for many years can really scare us. When we know the cause, at least we can find some way to avoid the condition, and at least know who should take the blame. In the case of pulpy butts, it was not the tanner, or the hide curing establishment, or the mode of feeding, but, as pointed out by Mary's presentation today, the problem is genetic in origin. The biopsy technique sounds like an ideal means of reducing the incidence of pulpy butts, which are not so paramount in our minds now that imports and pollution control problems have come into being. However, we are still being confronted with the problem of pulpy butts and we certainly hope that the U.S.D.A. continues with their invaluable research into the problem. We hope they can reduce the incidence, if possible.

Mary, you stated that the vertical fibers can be detected as early as one year of age. Do you believe that vertical fibers are present in the skins of new-born calves?

Miss Mary V. Hannigan (Eastern Regional Research Laboratory, USDA, Phila., Pa.): Genetically, the genes are present but the defect does not manifest itself until about nine months to a year, in the growing process. I have never seen it in a calfskin, nor has it ever been reported. It does show in kip skins, which would come from animals nine months of age.

Mrs. Tancous: I, personally, have seen the vertical fiber effect in kip and I know you tanners have complained about it in kip. The kip or the calfskin is not split; the skin is shaved at most. For this reason I don't think we notice the vertical fiber effect in these skins as we do in a full thickness hide, which is split.

You mentioned that the animals were force-fed at feeders for four hours. But other than the four hours, were they confined to pens? In previous experiments with twin calves, if one calf was out on the range and one calf was confined to quarters, the one allowed to exercise would show better hide strength. This is the reason for my question.

Miss Hannigan: As far as we know, they were confined to pens, or small enclosed areas. But since the food intake was measured, there was no actual grazing. The animals probably had some type of exercise, but just how much I don't know.

Mrs. Tancous: Are there any questions from the floor on this important problem of pulpy butts in hides? If there are no questions, we certainly thank the U.S.D.A. for this fine contribution.