TECHNICAL NOTE

CORRELATION OF CHROME AND FAT CONTENT WITH LEATHER STRENGTH

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INTRODUCTION

In a previous study (1) a variety of physical properties and sorting characteristics of combat boot leathers made from comparable bullhides and steerhides were closely compared. The cattle involved had similar genetic and management backgrounds as well as similar ages and slaughter weights. That study anticipated a possible trend towards raising young bulls for beef because of potential economic advantages. Results of the study indicated that leather from bullhide was significantly stronger by a number of standard tests than leather from steerhide. Since the leathers had been processed in three different tannery lots, there was later some question as to whether this had produced differences in chemical composition which could result in differences in physical properties.

It is commonly accepted in the trade that the strength of chrome-tanned leather decreases as its chrome (Cr_2O_3) content is increased. Noerr and Classen (2) observed this relationship, and Kanagy *et al.* (3) showed that chrome-retanned leathers are weaker than straight chrome-tanned leathers. Some tanners (personal communication) believe that five percent chrome on a moisture free basis (MFB) is the critical limit above which concentration leather strength decreases. It is also commonly accepted that leather strength is increased, to a point, by increasing amounts of fat (fat liquor). As early as 1920, Bowker and Churchill (4) observed this strengthening effect of stuffing materials in vegetable-tanned leather. Mattei and Roddy (5, 6) described fatliquor effects and improvement in a number of properties, including depth of oil penetration, over a range of six to 18 percent fat on a dry basis. Nishiyama *et al.* (7) found that most strength test values increased as the fat content of chrome side leather was increased from zero to 20 percent of wet-blue weight. Shirai and Okamura (8) reported that the tensile strength and elongation of collagen fibers increased after treatment with cod oil.

Except for these and a few other similar reports, the authors are not aware of any quantitative data relating the strength of chrome-tanned leather to variations in chemical composition. The sides from our comparative study (1) presented the opportunity to derive such data and also to confirm any possible differences between the two types of hides involved.

EXPERIMENTAL

Our previous report (1) described in detail the source and other pertinent facts about the experimental Hereford hides involved, including a number of cases of vertical fiber defect which produced very weak leather. The present report involves only those hides with normal fiber structure which produced leather having a normal range of strength values.

Thirteen normal sides in the crust stage were selected from each of the three tannery lots: one lot of steer sides and the other two of bull sides. Ten-gram samples were taken from each side at three standard (ALCA) locations (butt, shoulder, and belly) and were ground and combined to provide single representative samples. Moisture, ash, fat, and nitrogen were determined by standard (ALCA) analytical procedures, and chrome (Cr_2O_3) was determined by an atomic absorption method (9). Nitrogen was converted to hide substance by the usual factor, N $\times$ 5.62.

Physical tests, including the ERRC experimental penetrometer test, were performed in duplicate, according to methods described previously (1). The results from 12 locations were averaged to provide representative values for each side. Statistical correlations were computed by a standard linear regression analysis.

RESULTS AND DISCUSSION

Results of the chemical analyses of the three lots of samples are summarized in Table I, showing calculations on a moisture-free basis (MFB) as well as on a hide-substance basis (HSB). Values for each lot are the averages of three pooled samples from each of 13 sides. There were appreciable differences in all components among the three lots. On a hide-substance basis, the chrome content of the bull sides averaged about 6.4 percent compared with 7.3 percent for steer sides, and the fat content averaged, respectively, about 9.9 percent compared with

TABLE I

AVERAGE CHEMICAL COMPOSITION OF CRUST LEATHERS (PERCENT)

Composition*	Lot 1 Steerhide		Lot 2 Bullhide		Lot 3 Bullhide	
	MFB†	HSB†	MFB	HSB	MFB	HSB
Total Nitrogen	12.97		12.68		12.07	
Hide Substance	72.67		71.23		67.82	
Total Ash	7.36	10.13	8.07	11.33	7.76	11.44
Total Fat	5.35	7.40	5.80	8.19	7.86	11.60
Chrome (Cr_2O_3)	5.27	7.25	4.59	6.45	4.28	6.31

*Average of pooled samples from 3 standard locations on each side for 13 sides per lot; all sides had normal fiber structure.

†MFB — moisture free basis; HSB — hide substance basis.

7.4 percent. Since both lots of bullhide leathers contained less chrome and more fat than the steerhide leather, these composition differences might partially explain the greater strength of the former rather than any inherent differences in the raw hides. Corresponding physical test data for the three lots are shown in Table II. It is apparent that in general the bullhide leather was stronger than the steerhide leather, but, as explained above, these differences may have been

TABLE II

AVERAGE PHYSICAL TEST RESULTS FOR CRUST LEATHERS

Physical Tests*	Lot 1 Steerhide	Lot 2 Bullhide	Lot 3 Bullhide
Tensile, perp.†, lbs./in.^{2}	2031	2366	2471
Tensile, par.‡, "	2543	2988	3133
Slit Tear, perp.†, lbs./in.	540	626	622
Slit Tear, par.‡, "	514	563	574
Ball Burst, lbs./in.	1810	1907	1970
Penetrometer, lbs./in.	124	124	142
Grain Crack Load, kg./cm.	175	195	176
Grain Crack Extension, mm./cm.	37	42	33

*Average of 12 test locations on each side for 13 sides per lot; all sides had normal fiber structure.

†Perp. means perpendicular to the backbone.

‡Par. means parallel to the backbone.

partially due to processing in different lots. An analysis of variance on the complete physical test data reported previously (1, Table V) indicated the significant sources of variation between the two lots of bullhide leathers.

Statistical correlations between physical test data and the chrome and fat contents on a hide-substance basis for all 39 sides are shown in Table III. Correlation coefficients (R values) can range from 0 to $\pm$ 1, indicating stronger direct correlations as they approach $+1$ and inverse correlations as they approach -1. F values indicate the significance of the correlations as explained in the footnotes. Confirming the consensus in the trade, there is a highly significant, inverse correlation between chrome content and tensile strength (in both perpendicular and parallel directions to the backbone), but only the slit tear perpendicular test agrees with this conclusion among the other six tests listed. On the other hand, the fat content is significantly and directly correlated with the slit tear test (both directions) and grain crack extension but not with the other five tests listed.

Results of this study must be interpreted cautiously since they represent data from only 39 sides. Chrome contents ranged from about six to eight percent (HSB) or four to six percent (MFB), and fat contents from about seven to 12 percent (HSB) or five to eight percent (MFB). While these levels are fairly

TABLE III

CORRELATION OF PHYSICAL TEST RESULTS WITH CHROME AND FAT CONTENT OF 39 CRUST SIDES

Physical Tests	Chrome (Cr_2O_3) (HSB)		Total Fat (HSB)	
	R Value	F Value	R Value	F Value
Tensile, perp.	−0.478	11.0**	0.261	2.7 ns
Tensile, par.	−0.473	10.7**	0.265	2.8 ns
Slit Tear, perp.	−0.423	8.1**	0.336	4.7*
Slit Tear, par.	−0.295	3.5 ns	0.356	5.4*
Ball Burst	−0.280	3.2 ns	0.222	1.9 ns
Penetrometer	−0.301	3.7 ns	0.239	2.3 ns
Grain Crack Load	−0.073	0.2 ns	−0.084	0.3 ns
Grain Crack Ext.	0.062	0.1 ns	−0.327	4.4*

*Correlation is significant ($P < .05$).
ns means not significant.
**Correlation is highly significant ($P < .01$).
Physical test units same as in Table II.

representative of commercial production, the correlations found cannot be assumed to hold for lower or higher levels. Furthermore, the number of physical tests shown to be significantly correlated with composition were relatively few, amounting to only three out of eight in each case, and the correlation coefficients were all below 0.5. For these reasons we concluded that we found only partial confirmation of prevailing opinions. The trend towards increasing strength with higher fat content and towards decreasing strength with high chrome content, are correlations over limited ranges of concentration. These results would have been more conclusive if experiments had been designed specifically to study the effects of varying chrome content on leather strength at constant fat content and the effects of varying fat content at constant chrome content.

We can only speculate about how much these trends may have affected the physical test results of our previous (1) comparison of bullhide and steerhide leathers that were processed in different tannery lots. It seems likely that our prior conclusion is still correct: bullhide leather is somewhat stronger than steerhide leather. A study from South Africa (10) has also confirmed this difference for two of their principal breeds (Afrikaner and Friesland) and has shown additional effects due to age.

CONCLUSIONS

The separate influences of chrome and fat content on crust leather strength, within limited ranges of composition, were evaluated statistically in a small-scale study. Highly significant, inverse correlations were found between chrome content and tensile strength (both directions) and slit tear strength (one direction). Sig-

nificant, direct correlations were found between fat content and slit tear strength (both directions) and grain crack extension. In both cases the correlation coefficients were relatively low, and correlations with five other tests were not significant.

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