THE EFFECT OF TEMPERATURE AND MECHANICAL ACTION ON SALT UPTAKE DURING BRINE CURING OF CATTLEHIDES

Abstract

The effect of temperature on penetration of salt was measured at 36°, 50°, 60° and 80°F. The rate of uptake of salt by samples of cattlehide in saturated brine decreased as the temperature of the brine decreased. Continuous mechanical movement of the hide samples in brine increased the rate of salt uptake compared to static immersion. Data from salt-saturation measurements of more than 50,000 commercially processed hides were examined. It was found that more than 75% of the cattlehides cured during the winter months in the colder regions of the country had unsatisfactory levels of salt saturation.

Introduction

Brine curing of hides in a raceway began in the United States more than 50 years ago[1]. The process was developed to compete with "Frigorificos", which were well-preserved cattlehides from South America. These hides were first soaked in saturated-brine vats and then dry-salt packed. At the time that brine curing was introduced, most cattlehides in this country were preserved with dry salt. The major advantage of brine curing is that a satisfactory cure can be obtained in less than 24 hr., while dry salt packs require 30 days for proper cure. In addition, brine curing almost eliminates salt stains that were frequently seen on salt-packed hides. Many papers were published subsequent to the widespread commercial use of brine curing. Most dealt with a comparison of brine curing with salt packs[2,3]. Only one paper was concerned with the effect of temperature on brine curing[4], and that paper investigated the use of higher temperatures to increase the speed of brine curing.

In the past few years the tanning industry has expressed concern about the quality of brine-cured hides. Most of this concern is centered around the low salt-saturation measurements often found in commercial skins. Salt saturation is determined by measuring the amount of salt (ash) found in a hide and dividing by the moisture content. The resulting number is then compared to that of a saturated salt solution containing 35.9 g of salt per 100 ml at 20°C. The Leather Industries of America Hide Committee and the US Hide Skin and Leather Association Raw Stock Committee jointly published a document in May of 1985, "Trade Practices for Proper Packer Cattlehide Delivery". This publication defines a well-cured green-salted or a well-cured brined hide as one that has a moisture content between 40 and 48% and a brine saturation equal to or greater than 85%[5]. Lollar claimed, in studies made at the Leather Industries of America Laboratory at the University of Cincinnati, that 48% of 860 commercially cured lots of cattlehides that were examined in his laboratory over a 2-year period did not achieve these standards for saturation[6].

This study investigated the possible influence of the temperature of brine curing on the levels of salt saturation achieved commercially.

The rate of penetration of salt into hides and skins during brine curing is dependent on several factors. During brine curing, salt enters the hide as a result of diffusion. According to Fick's Law, the greater the difference in concentration between the salt in the brine and in the moisture inside the hide, the higher the rate of diffusion. At the later stages of curing, as the concentration of salt inside the hide begins to approach the concentration of the salt in the brine, the movement of salt becomes very slow. This effect can be minimized by maintaining the concentration of salt in the brine as close to saturation as possible.

Temperature also has an effect on diffusion. This effect is small when concentration differences are great but it becomes more important when the differences are small. The effect of temperature on diffusion is well known and the general trend of the results of these brine-curing experiments could be predicted. The work was conducted to find out if reducing the temperature of brine-curing baths would have a practical impact under the conditions normally employed for brine curing of cattlehides.

Increasing the mechanical action on a hide during wet-processing steps increases the movement of chemicals both into and out of the hide. Experiments were conducted to determine the relative effect of mechanical action on movement of salt into hide samples during brine curing compared to the temperature effect. The mechanical action of full-scale industrial equipment on a hide is far more vigorous than the mechanical action of laboratory-scale equipment on hide samples. This also suggests that, while results on a laboratory scale may indicate a trend, it will not always be certain that the trend has practical significance.

Evidence of the practical significance of our laboratory experiments was obtained from data on measurements of brine saturation of more than 60,000 commercially brine-cured cattlehides. The data came from 23 different commercial sources of hides from lots obtained over all 12 months of the year. This information made it possible to look at regional variations in curing as well as seasonal and monthly variations.

Materials and Methods

Samples approximately 8 by 10 in. were cut from a cattlehide obtained from a local abattoir within four hours of slaughter.

Temperature Effect

Four pieces of hide weighing about 150 g each were placed in a 1-gal. plastic container with a 4-in. screw cap. A 400% float of saturated brine was added along with an additional amount of solid salt to maintain the brine at saturation throughout the experiment. Several containers were then placed in each compartment of an experimental "TANNOX" drum. The TANNOX drum was segmented into three compartments, with perforated separators extending the full width of the drum from the center to the outside wall. The drum diameter was 30 inches. It was supplied by RIAT. The base of the TANNOX, with a total volume of 18 gal., was filled with water. During the constant-temperature experiments the interior drum was run continually at 17 RPM. The TANNOX bath was maintained at the desired temperature by recirculating the water in the bath at a rate of 10 gal./min. through a coil immersed in a temperature-controlled bath. At intervals the drum was stopped and four quarter-inch-diameter plugs were removed from each hide sample. The samples were blotted with paper towels to remove excess moisture, placed in plastic bags and sealed. The samples were stored frozen until analyzed for moisture and salt content. Samples were taken at the start of each run and after 4, 8, 12 and 24 hr. The sample plugs were taken from areas which were carefully separated from each other so that penetration of salt into the samples could only occur from one side of the hide or the other and not from an adjacent cut edge. The temperature-variation experiments were conducted at four different temperatures, i.e. 36°, 50°, 60° and 80°F.

Mechanical Action

The experiments to determine the effect of mechanical action on the salt penetration were done using 28 samples of cattlehide the same size as those used in the temperature experiments. These tests were run at ambient temperature in the tannery, which was between 57° to 60°F. One set of hide samples was placed directly in an experimental drum along with the appropriate amount of float and additional solid salt to maintain salt saturation. The drum was rotated at 4 RPM continuously over a 24-hr. period. Samples were taken for salt and moisture analysis in the same way as described in the previous experiments and at the same time intervals. A second set of hide pieces was placed individually flesh side down in a bath of saturated brine solution. Additional solid salt was added to the bath to saturate the moisture removed from the hide. These samples were only moved when samples were taken for analysis. At that time the solutions were mixed briefly to maintain salt saturation.

Salt Saturation

Moisture and ash determinations were made on the frozen samples in the following manner. Samples were thawed and weighed in a tared porcelain crucible and then placed in an electric convection oven for 18 hr. at 95°C. Fat was removed (from the flesh side of the samples) but the hair was not. Samples were reweighed to determine the moisture lost during drying. Ash measurements were made on the dried samples in a muffle furnace. The oven was programmed to increase temperature to 600°C over a period of 2 hr. and then to hold that temperature for 4 hr. After cooling, the samples were weighed to determine the ash content.

The hair and fat were removed from the sample plugs taken from the commercial hides. They were then weighed and dried overnight at 95°C in an oven and ashed in a muffle furnace after reweighing.

Results

Figure 1 shows the measured salt saturation as a function of time in samples of hides which were continuously drummed in saturated brine over a period of 24 hr. Each curve represents one of the four different temperatures tested. Each data point is the average of 32 salt and moisture determinations. Computer-generated curves (not shown), using an equation for best fit, demonstrated that the curves are statistically different, to a 95% confidence limit. At any particular time during the 24-hr. period of curing there is a clear relationship between the temperature and the amount of salt which has entered the hide.

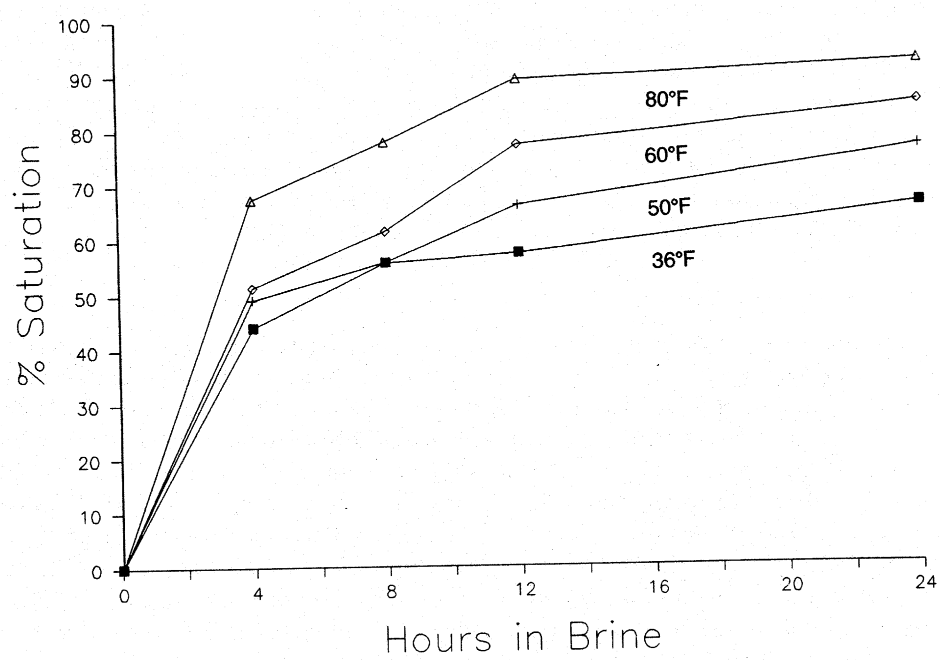

FIG. 1. — The effect of temperature on the degree of salt saturation in fresh cattlehides brine-cured over a period of 24 hr.

Figure 2 is a similar plot to the percent salt saturation of hide samples as a function of time comparing samples of cattlehide under continuous motion with samples which were held in a static condition. It can be seen that under continuous mechanical action the amount of salt penetrating the hides samples was greater at any particular time up to 24 hr. relative to that of the static samples. It can also be seen that, given enough time, the static samples would also become saturated with salt. This observed effect could be due to a lower rate of salt diffusion into the hide due to the buildup of concentration gradient of salt at the surface of the hide. The mechanical action prevented the buildup of these concentration gradients, allowing more rapid diffusion. Alternatively, the mechanical action itself caused repeated flexing of the samples, thereby increasing the rate of penetration of the salt. The available data are insufficient to determine which explanation is more likely, but in either case, the observed difference is not very large.

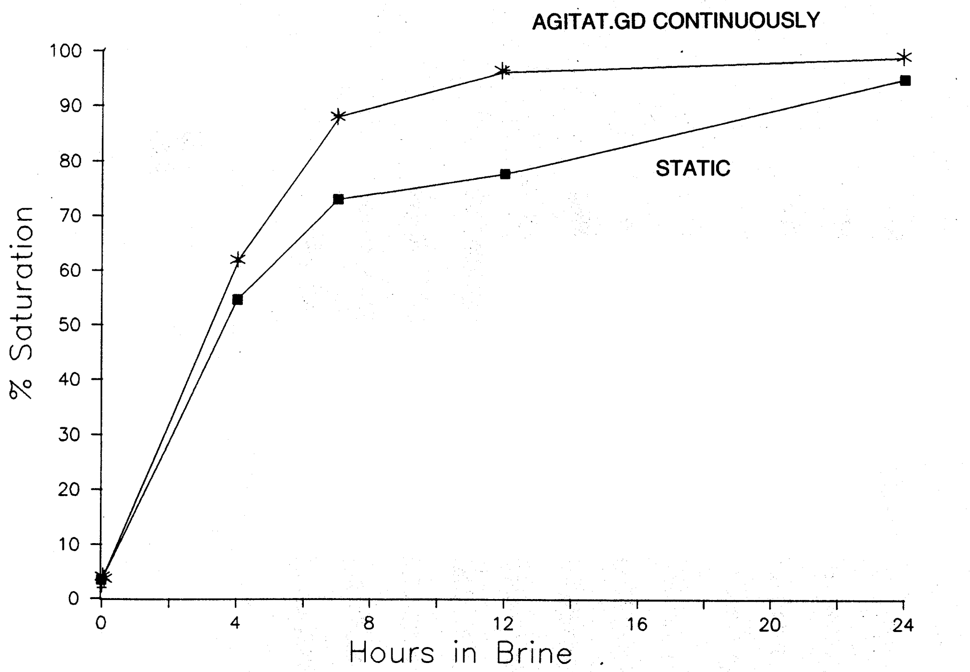

FIG. 2. — The effect of mechanical action on the degree of salt saturation in fresh cattlehides brine-cured over a period of 24 hr.

As suggested before, laboratory results can provide qualitative information about a commercial process but might not yield accurate quantitative information. To correlate the laboratory results with commercial practice, the levels of salt-saturation values found in a large number of commercially brined hides were investigated. Bluesides Tannery* in St. Joseph's, MO routinely analyzes one sample from five hides out of each shipment they receive for moisture and salt. The data were obtained over a period of 2 years and represented a total of 23 hide suppliers. The data were separated into two groups based on the average air temperature during November, December and January in the city nearest to the hide processor. Table I shows the average temperature during December, January and February for each hide supplier[6]. The two groups are referred to as the warm region and cold region. The cold region's temperatures ranged from 10° to 23°F and the warm group's were between 30° and 46.7°F (Table I). The data in each group were separated by the month of the year. Figure 3 is a bar chart with the data for hides received from suppliers in the warm region. The unfilled bar for each month represents the average temperature and the filled one the average percent salt saturation for all of the samples in that particular group. Most of the hides in this group were adequately cured throughout the year with the exception of one winter month and the small difference found in April and May.

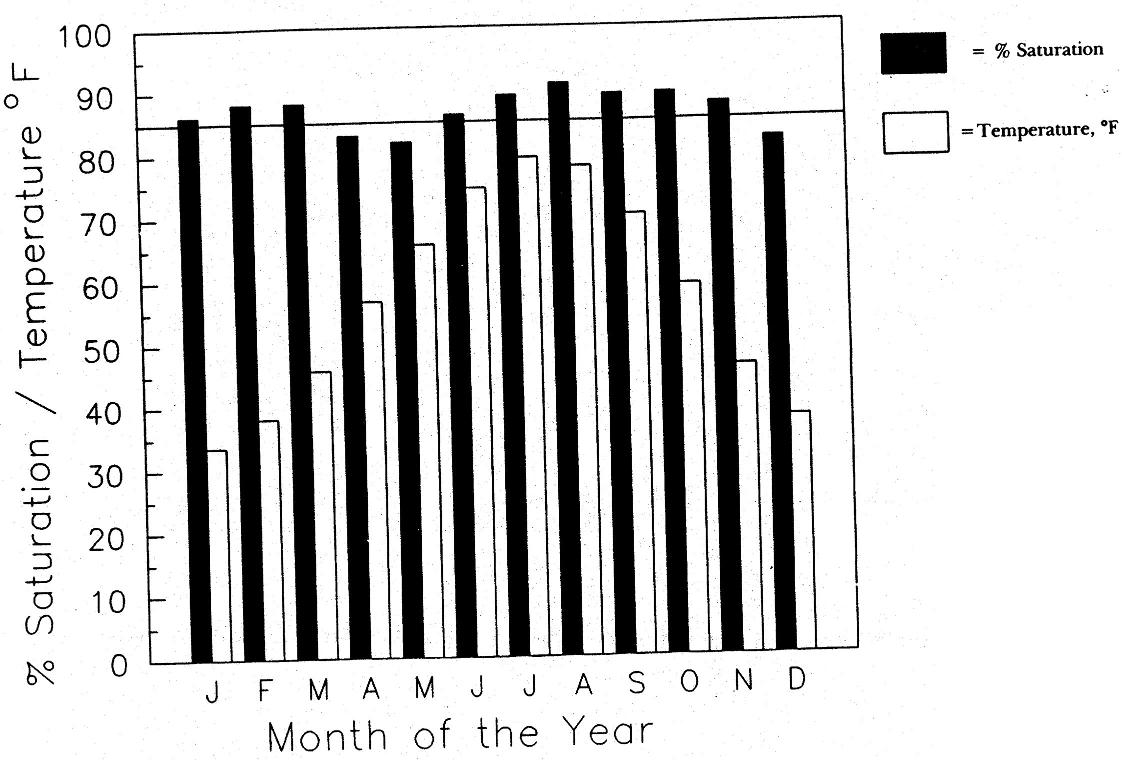

FIG. 3. — Comparison of average monthly hide salt-saturation with average monthly temperature in warm regions of the country. Solid bars represent salt saturation (%) and unfilled bars represent temperature (°F). The horizontal line is the minimum acceptable saturation (85%) of salt.

TABLE I

Average Winter Air Temperature* At Hide-Processing Facility

Warm Region		Cold Region	
Supplier	**Avg. Temp. °F**	**Supplier**	**Avg. Temp. °F**
A	30.0	B	16.0
C	31.9	D	22.9
E	31.9	F	22.9
G	33.0	H	22.9
I	33.0	J	22.9
K	35.2	L	22.9
M	42.1	N	24.9
O	43.8	P	24.9
Q	46.8	R	24.9
		S	24.9
		T	24.9
		U	25.0
		V	25.0
Avg.	36.4	Avg.	23.4

*Average daily air temperature of city nearest hide processor during November, December and January[6].

Figure 4 contains the same information obtained from the hides from the cold region. The salt saturation in these samples is lower across the entire year and well below the minimum standard for three months of the winter.

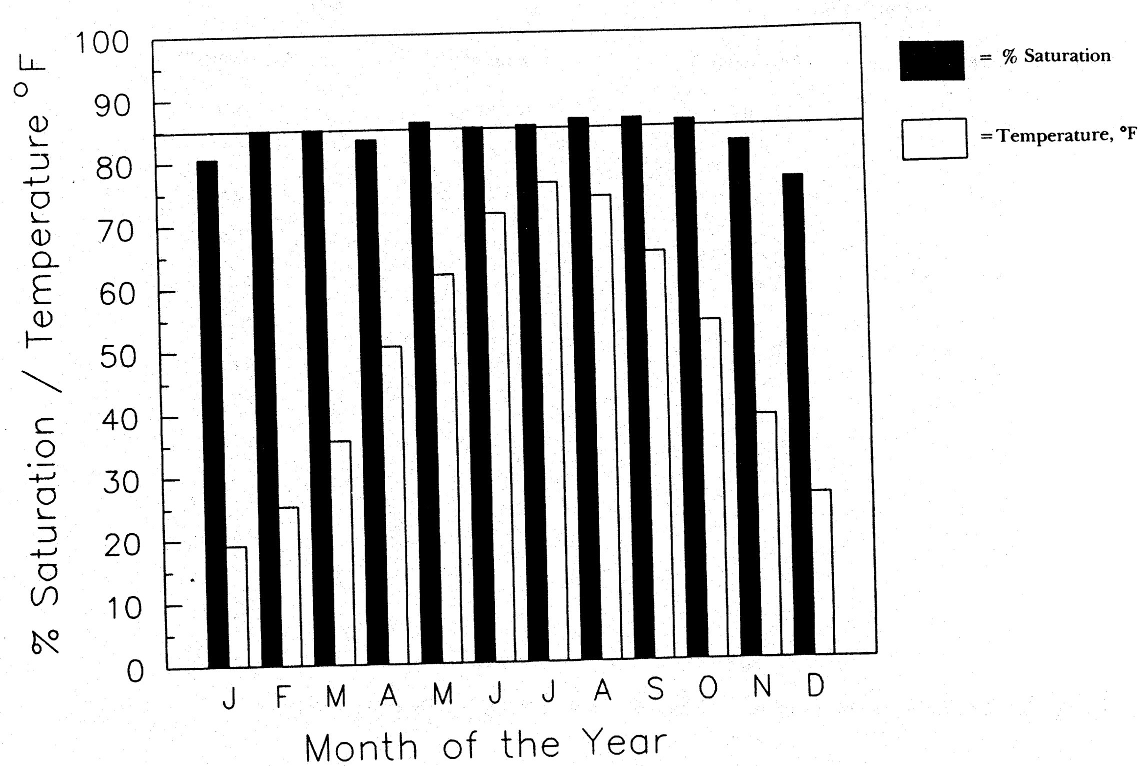

FIG. 4. — Comparison of average monthly hide salt-saturation with average monthly temperature in cold regions of the country. Solid bars represent salt saturation (5) and unfilled bars represent temperature (°F). The horizontal line is the minimum acceptable saturation (85%) of salt.

Discussion

The percent salt saturation data obtained in the laboratory experiments (Figure 1) were consistently below the 85% figure after 18 hr., the average time for commerical brining. While the temperature effect is clear, it is unlikely that commercial hides would be this much below the 85% saturation limit. This result could be partially explained by the fact that the hair was not removed from the experimental samples before they were analyzed for moisture and ash. In the standard analysis[5] of salt saturation the hair is removed. Hair contributes about 5% of the weight to the hide right off the animal and removal of the hair would therefore increase the calculated saturation by about 5%. Recalculation of the experimental data to include this difference, however, still does not bring the experimental values up to the 85% saturation. The difference could also be partially explained by the lack of mechanical action on these small samples of hides compared to the action of commercial brine raceways on whole hides. Mechanical action is important to the movement of chemicals into and out of a hide in commercial processing. The results of the second experiment support this concept although the impact experimentally was small (Figure 2). Hide processors, using much lower floats, obtain greater degrees of salt saturation than with a brine raceway in only 8 to 10 hr. The most likely explanation is that this is due to the much stronger mechanical action that takes place within a processor. This reduced mechanical action would tend to reduce the degree of saturation compared with that obtained under commercial conditions. For both these reasons the values we obtained in the laboratory are difficult to compare directly to commercial values. However, there is no doubt that as the temperature of the brine is reduced the rate of salt penetration is also reduced.

To obtain a correlation between the laboratory observations and commercial brine curing we examined the data obtained from the commercial samples. When this information is plotted as a function of the month of the year for the warm regions it can be seen that during the colder months of the year there was a considerably reduced level of saturation compared to the warmer months (Figure 3). The data from the cold regions reveal that the degree of salt saturation during the winter months is below the minimally acceptable level. The reduction of saturation found in the warm-region data during April and May was not as pronounced in this set although May saturation was lower than 85%. There is a consistent reduction in salt saturation for cold regions when they are compared with warm regions over the entire year.

Division of the hides into two groups serves another useful function for the interpretation of this information. It could be argued that the reduced salt-saturation effect could be a function of longer hair and heavier hides that occur in the winter months. Particularly during the winter, manure on hides prevents the fleshing machines from doing an adequate job on the removal of adipose tissue from the underside of the hide.

It is well documented that salt penetrates a hide from the flesh side during brine curing[8,9]. Fat and other tissues adhering to the flesh side of a hide can slow down the penetration of salt into the hide. When hides are heavily caked with manure, which often occurs in late winter and early spring, fleshing machines must be backed off to keep from cutting holes in the hide. This results in poor fleshing, which slows the penetration of salt, and could be responsible for the effect seen during the winter and early spring[10]. It is certainly possible that poor fleshing could enhance the observed effect during the winter but it is not solely responsible for it.

The observation of the second smaller reduction of salt penetration in April and May is difficult to explain. It appears that in both the warm and cold regions the curves may be related to a spring seasonal variation in the hides. It is also possible that there may be a lag effect in the transfer of heat from the brine raceway as winter begins and into the raceway in the spring. This would account for the delay in poor cure seen in the cold regions compared to the drop in seasonal temperature. A lag in the salt-saturation data behind the temperature in the figures could also be caused by the 1-to-3-wk delay between receipt of the hides in the tannery and the analysis of the hide for salt and moisture.

Summary and Conclusions

The experimental data show that the effect of lowering the temperature of a brine bath is to slow down the rate at which salt penetrates a hide. Mechanical action increases the rate of salt penetration into hide samples compared to a static bath but the differences are smaller than those due to temperature. The temperature effect was found to be of great practical significance because the majority of hides commercially cured in the winter in cold regions of this country were found to be badly cured. These data on commercially-brined hides showed that there is a reduction in salt saturation that correlates with lower temperatures. There is also a much smaller interference in salt penetration that is probably not temperature-dependent and may be related to a change in the hide itself as the season changes from winter to spring. One reason why this effect of cold weather has not been so apparent in the past is that the combination of cold weather and partially-cured hides will give the appearance of good preservation. If the hides are processed into leather shortly after curing there will probably be no ill effects on the leather due to the reduced salt saturation. Long-term shortage under elevated temperatures, however, would certainly reveal the fact that the hide was poorly cured.

It can be speculated that the reason 25% of the commercially-brined hides were able to achieve the desired saturation during periods of low temperature may be due to the use of safety salt. It is ironic that the use of safety salt may be more important in the cold winter months than during the summer.

Acknowledgements

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