

Sampling plans for evaluation of leather physical properties

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Summary

Given the increasing demands from customers on tanneries and the threat from manufacturers of plastic materials which compete with leather, it has become necessary to avoid sending problems to customers. This paper studies the physical-mechanical properties of leather, in particular tear strength. Several lots of the same article produced by a bovine tannery are examined piece by piece. Different sampling plans are offered in order to minimise the probability of a tannery shipping leather that could result in a claim. There are also recommended procedures to follow.

Introduction

There is a worldwide trend to demand high quality products and leather is no exception. On the contrary, on top of the natural pressure applied by the customers of tanneries for in-time deliveries and homogeneous quality, there are also demands to lower prices, to increase environmental sustainability, to guarantee safety for people, to collaborate with social responsibilities, etc. Moreover, lately a new propaganda onslaught by imitation leather manufacturers has been present in the press and social media in an attempt to discredit leather.

Under these circumstances, tanneries must take extreme care to supply their customers with the requested articles, in accordance with the agreed quality standards. In short, we should not deliver problems to our customers.

Objectives

The problem analysed in this work is: what are the variations that a tannery has to control in each of the shipments to be sent to its clients in order to assure their satisfaction?

Let us take the case of a large production of a certain article. A full container ready to be sent to a customer, for example, composed of a sum of production lots. Normally, these lots present small variations in their physical properties. These variations naturally occur in the raw material (raw hides) and may be increased with the successive processes and operations to which they are subjected in order to transform them into semi-finished or finished leather.

Broadly speaking, the production of finished leather can be divided into three main stages:

- | | |
|-----------|--|
| STAGE I | Processes of beamhouse and tanning. |
| STAGE II | Operations of wet blue, samming, splitting and shaving; retanning, dyeing and fatliquoring processes; and drying and conditioning operations |
| STAGE III | Finishing processes and operations. |

Taking the particular case of tear strength during Stage I,

Tournier studied the changes of tear strength of bovine hides during the beamhouse and tanning processes using sequential sampling in factory trials⁽¹⁾. It was found that fresh hides marginally increased their original tear resistance during liming but that the remaining processes and operations lead to reductions in tear resistance. Subsequent, as-yet unpublished studies showed that during Stage II the only process capable of increasing tear strength is the fatliquoring, while the rest either decrease it or were shown to have no influence at all.

The magnitude of the increase or decrease of the values of the physical properties depends on several factors. The overall influence of these factors over the hides of an individual lot corresponds with the identity of that lot, which is different from the rest. The work of the leather technicians and quality controllers in tanneries is to limit these differences as much as possible. Nevertheless, small variations in one operation or process can add up, with variations from other processes resulting in lots falling outside the standard.

Moreover, in lots that can be considered within range, there will be individual hides that are out of specification due to the original fresh hides being inconsistent with each other.

One of the main objectives when sending a container to the client is that the leather can be used without problem during the manufacture of goods and that there will be no issues due to the leather during the use of these goods by the final consumer.

If a statistical sampling of the leathers of the container were carried out, including between 1% and 3% of the hides in it, it could result, for example, that 5% of the hides are out of specification, a percentage that is normal and tacitly accepted by footwear manufacturers.

The point is that this percentage of defective hides could be accepted by the client, providing they are evenly distributed in the lot. However, it is highly probable that the out-of-specification hides will be grouped in one or several groups in the container. In that case, the client will experience problems during production when the sub-group of hides with the highest percentage of defects is reached. At this point, a high percentage of non-conforming goods will appear and production will be interrupted in order to investigate the cause of deviation, with all the inconvenience that this entails. When the client finds out that an unusual number of hides being out of specification is the cause of the problems, the tannery will be facing a claim.

A claim that starts like this can become more complicated for several reasons:

- If it takes place during a market decline, it can be used to demand a price reduction;
- The client can take advantage of the problem with the



Table 1

Batch	Batch size (hides)	Average (Kg) ($\bar{x}$)	Standard deviation (Kg) (σ)	Asymmetry Coefficient	Kurtosis Coefficient	% of values <3.5 Kg (real)	% of values <3.5 Kg (estimated)*
1	105	6.30	1.95	0.65	-0.25	2.9	7.5
2	100	6.01	1.96	0.51	0.00	12.0	10.0
3	106	6.07	1.52	0.35	-0.32	2.8	4.5
4	114	6.64	1.93	0.47	0.84	2.8	5.2
5	103	5.89	1.69	0.44	-0.37	2.0	7.9
6	103	5.70	1.50	0.05	-0.26	5.8	7.1
7	106	5.75	1.77	0.65	0.23	8.5	10.2
8	108	5.63	1.61	0.46	-0.20	5.6	7.9
9	107	5.86	1.82	0.19	-0.33	9.3	9.7
10	105	5.74	1.69	0.21	0.23	8.6	9.2
Average	105.7	5.96	1.79	0.50	-0.20	6.0	8.5

* The estimation of the % of values <3.5 Kg is based on the assumption of a normal distribution.

leather to try to 'clean up' other problems (problems of manufacture, design, low productivity, various inefficiencies, problems with personnel, non-conforming parts of other components, etc.);

- c) It generates mistrust in the rest of the shipment and/or the following ones could come under question;
- d) There is risk of an adjustment in the specifications, generally towards more stringent demands.

Materials and methods

It is necessary to avoid a situation of this type without going to a sampling level of 100% for the control of physical properties, which would be extremely cumbersome and expensive. The best alternative is to choose a strategic point between stages I, II and III in which to establish statistical control, lot by lot, for the most critical articles and variables. Once the article and the critical variables have been chosen, the question is: what is the minimum sampling level of the production lots that protects from exaggerated variations?

To try to answer this question, a comparative study of sampling levels was carried out. The article chosen is a softy semi-finished leather at the end of stage II and the critical variable studied is tear strength.

This study involves the analysis of several batches of the same article. A similar procedure was proposed by Landmann⁽²⁾ to predict the total area of a given lot in which properties are within certain limits.

The study consists of two parts:

- A) The distribution of values for the tear strength of each lot will be analysed;
- B) Different sampling plans based on Military Standards⁽³⁾ will be compared for that trial.

A) Distribution analysis of the tearing values

Procedure

The softy semi-finished leather, with a thickness of 1.3 millimetres, was selected. This article is intended for the

manufacture of sports shoes; it is chrome-tanned, retanned and fatliquored to obtain a soft touch.

A sampling of 100% was carried out on 10 lots of the article, containing approximately 100 leathers each. The determination of tearing strength was carried out according to the standard IUP 8 double edge tear test (sometimes described as the Baumann test). Samples were taken with specimens parallel to the spine only, in the official sampling area.

No vertical samples were taken since several researchers have found that in this area the tear strength varies slightly with the sampling angle and that these variations are not significant^(1,4,5).

The results of the tests were analysed using statistical criteria: average, standard deviation, asymmetry coefficient and the coefficient of kurtosis. The asymmetry and kurtosis coefficients are indicators of the shape of the distribution, when compared with a normal distribution curve, in which both coefficients are equal to 0. Values of the asymmetry coefficient greater than 0 indicate that the curve is skewed to the right and, inversely, values lower than 0 indicate that it is skewed to the left. Values of the kurtosis coefficient greater than 0 indicate that the distribution has more values close to the centre than a normal distribution (high bell) and values lower than zero indicate that the distribution has more values far from the centre than a normal distribution (flattened bell).⁽⁶⁾

Results

Table 1 summarises the parameters of the different batches, where $\bar{x}$ is the average population of each lot and σ the population standard deviation.

Comparing lots 3 and 5, it is observed that lot 3 has higher average and lower standard deviation. However, the actual percentage of defective hides is higher (2.8 compared to 2.0). This is justified by the shape of their distributions, which imply different values in the coefficients of asymmetry and kurtosis. The distribution of lot 5 is more biased at high values than that of lot 3.



Table 2

	LOT 1	LOT 2	LOT 3	LOT 4	LOT 5	LOT 6	LOT 7	LOT 8	LOT 9	LOT 10
-2.75	0	0	0	0	0	0	0	0	0	0
-2.25	0	0	2.8	2.6	0	2.8	0	0	3.7	4.8
-1.75	7.5	13.0	6.6	8.8	12.6	9.7	11.3	8.3	7.5	5.7
-1.25	17.1	13.0	12.3	7.0	12.6	16.5	11.3	17.6	10.3	12.4
-0.75	25.7	18.0	19.8	28.1	15.5	13.6	23.6	22.2	17.7	19.0
-0.25	14.3	15.0	17.0	18.4	24.3	14.6	16.0	13.0	21.5	16.2
0.25	12.4	17.0	14.1	9.6	13.6	20.4	17.0	15.8	13.1	24.8
0.75	6.7	12.0	17.0	14.9	4.9	14.6	7.6	14.8	14.9	6.7
1.25	10.5	5.0	4.7	7.0	9.7	3.9	6.6	4.6	7.5	6.7
1.75	2.9	4.0	3.8	0.9	5.8	2.9	3.8	2.8	1.9	0.9
2.25	2.9	3.0	1.9	0.9	1.0	0	1.9	0	1.9	1.9
2.75	0	0	0	1.8	0	1.0	0.9	0	0	0.9
3.25	0	0	0	0	0	0	0	0.9	0	0

In order to analyse and compare the distributions of the different batches, the distributions of their typified variables $y = (x - \bar{x}) / \sigma$ is considered.

In this way, the “shape” of the distributions can be compared without having the “noise” generated by the difference in its basic parameters $\bar{x}$ and σ .

The typifying or normalisation of distributions is a tool frequently used to compare distributions that have different average and standard deviation values. They are also used to compare the distributions of variables expressed in different units in order to analyse the shapes of the distribution curves, as is the case here.

Table 2 shows the distribution of the typified variables for the 10 lots (1057 hides).

The first column contains the values of the typified variable ‘y’, taken as interval limits, while the rest of the columns contain the percentage of hides within each lot with values that fall within the defined intervals.

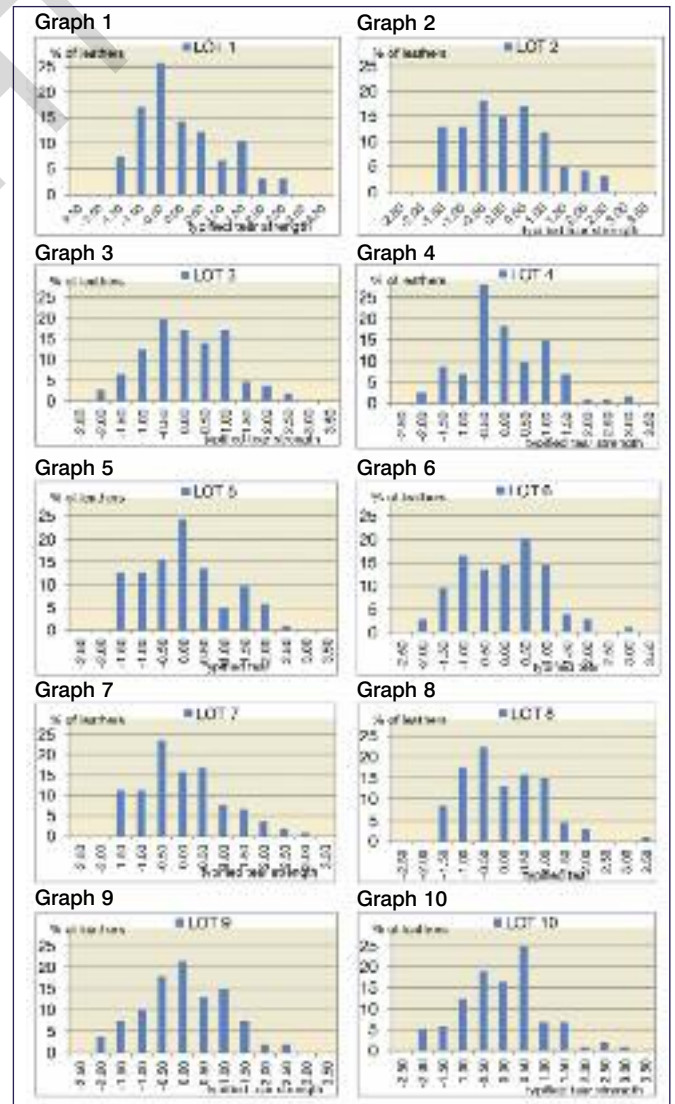
In *Graphs 1 to 10* the distributions of these lots are presented and in *Graph 11* the distribution of the total of the hides from the 10 lots is presented.

When looking at the graphs, it is noted that practically all the distributions are biased towards high values, which agrees with the asymmetry coefficient of each, which was > 0 in all cases.

The kurtosis coefficient in most distributions is negative, which indicates that the shape of the bell is more flattened than in a normal distribution with equal $\bar{x}$ and σ .

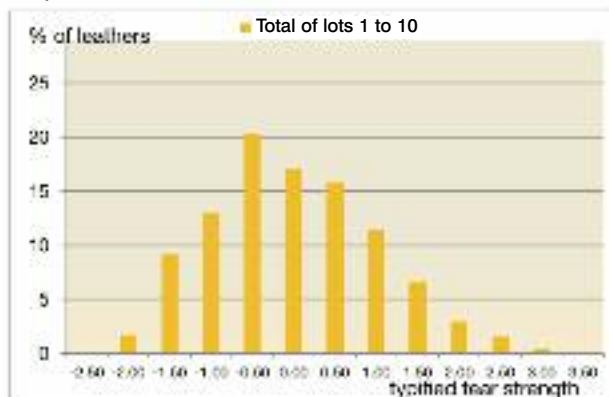
The only cases with kurtosis coefficient > 0 are recorded in lots 4, 7 and 10, which also have a lot of asymmetry towards high values (especially 4 and 7).

These arguments lead to the conclusion that when sampling randomly and making estimates of the percentage of defective hides in the lot, assuming a normal distribution, these estimates are conservative. In other words, the actual defective percentage of the lot, in general, will be lower than the estimated value based on the results of a sample and assuming normal distribution. See *Table 1*.

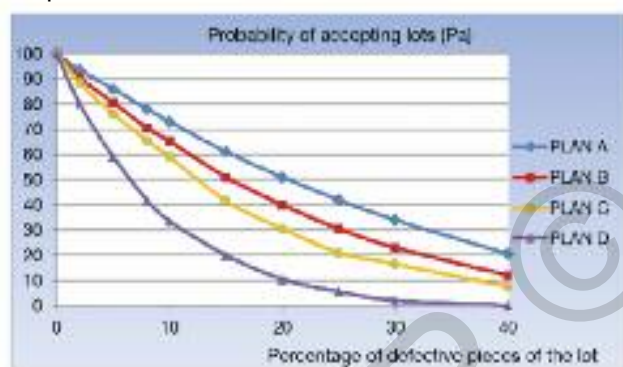




Graph 11: Total: batches 1 to 10



Graph 12



B) Comparison of sampling plans⁽⁹⁾

It must be kept in mind that, given the fact that the fibrous structure of the hides is not uniform throughout, it cannot be assured categorically that a client will not have any problem assembling a shoe with any part of the leather. This is even the case when a sample of that leather has passed the minimum specifications.

The presence of veins, small differences in thickness, and differences in the fibrous structure (length and inclination of the fibres), make it impossible to ensure the result in a specific part of the hide, despite knowing the result in another sector. From the above, it is clear that no sampling plan can offer complete protection or assurance. This fact must be considered by everyone who issues or handles leather specifications.

The selection of an acceptance plan by sampling requires deciding on the magnitude of the risk to manage, which must also be considered from a strategic and economic point of view.

There are two kinds of risks, which are in opposition in the sampling plans, that is to say that when decreasing one, the other one increases:

- manufacturer's risk, which is to reject a conforming lot;
- customer's risk, which consists of accepting a non-conforming lot.

Of these two risks the second one is the most serious since it can lead to complaints, disagreement and even loss of the client.

In the sampling plans compared below, the following symbols are used:

- N = number of pieces in a batch
- n = number of pieces in a sample
- c = acceptance number (maximum admissible number of defective pieces in the sample)
- p = defective fraction or percentage of defective pieces
- α = manufacturer risk (reject a conforming lot)
- β = customer risk (accept a non-conforming lot)
- P_a = probability of acceptance of a lot

Consider that the lots have 100 pieces ($N = 100$).

Sampling Plan A: $n = 3$, $c = 0$; a sample of 3 hides is taken out and no defective hide is accepted. If one or more defective hides appear, 100% inspection is carried out.

Sampling Plan B: $n = 4$, $c = 0$

Sampling Plan C: $n = 5$, $c = 0$

Sampling Plan D: $n = 10$, $c = 0$

Graph 12 shows the probability of accepting lots (P_a) using sampling plans A, B, C, D as a function of the percentage of defective pieces in the lot (p).

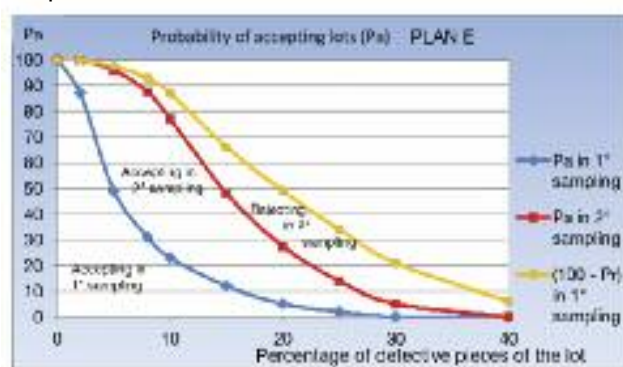
SAMPLING PLAN E: based on double sampling and strict inspection.

$n_1 = 13$; $c = 0 // 3$

$n_2 = 26$; $c = 3 // 4$

A sample of 13 pieces is taken and all of them are examined. If none fail, all the lot is approved. If 3 or more pieces fail, 100% inspection takes place. If 1 or 2 pieces fail, a second sample of 13 pieces is taken (meaning $n_2 = 26$ pieces). If from the 26 pieces 3 or less are defective, the batch is approved. If 4 or more are defective, 100% inspection is carried out.

Graph 13



Graph 13 shows the probability of accepting lots in the first sampling, accepting lots in the second sampling, or rejecting them, according to the percentage of defective pieces present, using sampling plan E.

Sampling Plan F: $n = 10$, $c = 1$; a maximum of 1 defective hide is accepted in the sample of 10 hides.

Sampling Plan G: $n = 6$, $c_1 = 1$, $c_2 = 2$. This sampling plan could be called "double barrier". With the first barrier (c_1)



the fact that there is no more than one defective hide in the sample of 6 hides is verified. With the second barrier (c2) the fact that there are no more than 2 hides below a certain value is verified.

The value to be considered for the second barrier should be that considered for the first one (the specification) plus 0.5σ , with σ being the standard deviation of the population considered. For example, if a hide of a certain article is considered defective when the tearing value is less than 3.5 kilogrammes and the population of tearing values of such article (according to previous data) has a standard deviation $\sigma = 2\text{kg}$, the second barrier would be adopted in $3.5 + (0.5 \times 2) = 4.5\text{kg}$.

Sampling Plan H: $n = 8$, $c_1 = 1$, $c_2 = 2$

Sampling Plan I: $n = 10$, $c_1 = 1$, $c_2 = 2$

Graph 14 shows the probability of acceptance of lots using sampling plans F, G, H & I, according to the percentage of defects in the lot.

In Table 3, for these nine sampling plans the average sample size (in percentage), the α error (probability of rejecting lots with less than 5% defective pieces) and the β_5 and β_{10} errors (probability of accepting lots with 5% or more and 10% or more of defective pieces respectively) are compared.

It is noted that sampling plans A, B, C, and D have high α and β errors, relative to their sample size. Reasonable β errors are only achieved when the average sample size is greater than 22%.

The sampling according to plan E substantially improves the aforementioned event for sampling plans A, B, C and D, but has the disadvantage (from a practical point of view) that 27% of the lots must be re-sampled due to α error in the first sampling.

Sampling plan F is similar to sampling plan D, but accepting $c = 1$; in this way, the α risk and the average check-up level are greatly reduced, but the β risk is inadequately increased.

The G, H, and I double-barrier sampling plans achieve a reasonable balance. Sampling plan H, for example, provides a customer protection (β risk) similar to sampling plan E, but with a somewhat lower average check-up level and without the inconvenience of having to locate lots again to re-sample.

Table 3

Sampling plans	Average sample size (%)	α Error (%)	β_5 Error (%)	β_{10} Error (%)	Re-sampling (%)
A	9.3	6.5	20.8	17.6	0
B	12.6	9.0	15.4	12.2	0
C	16.4	12.0	12.3	9.2	0
D	28.9	21.0	5.1	2.9	0
E	13.5	0.6	9.4	5.0	27
F	12.5	2.8	14.0	10.2	0
G	7.8	1.9	14.9	10.9	0
H	11.7	4.0	9.6	6.0	0
I	16.0	6.7	6.6	3.4	0

Recommendations

For the selection of a sampling plan, two situations must be differentiated:

- Control of hides that go to new customers or as samples of new articles;
- Normal production control.

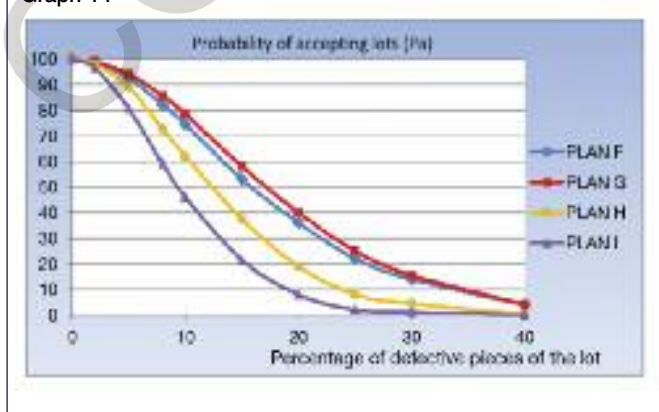
In the case of control of samples of new articles for customers, the most appropriate is 100% control, since there should be no risk in the approval of an article or a new client, just to reduce the percentage of inspection.

In the case of normal production, plan H ($n = 8$, $c_1 = 1$, $c_2 = 2$) applied to all batches seems to be the one that provides sufficient protection.

It should be noted that even with sampling plan H a risk of β error of 9.6% is assumed in the lot-to-lot control, which is reasonably good for controlling a production of several lots but it is high for only one in particular.

Finally, the selection of a sampling plan must have the approval of the company's management, being aware of the cost and the β risk that is assumed. As was discussed earlier in the control of the tear strength of a leather production, there is no sampling plan capable of providing a β risk = 0.

Graph 14



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