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THE DISTRIBUTION OF FAILURE DATA FOR MEAT PRODUCTS

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SUMMARY

The cumulative relative frequency distributions of complete failure data for i) evident microbial growth on the surface of frankfurters, ii) off-flavor development in frankfurters and iii) off-flavor development in hamburger mix, did not differ significantly from those of the corresponding normal distributions.

Good fits were obtained in hazard plots for the Weibull and log-normal distributions for i), ii) and iii). The fit of the normal hazard plot was also good for iii) and acceptable for i) and ii).
The percentiles of these distributions were in very close agreement. Typical results were, for the 50th percentile of i): 10,1; 10,4; 10,1 days for the Weibull, normal and log-normal hazard plots, and 9,9 days for the corresponding normal distribution. The latter did not, however, differ significantly from the hazard plot percentiles.

INTRODUCTION

The determination of shelf-life is associated with the definition of critical limits to the useful life of the product. These may be very easy to set for items like light bulbs, but in the case of food products they are always debatable. It is not only that deterioration processes of foods do not generally lead to a sudden termination of products life, but also that quality is often monitored through sensory testing, a very peculiar analytical tool (Dethmers, 1979; Griffiths, 1985).

The situation with some essential aspects, such as the precision of the determination, is thus very different in the case of food products, as compared with other commodities.

Still another matter is the treatment of shelf-life data of food products. Literature on the subject is rather scarce. Many papers have been published in which the shelf-life of meat products is determined, but very few have tackled the problem from a strict mathematical statistical point of view. Gacula (1975) and Gacula and Kubala (1975) pioneered the efforts to apply to food products methods originally developed for other commodities and situations (Nelson 1969). Newell (1981) has also given consideration to the problem.

This aspect of the problem acquires particular importance if shelf-life is to be expressed - as it should be - with a statistical meaning, that is, taking into account the unavoidable error margins of the determination.

Hazard plot methods for incomplete failure data (Nelson, 1969) have received special attention (Gacula, 1975; Gacula and Kubala, 1975), but their results have been accepted without comparing them with those obtained through an alternative method established as standard. Complete failure data have not been considered in this context.

The aim of this paper is to study the distribution of complete failure data of two meat products and to determine the compliance of statistically meaningful estimates of shelf-life obtained by this method with those achieved through hazard plotting.

MATERIALS AND METHODS

A total of 20 batches of frankfurters were prepared according to standard manufacturing methods, from 53 % pork (ca. 20 % fat); 15 % pork backfat; 1,4 % sodium caseinate; 28 % ice and 2,6 % salt, sodium nitrite and spices. The emulsion was filled into regenerated collagen casings 18-20 mm in diameter, hot smoked, steam cooked, water spray cooled and chilled in air at 0 °C overnight.

The sausages were loosely wrapped in paper, packaged in corrugated cardboard boxes - a common packaging procedure in many Cuban meat plants - and stored at 2° - 4 °C.

Every batch was inspected daily for occurrence of surface microbial growth and submitted to a test panel of 10-12 experienced judges in a simple acceptance-rejection test for development of off flavor. Tasting was carried out after scalding the sausages at 70° - 80 °C.

Statistical significance was determined according to a binomial distribution with p=0,1, rather than p=0,5, as the latter was considered too lenient from the point of view of the consumer. It is true, on one hand, that the strictly limiting condition of keeping quality is that in which the same sample, when assessed n times by the same judge, is accepted n/2 times. This situation, on the other hand, would mean rejection by 50 % of a population of similarly qualified tasters, which would be commercially unaceptable. The test, as applied, is biased towards an easier rejection of failed samples.

For every bacth evaluations were continued until final rejection. Two rejection times were noted: an earlier one, marked by evident surface microbial growth, and a later one, corresponding to off-flavor development.

The cumulative relative frequency distributions of both failure times were compared with the ones predicted for normal distributions of the same mean and variance, by a two-tail Kolmogorov-Smirnov test (Ostle, 1974).

Complete failure data, together with the corresponding censoring times, were analyzed by the hazard plot method, assessing their fit to the exponential, normal, log-normal, Weibull and extreme value distributions. Straight lines were fitted in all cases by the method of least squares.

Cumulative relative frequency distributions obtained from the percentiles estimated in the best fitting plots were compared with those derived from the normal distribution of the same mean and variance, also using the Kolmogorov-Smirnov test.

The same procedure was followed with 20 batches of hamburger mix (97,9 % beef; 1,8 % salt; 0,3 % spices). Portions of 250 g each, wrapped in plastic film, were the sampling units, from which portions of ca. 20 g were cooked and served hot to the judges.

Only off-flavor development was recorded in this case, but otherwise data collection and processing was identical to that of the sausage experiment.

RESULTS AND DISCUSSION

Table 1 shows the results of the goodness of fit test for the failure data obtained: the distribution of the experimental data does not differ at the 5 % level from the normal distribution of equal mean and variance.

This result supports the assumption that the probability of failure at a given time of storage can be calculated following the usual procedure based on the areas under the normal distribution curve. The calculation procedure, though, is somewhat complicated, as compared with the simpler approach offered by hazard plot methods.

Figures 1 to 5 show the Weibull, log-normal, normal, exponential and extreme value hazard plots, respectively, of experimental failure data for off-flavor development in frankfurters. It can be noticed that both the Weibull and log-normal hazard plots show a very close fit to a straight line, whereas in the normal and extreme value plots - particularly in the latter - the points are more scattered. The exponential plot, on the other hand, shows a large deviation from linearity.

the observed behaviour is very similar to that reported by Gacula and Kubala (1975), from the point of view of both the goodness of fit to a straight line and the deviation from linearity.

Table 2 shows the data of the test of goodness of fit of failure probability data obtained from the hazard plots to those estimated from the normal distribution adjusted to the experimental data. It can be seen that there is a very good fit, even in the case of hazard plots in which the scattering of the points is considerable, i.e. the normal hazard plot in Fig.3.

In his discussion of hazard plot methods, Nelson (1969) has stressed deviations from linearity, rather than scattering, as an important source of error. Scattering, however, increases uncertainty in the determination of regression parameters by the method of least squares, more so if the straight line is drawn by visual estimation.

Tables 3 and 4, finally, show storage times corresponding to the 50th and 5th percentiles, respectively, of the distributions that exhibited good fit in hazard plots, as compared to those of the normal distribution adjusted to the experimental data.

Whereas Gacula and Kubala (1975) tend to utilize the 50th percentile - corresponding to the mean for symmetrical distributions - as the estimate for shelf-life, it would seem more convenient to use a lower percentile, for the same reasons discussed before in connection with the binomial test for sensory data (cf. MATERIALS AND METHODS). A 5 % of failure probability is considered in our laboratory a convenient limit.

Newell (1981) has calculated probabilites of shelf-life failure at various times, another approach to more flexible ways of expressing shelf-life data.

As shown by the data in Tables 3 and 4, shelf-life estimates obtained by hazard plot methods are in close agreement with those obtained according to the alternative calculation using the normal distribution. This emphasized the advantage of hazard plot methods particularly when so many pocket calculators are programmed for straight line fitting by least squares.

The Weibull hazard plot is particularly convenient, since data can be plotted on ordinary "log-log" graph paper, to which only the probability scale must be added.

CONCLUSIONS

Complete failure data for the spoilage processes studied showed a distribution of frequencies which did not differ from that of a normal distribution.

Hazard plots for incomplete failure data showed good fit for the Weibull and log-normal, but not the extreme value and exponential distributions. The fit of the normal hazard plot was not so good as that of the Weibull or the log-normal, but was considered acceptable.

Probabilities of shelf-life failure obtained from Weibull, log-normal and normal hazard plots did not differ significantly from those calculated from the normal distribution.

Estimates of storage time for given values of shelf-life failure probability obtained from Weibull, log-normal and normal hazard plots were in close agreement with those calculated from the normal destribution adjusted to the experimental data.

Hazard plot methods are considered most convenient, given their results and ease of utilization. Weibull hazard plots are particularly attractive, since only ordinary "log-log" graph paper is required.

Table 1. Test of goodness of fit of sensory failure time data to the normal distribution

Product and type of spoilage	Kolmogorov-Smirnov Tabulated (5%)	Statistcs Calculated
Sausages, off-appearance	0,294	0,1651
Sausages, off-flavor	0,294	0,1646
Hamburger mix,off-flavor	0,294	0,0672

Table 2. Test of goodness of fit of failure probability data estimated from hazard plots to estimates obtained from the adjusted normal distribution (critical tabulated value for the Kolmogorov-Smirnov statistic, 20 samples, 5% 0,294)

	Kolmogorov-Smirnov statistics		
	Weibull	Log-normal	Normal
Sausages, off appearance	0,1102	0,1102	0,1202
Sausages, off-flavor	0,1881	0,1609	0,1381
Hamburger mix,off-flavor	0,1175	0,1079	0,0775

Table 3. Storage times corresponding to the 50th percentile of tested distributions

	Hazard plot			Normal distrib.
	Weibull	Log-normal	Normal	
Saus.off-apperar.	10,1	10,1	10,4	9,9
Saus.off-flavor	15,4	15,0	15,1	14,4
Hamb.off-flavor	6,2	6,2	6,3	6,1

Tabla 4. Storage times corresponding to the 5th percentile of tested distributions

	Hazard plot			Normal distrib.
	Weibull	Log-normal	Normal	
Saus.off-appear.	7,0	7,3	7,2	6,5
Saus.off-flavor	11,5	11,2	11,6	10,8
Hamb.off-flavor	4,6	4,8	4,7	4,6

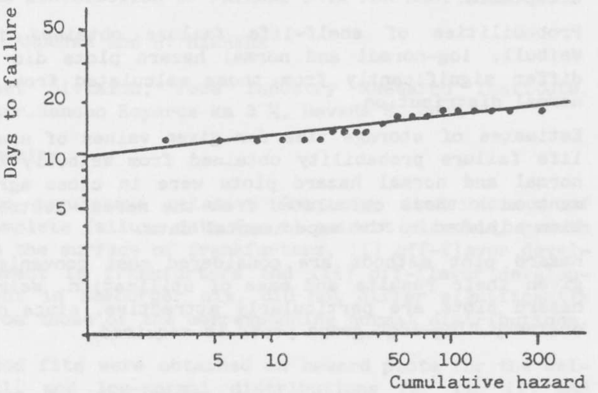

Figure 1. Weibull hazard plot. Off-flavor development in frankfurters.

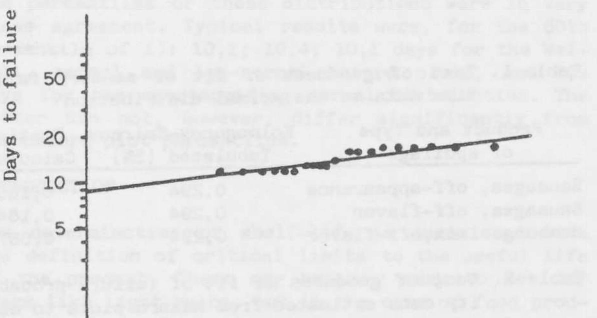

Figure 2. Log-normal hazard plot. Off-flavor development in frankfurters.

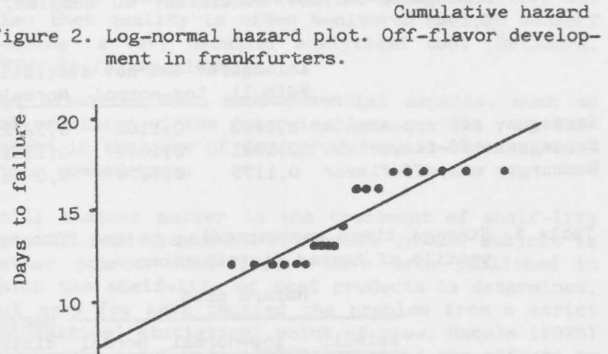

Figure 3. Normal hazard plot. Off-flavor development in frankfurters.

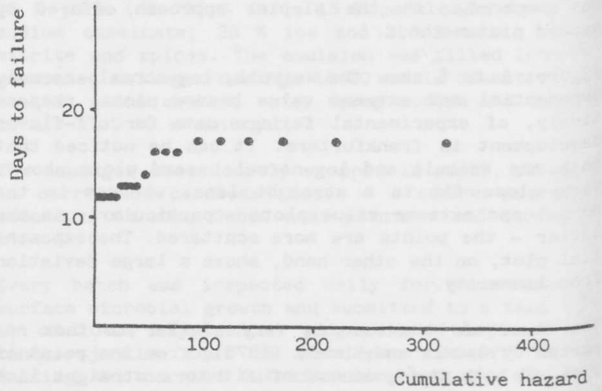

Figure 4. Exponential hazard plot. Off-flavor development in frankfurters.

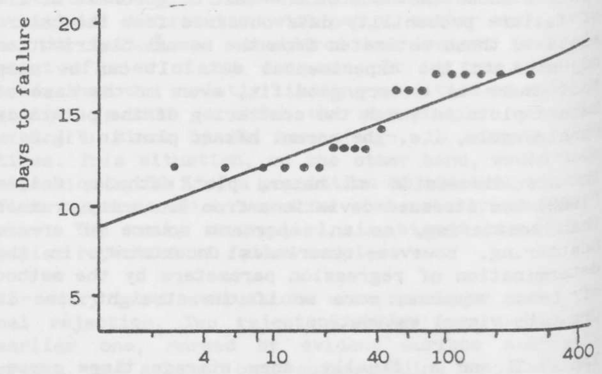

Figure 5. Extreme value hazard plot. Off-flavor development in frankfurters.

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