THE PREDICTION OF FOOD-PRODUCT SHELF-LIFE

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INTRODUCTION

The prediction of spoilage is an interesting field in food microbiology. Microbiologists have developed various approaches to the prediction of the likely shelf-life or microbiological safety of foods (Baird-Parker 1987). The formula given by Sinell (1980) predicts the shelf-life as a function of temperature, making it possible to calculate the shelf-life of the product at a certain temperature, if the shelf-life of the same product is known at some other temperature. The formula is the following:

$$D = D_0 * 10^{(t_0 - t)/20}$$

where D_0 is the shelf-life at a known temperature t_0.

The spoilage of vacuum-packed cooked ring sausages has been studied during the last few years in some detail (Korkeala **et al.** 1985; Korkeala and Lindroth 1987; Korkeala **et al.** 1987). The main sensory defects arising during storage have been shown to be a fermented, sour aroma and taste; lactobacilli have been shown to predominate in the surface layer of the sausages. This knowledge can be used in the development of spoilage models.

The purpose of the present work is to test the formula given by Sinell (1980) on vacuum-packed cooked ring sausages.

MATERIALS AND METHODS

The Sausage Samples

The study dealt with the shelf-life of 28 production runs of vacuum-packed cooked ring sausages at different temperatures. The storage temperatures were 2, 4, 8 and 12°C, at which sausages of 6, 10, 6 and 6 production runs, respectively, were stored. Every production run included 9-14 sausage packs, which were investigated after different storage times. A total of 313 sausage samples was studied.

Sensory Evaluation

The samples were evaluated using the scoring method (Amerine **et al.** 1965). The details of the evaluation procedure have been described by Korkeala **et al.** (1987).

Microbiological Methods

A 5 g sausage sample (2 mm layer of the surface, including the skin) was homogenized with 45 ml of 0.1% (w/v) peptone water. The homogenate and serial 10-fold dilutions in 0.1% peptone water were used for microbial analyses. The pH was measured from the homogenate.

The aerobic plate count was determined by the poured plate method using APT agar (Difco). The plates were incubated for 5 days at 20°C. The colony forming units (cfu) determined on Rogosa SL agar (Orion Diagnostica, Espoo, Finland) by the method of Rogosa et al. (1951) are referred to as lactobacilli. The detection limit for lactobacilli was 10 bacteria/g. When no lactobacilli were detected in the sample, a value of 5 was assigned for statistical purposes.

Shelf-life

The shelf-life of the production run was defined sensorily as the time when 2 out of ten judges considered the sausage of the production run unfit and microbiologically as the time when the lactobacilli count exceeded 10^7 cfu/g.

Statistical Analysis

The formula given by Sinell (1980) can be expressed in linearized form as

$$(1)\ \text{Log}(D) = \text{constant}_0 - 0.05 * t$$

where $\text{constant}_0 = \text{Log}(D_0) + 0.05 * t_0$.

This expression can be tested in two ways. If empirical shelf-lives for a number of temperatures and production runs are available, the following linear regression formula is suggested:

$$(2)\ \text{Log}(D_i) = a + b * t_i + \text{error}_i$$

where D_i is the observed shelf-life of production run i, t_i is the storage temperature of production run i and error_i is the statistical error term related to observation i. The two unknown parameters a and b can be determined from the data by the least-squares method. The values of a and b thus arrived at can then be used to predict the shelf-lives of the same product at other temperatures; with a sufficient number of observations, statistical confidence limits can also be established for the predictions. The formula given by Sinell actually goes further, and makes the claim that the value of b equals -0.05. This hypothesis has been tested by an F-test appropriate for regression coefficients.

Another way to test the formula is to apply the original

Table 1

Shelf-life (mean and range) of cooked ring sausages evaluated sensorily and microbiologically at different storage temperatures

Temperature	Shelf-life (days)	
	Deemed sensorily unfit	Lactobacilli > 10^7 (cfu/g)
2° C	52 (48-62)	ND[a]
4° C	42 (27-55)	29 (16-51)
8° C	28 (21-32)	18 (13-22)
12° C	16 (11-22)	13 (9-16)

[a] ND = not determined

formula or formula (1) directly. All that is needed is an estimate of shelf-life at one temperature. We determined D_0 by substituting the arithmetical average of shelf-lives at temperature t_0 for D_0. We calculated D_0 for each temperature available in the data (2°C, 4°C, 8°C and 12°C) and tabulated the predictions given by each temperature for all other temperatures. The T-test was used to test the predictions against the outcomes. The confidence limits for these t-tests were adjusted for the large number of mutually dependent tests.

Table 2

Predicted shelf-lives calculated from a given temperature for other temperatures using the formula of Sinell

Given temperature	Predicted shelf-life (days)						
	Deemed sensorily unfit				Lactobacilli > 10^7 (cfu/g)		
	2° C	4° C	8° C	12° C	4° C	8° C	12° C
2° C		41	26	16			
4° C	52		25	16		18	11
8° C	55	44		17	28		11
12° C	52	38	24		31	20	

RESULTS

The shelf-lives of vacuum-packed cooked ring sausages at different temperatures are presented in Table 1. At 2°C, microbial growth was detected only in some of the production runs, and the determiantion of shelf-life was therefore possible at this temperature only by sensory evaluation.

The coefficient estimates from our data were -0.053 when spoilage was evaluated sensorily and -0.047 when based on the lactobacilli count (10^7 cfu/g). These coefficients do not deviate significantly from those given by the formula of Sinell (1980) (-0.05) (F-test, $p = 0.90$ and 0.78, respectively). The overall fit of the formula was also fairly good using both sensory spoilage criteria and lactobacilli count ($R^2 = 0.77$ and $R^2 = 0.61$, respectively).

Table 2 shows the predicted shelf-lives at other temperatures calculated from a given temperature using the formula of Sinell. No statistically significant differences were found between the predictions and the outcomes.

DISCUSSION

The shelf-life evaluated in terms of sensory criteria is much longer than that based on a lactobacilli level of 10^7 cfu/g. Delayed changes in nonmicrobial parameters in vacuum-packed meat products were also reported by Reuter (1970). However, the formula given by Sinell (1980) gives a good prediction using both sensory and microbiological criteria. In addition, the formula is simple to apply.

Our findings show that Sinell's formula offers a useful approximation to the prediction of shelf-life when the shelf-life at a given temperature is known from past experience or, preferably, when the shelf-life for several temperatures has been established experimentally.

However, further research may produce more accurate prediction tools, using another type of functional dependence (the formula is linear on the logarithmic scale) and/or including other background factors in the prediction formula.

REFERENCES

Amerine, M.A., Pangborn, R.M. and Roessler, E.B. (1965). Principles of Sensory Evaluation of Food, Academic Press.

Baird-Parker, A.C. and Kilsby, D.C. (1987). *J. Appl. Bacteriol.* Symposium Supplement No. 16, **63**: 43S-49S.

Korkeala, H. and Lindroth, S. (1987). *Int. J. Food Microbiol.* **4**: 105.

Korkeala, H., Lindroth, S., Ahvenainen, R. and Alanko, T. (1987). *Int J. Food Microbiol.* **5**:311.

Korkeala, H., Lindroth, S., Suihko, M., Kuhmonen, A. and Penttilä, P-L. (1985). *Int J. Food. Microbiol.* **2**:279.

Reuter, G. (1970). *Arch. Lebensmittelhyg.* **21**:257.

Rogosa, M., Mitchell, J.A. and Wiseman, R.F. (1951). *J. Dent. Res.* **30**:682.

Sinell, H.-J. (1980). Einführung in die Lebensmittelhygiene, Verlag Paul Parey, Berlin.