A New Shelf-Life Failure Model

G. J. NEWELL
Hawkesbury Agricultural College, Richmond, N.S.W. 2753, Australia

(Received for publication October 14, 1980)

ABSTRACT

A new statistical model for shelf-life failure is proposed. This model is based on consideration of the basic physical characteristics of the shelf-life failure process rather than ad hoc reasons such as goodness-of-fit tests.

In food protection, considerable attention has been paid to determining the shelf-life of food products (1, 2, 4, 7, 8, 9, 10). Recently designs for use in stability studies of food products have been developed (5), as well as statistical models for shelf-life failure (6). However, in development of these shelf-life failure models, the distributions were chosen based on ad hoc reasons, such as statistical goodness-of-fit tests. In this paper, a new shelf-life failure model is proposed, which is based on considerations of the basic physical characteristics of the shelf-life failure process rather than those of goodness-of-fit. This model is illustrated with an example from shelf-life data.

MATERIALS AND METHODS

In development of shelf-life failure models, Gacula and Kubala (6) introduced the Weibull and lognormal distributions. The choice of these models was based on adequacy of fit as assessed by graphical techniques and the Kolmogorov-Smirnov goodness-of-fit test. While these distributions met these criteria, the decision was not based on any consideration of the characteristics of the shelf-life failure process. As such, any further shelf-life failure models that are developed should take these characteristics into account.

A fatigue-life model has been developed (3) which takes the failure process into account and as such, the resulting Birnbaum-Saunders distribution appears quite suitable to explain shelf-life failure. This fatigue-life model treats the food product as being subjected to a series of stresses during its shelf-life, with failure being due to the cumulative effect of these stresses exceeding a critical level for the first time. This is typically the process during the shelf-life of refrigerated food products. For this model, the resulting probability of shelf-life failure at or before a given time $t$ has been shown (3) to be given by

$$ F(t) = \Phi \left( \frac{1}{\alpha} \left( \frac{t}{\beta} \right)^{\frac{1}{2}} \right) $$

where $\Phi (t)$ is the distribution function of the standard normal distribution. This functional model involves two parameters with the parameter of main importance, $\beta$, being the scale parameter which may be interpreted as the median shelf-life and $\alpha$ being the shape parameter which may be interpreted as a measure of the stresses that a food product undergoes during its shelf life. From this distribution, the median shelf-life can be obtained as well as the probability of shelf-life failure by some specified time, thus enabling a reasonable shelf-life to be determined for the food product.

RESULTS AND DISCUSSION

The Birnbaum-Saunders distribution was fitted to shelf-life failure data from (6) with the Kolmogorov-Smirnov test indicating a suitable fit ($P < 0.05$). Estimates of $\alpha$ and $\beta$ were obtained using the procedures of (3), these being 0.29 and 41.10, respectively. Since $\beta$ can be interpreted as the median shelf-life, this procedure gives a median shelf-life of approximately 41 days as compared to that obtained by (6) of approximately 42 days when using the Weibull distribution. Table 1 gives the probability of shelf-life failure for various shelf-times, with these results indicating shorter shelf-life than those obtained by (6).

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Birnbaum-Saunders</th>
<th>Weibull</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>4.4</td>
<td>7.0</td>
</tr>
<tr>
<td>30</td>
<td>14.0</td>
<td>13.5</td>
</tr>
<tr>
<td>35</td>
<td>29.1</td>
<td>26.0</td>
</tr>
<tr>
<td>40</td>
<td>46.4</td>
<td>39.0</td>
</tr>
<tr>
<td>45</td>
<td>62.1</td>
<td>55.0</td>
</tr>
<tr>
<td>50</td>
<td>74.9</td>
<td>72.0</td>
</tr>
</tbody>
</table>

Because of the ability of the Birnbaum-Saunders distribution to conform to the observed shelf-life failure data as well as its physical justification as an explanation of the shelf-life failure process, it is evident that this distribution is a highly suited model for shelf-life failure.

REFERENCES

Ten yeasts were isolated from the ‘khundi’ samples in counts of \(5.0 \times 10^3\) to \(6.2 \times 10^2\): Candida albicans (from 41 samples), Candida krusei (from 20 samples), Candida tropicalis (from 35 samples), Rhodotorula glutinis (from 33 samples), Saccharomyces guttulata (from 25 samples), Saccharomyces tellulidis (from 30 samples), Torulopsis candida (from 40 samples), Torulopsis glabrata (from 30 samples), Trichosporon cutaneum (from 25 samples), and Tricosporon pullulans (from 30 samples). Seven of these yeasts were isolated from the fresh meat: C. albicans, C. krusei, C. tropicalis, R. glutinis, S. guttulata, S. tellulidis, and T. glabrata; two additional ones were present in the fresh meat: Candida slooffii and Candida utilis. The counts in the fresh meat were \(0.73 \times 10^2\) to \(5.8 \times 10^4\).

Sixteen species of molds were isolated from the ‘khundi’ samples: Aspergillus flavus (from 42 samples), Aspergillus glaucus (from 20 samples), Aspergillus niger (from 34 samples), Aspergillus oryzae (from 35 samples), Cladosporium fulvum (from 15 samples), Fusarium moniliforme (from 20 samples), Geotrichum candidum (from 18 samples), Mucor mucedo (from 34 samples), Mucor racemosus (from 20 samples), Penicillium candidum (from 20 samples), Penicillium citrinum (from 28 samples), Penicillium expansum (from 21 samples), Phycyomyces sp. (from 10 samples), Rhizopus stolonifer (from 25 samples), Sporotrichum carnis (from 20 samples), and Staphylococcus cocosporum (from 12 samples). Eight of the same molds were found in the fresh meat: A. flavus, A. niger, A. oryzae, C. fulvum, G. candidum, M. mucedo, M. racemosus, and P. expansum; two additional ones were found: Rhizopus nigricans and Thanamidium elegans.

Boiling, smoking, and drying can produce dual effects on the meat. Only a few of the microorganisms will survive the boiling and the hydrocarbons from the smoke. Drying reduces the water activity of the meat which results in further reduction in number of surviving organisms. Some of the sporeforming organisms may survive these adverse conditions and remain to contaminate the dried meat. However, it is expected that most contaminants found in the dried meat resulted from recontamination because the procedures of handling the dried meat were no better in most instances than those used in handling the fresh meat. It is expected that the sources of contamination will vary from place to place as the methods for preparing and transporting the dried meat are not standardized. ‘Khundi’ is transported in various containers, such as metallic bowls and jute bags, and the meat may be left uncovered in the market where it is touched by many customers during examination for purchase. It is not surprising that ‘khundi’ is highly contaminated.

Although the types of illnesses that occur after the eating of ‘khundi’ are not well documented, the high degree of contamination, particularly with molds, implicates microbial contamination in the illnesses. A study is underway to determine what toxins may be present in the ‘khundi’.

**REFERENCES**


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Newell, *con't. from p. 580*