SHELF-LIFE PREDICTION OF VACUUM-PACKAGED, COOKED MEAT PRODUCTS

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SUMMARY

In order to develop mathematical models to predict the shelf life of vacuum-packed cooked meat products, the effects of four important controlling factors on the growth of Lactobacillus curvatus was determined in a meat model system. Growth curves were modelled using the modified Gompertz model (Zwietering et al., 1990). Subsequently models were developed that described the effects of the controlling factors on lag time and growth rate of Lactobacillus curvatus. Models describing the effect of temperature on lag time and growth rate will be discussed here. An extended model describing the combined effect of temperature, salt, nitrite and lactate is being developed.

Introduction

The shelf-life of refrigerated vacuum-packaged, cooked meat products mainly depends on the growth and spoilage activity of lactic acid bacteria. Some time after the number of lactic acid bacteria has reached 10^7 - 10^8 per gram or per cm^2, spoilage becomes evident by souring and possible slime and/or gas formation. A level of 10^7 cfu/g is often used as a practical level to determine the product's shelf-life.
Lactic acid bacteria often isolated from spoiled vacuum-packaged meat products include Lactobacillus curvatus and Leuconostoc dextranicum (Dainty et al., 1992; von Holy et al., 1991). In our research, these species were also found to be important species within the spoilage flora.
Important intrinsic and extrinsic factors determining the growth and spoilage activity of the spoilage flora in vacuum-packaged cooked meat products are salt, nitrite, lactate and storage temperature. The effect of these so-called "controlling factors" has to be quantified in order to develop models that predict the shelf-life of these products.

Experimental design

The effect of temperature, salt, nitrite and lactate on the growth of these lactic acid bacteria was determined in a meat model system, i.e. vacuum-packaged Bologna-type sausage. This meat model system was used in place of liquid laboratory media to approach practical conditions as closely as possible. The Bologna-type sausage was prepared according to a standard recipe, with different contents of salt (1, 2% NaCl), nitrite (30, 60 mg/kg $NaNO_2$) and lactate (0, 1, 2 and 3% sodium lactate). After pasteurization, the sausage was inoculated with a pure culture of L. curvatus while mixing and mincing in a laboratory cutter. The initial level of L. curvatus was 10^4 cfu/g. Single packages were prepared and stored at 0, 3, 7 and 15°C. At different time intervals, varying with storage temperature, samples were taken. Growth of L. curvatus was measured using the Man-Rogosa-Sharpe agar (MRSA, Oxoid code CM361). Spread plates were incubated anaerobically (BBL, Gaspack plus) at 30°C, and counted after 3 days.

Fitting of the data

Growth curves were fitted with the modified Gompertz model (Zwietering et al., 1990). This resulted in estimates of the length of the lag time (λ, in h), maximum specific growth rate (μ_{max}, in h^{-1}) and the asymptotic value $A = \ln(N_\infty/N_o)$ with N_∞ being the maximum number of bacteria reached (cfu/g) and N_o being the initial number of bacteria present (cfu/g).

The effect of temperature (T) on growth rate (μ_{max}) was described with the square-root model of Ratkowsky (Ratkowsky et al., 1982; Muermans et al., 1993; Zwietering et al., 1991):

$$\sqrt{\mu_{max}} = b_1 (T - T_{min}) \qquad (1)$$

where b_1 is a regression coefficient (in $h^{-1/2}K^{-1}$), and T_{min} is the theoretical temperature at which the growth rate is zero (K).
The effect of temperature (T) on lag time (λ) was described with another modification of the square root model (Muermans et al., 1993; Zwietering et al., 1991):

$$\ln(\lambda) = \ln\left\{\left[b_2 (T - T_{min}) \right]^{-2}\right\} \qquad (2)$$

where b_2 is a regression coefficient (in K^{-1}), and T_{min} is the theoretical temperature at which the lag time is infinite (K).

Results

Both temperature and salt are important controlling factors. Nitrite and lactate have an additional inhibitory effect, especially at low temperature and high salt concentrations. Figures 1 and 2 show the datum points and fitted growth curves of L. curvatus in Bologna-type sausage at different storage temperatures and salt concentrations (Figure 1) and different nitrite and lactate concentrations (Figure 2).
As storage temperature decreases and salt concentration increases, the lag phase increases and the growth rate decreases. The inhibitory effect of salt increases at lower storage temperatures (see Figure 1). The additional inhibitory effect of nitrite and lactate is evident especially when temperatures are low and salt concentrations are high. Extreme conditions also have an effect on maximum cell number (see Figure 2): maximum cell number decreases when temperatures are low and salt (results not shown), nitrite and lactate concentrations are high. This illustrates the risk if shelf-life is predicted solely on the basis of cell numbers. Under extreme conditions, a "spoilage level" of 10^7 cfu/g may not be reached, but the metabolic activity of the spoilage flora will still cause spoilage eventually.

Modelling the effect of temperature

The square-root model (equation 1) and the lag-time model (equation 2) were fitted to the square root of the growth rate and the logarithm of the lag time, respectively. Datum points and fitted curves for Bologna-type sausage containing 2% salt and 0, 1, 2 and 3% lactate are shown in Figures 3 and 4.
Both models described the data very well. The estimated value of T_{min} was 269 K in equation 1 and 268.5 K in equation 2. This is in fair agreement with previous research (Muermans et al., 1993), where values of 267.7 K and 267.9 K were found respectively.

Shelf life prediction

In Figure 5, an example is given of the use of equations 1 and 2 for predicting the effect of a change in storage temperature during a imaginary distribution process of a vacuum-packaged, cooked meat product.
Figure 5 clearly illustrates that temperature has an important effect on shelf-life, especially when storage times increase.

Conclusions

- Modifications of the square-root model of Ratkowsky can be used to describe the effect of temperature on lag-time and growth rate of lactic acid bacteria in vacuum-packaged, Bologna-type sausage.
- For reliable shelf-life predictions, besides predicting growth of the spoilage flora, also the spoilage activity of the relevant spoilage flora should be taken into account
- Predictive models are useful tools in process optimization, product development and HACCP.

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