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Abstracts of Poster Presentations

J.S. Almeida, M.T.O. Barreto, E.P. Melo and M.J.T. Carrondo
A Kinetic Method for Calculating the Viability of Lactic Starter Cultures

J.M. Baker and M.W. Griffiths
Predictive Modeling of Psychrotrophic *Bacillus cereus*

T. Mattila-Sandholm, E. Skyttä and S. Piepponen
Application of a Temperature Gradient Incubator and Automated Turbidometry in Predicting the Antibacterial Activity of *Pediococcus damnosus* against Gram-negative Organisms

H. Chen and C.W. Donnelly
Development of a Computer-aided HACCP Program to Control *Listeria* in Dairy Plant Environment

P. Dalgaard
Modelling of Growth and Metabolic Activity of Fish Spoilage Bacteria

M.W. Peck, D.A. Fairbairn and B.M. Lund
Growth from Heat-Damaged Spores of Non-Proteolytic *Clostridium botulinum*

Y.-H. Duh, S.A. Alber and D.W. Schaffner
A Comparison of the Effect of Temperature on the Growth Rates of *Listeria innocua* and *Listeria monocytogenes*

J.S. Dickson, G.R. Siragusa and J.E. Wray, Jr
Predicting the Growth of *Salmonella typhimurium* on Beef Using the Temperature Function Integration Technique

R.C. McKellar, H.W. Modler, H. Couture, A. Hughes, P. Meyers and T. Gleeson
Predictive Modeling of Milk Pasteurization

J. Meng and C.A. Genigeorgis
Modeling Lag Phase of *Clostridium botulinum* Toxigenesis in Cooked Turkey Meat: Effects of Temperature, Sodium Lactate, Sodium Chloride and Spore Inoculum

J.H. Wells, Y.Y. Zhao and D.L. Marshall
Modifications to the Classic Arrhenius Equation for Microbial Growth Rate Determinations during Modified Atmosphere Storage

J. Torsella, C. Lam and K.M. Pruitt
Applications of Statistical Distribution Functions to Survival Curves

D.N. Kamau and K.M. Pruitt
D Value Estimates for Complex Survival Curves

Laura L. Zaika, John G. Phillips and Robert L. Buchanan
Model for Aerobic Growth of *Shigella flexneri* under Various Conditions of Temperature, pH, Sodium Chloride and Sodium Nitrite Concentrations

Robert L. Buchanan, James L. Smith, Christina McColgan, Benne S. Marmer and Brian Dell
Response Surface Model for the Effects of Temperature, pH, Sodium Chloride, and Sodium Nitrite on the Growth of *Staphylococcus Aureus* 196E

Robert L. Buchanan, Lori K. Klawitter, Ricarda V. Goins and John G. Phillips
Updated Response Surface Models for Predicting the Effects of Temperature, pH and Sodium Chloride Concentration on the Aerobic and Anaerobic Growth of *Escherichia coli* 0157:H7

C.L. Little, M.R. Adams, M.B. Cole and W. Anderson
Modelling the Effect of Temperature, pH and Acidulant on the Survival of *Yersinia enterocolitica*

C.L. Little, M.R. Adams, M.B. Cole and W. Anderson
Comparison of the Quadratic-type Response Surface Model and the Square Root Model for Predicting the Growth Rate of *Yersinia enterocolitica*

A Kinetic Method for Calculating the Viability of Lactic Starter Cultures. J. S. ALMEIDA*[1]. M.T.O. BARRETO[2], E.P. MELO[1], M.J.T. CARRONDO[12]. 1) Lab. Eng. Bioquimica FCT/UNL, 2825 Mt da Caparica, Portugal; 2) CTQB/IBET Apartado 127, 2780 Oeiras, Portugal.

A simple kinetic method of assessing the viability of a lactic starter culture is presented. The method is based on a two population growth model that evaluates the inocula growth capacity. It was used on Lactobacillus plantarum inocula samples of different ages and with samples taken during chemostat runs at different dilution rates. The inocula were grown on sterile 100 mL flasks which were sampled at constant time intervals. The model predicted the culture behavior with accuracy and gave meaningful viability results. The parametric sensitivity evaluation was made in order to optimize the test sampling times. The advantages of this method are its simplicity once the intrinsic kinetic parameters have been established, its use of standard laboratory equipment and the fact that the results reflect the inocula growth capacity. This method is particularly suitable for starter cultures to be used in agroindustry.

Predictive Modeling of Psychrotrophic Bacillus cereus. J.M. BAKER* and M.W. GRIFFITHS. Dept. Food Sci., University of Guelph, Guelph, Ont. Canada.

Bacillus cereus has been implicated as the causative organism in many outbreaks of foodborne illness. Amongst the foods identified as vectors are dairy products, rice, and meat products. Many strains of the organism are capable of growth at refrigeration temperatures, and toxin production in milk at low temperatures (6°C) has been demonstrated. There is little information on the factors affecting toxin production by psychrotrophic Bacillus cereus. This study was designed to determine the effects of a number of environmental conditions including Aw, pH, temperature, aeration and starch concentration on growth and toxin production by strains of psychrotrophic Bacillus spp. using multivariate analysis. Brain Heart Infusion broth was used as basal medium, and growth was measured by monitoring optical density and plate counts. Toxin production was assayed by an immunological method and cytotoxicity with Vero and Hep-2 cells. Predictive equations for growth and toxin production will be described that show the factors having the greatest influence on both growth and toxicity were water activity and temperature.

Application of a temperature gradient incubator and automated turbidometry in predicting the antibacterial activity of Pediococcus damnosus against gram-negative organisms. T. MATTILA-SANDHOLM[1], E. SKYTTÄ[1] AND S. PIEPPONEN[2]. [1]Food Research Laboratory, VTT, Finland[2], Chemical Laboratory, VTT, Finland.

The stability and effectiveness of the antibacterial compounds produced by Pediococcus damnosus were studied against Gram negative organisms in minced meat medium at temperatures between 4 and 30°C. The gram-negative organisms investigated included Salmonella spp. and Pseudomonas spp. The samples were incubated in a temperature gradient system using Honeycomb strips (Labsystems, Finland) or grid cuvettes (Biodata, Finland). The samples were taken out every second day for quantitative analysis using an automated turbidometer, Bioscreen (Labsystems, Finland). The turbidometer unit contained calibration curves for each tested strain and thus converted the bacterial growth curve parameters (area under the growth curve) to CFU-values. The results showed that the antibacterial compounds produced by Pediococcus damnosus were stable within the temperature range studied. The follow-up results were evaluated chemometrically in order to evaluate whether the antibacterial functions could be predicted for the growth risk of Gram negative organisms.

Development of a Computer-aided HACCP Program to Control Listeria in Dairy Plant Environment. H. CHEN* and C.W. DONNELLY. Dept. of Animal Sciences, The University of Vermont, Burlington, VT.

The Hazard Analysis Critical Control Points (HACCP) concept has been proven as a useful, workable and reliable tool for achieving quality assurance of food production. The implementation of a HACCP program includes developing a production flow chart, conducting risk analysis, selecting critical control points (CCPs), establishing the CCP criteria, monitoring the CCPs, correcting variation which exceeds a tolerable deviation, and recording. A system simulation technique could be used to enhance a HACCP program by mathematically integrating processing variables, environmental conditions and cleaning schedule to dynamically representing risk probability at each CCP. A simplified dairy foods plant with potential Listeria monocytogenes contamination was simulated as a model system to demonstrate the concept of the computer-aided HACCP program at work. Mathematical relationships used in the simulation included thermal resistance and growth of Listeria monocytogenes with processing engineering models. A hypothetical probabilistic model was also used to represent microbial contamination into production flow derived based upon the environmental presence of Listeria.

Modelling of Growth and Metabolic Activity of Fish Spoilage Bacteria. P. DALGAARD. Technical University, Bldg. 221, DK-2800 Lyngby, Denmark.

The aim of this study was to construct a predictive model for the effect of CO_2 on growth and activity of H_2S- and Trimethylamine (TMA) producing spoilage bacteria in cod fillets (GADUS MORHUA) stored at 0°C. The effect of CO_2 in concentrations ranging from 0 to 100% was studied with modified atmospheres containing only CO_2 and N_2. Storage experiments with fillets of freshly caught cod packed in plastic bags and studies with bacterial isolates inoculated into fish juice were carried out at 0°C. Growth of H_2S-producing bacteria were determined by pour plating in Iron Agar and the change in concentration of TMA were measured. Growth curves of H_2S- producing bacteria could in all experiments be described by the log-transformed 3-parameter logistic model and the production of TMA could be modelled by combining the growth model with the average yield factor for TMA (mg-N TMA/cfu of H_2S-producing bacteria). TMA has been proposed as a quality index for white fish stored at chill temperature. This model makes it possible to relate the growth of spoilage bacteria to the change in quality index. The effect of CO_2 on the specific growth rate and the yield factor could be described by simple equations.

Growth from Heat-Damaged Spores of Non-Proteolytic Clostridium botulinum. M.W. PECK*, D.A. FAIRBAIRN and B.M. LUND. AFRC Institute of Food Research, Norwich, UK.

Heat treatment at 85°C of spores in phosphate buffer, 0.067M pH 7.0, and enumeration of survivors on a nutrient medium gave a D-value of less than 1 min. Lysozyme inclusion in the nutrient medium increased the number of survivors detected; 5-10 μg/ml gave maximum recovery for most of the 6 strains tested (4B, 2E). Heat treatment of spores of 12 strains (5B, 5E, 2F) at 85°C and enumeration of survivors on medium containing lysozyme gave biphasic curves of log survivors against time of heating. A majority of the spores were inactivated rapidly, while inactivation of the remainder required a greater heat-treatment. Heating spores of strain 17B at 85°C for 120 min gave a 4.1 log inactivation, corresponding to a D-value of 29 min. Treatment of heated spores with agents to increase the permeability of the spore coat, prior to plating on medium containing lysozyme, increased the number of colonies formed by up to 100-fold for 3 strains tested (2B, 1E). With this treatment, heating spores of strain 17B at 85°C for 120 min gave a 1.6 log inactivation, corresponding to a D-value of 73 min. These results suggest that during heat treatment a lytic enzyme involved in spore germination was inactivated. In a small proportion of heated spores the spore coat was permeable to lysozyme, which resulted in germination and colony formation, whilst in the case of the majority of heated spores the spore coat was impermeable to lysozyme and the spores remained dormant and failed to germinate.

A Comparison of the Effect of Temperature on the Growth Rates of Listeria innocua and Listeria monocytogenes.
Y.-H. DUH, S.A. ALBER and D.W. SCHAFFNER. Department of Food Science, Rutgers University, New Brunswick, NJ.

The growth rates of Listeria innocua and Listeria monocytogenes Scott A were determined in Brain Heart Infusion broth between 2 and 46°C. The growth rate of L. innocua is greater than that of L. monocytogenes above 40°C. Several mathematical models which predict growth rate as a function of temperature were compared. TableCurve 3.01 (Jandel Scientific) was used fit model parameters to the data and to evaluate the models. All models evaluated, except the Cardinal Temperature model fit the L. innocua data better than the L. monocytogenes data. The Schoolfield model gave the best fit of the data for L. monocytogenes data (F-value 864). The Square Root model appears to fit the data better at low temperatures than at high temperatures for both organisms. At high temperatures the Schoolfield model fits the data for both organisms better than the Square Root model. The Cardinal Temperature model fit the data poorly for both L. innocua (F-value 60) and L. monocytogenes (F_2-value 84). A function of the form $y=(a+cx+ex^2)/(1+bx+dx^2+fx^3)$ was identified by TableCurve and fit the data well for both L. innocua (F-value 1039) and L. monocytogenes (F-value 476).

Predicting the Growth of Salmonella typhimurium on Beef Using the Temperature Function Integration Technique.
J.S. DICKSON*, G.R. SIRAGUSA and J.E. WRAY, JR. USDA-ARS, Roman L. Hruska, U.S. Meat Animal Research Center, Clay Center, NE.

Lag and generation times for the growth of Salmonella typhimurium on sterile lean beef were modelled as functions of cooling time under various carcass chilling scenarios. Gompertz growth models were fit to the $\log_{10}$ colony counts over time at each of six temperatures in the range of 15°C to 40°C. Lag and generation times were defined to be the points at which the second and first derivatives, respectively, of each growth curve attained a maximum. Generation time and lag time were modelled as functions of temperature using exponential decay models of the form $y = A + B*e^{-C}(temp.)$. Observed and hypothetical "cooling functions" of temperature over time were then combined with the models to predict the potential growth of S. typhimurium during the cooling cycle of beef carcasses, using a temperature function integration technique.

Predictive Modeling of Milk Pasteurization. R.C. MCKELLAR, H.W. MODLER, Agriculture Canada, and H. COUTURE, A. HUGHES, P. MEYERS, and T. GLEESON, Bureau of Microbial Hazards, Health & Welfare, Ottawa, Canada.

In order to support regulations aimed at ensuring the safety of heat processed dairy products, data on survival of food-borne pathogens and native milk enzymes in a pilot plant high-temperature short-time pasteurizer were obtained. A computer program was designed to calculate the integrated lethal effect, or pasteurization effect (P^*), at temperatures of 60-74°C and with holding tubes of 3-60 sec. Equations will be derived to relate values for P^* to log survival of enzymes or pathogens. Preliminary results with alkaline phosphatase the milk enzyme used as an indicator of pasteurization, indicate a good correlation between log survival and P^* (r^2 of .935), and suggest that predictive equations based on P^* could be used to assess the lethal effect of commercial pasteurization processes.

Modeling Lag Phase of Clostridium botulinum Toxigenesis in Cooked Turkey Meat: Effects of Temperature, Sodium Lactate, Sodium Chloride and Spore Inoculum. J. MENG and C.A. GENIGEORGIS*. Department of Epidemiology and Preventive Medicine, University of California, Davis, CA.

A mathematical model was developed for the lag phase (LP) of nonproteolytic C. botulinum types B and E in cooked turkey meat as affected by storage temperature (T) (4, 8, 12, 16, 20 and 30°C), sodium lactate (L) (0, 1.2, 2, and 3%) sodium chloride (S) (0, 1, and 2%), botulinal spore inoculum (I) (10^{-2} to 10^4), and their interactions. The derived model predictive of LP was: $\text{Log}(1/LP) = -2.2877 - 0.1235\,(S) - 0.2174\,(L) + 0.4391\,(t) + 0.0204\,(t)(I)$, where t is square root of temperature. The model explained 94.5% of the variation in results, in which t was the most influencing factor (65%), followed by L (21.2%), interaction of I and t (4.9%), and S (3.4%). The reliability of the model to predict LP was evaluated. The beneficial effect of increasing L and S concentrations and lowering of T on delaying toxigenesis was demonstrated quantitatively. The model predicted LP's longer than those observed in 28.3% comparisons, but only in 5.3% comparisons when 95% confidence intervals were calculated.

Modifications to the Classic Arrhenius Equation for Microbial Growth Rate Determinations during Modified Atmosphere Storage. J.H. WELLS, Y.Y. ZHAO and D.L. MARSHALL. Dept. of Agricultural Engineering and Dept. of Food Science, Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA.

Two modifications of the classic Arrhenius equation were developed to describe the combined effects of time, temperature and initial gas composition on the population growth rates of Listeria monocytogenes and Pseudomonas fluorescens during modified atmosphere storage. The first description was based on a modified and additive Arrhenius equation. Statistical analysis revealed that there was no significant interaction between temperature and $[O_2]/[CO_2]$ ratio such that a combined temperature and gas composition ratio term was not needed in an additive Arrhenius model. Within the additive model, the collision factor was expressed as an exponential function of $[O_2]/[CO_2]$ ratio. A second description related the activation energy term to initial $[O_2]/[CO_2]$ ratio for a modified atmosphere system. Growth rates of bacterial populations could be estimated by substituting a quadratic function of $[O_2]/[CO_2]$ ratio for the E_A constant in the Arrhenius expression. The mathematical descriptions were shown to be applicable for determining bacterial population growth rates in modified atmospheres for oxygen concentrations from 0% to 20.99% and carbon dioxide concentrations from 0.03% to 80%.

Applications of Statistical Distribution Functions to Survival Curves. J. TORSELLA, C. LAM, and K.M. PRUITT, Medical University of S.C., Charleston, SC 29425, and the University of Alabama at Birmingham, AL 35294.

Bacteria may be killed or inhibited by events which affect critical sites or cellular components. If these sites are randomly and independently distributed over the cell population and are affected independently with equal probabilities, then the fraction of the population responding as a function of the fraction of sites affected will follow statistical distribution functions. If a threshold, R, of the total, N, of critical sites on a cell must be affected before the cell responds, then the curves will follow the cumulative binomial distribution function (CUBINOM). We have used the incomplete beta function as an approximation to the CUBINOM and have developed methods for determining R from experimental data. When N is 10^4 or more, as it would be for many types of bacterial sites or components, the CUBINOM predicts very sharp transitions which do not resemble the experimental curves. For these cases, the experimental curves can be predicted from the CUBINOM by assuming that R and N vary from cell to cell.

D Value Estimates for Complex Survival Curves. D.N. KAMAU and K.M. PRUITT, Tuskegee Univ., AL 36088 and Univ. of Alabama at Birmingham, AL 35294.

The D value is the time required for a 10-fold reduction in cell number (N) after exposure to stress such as heat. When plots of $\log_{10}$ (N) vs. time are linear, D is a convenient measure of the sensitivity of the cells to the particular stress. When such plots are not linear, it is common practice to estimate D from the "linear" portion of the curve. For biphasic survival curves, there are two cell populations which differ significantly in their stress-sensitivities. Therefore such curves must be characterized by at least two D values together with an estimate of each population size. The "D value" alone provides no information about the length of time required for significant reduction in N when there is a pronounced lag in death. We have used a family of logistic models for analysis of biphasic survival curves and survival curves with a significant lag period. We used these models to quantiate the maximum killing rates (R_{max}) for each cell population and, as a measure of the lag phase, the time ($t_{1/2}$) required for a 50% reduction in N. We have also derived quantitative relationships between R_{max}, $t_{1/2}$, and the traditional D value.

Model for Aerobic Growth of Shigella flexneri under Various Conditions of Temperature, pH, Sodium Chloride and Sodium Nitrite Concentrations. LAURA L. ZAIKA*, JOHN G. PHILLIPS and ROBERT L. BUCHANAN. USDA, ARS, ERRC, Philadelphia, PA 19118.

Shigella is a major cause of foodborne gastrointestinal illness. A study was conducted to determine the growth characteristics of Shigella flexneri as influenced by several factors that have a large impact on bacterial growth. A modified factorial design was used to measure the effects and interactions of temperature (10 to 37°C), pH (5.5 to 7.5), sodium chloride (0.5 to 5.0%) and sodium nitrite (0 to 1000 ppm) on the aerobic growth of S. flexneri in Brain-Heart Infusion broth. A total of 592 cultures were analyzed, with growth curves being generated using the Gompertz equation. A quadratic model for growth of S. flexneri in terms of temperature, pH, sodium chloride and sodium nitrite concentrations was obtained by response surface analysis. This model provides an estimate of how bacterium will respond to any combination of the four variables within the specified ranges. Predictions obtained with the model compared favorably with observed growth of S flexneri in milk.

Response Surface Model for the Effects of Temperature, pH, Sodium Chloride, and Sodium Nitrite on the Growth of Staphylococcus Aureus 196E. ROBERT L. BUCHANAN*, JAMES L. SMITH, CHRISTINA MCCOLGAN, BENNE S. MARMER and BRIAN DELL. USDA, ARS, ERRC, Philadelphia, PA 19118.

The effects and interactions of temperature (12° - 45°C) initial pH (4.5 - 9.0), NaCl (0.5 - 16.5%), and $NaNO_2$ (0 - 200 ug/ml) the aerobic growth of Staphylococcus aureus 196E was studied using 250-ml baffled Erlenmeyer flasks containing 50 ml of Brain Heart Infusion broth (BHI). The flasks were inoculated with 0.3 ml of a diluted overnight culture to achieve approximately 10^3 cfu/ml. The cultures were incubated on a rotary shaker, sampled periodically, and enumerated on Tryptic Soy Agar. Growth curves were generated by fitting the data to the Gompertz equation using non-linear regression analysis. Growth kinetics were independent of inoculum size which allowed the Gompertz A term to be treated as a constant. However, the maximum population density (MPD) achieved by the cultures was dependent on the independent variables, requiring that it be modeled in addition to the Gompertz B and M terms. The MPD was then used to calculate the Gompertz C term. Quadratic and cubic response surface models were generated using various transformations of the data. Quadratic models using a LN-transformation provided reasonable predictions of the effects of the four variables on the growth kinetics of S. aureus, though additional data may be needed to increase the accuracy of the predictions at variable combinations producing marginal growth.

Updated Response Surface Models for Predicting the Effects of Temperature, pH and Sodium Chloride Concentration on the Aerobic and Anaerobic Growth of Escherichia cola 0157:H7. ROBERT L. BUCHANAN*, LORI K. KLAWITTER, RICARDA V. GOINS and JOHN G. PHILLIPS. USDA, ARS, Eastern Regional Research Center, Philadelphia, PA.

A three strain mixture was used to quantify the effects of temperature (5-42°C), initial pH (4.5 - 8.5), and NaCl content (0.5 -5.0%) on the aerobic and anaerobic growth of Escherichia coli 0157:H7 in Brain Heart Infusion (BHI). The microorganism was inoculated (approximately 1000 cfu/ml) into 50 ml portions of BHI in either 250-ml Erlenmeyer (aerobic) or sealed trypsinzing (anaerobic) flasks, and incubated on rotary shakers. Samples were removed periodically and enumerated by viable counts on BHI Agar. Growth curves were fitted to the data using a non-linear regression analysis in conjunction with an asymetrical sigmoidal (Gompertz) model. A total of 200 aerobic and 160 anaerobic growth curves were evaluated in three rounds of data generation/model validation, this represented 74 and 68 discrete variable combinations respectively. The Gompertz B and M terms were subsequently modeled in conjunction with various transformations of the data. A square root transformation of B and 1/M was favored since it allowed the incorporation of no growth data. The model provided reasonable estimates of how the microorganism is likely to behave in response to the four variables.

Modelling the Effect of Temperature, pH and Acidulant on the Survival of Yersinia enterocolitica. Little, C.L.*, Adams, M.R.*, Cole, M.B.§ & Anderson, W§. University of Surrey, Guildford, Surrey GU2 5XH, UK and §Unilever Research, Sharnbrook, Bedford MK44 1LQ, UK.

Many foods depend upon a combination of factors such as pH and reduced temperature for their shelf-life. Although growth of pathogens can be inhibited in such foods, they may survive for extended periods at levels that may be of concern to food safety. In view of the increasing use of multifactorial techniques of food preservation, there is a need for models which allow prediction of microbial survival times in such circumstances. Survival of the psychrotrophic foodborne pathogen, Yersinia enterocolitica, was studied at different temperatures and growth inhibitory pH values using a range of acidulants to develop such a model. At a given pH, survival was greater the lower the temperature. The bactericidal activity of the different acidulants was acetic ~ lactic > citric > sulphuric. Predictive survival models were constructed by analyzing the rate of death for a single curve fit. For each acid and pH a single predictive equation was constructed which described the rate of death over a range of temperature. The quality of the model was indicated by low mean square errors when predicted and observed values were compared. By placing the appropriate parameter estimates of the curve into the death rate equation with both the temperature and log time, survival of Y. enterocolitica could be predicted for each acid and pH over a range of temperature.

Influence of Wort Density and Cell Concentration on the Alcoholic Fermentation Kinetics and Intracellular and Extracellular Carbon Metabolites. P.H.A. SILVA[1], AND P. GERMAIN[2], DTA/UFV, Vicosa, MG, Brasil[1] and ENSAIA/INPL, Vandoeuvre-Les-Nancy-France.

Higher productivity in alcoholic fermentation is of great economic importance. The goals of this work are a comparative study of the ethanolic fermentation productivity and performance at two sugar concentrations and the characterization of the intracellular and extracellular evolution of some carbon metabolites according to the wort density and cell concentration at the start of each fermentation. The analytical points evaluated were cell concentration, ethanol production and sugar consumption during a usual brewery wort density fermentation (14°P) and a high brewery wort density fermentation (23°P). We also analyzed the concentration of fermentable carbohydrates, ethanol, acetic acid, pyruvic acid, glycerol, trehalose and glycogen inside and outside the cells during fermentations. A physiological model is analyzed.

A Predictive Polynomial Model for the Growth of Enterobacter agglomerans. A.P. DAMOGLOU* and R.K. BUICK, Department of Agriculture for Northern Ireland.

The prediction of spoilage of many foods is becoming a problem as food manufacturers move towards the use of minimal processing and fewer preservatives for many foods. One way of overcoming this problem is to develop mathematical models of the growth of spoilage organisms. The growth of the spoilage organism Enterobacter agglomerans has been measured over a wide range of temperature, pH and salt conc. The growth of the organism has been followed turbidimetrically using a temperature gradient incubator and a microtitre plate reader. Growth curves were fitted to these using a curve fitting program "Intersect" and employing a mathematical method which incorporated a transformation from optical density to numbers (M. Cole, personal communication). From these growth curves polynomial equations have been derived relating temperature, pH, salt conc. to the parameters of the sigmoid growth curves.

Comparison of the Quadratic-type Response Surface Model and the Square Root Model for Predicting the Growth Rate of Yersinia enterocolitica. Little, C.L.*, Adams, M.R.*, Cole, M.B.§ & Anderson, W.§ University of Surrey, Guildford, Surrey GU2 5XH, UK and §Unilever Research, Sharnbrook, Bedford MK44 ILQ, UK.

Various predictive models have been proposed that relate the effect of different parameters on the growth of microorganisms in foods. The Square Root model and the quadratic-type Response Surface model have both been used to describe the time to a given cell concentration (10^8) of Yersinia enterocolitica at varying conditions of sub-optimal temperature, pH and acidulant. Predictions from both models were compared with observed values for each acid and pH to look at the 'goodness-of-fit'. The Mean square error (MSE) for the Response Surface model was always smaller than that for the Square Root model except in 3 cases; Lactic acid/pH 5.5, Citric acid/pH 5.5 and Sulphuric acid/pH 6. This indicated that the Response Surface model is more reliable in predicting the growth rate of Y. enterocolitica under conditions of sub-optimal temperature and pH. Predictions from both models were compared with observed values of growth of Y. enterocolitica in UHT whole milk. The MSE for the Response Surface model was again smaller than that for the Square Root model. Differences in the fit of the two models was particularly noticeable at low temperatures (below 4°C) with the Square Root model predicting much longer times to growth than either the Response Surface model or the observed data. Use of the Square Root model under these circumstance would be 'fail dangerous'. It is therefore recommended that the Response Surface model is used in the prediction of food safety with respect to Y. enterocolitica under sub-optimal conditions.

The Use of Predictive Modeling for the Design of Microbiologically Safe Food. C. Adair, Unilever Research, Bedford, England.

Predictive models for the growth, death and survival of microorganisms in foods have become an essential tool for both product and process design with regard to their microbiological safety.

Bacterial growth models have been used for a number of years at Unilever Research in situations where temperatures are fluctuating. Simple integration of times and temperatures with the models are used, for example, to predict growth in foods in a chill distribution system from the factory to the consumer, and during a process where a bulk product is cooling after cooking to establish safe cooling times. In addition, growth models have been used in conjunction with models from other disciplines. For example, numerical simulations of flow and temperature distributions in process lines have been combined with bacterial growth models to predict bacterial numbers throughout a process line and give guidance on the hygienic design of processing equipment containing dead legs.

More recently, predictive microbial models have been incorporated into an expert system to provide an intelligent interface for the safe and consistent interpretation of predictions by the non-specialist.

A response surface model for predicting the effects of temperature, NaCl concentration, and pH on the aerobic growth of Aeromonas hydrophila. P.J. McCLURE. Unilever Research, Colworth Laboratory, Colworth House, Sharnbrook, Bedford, MK44 1LQ, U.K.

The combined effects of temperature (3°C to 20°C), NaCl (0.5% to 4.5%) and pH (4.6 to 7.0) on the aerobic growth of A. hydrophila (cocktail of strains) were studied in Nutrient Broth. Growth curves were generated from viable counts and fitted using the Gompertz equation. Quadratic response surface equations were fitted to the B and M Gompertz values, in response to the variables of temperature, NaCl and pH. The effects of various combinations of these controlling factors on growth of A. hydrophila are described. Comparisons between predicted growth rates from our response surface equations and other models, developed with viable counts and optical density measurements, are made, together with comparisons with data in the literature.

Shelf-life Predictions of vacuum-packed Bologna-type Sausage. M.L.T. Muermans*[1], F.K. Stekelenburg[2], and J.H.J. Huis IN T Veld[1,2]. [1]Utrecht University, Faculty of Veterinary Science, Dept. of the Science of Food of Animal Origin, PO Box 80.175, 3508 TD Utrecht; [2]TNO Nutrition and Food Research, PO Box 360, 3700 AJ Zeist, Netherlands.

The spoilage flora of vacuum-packed Bologna-type sausage consists of lactic acid bacteria, with the predominant species being Lactobaciluus curvatus and Leuconostoc dextranicum. A model for shelf-life prediction was developed using temperature (Temp) and water activity (A_w). Bolognas with A_w values of 0.992, 0.978, 0.965, and 0.952 were inoculated with one of the lactic cultures (starting count of 10^4 cfu/g), vacuum packed, and stored at 0, 3, 7, 15 and 25°C). Growth was measured by standard plating methods and growth curves characterized by Zwietering's modification of the Gompertz equation. The models of Ratkowsky and McMeekin were used to described the influence of controlling growth factors on growth rate. The growth curves for both organisms were similar at the lower three Temps and higher two A_ws. Both models describe the data well and may be used to predict the growth rate of the organisms in the product. Temp was an important factor controlling shelf life of the product, with shelf life doubling with a decrease of Temp from 7 to 3°C. Because the length of the lag phase was not considered, the shelf life predictions will be conservative.