

Meaningful Modeling of Microbial Growth Potential

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Outline

- Explanation of “useful” experimental modeling designs
- Show a method of analyzing data using a Time-to-Growth (TTG) technique

Useful Experimental Designs

- Accurate microbial challenge data in actual meat products can be difficult due to:
 - Variability in the data
 - Complexity of the meat products
- Desirable to have a model that covers a wide range of conditions and meat products
- The goal is to have a single model that works accurately for a wide range of commercial products, thereby providing a guide for product developers for formulations

Considerations for model selection

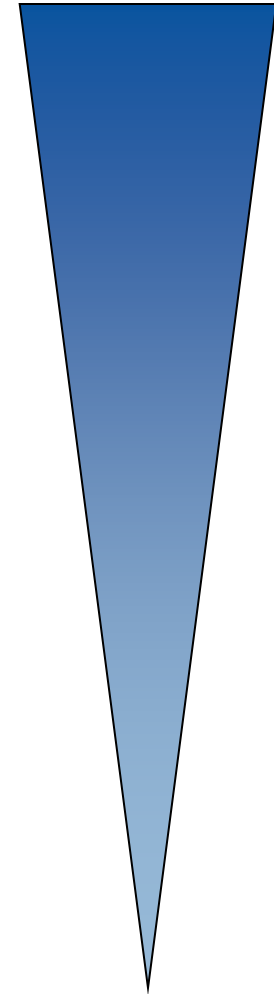
- **Parameter estimation properties** – relates to the procedures of estimating model parameters (estimates should be independent, identically distributed, normal)
- **Stochastic assumptions** – residuals should be normally distributed and independent of the magnitude of response
- **Parameter interpretability** – should have a biological interpretation of parameters
- **Parsimony** – no more parameters than are necessary
- **Correct qualitative features** – the analytical properties of the model function
- **Extendability** – when models are developed further, they should include the original simpler one as a special case

Ross et al., (1999). Predictive microbiology and Food Safety, Academic Press

Sources of error*

- **Homogeneity error** – complexity of food
- **Completeness error** – models are simplifications
- **Model function error** – models only approximate reality
- **Measurement error** – inaccuracies in the raw data
- **Numerical procedure error** – all errors that are a consequence of the numerical procedures used

Relative contribution to overall error

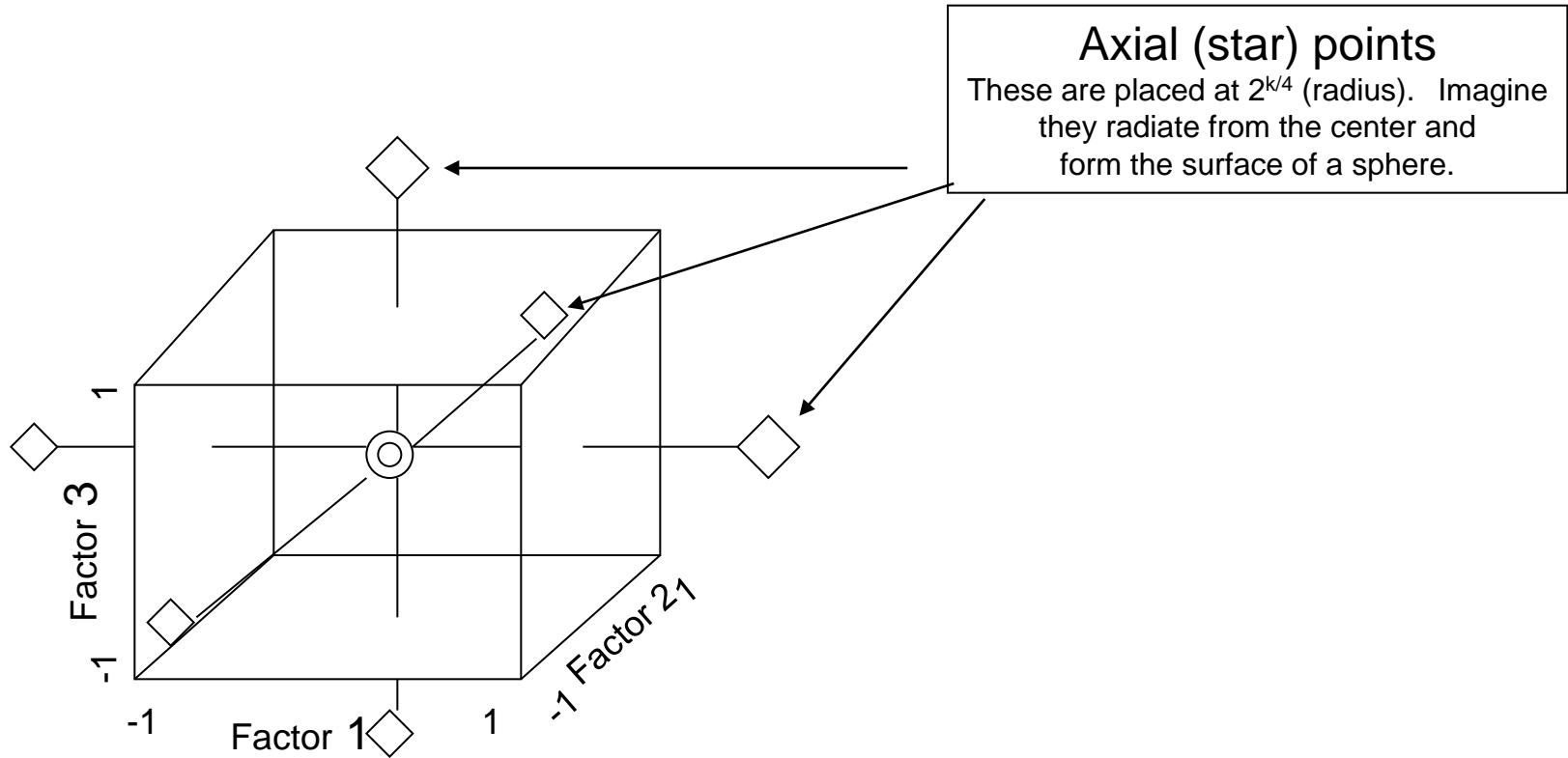


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Central Composite Experimental Designs

- Efficient
- Offer a systematic investigation of the main factors of interest as well as their interactions
- The number of factors is limited due to the number of runs; five or more becomes unmanageable
- The skill is for the experimenter to determine and control the important factors while minimizing and understanding the ones that cannot be controlled

Basic three factor central composite design



Experimental Design – Influence of sodium benzoate and sodium diacetate on growth of *Listeria monocytogenes* (Seman et al., 2008)

- Designed experiment: Central composite design with star (axial) points and repeated center points
- Decided upon the factors and ranges:

Factors	Low	Middle	High
Salt (%)	0.8	1.4	2
Benzoate (%)	0.08	0.165	0.25
Diacetate (%)	0.05	0.10	0.15
Moisture (%)	55	65	75

Considerations for product formulation

- Setting the values can cause treatment formula difficulties
- Formulate to minimum formula protein content
- Formula fat content co-varied with water content – this was not taken into account in the analysis
- Meat block in most treatments consisted of a blend of ham and small amounts of turkey breast

Growth models

- Kinetic models

- Plot cell numbers by time
- Use curve fitting programs to calculate growth parameters (growth rate, lag phase)
- Use the calculated growth parameters for prediction purposes

- Time-to-Growth models

- Plot cell numbers by time; determine the time to exceed a threshold
- Uses lifetime regression to calculate time-to-growth
- Can use all the data not just the data that exhibits growth

Data analysis of benzoate/diacetate data

- Listeria growth was plotted as count (log CFU/g) by time (weeks)
- Time-to-Growth (TTG) was defined as the time at which the average counts exceeded the inoculated level plus one log
- TTG values exceeding 18 weeks was noted as 18 weeks and were right censored
- The TTG data was analyzed using “Regression with Life Data” (Minitab)

Final regression equation

(after removal of non-significant terms)

$$\begin{aligned} \text{TTG} = & \exp[2.9169 + (0.56124S) + (1.00B) \\ & + (0.5408D) - (0.002M) + (0.1663SB) + \\ & (0.3155SD) - (0.101357SM) - (0.0718BD) \\ & + (0.356149BM) - (0.2656DM) - (0.08085BD) \\ & + (0.221129BM) - (0.373129DM) \\ & + (0.126852BDM)] \end{aligned}$$

TTG = log time-to-growth

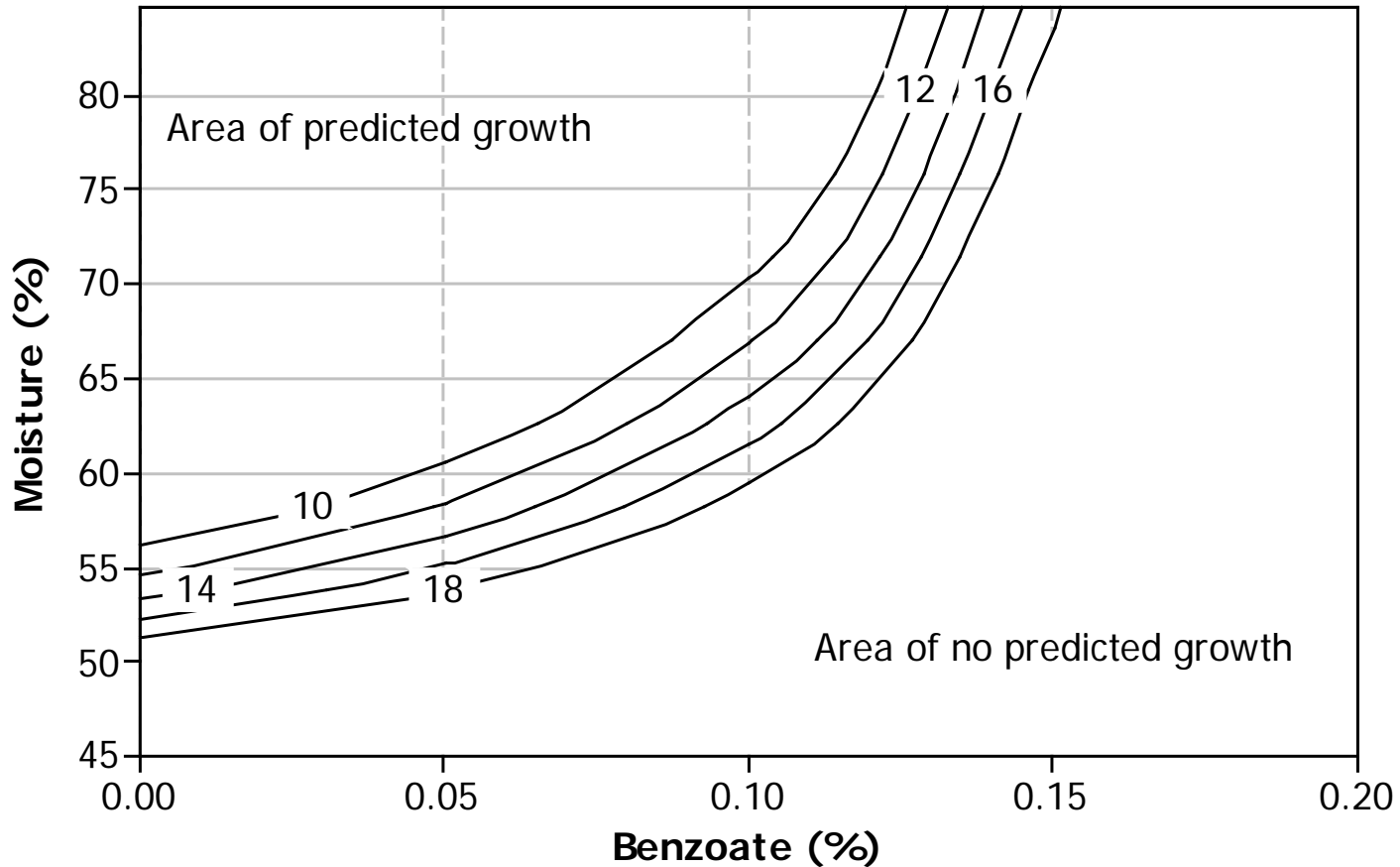
S = coded value for salt (%)

B = coded value for benzoate (%)

D = coded value for diacetate (%)

M = coded value for moisture (%)

Contour plot of moisture and benzoate



Salt content set at 2% and Diacetate content set at 0.1%



Thank you for your time!



Limitations to predictive modeling

- Assessment of initial conditions
- Relevance of model systems to foods
- Variability in responses
- Provision of 'user-friendly' technology
- Empirical nature of the current generation of models

Ross, McMeekin, and Baranyi, 1999., Predictive microbiology and food safety.

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Regression with Life Data

(Minitab)

- A regression using one or more predictors
- This differs from linear regression since it uses different distributions (rather than the normal distribution) and accepts censored data
- Censored observations are those for which the exact failure time is unknown

Modelling Scheme

