International Association for Food Protection®

WEBINAR

PRACTICAL APPLICATIONS OF MICROBIAL MODELING - WEBINAR SERIES

November 29, 2017 10:00 a.m. EST

Practical Applications of Microbial Modeling Webinar Series

Webinar Series:

Part I of III

- This IAFP webinar is sponsored by the following Professional Development Groups:
  - Microbial Modelling and Risk Analysis
  - Meat and Poultry Safety and Quality

International Association for Food Protection®
WEBINAR

Practical Applications of Microbial Modeling

Webinar Series: Part I of III

International Association for Food Protection®
WEBINAR

Dr. Betsy Booren

Senior Policy Advisor

Olsson, Frank, Weeda, Terman, and Matz PC

Washington, DC

WEBINAR HOUSEKEEPING

For best viewing of the presentation material, please click on 'maximize' in the upper right corner of the 'Slide' window, then 'restore' to return to normal view.

Audio is being transmitted over the computer so please have your speakers 'on' and volume turned up in order to hear. A telephone connection is not available.

Questions should be submitted to the presenters during the presentation via the **Q & A section** at the right of the screen

WEBINAR HOUSEKEEPING

It is important to note that all opinions and statements are those of the individual making the presentation and not necessarily the opinion or view of IAFP

This webinar is being recorded and will be available for access by IAFP members at **www.foodprotection.org** within one week.

Agenda

- Introduction
  - Dr. Betsy Booren
- Overview of Predictive Microbial Modeling
  - Dr. Tom Ross
- Tertiary Models for Estimation of Microbial Behavior in Real Situations – Meat Products
  - Dr. Peter Taormina
- Questions and Answers

Dr. Tom Ross

Director

ARC Industrial Transformations Training Centre for Innovative Horticultural Products

University of Tasmania

Tasmania, Australia

Dr. Peter Taormina

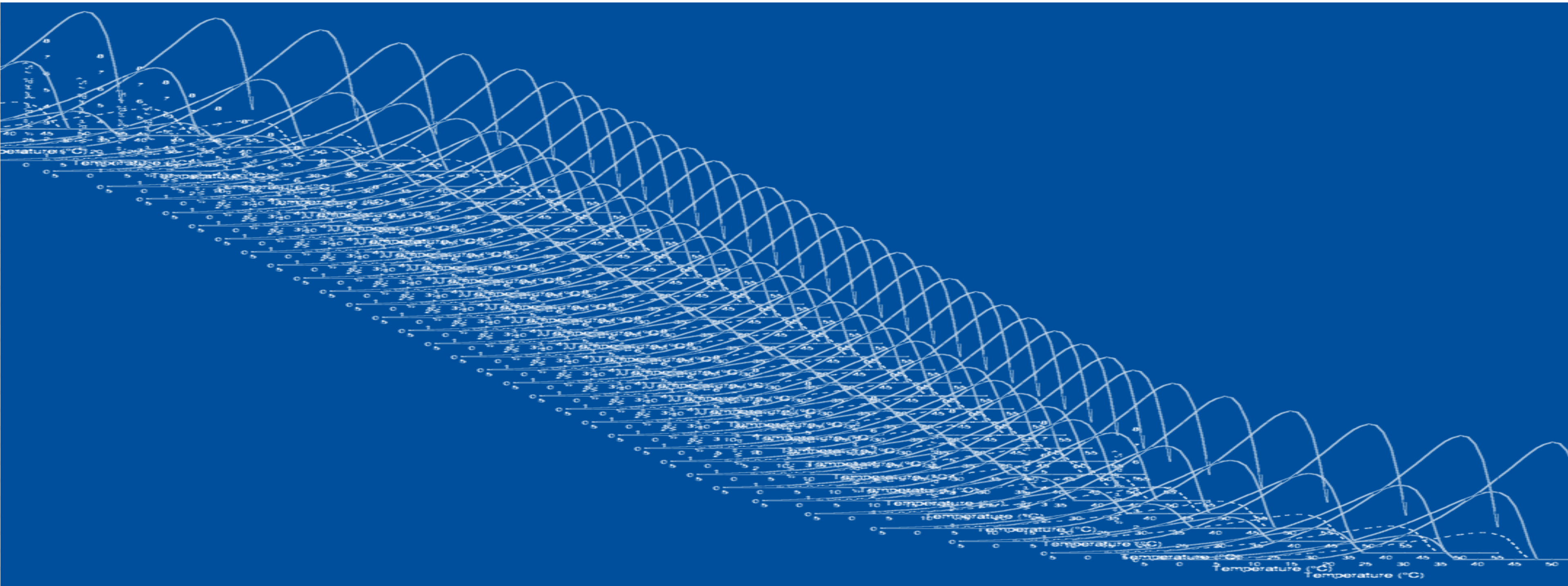
President

Etna Consulting Group

Cincinnati, OH

Overview of Predictive Microbial Modeling

Assoc Prof Tom Ross



Predictive Microbiology

- The ***quantitative*** microbial ecology of foods

Overview

- Basic concept of predictive microbiology
- Basic mathematical ideas
- Kinds of microbial responses that can be predicted
- Current status of predictive microbiology
- Building models
- How can predictive microbiology models help the food industry
- Critically assessing model applicability and reliability

Predictive Microbiology – basic ideas

- microorganisms react reproducibly to environmental conditions
  - the fundamental premise is that ***microorganisms [illegible] think***, so that they behave reproducibly (or "predictably") in ways dictated by their environment.

  thus

  - if we can measure their environment, we can predict what they will do, and how quickly they will do it.

do *you* all believe this?

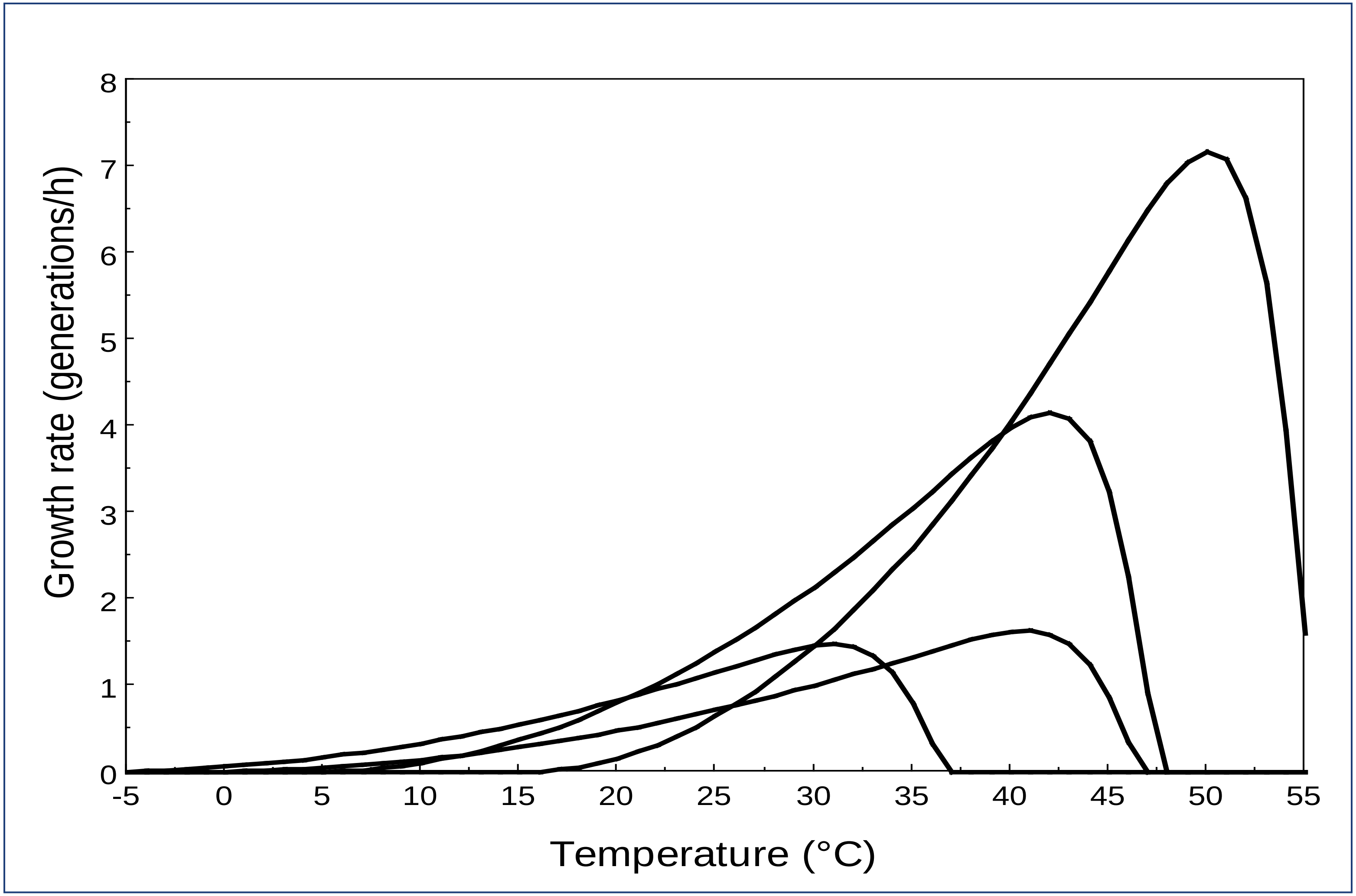
Modern Predictive Microbiology

"the growth responses of the microbes of concern would be modelled with respect to the main controlling factors such as temperature, pH and a_w *...*

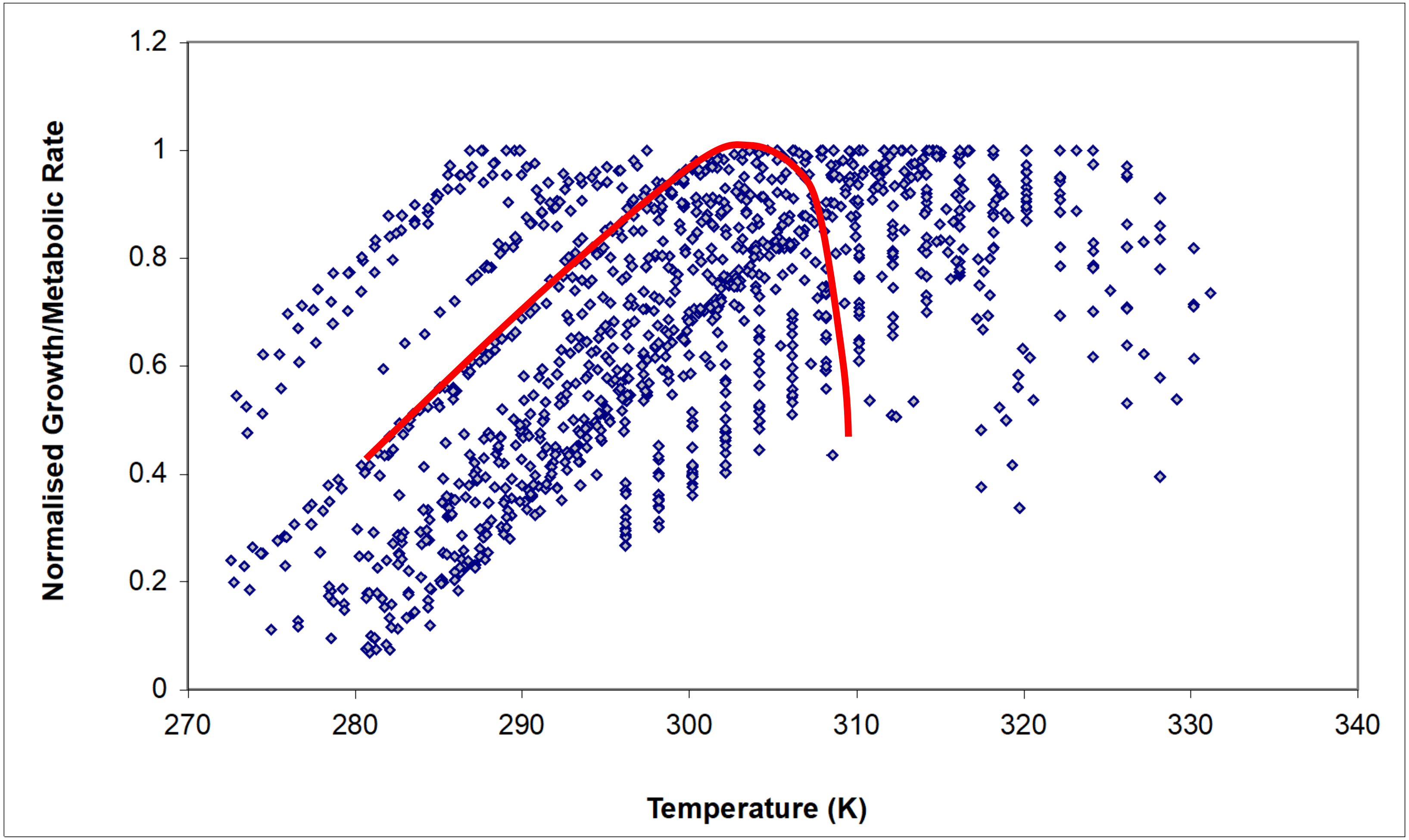
... Models relevant to broad categories of foods would greatly reduce the need for ad hoc *microbiological examination and enable predictions of quality and safety to be made speedily with considerable financial benefit."*

Roberts and Jarvis (1983; *Food Microbiology: Advances and Prospects*, Academic Press, New York, NY)

Consistent patterns of response: *the temperature-growth rate relationship*



Universality of the temperature-growth rate relationship



Predictive Microbiology - concepts

- there is a small number of environmental factors of main importance, namely:
  - *temperature*
  - *pH*
  - *water activity*
- for some foods this works, for processed foods its probably an oversimplification, so
  - *increasingly, as we adopt 'hurdle technology', other factors need to be considered explicitly:* e.g., *organic acid type and level, nitrite, gaseous atmosphere, smoke compounds, other microbes in the food, etc.*

Predictive Microbiology - concepts

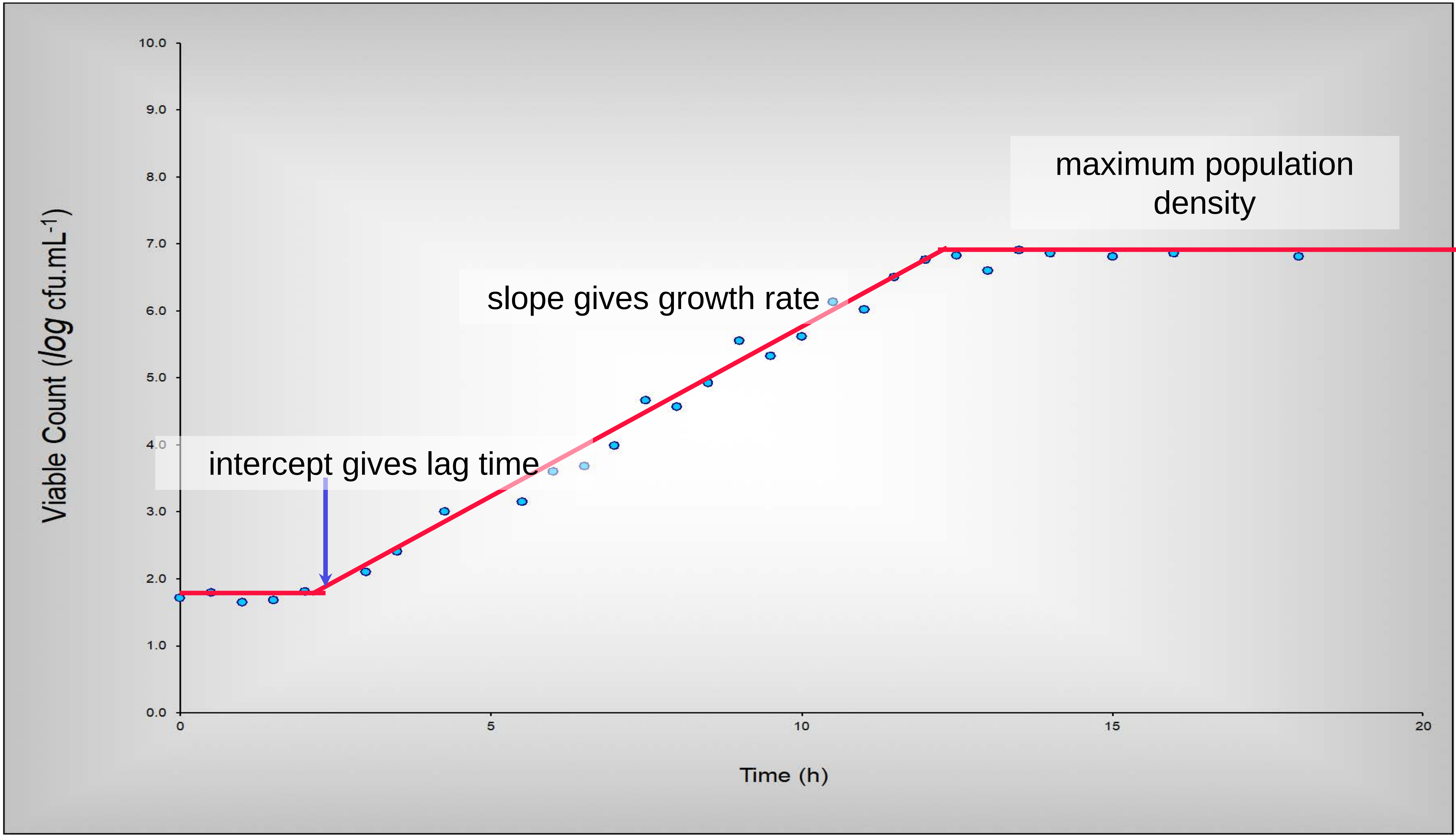
- main controlling factors - ***microbial death***

  its also assumed that *death rate* is affected by physicochemical conditions in the food, but normally death rate is most strongly governed by the treatment, *e.g.:*

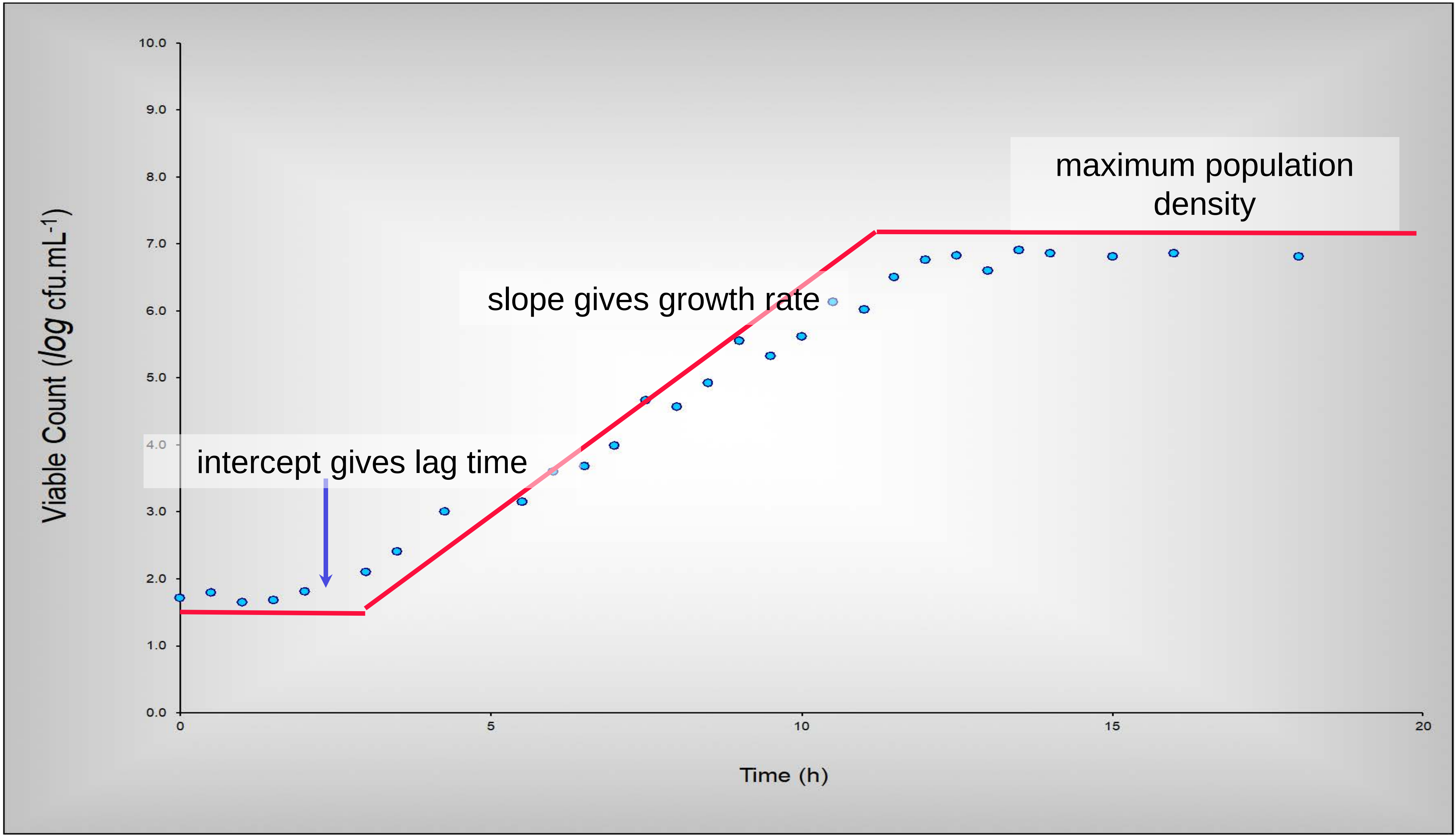
  - *temperature*
  - *pressure*
  - *irradiation (UV, gamma etc.)*
  - *electric field strength*

Basic mathematical ideas

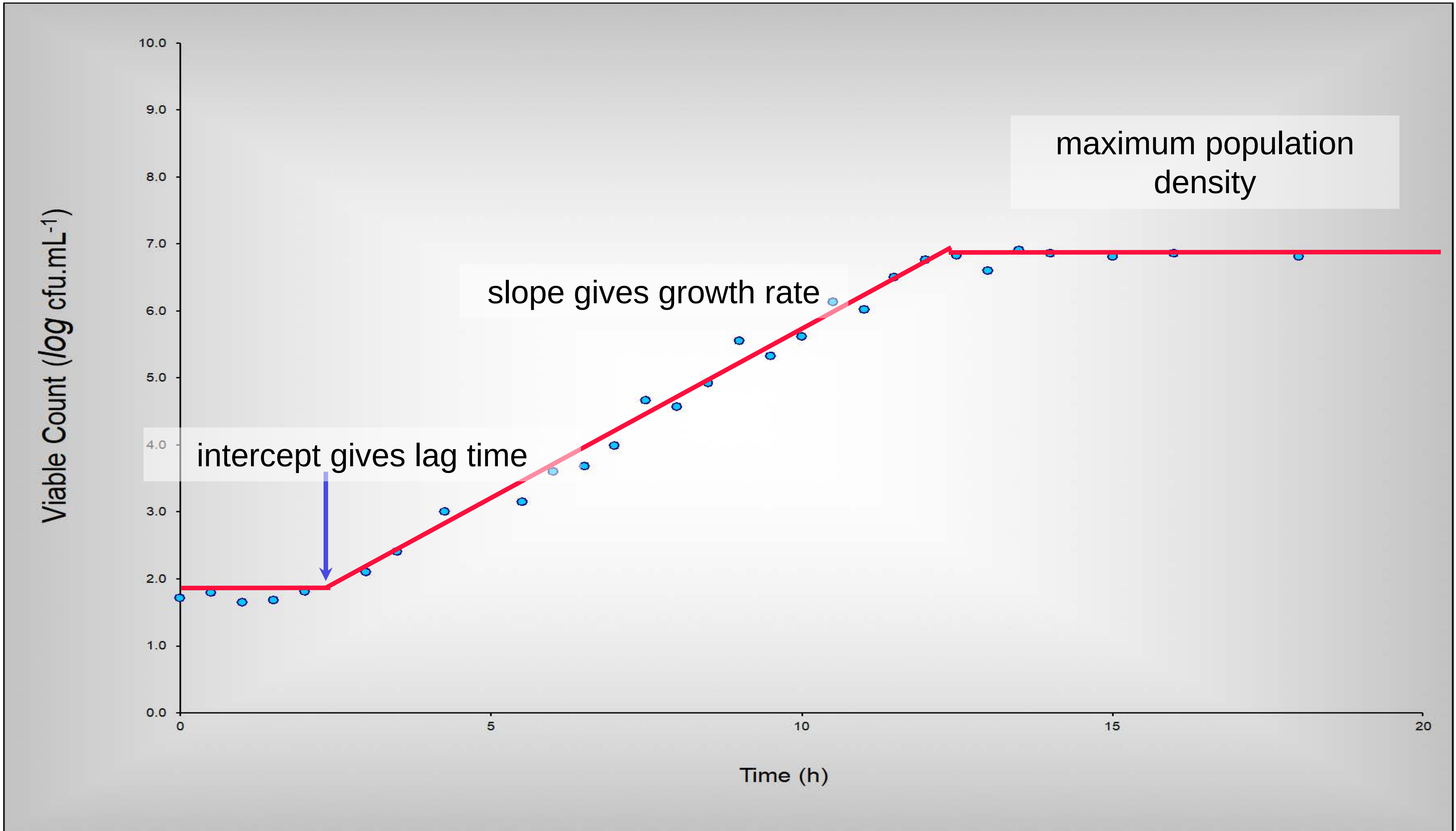
Summarising the microbial growth curve



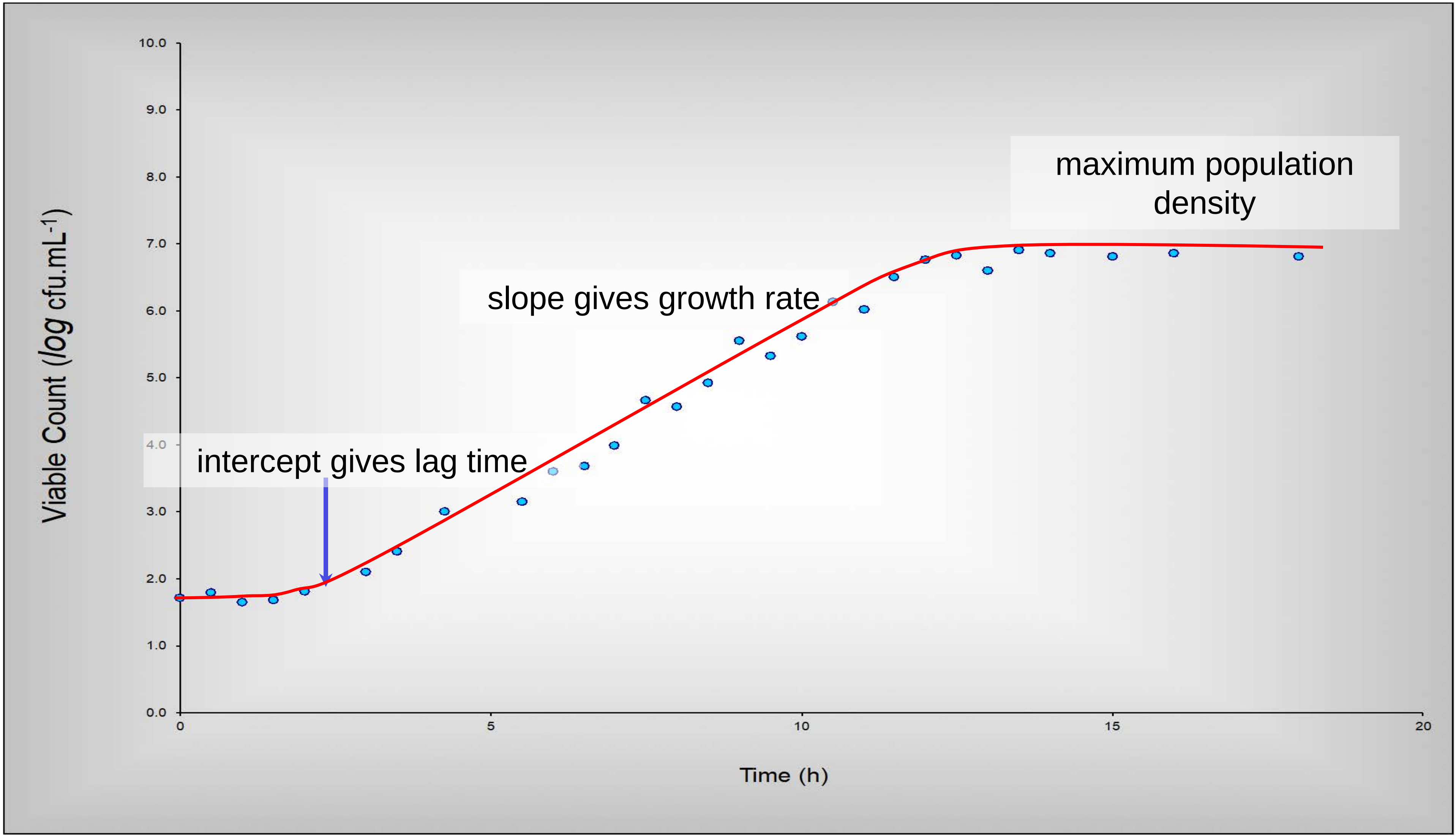
Summarising the microbial growth curve



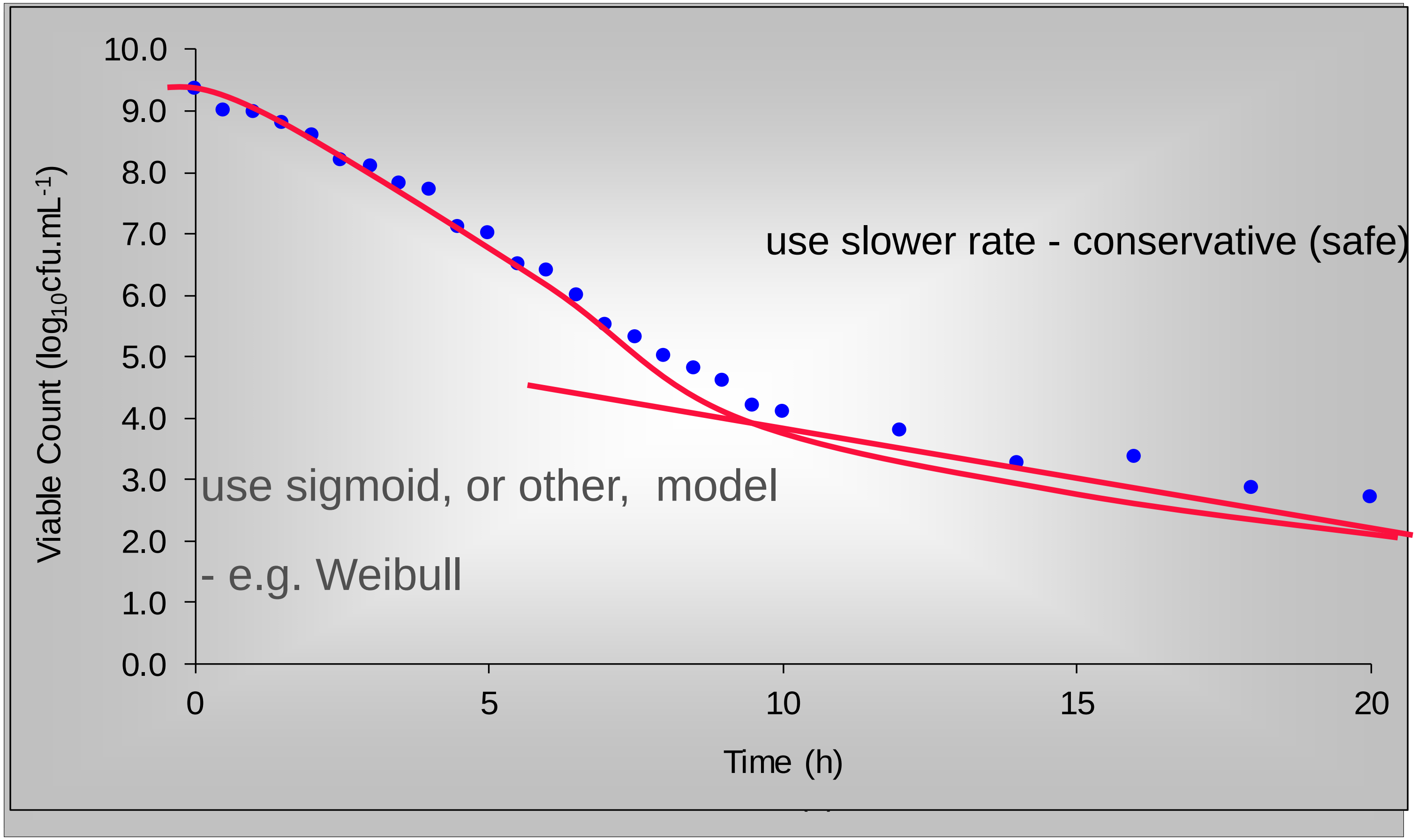
Summarising the microbial growth curve



Summarising the microbial growth curve



Inactivation modelling



Thermal inactivation kinetics: summary

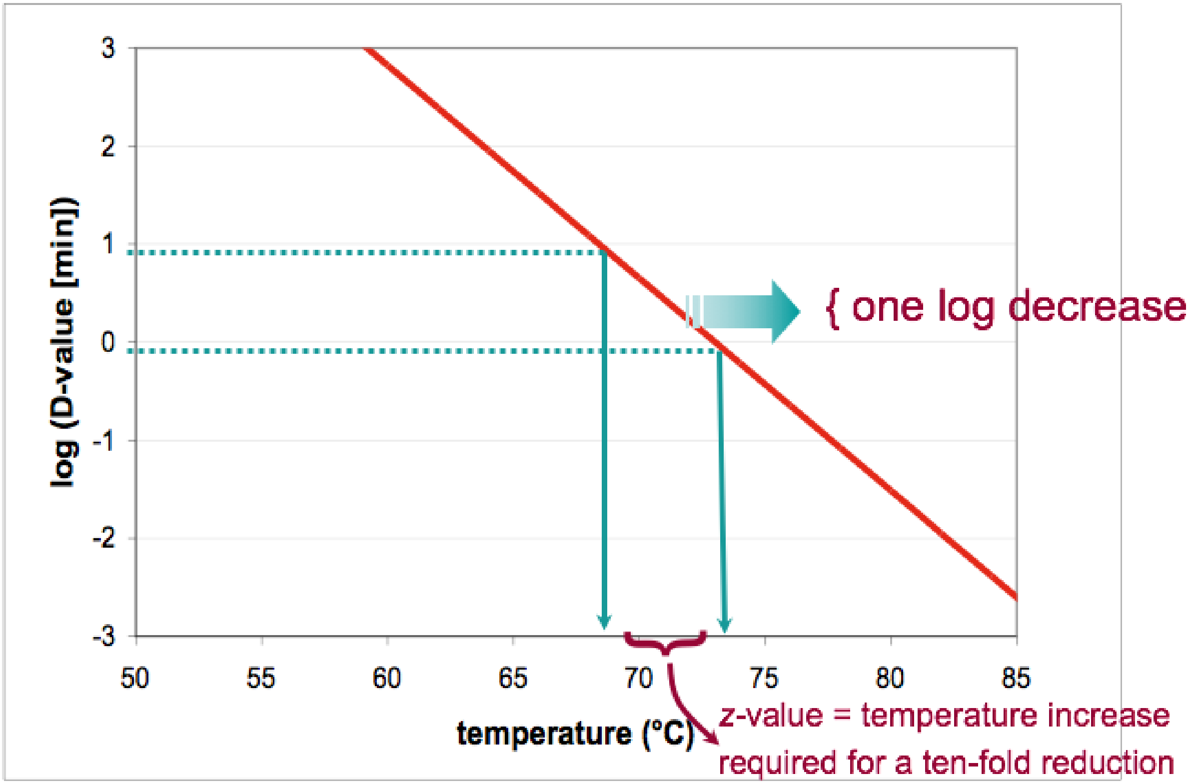
D-value

time required at given temperature to reduce microbial load by a facto of of 10

z-value

temperature increase required to reduce D-value by a factor of 10

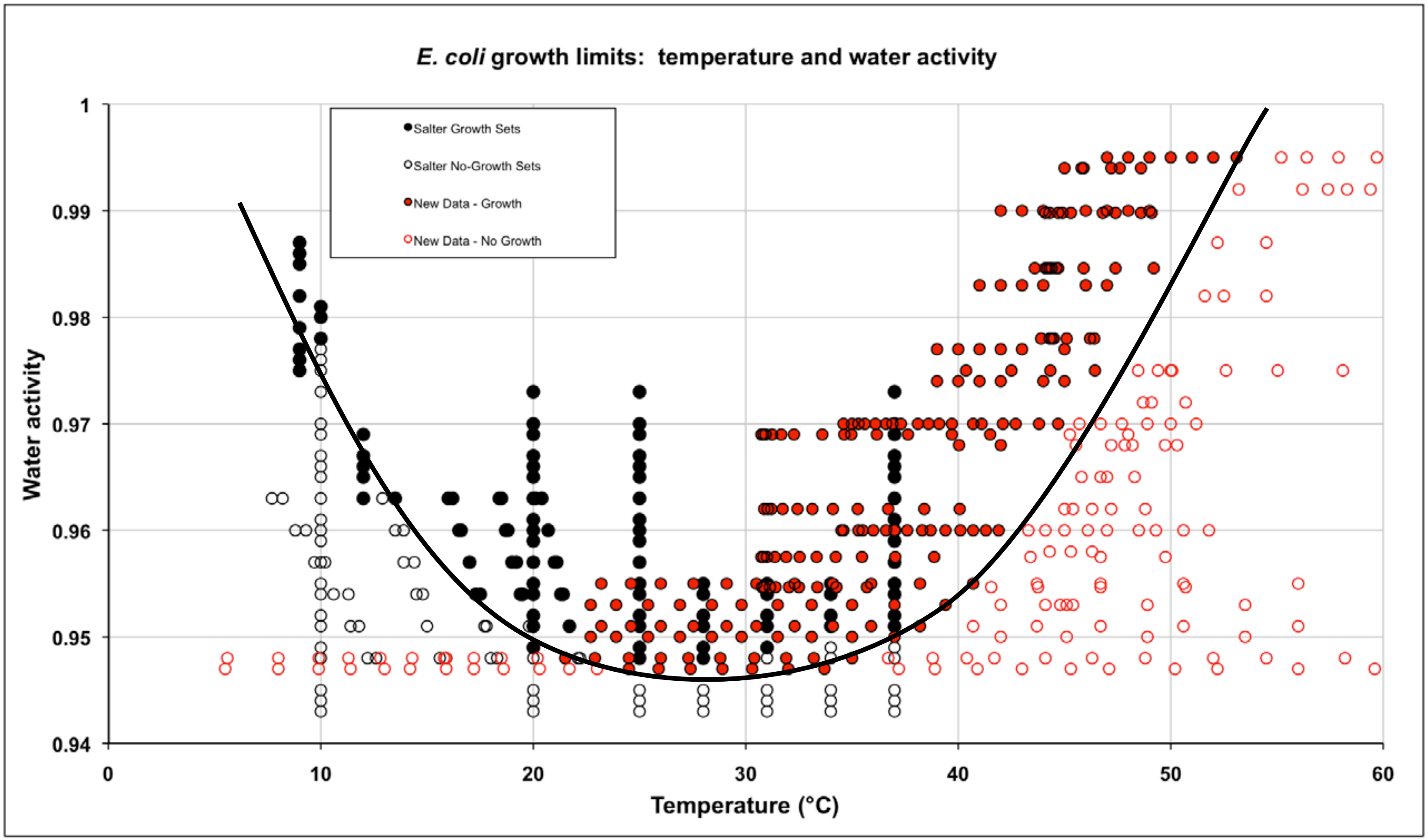
Analogous terms (Dp, Zp, ZpH) proposed for other lethal factors



What else can (or would) we 'predict'

- amount of microbial ***growth*** after time, (from temperature and product formulation; includes lag time, growth rate, germination and outgrowth of spores)
- ***reduction*** in microbial numbers over time, from knowledge of treatment conditions and product formulations (includes delay, death rate)
- ***probability of growth/toxin*** production
  - stability of foods (absolute or within defined time)
- ***sporulation***
- ***recontamination/cross-contamination processes***

Interaction of a_w and temperature on ***growth limits*** of *E. coli*



Data of Salter *et al*. (2000) for *E. coli* (augmented 2002)

What is modelled?

- growth rates
  - *bacteria*
  - *yeasts and molds*
- inactivation (death) rates
  - *bacteria*
  - *yeasts and molds*
  - *viruses*
  - *protozoa*
  - *microbial toxins?*
- probability of growth/toxin formation
  - *bacteria*
  - *yeasts and molds*
  - *micro-algae**

Current status of Predictive Microbiology ...

- PM approach is now firmly established:
  - in the scientific literature
  - in industry for HACCP planning, product/process design
  - supports food safety risk assessment and “Science-based” risk management decisions
  - is used in setting government regulations/laws
    - *e.g.*, Codex (and (EFSA) regulations for *Listeria monocytogenes* in RTE foods
    - *e.g.*, *C. perfringens* model for meat cooling (USDA)
    - *e.g.*, *E. coli* growth in raw meats (NZ and Australia)

How models are 'built'

- based on measurements of changes in microbial numbers over time and environmental conditions
- can be from
  - *deliberately designed* de novo *studies*
  - *"data mining"*
  - *studies in broths, or in foods*
    - *n.b.,* assumed that the actual food is less important than the physico-chemical properties of the environment (*i.e.,* the food and its storage conditions), so long as basic nutritional needs are met*, i.e.,* nutrients are non-limiting
    - Sometimes a model is developed *for just one food*

How models are 'built'

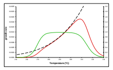
- data are analysed and patterns of response are identified
- these patterns are expressed in the form of mathematical relationships
- the relationships are turned into equations by finding the best values of the parameters to describe individual sets of data, *i.e.*, specific to a particular organism - this is the process of 'model fitting'
- ***performance of the model is then evaluated*** and, if necessary, the model revised or new models constructed

Predictive Microbiology modelling

- systematically make/collate lots of observations
- summarise the data as mathematical equations

Mathematical descriptions of temperature-growth rate relationship

- ‘mechanistic model’



$$rate = \frac{CT\exp(\Delta H^{\ddagger} / RT)}{1 + \exp(-n(\Delta H^{*} - T\Delta S^{*} + \Delta C_p[(T - T^{*}_{H}) - T\ln(T / T^{*}_{S})]) / RT)}$$

- square root model (“empirical”)

$$\sqrt{rate} = b \times (T - T_{min}) \times (1 - e^{(c \times (T - T_{max}))})$$

Predictive Microbiology models

- systematically make/collate lots of observations
- summarise the data as mathematical equations
- convert into computer software, spreadsheets
- users enter data/numbers in, get answers out

‘Nomenclature’ of models

- *Primary model*
  - describes the response of microbial numbers over time (e.g., inactivation curve, growth curve, etc.)
- *Secondary model*
  - describes how outputs of the primary model (death *rate*, growth *rate*, combined limits to growth) are affected by environmental conditions (*i.e.*, quantifies microbial ecology)
- *Tertiary model*
  - makes the knowledge and data contained in the primary and secondary models available for prediction via an accessible software interface (software program, web-site, ‘app’)

Refrigeration Index Calculator

Welcome to the

Refrigeration Index Calculator

Version 2.0.1896.19881

MEAT & LIVESTOCK AUSTRALIA

Paste temperature data here:

	A
13	23.7
14	22.3
15	20.9
16	19.8
17	18.8
18	17.7
19	16.7
20	15.6
21	15.4
22	13.5
23	12.8
24	11.7
25	10.6
26	9.9
27	8.6
28	8
29	6.9
30	6.2
31	5.4
32	4.6
33	

Select the product type:

- ( ) Carcase
- ( ) Boxed Trim
- (•) Primal where the slowest cooling point is lean
- ( ) Primal where the slowest cooling point is fat OR a mixture OR you're not sure
- ( ) Offal
- ( ) Recovered meat products

The starting temperature is hot (as for initial cooling of a carcase):

- (•) Yes
- ( ) No

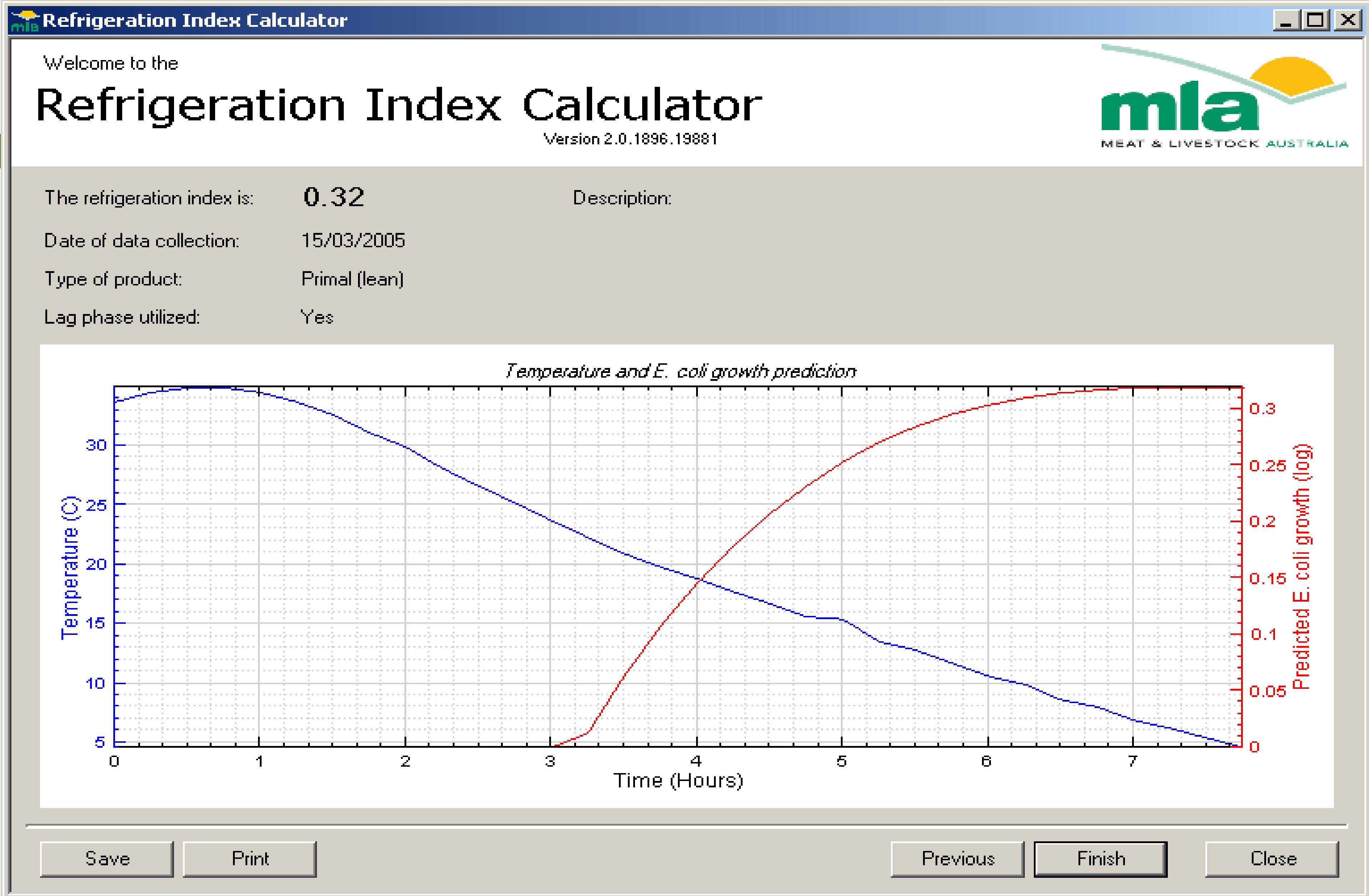
Specify other parameters and information:

Temperature measurement interval: 15 min

Date of data collection: 15/03/2005

Description of product, processing conditions, etc.:

Previous | Next | Close


Refrigeration Index Calculator
Welcome to the
Refrigeration Index Calculator
Version 2.0.1896.19881
mla
MEAT & LIVESTOCK AUSTRALIA
The refrigeration index is: 0.32
Description:
Date of data collection: 15/03/2005
Type of product: Primal (lean)
Lag phase utilized: Yes
Temperature and E. coli growth prediction
Temperature (C)
Predicted E. coli growth (log)
Time (Hours)
0 1 2 3 4 5 6 7
5 10 15 20 25 30
0 0.05 0.1 0.15 0.2 0.25 0.3
Save
Print
Previous
Finish
Close

https://symprevius.eu/en/

SYM'PREVIUS

Software | Food industry | Predictive microbiology | Help | About us | Log in

Sym'Previus is a complete tool for microbiological data prediction. It helps food manufacturers, from international groups to SMB, in their product development. Recognized by the scientific community and regulations, it provides a guarantee in quality and food safety. Thanks to the expertise provided by its partners and to its ease of use, Sym'Previus supplies its users with personalized results, adapted to their industrial issues.

Sym'Previus in brief

- Multi-matrix, multi-strain, multi-process tool
- Recommended and recognised by regulation (ISO WG19, EC 2017/2005))
- A network composed of industrial and technical centres bringing their expertise
- Its use allows increased result relevancy and so reduces costs
- A user-friendly interface and dynamic graphics allow for quick analysis
- Over 40 microorganisms available and the possibility of adding customised strains
- New product formulation and development assistance
- The Sym'Previus network of experts can provide made-to-measure solutions

Applications of Predictive Microbiology

- proactive
  - product or process design
- reactive
  - recognising, averting or minimising a problem
  - managing consequences of loss of control

Pro-active Predictive Microbiology

using knowledge of microbial ecology in models we can

- design products to extend their shelf life
- find minimal conditions (better product quality) to achieve required shelf life
- design shelf-stable products
  - *e.g.*, processed cheese spread

Re-active Predictive Microbiology

using knowledge of microbial ecology and models

- how much growth has already occurred?
- how much loss of shelf life has occurred?

or

- how long will it take for the initial levels of SSOs to grow to the spoilage level, if we know:
  - product characteristics (pH, a_w, etc)
  - storage conditions (temperature, atmosphere)
  - characteristics (growth rate, limits) of the SSO

Data and Models

analysis, synthesis

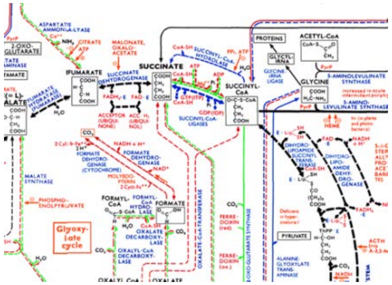
data (observations) → knowledge

databases

hypothesis; theory

(mathematical) models

software/interfaces



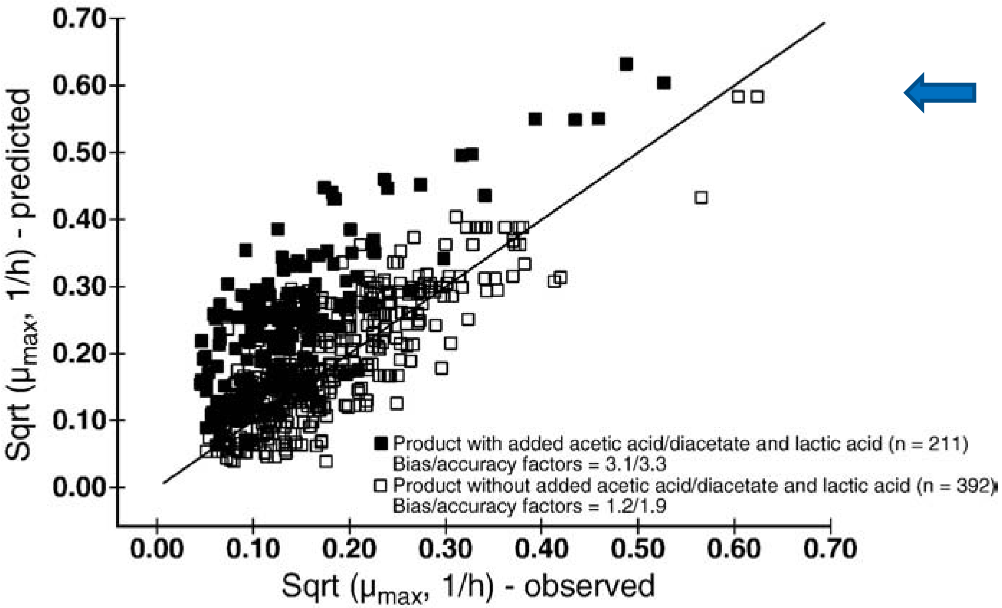
predictions

by precedent
or analogy

by (objective) interpolation
(extrapolation?)

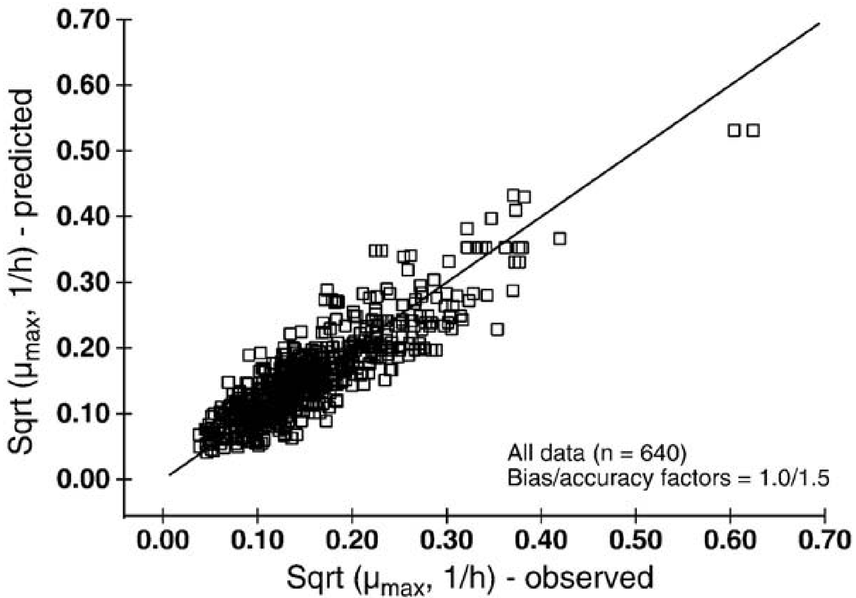
Choosing a Model/Assessing its Reliability

- Model applicability
  - Does the model describe the right organism? Are there strain differences?
  - Is the model relevant to the food – does it include all influential factors?
- Model reliability
  - Does the model accurately describe the biological phenomena?
- Various measures of reliability
  - Two aspects – goodness of fit, systematic lack of fit
  - e.g., Bias and accuracy factors; bias and precision factors; t-test and F-test; etc.



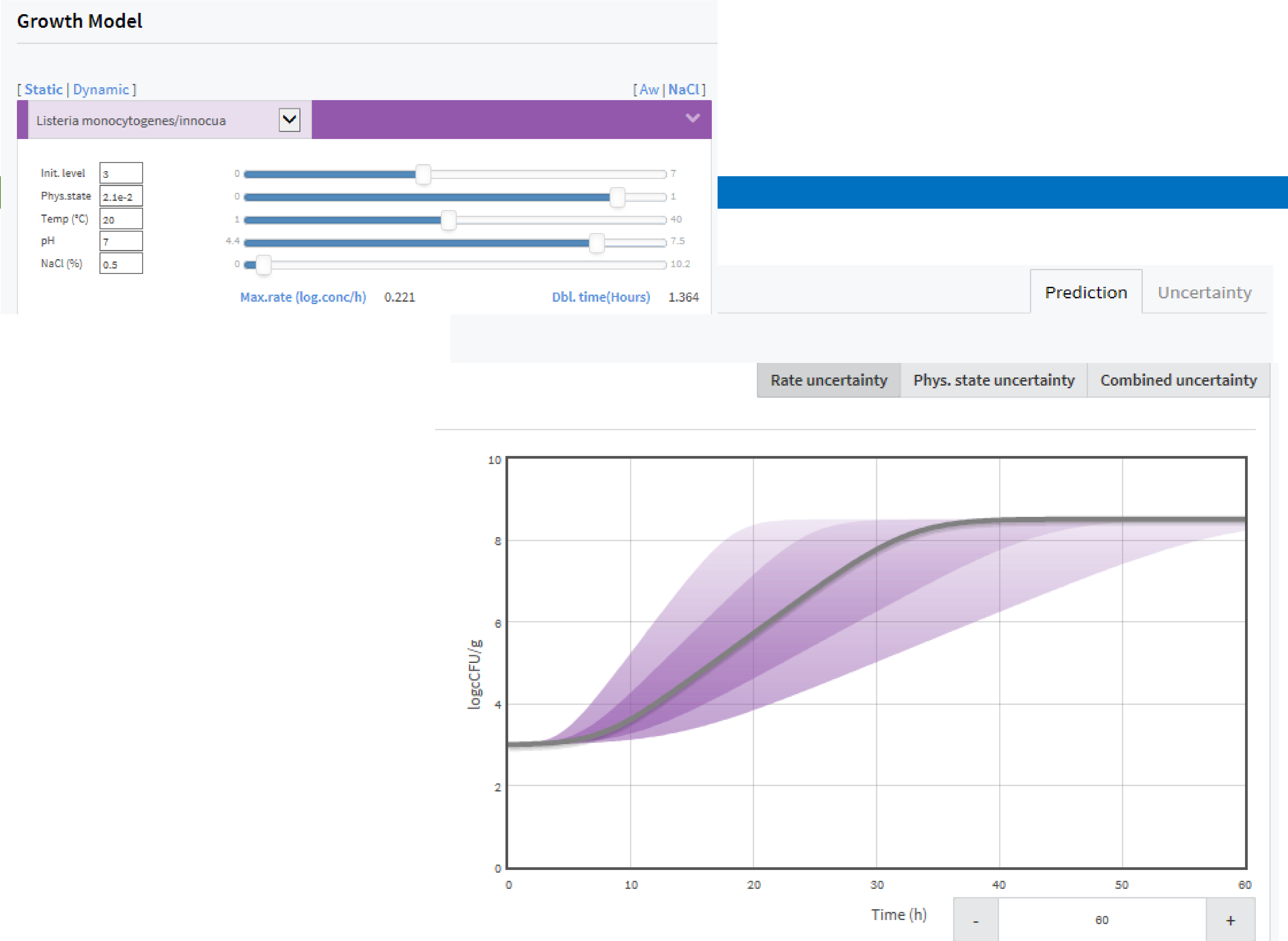
Model without terms for effect on growth rate of common organic acids

Model with terms for effect on growth rate of common organic acids



Variability

- Variability
  - between strains
  - experimental (*e.g.*, variations within food matrix, sampling error)
  - models should detail ‘confidence intervals’ on predictions, or ‘error term’



Growth Model
[Static | Dynamic]
[Aw | NaCl]
Listeria monocytogenes/innocua
Init. level
3
Phys.state
2.1e-2
Temp (°C)
20
pH
7
NaCl (%)
0.5
Max.rate (log.conc/h)
0.221
Dbl. time(Hours)
1.364
Prediction
Uncertainty
Rate uncertainty
Phys. state uncertainty
Combined uncertainty
logCFU/g
Time (h)
60

Thank you…

- and over to Peter ☺

Tertiary Microbial Models

Utilization of Tertiary Models for Estimation of Microbial Behavior in Meat-Containing Products

Dr. Peter Taormina

Reasons for Using Predictive Models

- Hazard Analysis
  - Assessing microbiological risks
- Process Preventive Control Limits
  - Times, Temperatures
- Product Development
  - Formulation (e.g., pH, a_w, preservatives)
  - Shelf Life
- Preliminary Assessment of Process Deviation
  - Cooking, cooling deviations

Types of Tertiary Models

- Bacterial Transfer
  - Surface/Product/Human
- Survival
  - Shelf Life
- Growth
  - Boundary
  - Rate
- Inactivation

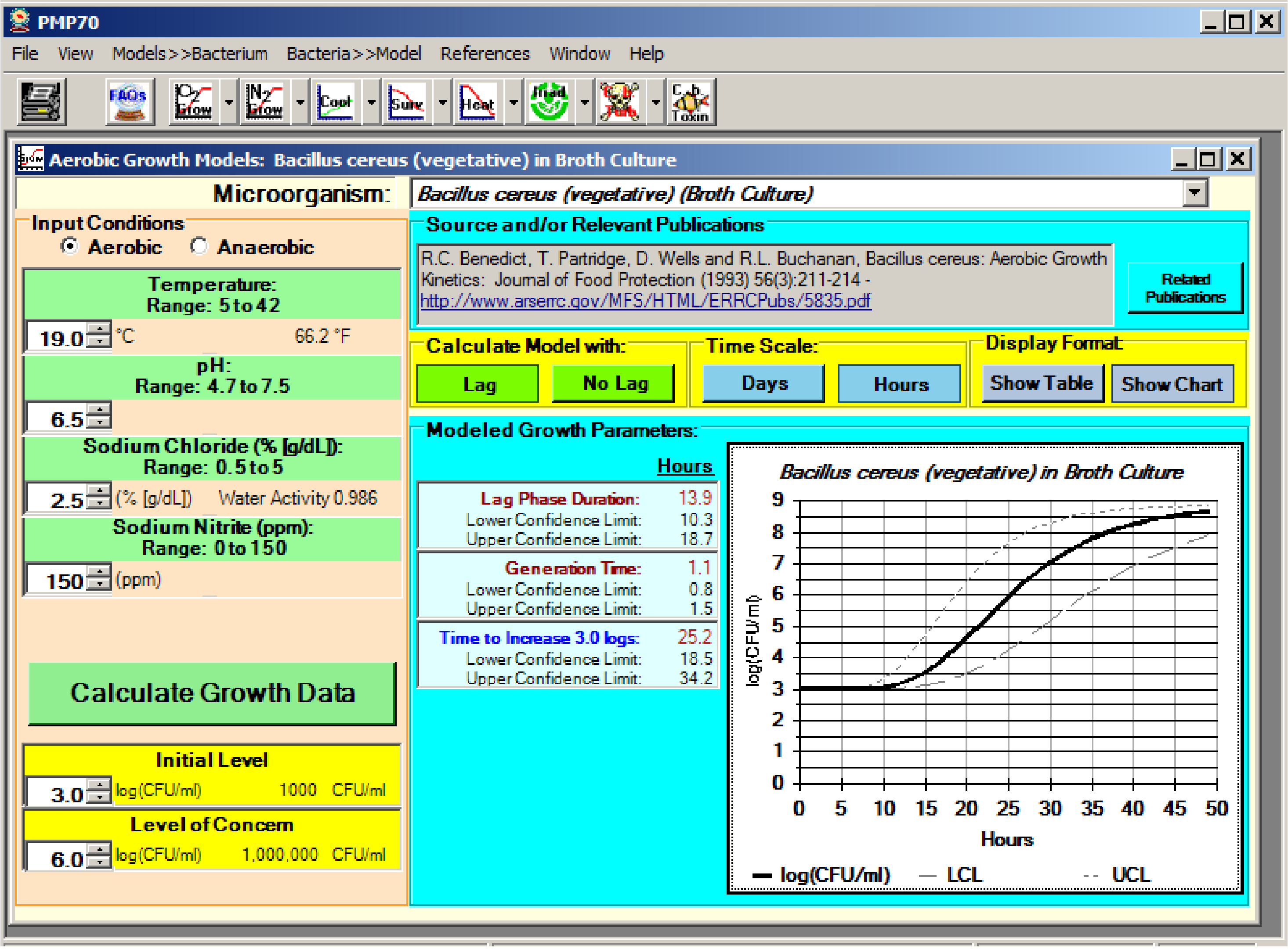
Available Predictive Tools

- Baseline Software Tool
- Bioinactivation SE
- ComBase Predictor
- Dairy products safety predictor
- DMRI – predictive models for meat
- E. coli Inactivation in Fermented Meats Model
- EcSF – E. coli SafeFerment
- FDA-iRISK®
- Food Spoilage and Safety Predictor (FSSP)
- *FISHMAP*
- GroPIN
- Listeria Control Model 2012
- Listeria Meat Model
- Microbial Responses Viewer (MRV)
- MicroHibro: Predictive Models
- MLA Refrigeration Index Calculator
- PMM-Lab
- Process lethality determination spreadsheet
- Perfringens Predictor
- Praedicere
- Salmonella predictions
- Shelf Stability Predictor
- SWEETSHELF
- Sym'Previus
- Therm 2.0

Some Examples of Tertiary Models

- USDA Pathogen Modeling Program
  - https://pmp.errc.ars.usda.gov
- ComBase
  - https://www.combase.cc
- DANISH MEAT RESEARCH INSTITUTE PREDICTIVE MODELS FOR MEAT
  - http://dmripredict.dk

Pathogen Modeling Program 7.0



Corbion® *Listeria* Control Model

Corbion® *Listeria* Control Model

Food characteristics

Enter the characteristics of your finished cured meat product as specifically as possible. If you are unsure of a food parameter, please use the default value. You may also select a Corbion ingredient and enter an addition level.

Moisture	70	%
pH	6.2	
NaCl	1.7	%
Sodium nitrite	0	ppm (on total formulation)

Storage conditions

Temperature	40	ºF

Corbion Solution

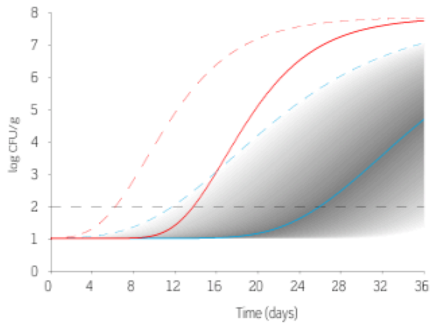
Opti.Form PD4	2.5	%

Microorganism data

Initial level	1	log CFU/g
Maximum allowed level	2	log CFU/g

Reset to defaults

Listeria growth in chicken



About this graph

Time to 1 log outgrowth in days

	Control	With Opti.Form PD4
Best fit	14	26
95% line*	6	12

** The lines are based on specifically designed and validated Listeria challenge studies. According to these studies, 95% of growth is expected to be slower than the 95% line.*

Calculate

Spoilage Model

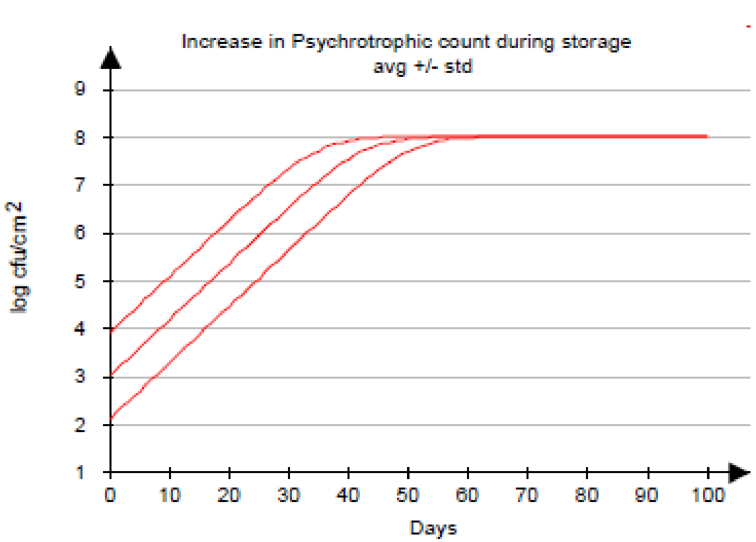
PREDICTIVE MODELS FOR MEAT

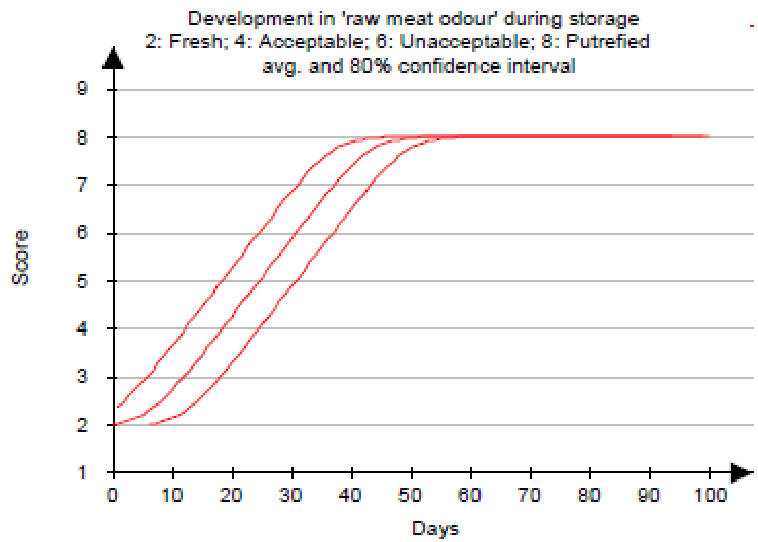
DANISH MEAT RESEARCH INSTITUTE

Shelf life of Bacon (cured pork)

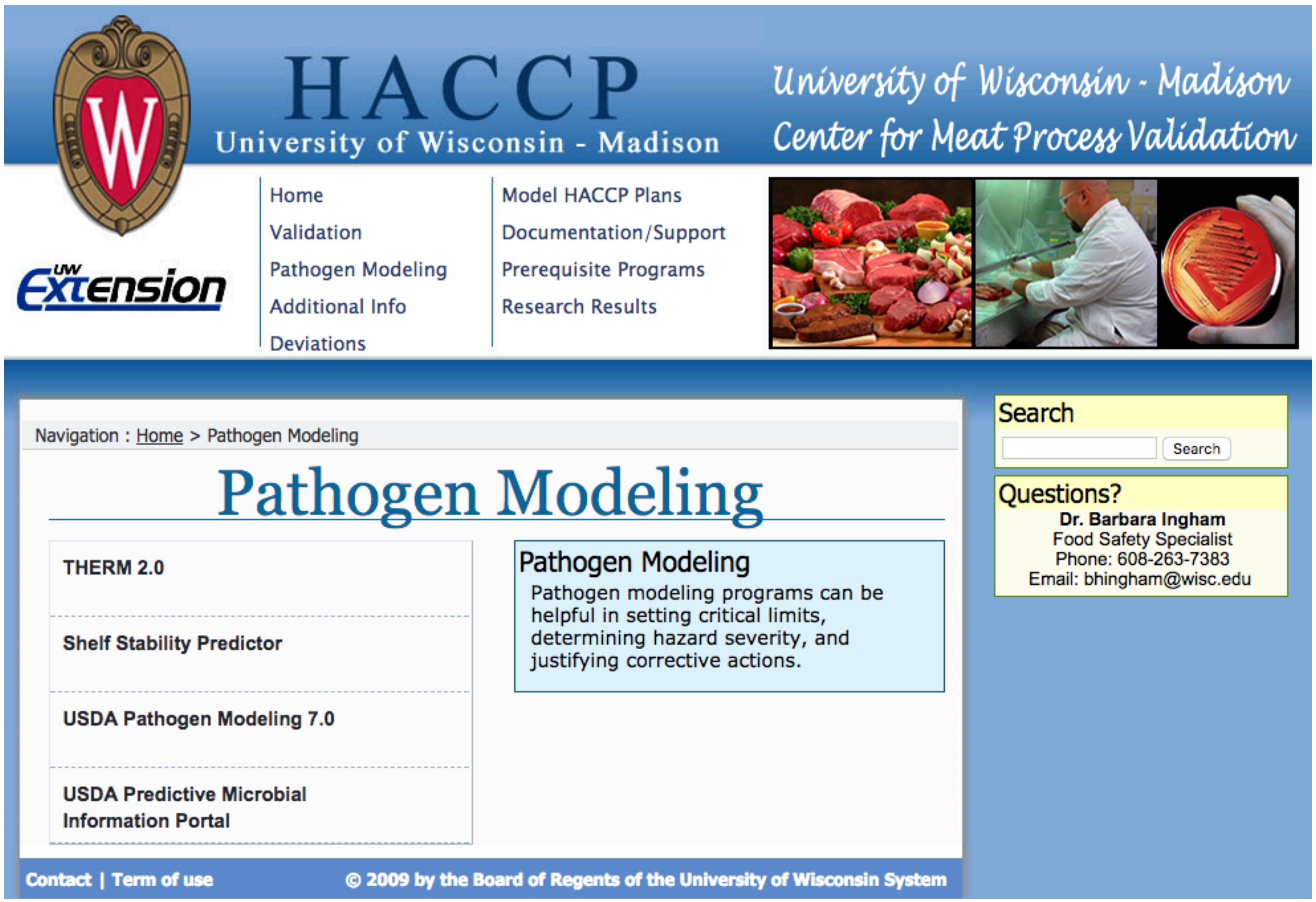
Vacuum packed, 2-5,5 % salt in aqueous (% Sodium Chloride in the water phase, w/w), With/without Ascorbate, 60-120 ppm nitrite/nitrate added, No smoke. Version 1.0

Average	3.00	log cfu/cm^2		
Standard deviation (std)	0.90	log cfu/cm^2		
% salt in aqueous	2.00	%		
1. Temperature	7.00	°C in	100	days
2. Temperature	5.00	°C in	0	days
3. Temperature	5.00	°C in	0	days
4. Temperature	5.00	°C in	0	days





Australia's Food Safety Information Portal



HACCP

University of Wisconsin - Madison

University of Wisconsin - Madison

Center for Meat Process Validation

UW Extension

Home

Validation

Pathogen Modeling

Additional Info

Deviations

Model HACCP Plans

Documentation/Support

Prerequisite Programs

Research Results

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Pathogen Modeling

THERM 2.0

Shelf Stability Predictor

USDA Pathogen Modeling 7.0

USDA Predictive Microbial Information Portal

Pathogen Modeling

Pathogen modeling programs can be helpful in setting critical limits, determining hazard severity, and justifying corrective actions.

Search

Search

Questions?

Dr. Barbara Ingham
Food Safety Specialist
Phone: 608-263-7383
Email: bhingham@wisc.edu

Contact | Term of use

Cooked Chicken Cooling

Marinated Chicken Breast

Cooked Chicken Cooling – Marinated, Cooked Chicken Breast

- Chicken breasts are vacuum tumbled in a marinade containing phosphates, sea salt, seasonings, and potassium lactate.
- Marinated chicken breasts are cooked through continuous impingement oven, then cooled on racks.
- pH 6.8, a_w 0.987, 1.7% salt
- Temperature probes:
  - 5 hours from 130 to 60ºF (54.4 to 15.6ºC)

- Which Model?

Pathogen Modeling Program (PMP) Online

USDA United States Department of Agriculture
Agricultural Research Service

Pathogen Modeling Program (PMP) Online

- PMP Home
- **PMP Online**
- About PMP
- Tutorial
- Frequently Asked Questions
- Reference Material
- Project Scientists

You are here: PMP Home / PMP Online

SELECT A PATHOGEN MODEL ▸

The models are based on extensive experimental data of microbial behavior in liquid microbiological media and food.

There can be no guarantee that predicted values will match those that would occur in any specific food system. Before the models could be used in such a manner, the user would have to validate the models for each specific food of interest.

OK

ARS.USDA.gov

Pathogen Modeling Program (PMP) Online

Model >> Bacterium

COOLING

- Clostridium botulinum (broth culture)
- Clostridium perfringens in cooked cured pork
- Clostridium perfringens in cooked beef
- Clostridium perfringens in cooked uncured beef
- Clostridium perfringens in cooked uncured chicken
- Clostridium perfringens in cooked uncured pork

GROWTH

HEAT INACTIVATION

SURVIVAL

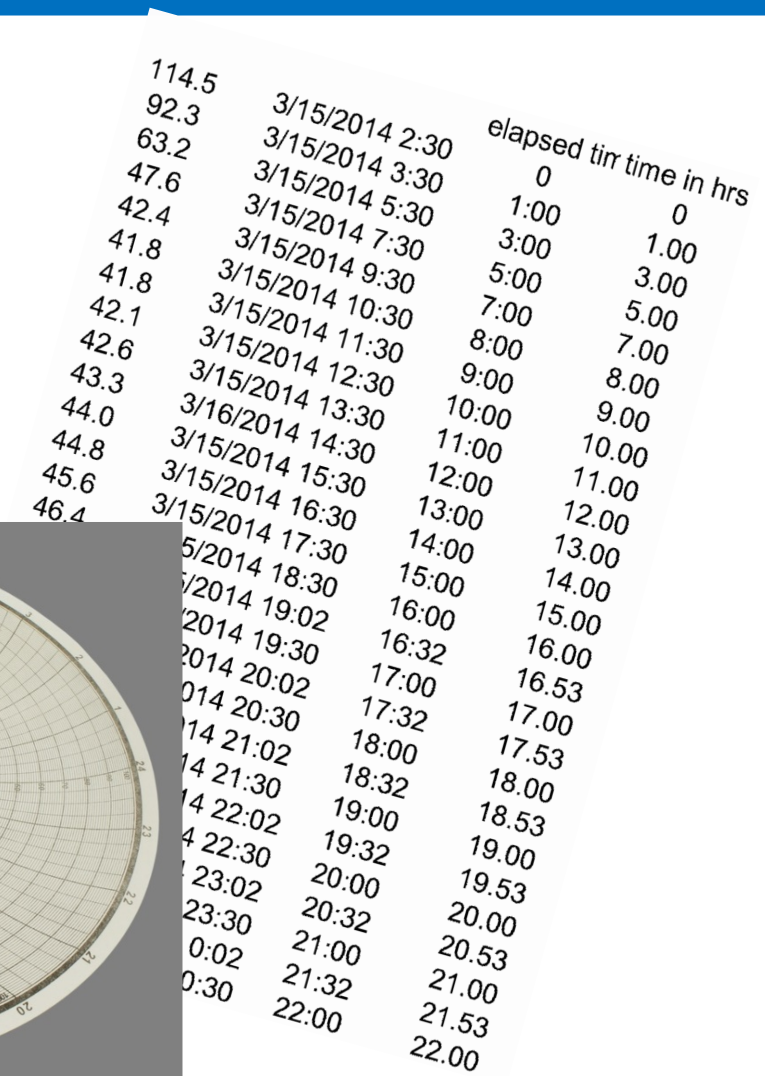
TRANSFER

Bacteria >> Model

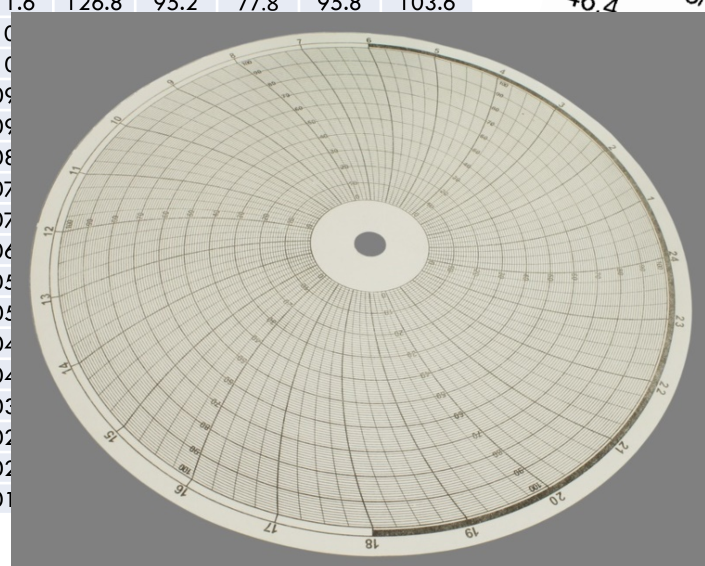
- AEROMONAS HYDROPHILA
- BACILLUS CEREUS
- CLOSTRIDIUM BOTULINUM
- CLOSTRIDIUM PERFRINGENS
- ESCHERICHIA COLI [O157:H7]
- LISTERIA MONOCYTOGENES
- SALMONELLA DUBLIN
- SALMONELLA ENTERITIDIS
- SALMONELLA HADAR
- SALMONELLA KENTUCKY
- SALMONELLA TYPHIMURIUM
- SALMONELLA SPP.
- SHIGELLA FLEXNERI
- STAPHYLOCOCCUS AUREUS
- YERSINIA PSEUDOTUBERCULOSIS

Time and Temperature Data

18.85	133.0	114.2	114.1	101.8	149.5	122.6	137.0	106.4	89.8	105.9	115.0
18.87	132.2	113.4	113.4	100.9	148.9	121.8	136.3	105.6	89.4	105.2	114.2
18.88	131.5	112.7	112.7	100.1	148.2	121.0	135.6	104.8	89.0	104.5	113.3
18.90	130.7	111.9	112.0	99.3	147.6	120.3	134.8	104.0	88.6	103.8	112.6
18.92	129.9	111.1	111.3	98.5	146.9	119.5	134.1	103.2	88.1	103.1	111.8
18.93	129.2	110.4	110.6	97.8	146.3	118.8	133.4	102.4	87.8	102.5	111.0
18.95	128.4	109.6	109.9	97.0	145.6	118.0	132.7	101.7	87.2	101.8	110.2
18.97	127.7	108.9	109.3	96.2	145.0	117.3	132.0	100.9	85.9	101.1	109.4
18.98	127.0	108.1	108.6	95.5	144.3	116.6	131.4	100.2	84.7	100.4	108.7
19.00	126.2	107.4	108.0	94.7	143.7	115.9	130.7	99.4	83.5	99.7	107.9
19.02	125.5	106.7	107.4	94.0	143.0	115.1	130.0	98.7	82.4	99.1	107.2
19.03	124.8	105.9	106.7	93.3	142.4	114.4	129.4	98.0	81.3	98.4	106.5
19.05	124.1	105.2	106.1	92.6	141.7	113.7	128.7	97.3	80.3	97.8	105.7
19.07	123.3	104.5	105.5	91.9	141.1	113.0	128.0	96.6	79.5	97.1	105.0
19.08	122.6	103.8	104.9	91.2	140.4	112.3	127.4	95.9	78.7	96.5	104.3
19.10	121.9	103.1	104.2	90.5	139.8	111.6	126.8	95.2	77.8	95.8	103.6
19.12	121.2	102.4	103.6	89.8	139.1	110					
19.13	120.5	101.8	103.0	89.2	138.5	110					
19.15	119.9	101.1	102.4	88.5	137.9	109					
19.17	119.2	100.5	101.8	87.9	137.2	109					
19.18	118.5	99.8	101.2	87.3	136.6	108					
19.20	117.8	99.2	100.7	86.6	135.9	107					
19.22	117.2	98.6	100.1	86.0	135.3	107					
19.23	116.5	97.9	99.5	85.4	134.6	106					
19.25	115.8	97.3	98.9	84.8	134.0	105					
19.27	115.2	96.7	98.4	84.2	133.4	105					
19.28	114.5	96.1	97.8	83.7	132.7	104					
19.30	113.9	95.6	97.3	83.1	132.1	104					
19.32	113.2	95.0	96.7	82.5	131.4	103					
19.33	112.6	94.4	96.1	82.0	130.8	102					
19.35	112.0	93.8	95.6	81.5	130.2	102					
19.37	111.3	93.3	95.1	80.9	129.5	101					



		elapsed tir	time in hrs
114.5	3/15/2014 2:30	0	0
92.3	3/15/2014 3:30	1:00	1.00
63.2	3/15/2014 5:30	3:00	3.00
47.6	3/15/2014 7:30	5:00	5.00
42.4	3/15/2014 9:30	7:00	7.00
41.8	3/15/2014 10:30	8:00	8.00
41.8	3/15/2014 11:30	9:00	9.00
42.1	3/15/2014 12:30	10:00	10.00
42.6	3/15/2014 13:30	11:00	11.00
43.3	3/16/2014 14:30	12:00	12.00
44.0	3/15/2014 15:30	13:00	13.00
44.8	3/15/2014 16:30	14:00	14.00
45.6	3/15/2014 17:30	15:00	15.00
46.4	5/2014 18:30	16:00	16.00
	/2014 19:02	16:32	16.53
	2014 19:30	17:00	17.00
	2014 20:02	17:32	17.53
	014 20:30	18:00	18.00
	14 21:02	18:32	18.53
	14 21:30	19:00	19.00
	14 22:02	19:32	19.53
	4 22:30	20:00	20.00
	23:02	20:32	20.53
	23:30	21:00	21.00
	0:02	21:32	21.53
	0:30	22:00	22.00



Pathogen Modeling Program (PMP) Online

Time-Temperature Data Format

This page loads with sample data in the textbox. This format should be followed when entering or pasting data into the textbox. Specifically, please enter cooling profile data as follows:

- Start with header row (e.g. time(hour), temperature)
- Enter each data point on a separate line, separated by a comma (e.g. 1.0, 44)
- Specify time first, in cummulative hours (e.g. 15 minutes = 0.25 hours)
- Specify temperature second, in the units selected using the radio buttons (°C or °F)
- A minimum of five (5) data time-temperature points must be provided
- At least three of the data points must be above 70°F (21°C)
- The time point in row 1 must always be 0 hours
- Data not following this format will be ignored

If using the **Browse** button to load the data from a text file, the file must:

- Follow the same format as above
- Be in text format (e.g. .txt, .csv)

Clicking on the **Calculate Growth Data** button will use data provided in the file, if specified, or the data in the textbox if no file is specified. The data from the file will be loaded into the textbox. Please confirm the temperature profile is charted correctly.

Prepare Time/Temp Data

- Download or Manual Entry
- Select data range or points
  - Convert units
- Save as .CSV file (optional)
- Adjust for temperatures outside of model range

11/14/17 0:34	**54.4**		
11/14/17 0:44	52.0		
11/14/17 0:54	50.0		
11/14/17 1:04	48.0		
11/14/17 1:14	47.5		
11/14/17 1:24	45.2		
11/14/17 1:34	**44.3**		
11/14/17 1:44	42.1		
11/14/17 1:54	40.5		
11/14/17 2:04	38.8		
11/14/17 2:14	37.2		
11/14/17 2:24	**35.6**		
11/14/17 2:34	33.9		
11/14/17 2:44	32.2		
11/14/17 2:54	30.5		
11/14/17 3:04	30.0	time (hour)	temperature (℃)
11/14/17 3:14	29.6	0,	54.4
11/14/17 3:24	29.1	1,	44.3
11/14/17 3:34	**28.1**	2,	35.6
11/14/17 3:44	27.7	3,	28.1
11/14/17 3:54	27.2	4,	21.6
11/14/17 4:04	26.6	5,	16.1
11/14/17 4:14	26.0	5.25,	15.3
11/14/17 4:24	25.4	6,	12.5
11/14/17 4:34	**21.6**	7,	10.5
11/14/17 4:44	21.7	8,	8.2
11/14/17 4:54	20.4	9,	7.4
11/14/17 5:04	19.2	10,	5.8
11/14/17 5:14	18.0	11,	4.4
11/14/17 5:24	16.8		
11/14/17 5:34	**16.1**		
11/14/17 5:44	15.8		
11/14/17 5:54	**15.3**		
11/14/17 6:04	14.6		
11/14/17 6:14	14.3		
11/14/17 6:24	14.1		
11/14/17 6:34	13.9		

PMP Online – Marinated, Cooked Chicken Breast Example

Growth of Clostridium perfringens during cooling of cooked uncured Chicken

Input Conditions

Temperature in: (•) °C ( ) °F

Cooling Profile (Linear Model)

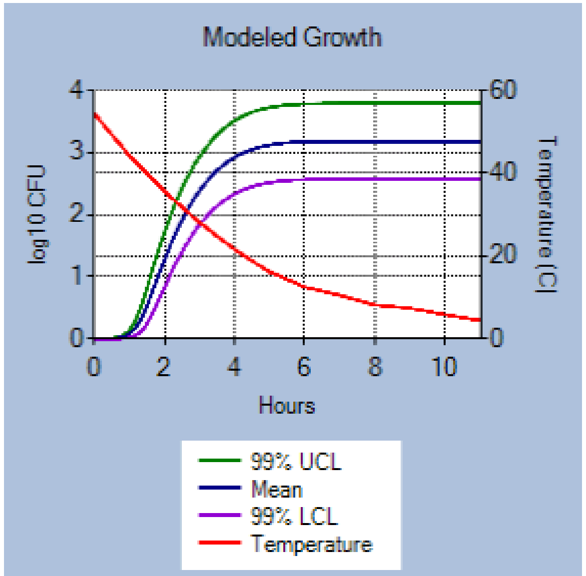
```
time(hour), temperature
0,          54.4
1,          44.3
2,          35.6
3,          28.1
4,          21.6
5,          16.1
5.25,       15.3
6,          12.5
7,          10.5
8,           8.2
9,           7.4
10,          5.8
```

Or import cooling profile from a file in comma-separated values (.csv) format. (See instructions after the table of results below.)

Choose File No file chosen

Note: Model based on parameters in Table 1. However, after further analysis, a value of 0.02 has been substituted for q0 for pork. Growth is computed assuming a starting concentration of 1 cfu/g (0 log cfu/g). As such, it will not exceed the maximum popluation density.

CALCULATE GROWTH DATA



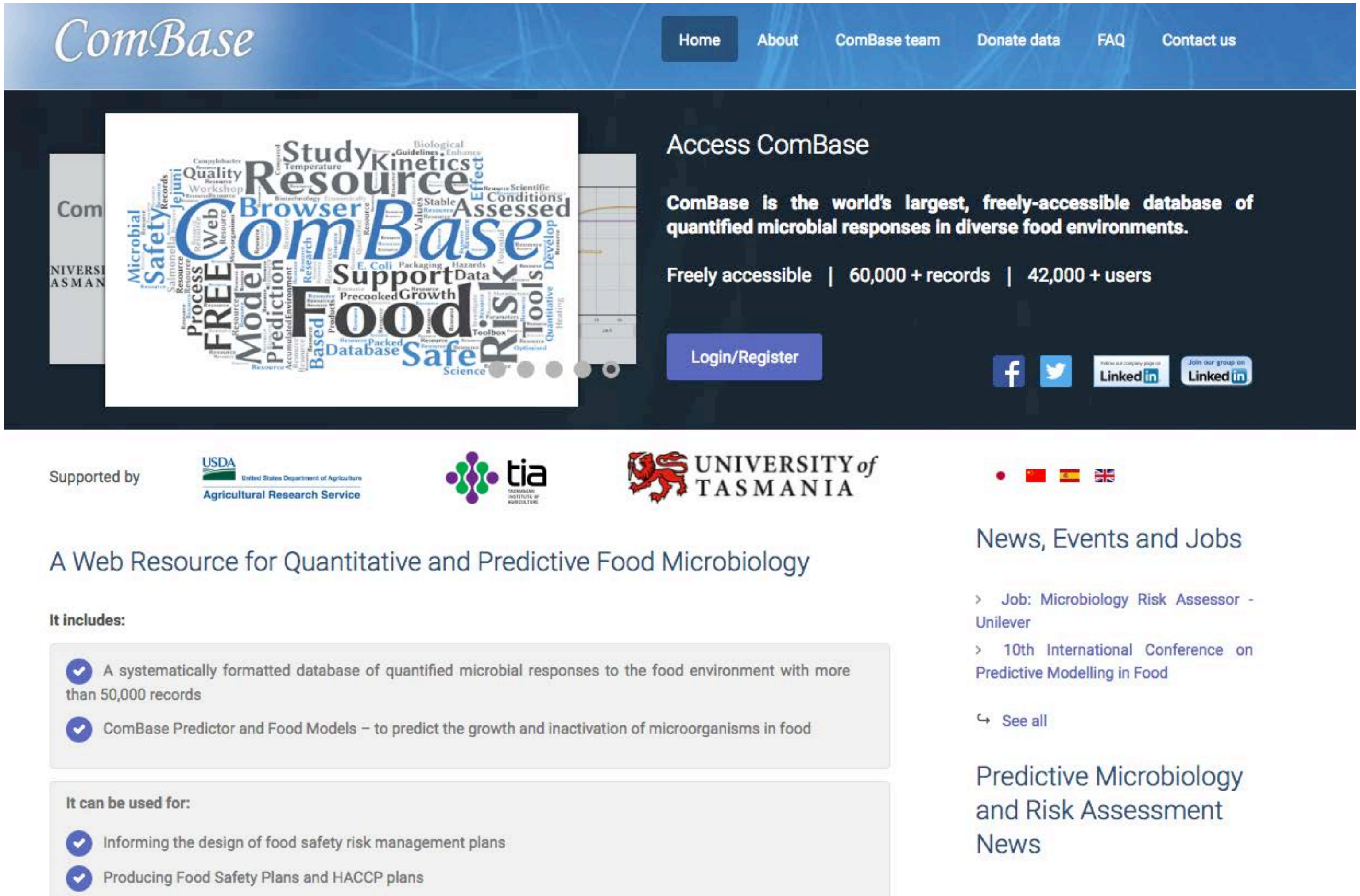
Modeled Growth Parameters

- Total Cooling Time: 11.00 (hours)
- Predicted Mean Growth: 3.18 (log10 CFU)
- 99% UCL: 3.80 (log10 CFU)
- 99% LCL: 2.57 (log10 CFU)
- Maximum Population Density: 8.00 (log10 CFU/g)

PMP Online – Marinated, Cooked Chicken Breast Example

- 3.18-Log Increase (2.57 to 3.80 99% CL)
- **Source:** Juneja V.K., Marks H., Huang L., and Thippareddi H. Predictive model for growth of *Clostridium perfringens* during cooling of cooked uncured meat and poultry. Food Microbiology 28 (2011). P. 791-795.

  - What about pH, a_w, % salt?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It includes:
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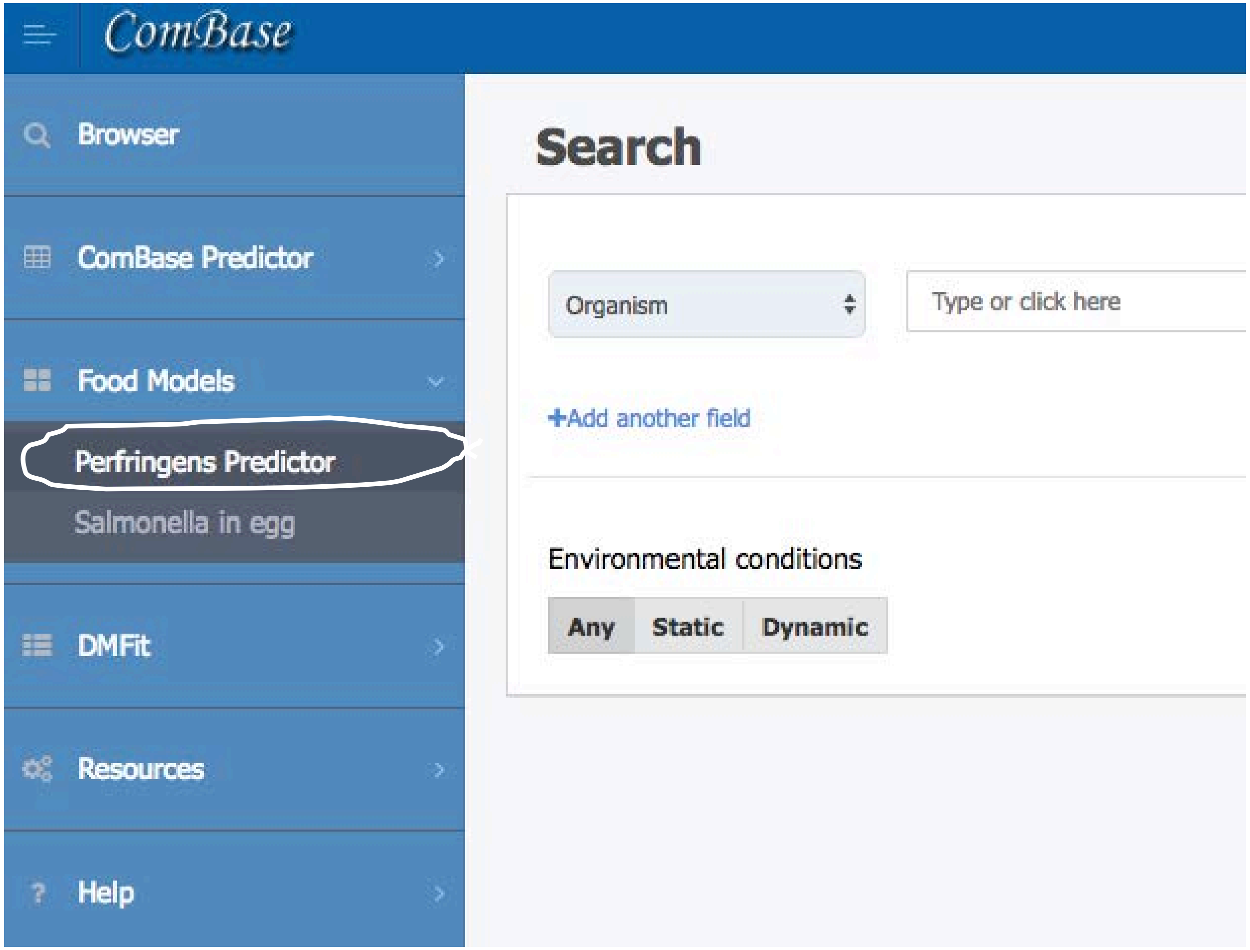
Combase – Perfringens Predictor



1.3-Log Increase

Perfringens Predictor

Uncured meat | Cured meat

pH [5.2-8.0] 6.8

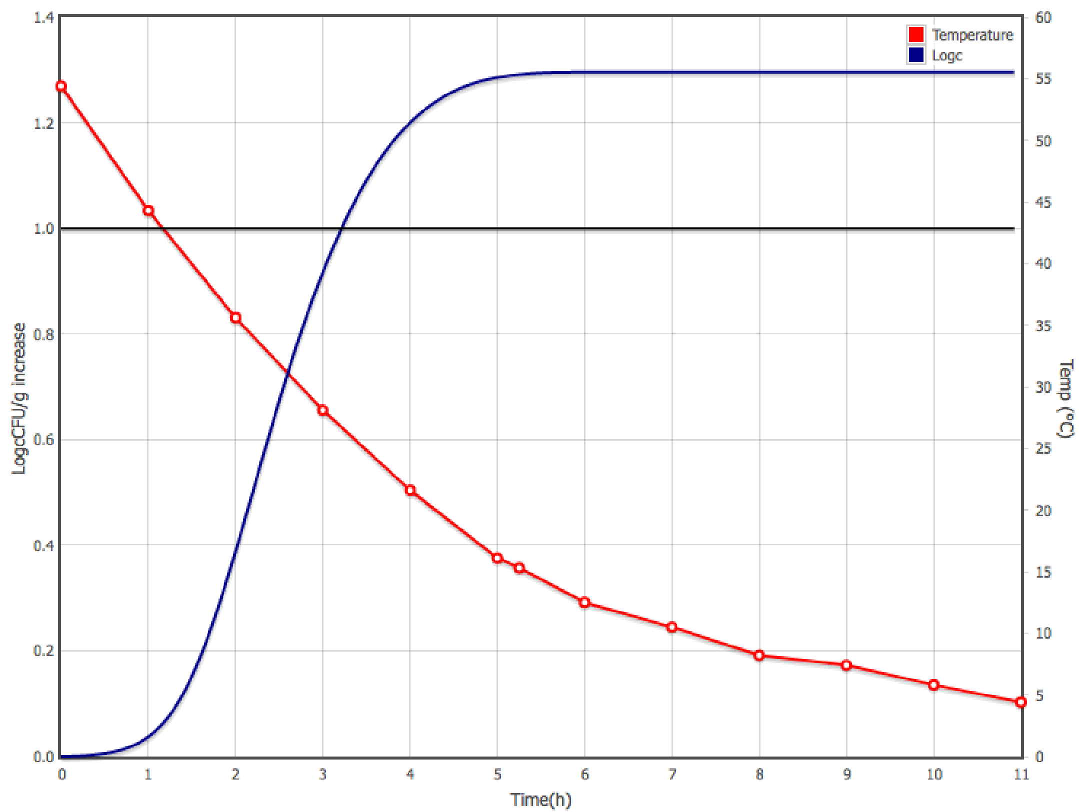
[**Aw** | NaCl]

Aw [0.977-1] .987

Time(h)	Temp (°C)
0.00	54.40
1.00	44.30
2.00	35.60
3.00	28.10
4.00	21.60
5.00	16.10
5.25	15.30
6.00	12.50
7.00	10.50
8.00	8.20
9.00	7.40
10.00	5.80
11.00	4.40

Predict

Chart | Data points



1.92-Log Increase

Perfringens Predictor

Uncured meat | Cured meat

pH [5.2-8.0]: 6.8

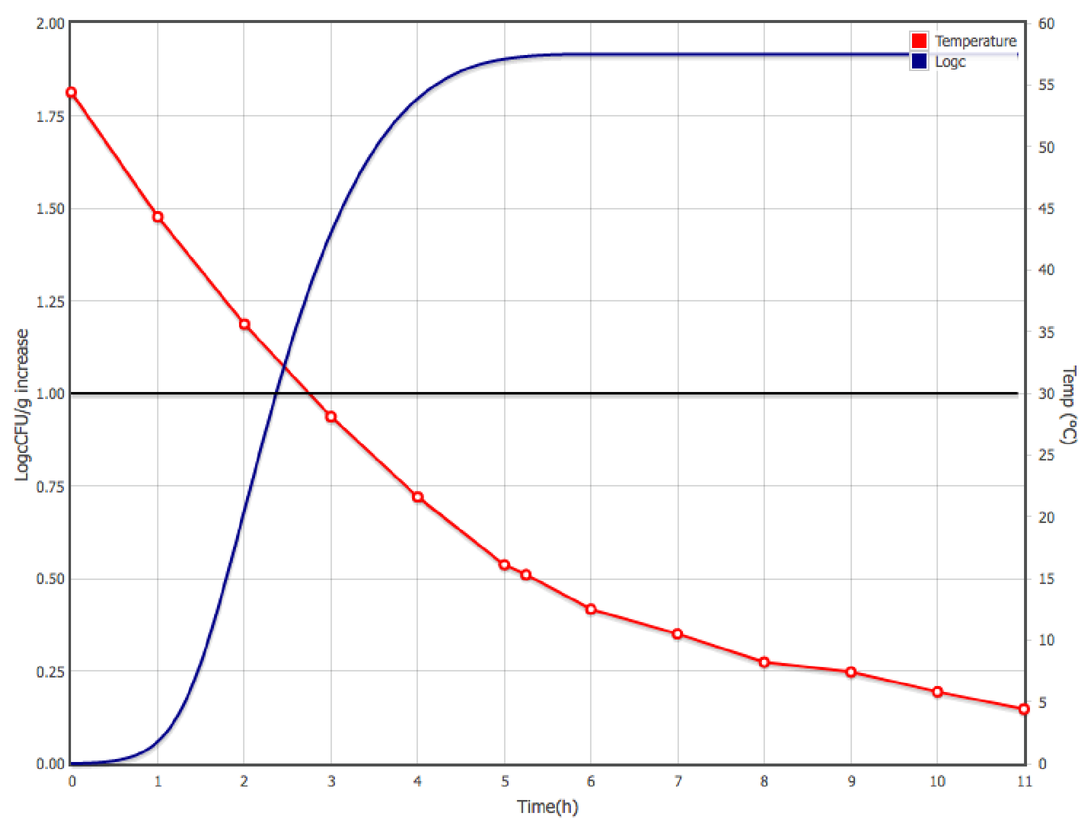
[Aw | NaCl]

NaCl [0-4]: 1.7

Time(h)	Temp (°C)
0.00	54.40
1.00	44.30
2.00	35.60
3.00	28.10
4.00	21.60
5.00	16.10
5.25	15.30
6.00	12.50
7.00	10.50
8.00	8.20
9.00	7.40
10.00	5.80
11.00	4.40

Predict

Chart | Data points



Cooked Chicken Cooling – Marinated, Cooked Chicken Breast

- Chicken breasts are vacuum tumbled in a marinade containing phosphates, sea salt, seasonings, and **potassium lactate**.
- Marinated chicken breasts are cooked through continuous impingement oven, then cooled on racks.
- pH 6.8, a_w 0.987, 1.7% salt
- Temperature probes:
  - 5.5 hours from 130 to 60ºF (54.4 to 15.6ºC)

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doi:10.4315/0362-028X.JFP-13-106

Research Note

Inhibition of *Clostridium perfringens* Growth by Potassium Lactate during an Extended Cooling of Cooked Uncured Ground Turkey Breasts

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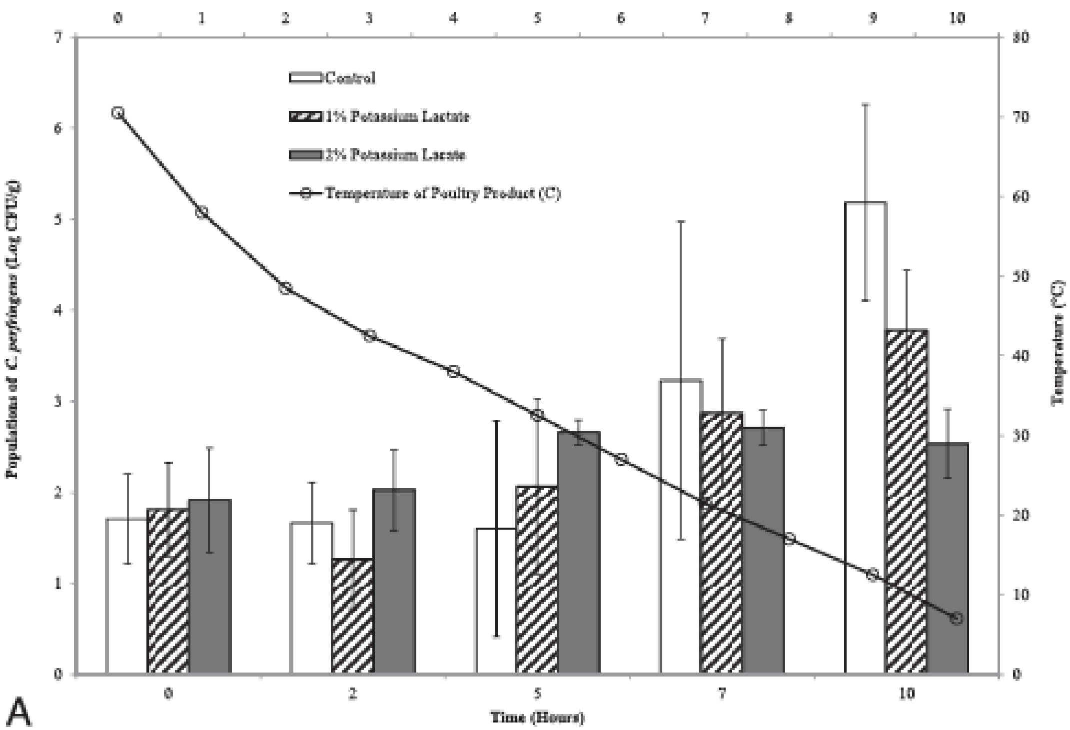
MS 13-106: Received 17 March 2013/Accepted 26 June 2013

ABSTRACT

The U.S. Department of Agriculture's Food Safety and Inspection Service compliance guideline known as Appendix B specifies chilling time and temperature limits for cured and uncured meat products to inhibit growth of spore-forming bacteria, particularly *Clostridium perfringens*. Sodium lactate and potassium lactate inhibit toxigenic growth of *Clostridium botulinum*, and inhibition of *C. perfringens* has been reported. In this study, a cocktail of spores of three *C. perfringens* strains (ATCC 13124, ATCC 12915, and ATCC 12916) were inoculated into 100-g samples of ground skinless, boneless turkey breast formulated to represent deli-style turkey breast. Three treatment groups were supplemented with 0 (control), 1, or 2% potassium lactate (pure basis), cooked to 71°C, and assayed for *C. perfringens* growth during 10 or 12 h of linear cooling to 4°C. In control samples, populations of *C. perfringens* increased 3.8 to 4.7 log CFU/g during the two chilling protocols. The 1% potassium lactate treatment supported only a 2.5- to 2.7-log increase, and the 2% potassium lactate treatment limited growth to a 0.56- to 0.70-log increase. When compared with the control, 2% potassium lactate retarded growth by 2.65 and 4.21 log CFU/g for the 10- and 12-h cooling protocols, respectively. These results confirm that the addition of 2% potassium lactate inhibits growth of *C. perfringens* and that potassium lactate can be used as an alternative to sodium nitrite for safe extended cooling of uncured meats.

- Compare pH, a_w, percent lactate in published study with your product.



Kennedy et al., 2013

Prepared Meal Cooling Example

Gumbo with Rice

Prepared Meal Cooling - Gumbo

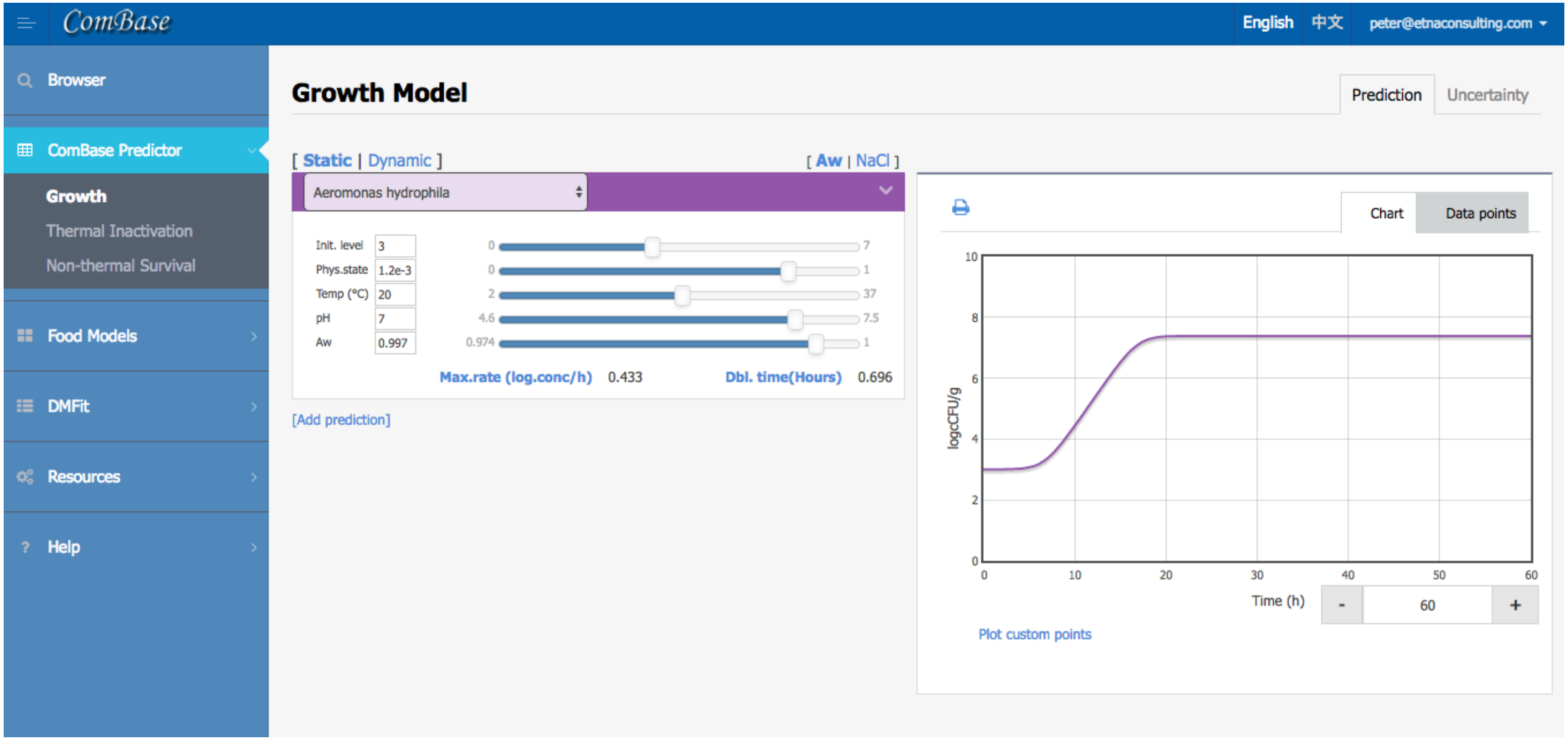
- Gumbo ingredients: Cooked rice, Andouille sausage, vegetables, shrimp, seasonings
- Rice is cooked in a commercial rice cooker. Meat, shrimp, and vegetables are cooked separately in a kettle.
- Rice is dispensed into plastic trays, and Gumbo mixture is ladled onto rice. Trays are sealed, placed on racks and wheeled into walk-in freezer.
- Reaches 41ºF (5ºC) in 6 h.

Prepared Meal Cooling - Gumbo

- Oops!
- Temperature Deviation

Image source: Bing search – "free to share and use"
https://hongkongphooey.wordpress.com/2009/02/

Combase Predictor – Growth Model



Gumbo Example - Combase

Growth Model

Prediction | Uncertainty

[Static | **Dynamic**]

[**Aw** | NaCl]

Time(h)	Temp (°C)
0.00	30.00
1.00	28.20
2.00	25.00
3.00	23.10
4.00	25.20
5.00	28.00
6.00	30.00
7.00	29.70
8.00	27.00
9.00	18.00
10.00	15.00
11.00	7.20
12.00	4.40

Bacillus cereus

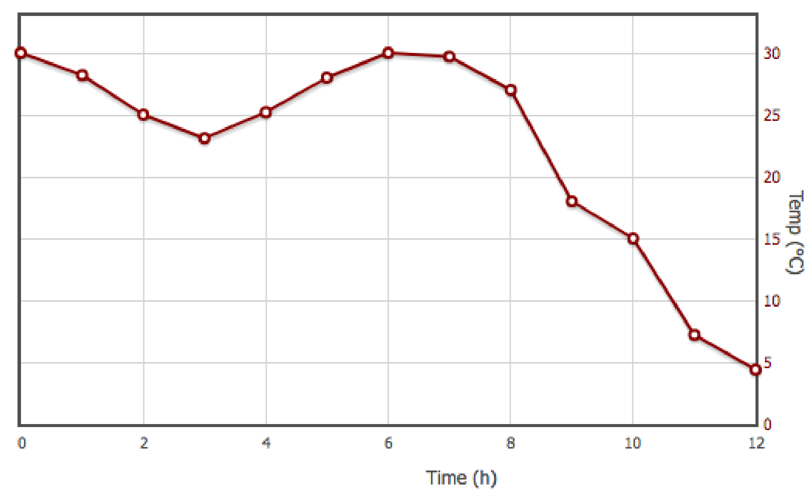
Temperatures range [5,34]

Init. level	1	0	7
Phys.state	2.7e-4	0	1
pH	7.2	4.9	7.4
Aw	.979	0.94	1

[Add prediction]

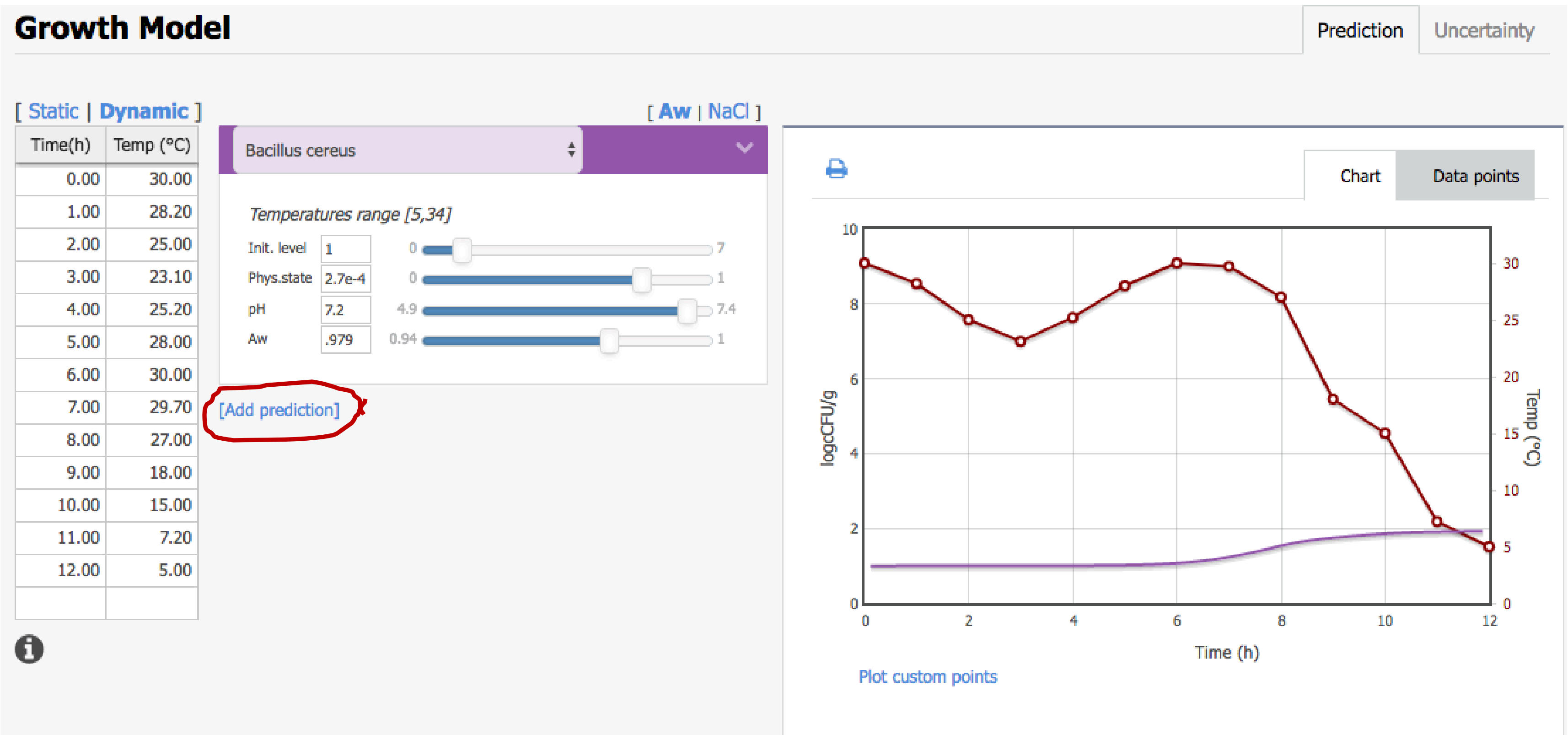
Chart | Data points

Invalid temperature profile: temperature out of allowed range

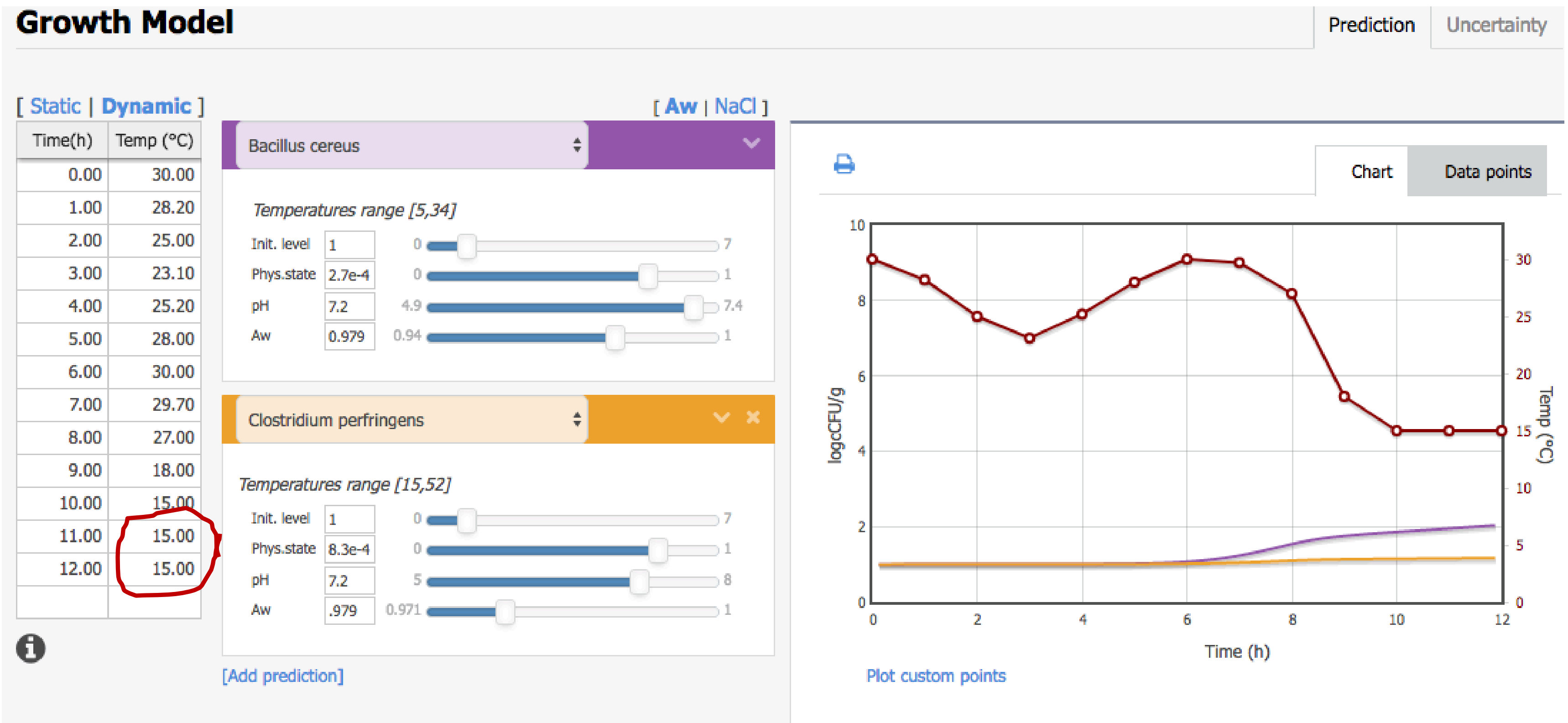


Plot custom points

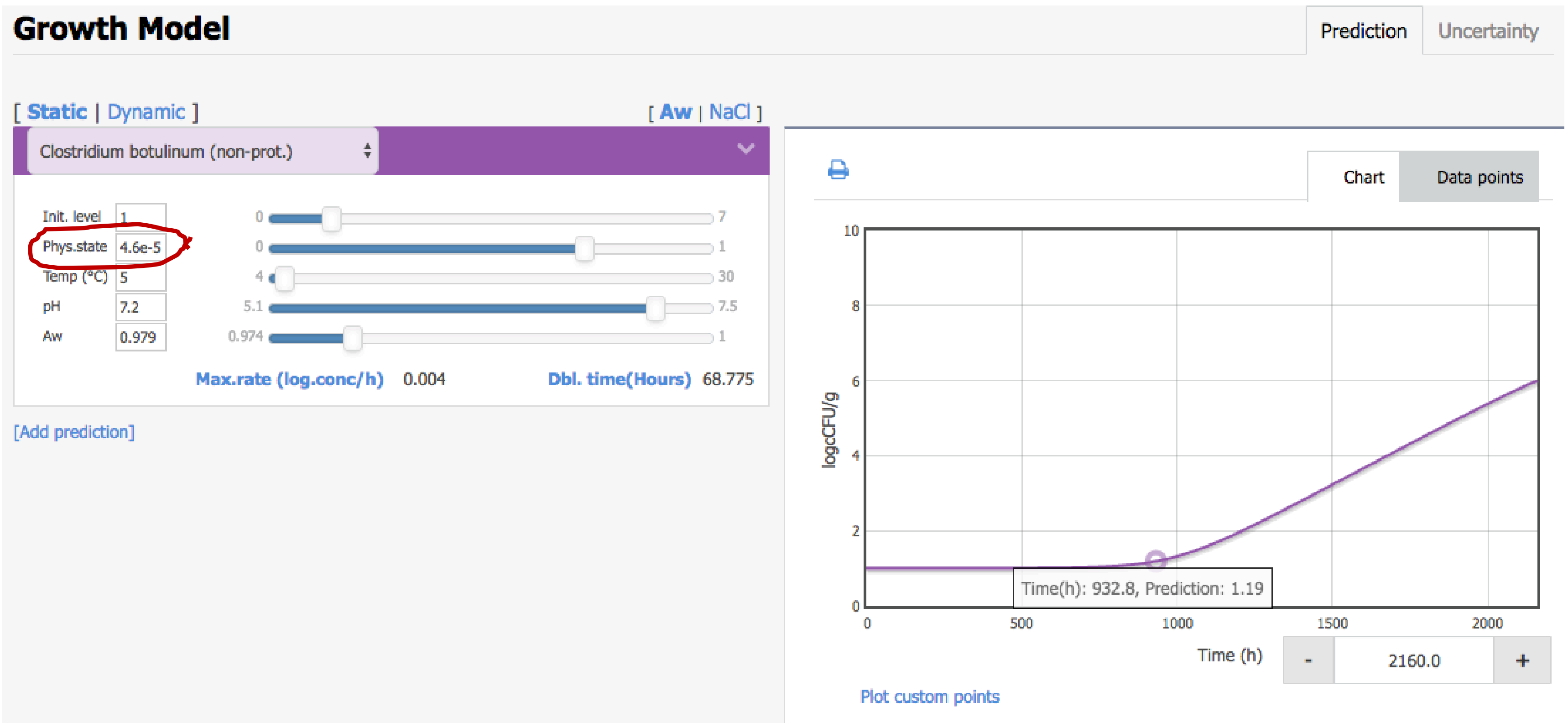
Gumbo Example – Combase 0.92-Log Increase *Bacillus cereus*



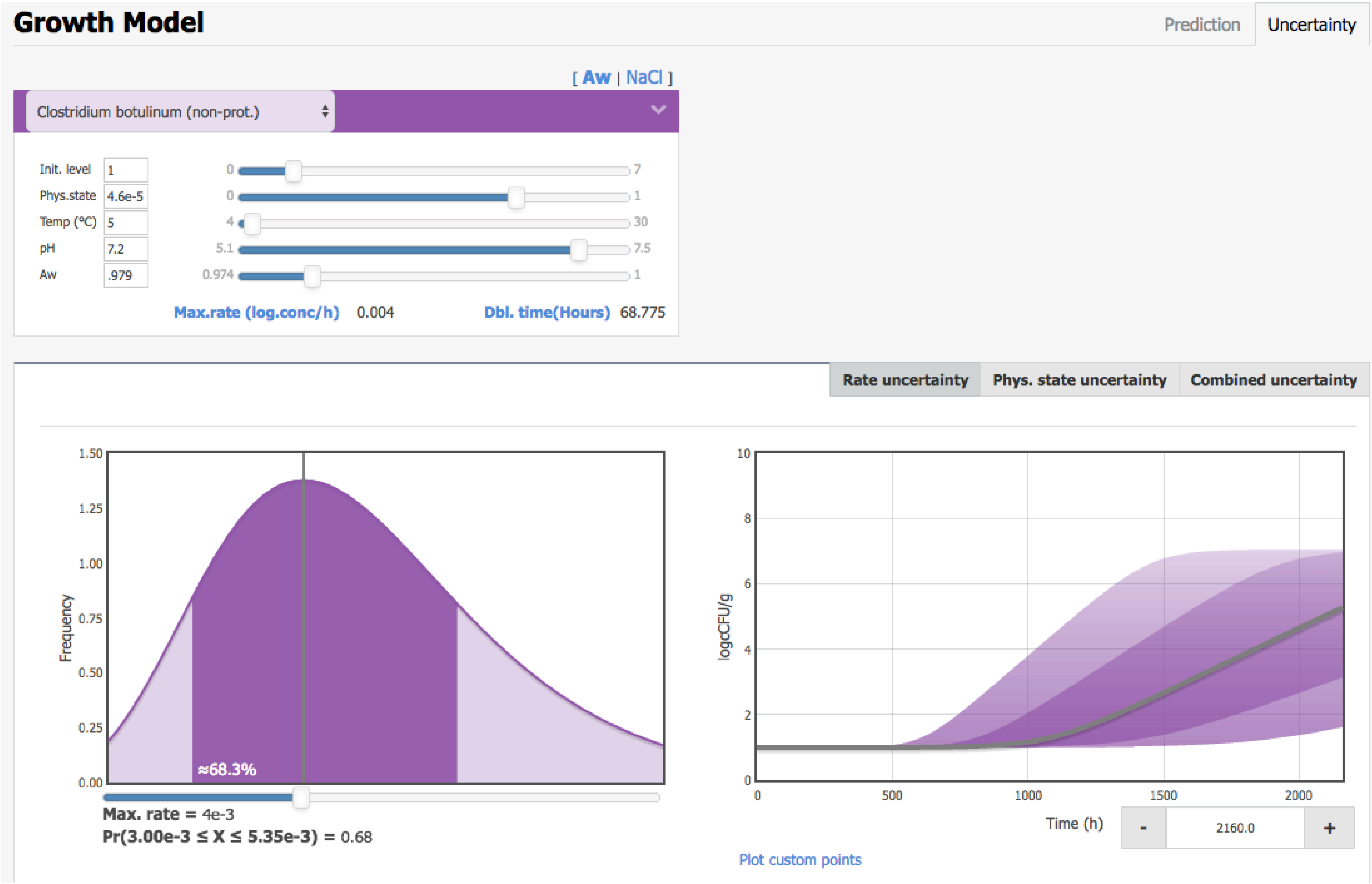
Gumbo Example – Combase



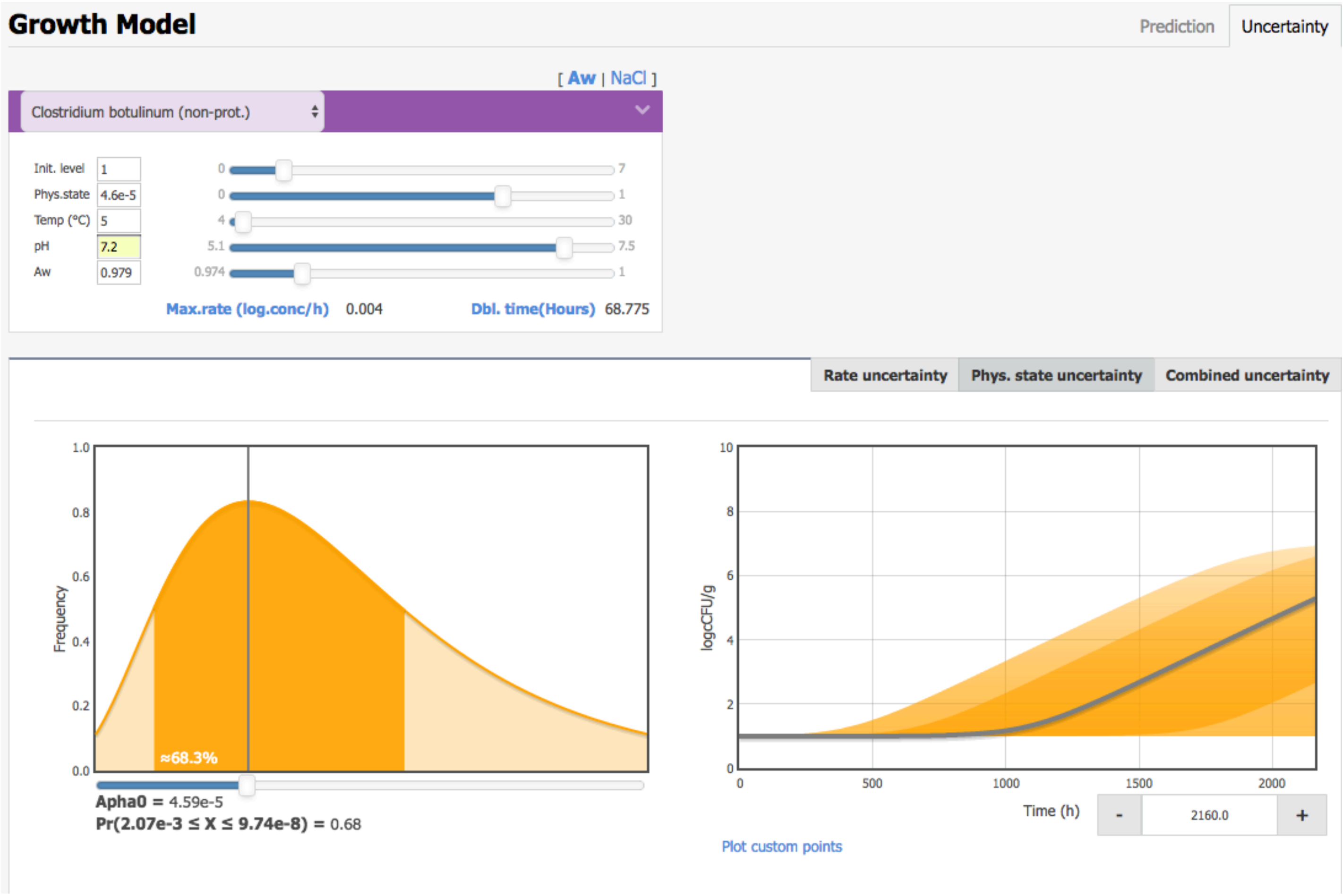
Growth of non-proteolytic C. *botulinum* at 5ºC within about 40 days



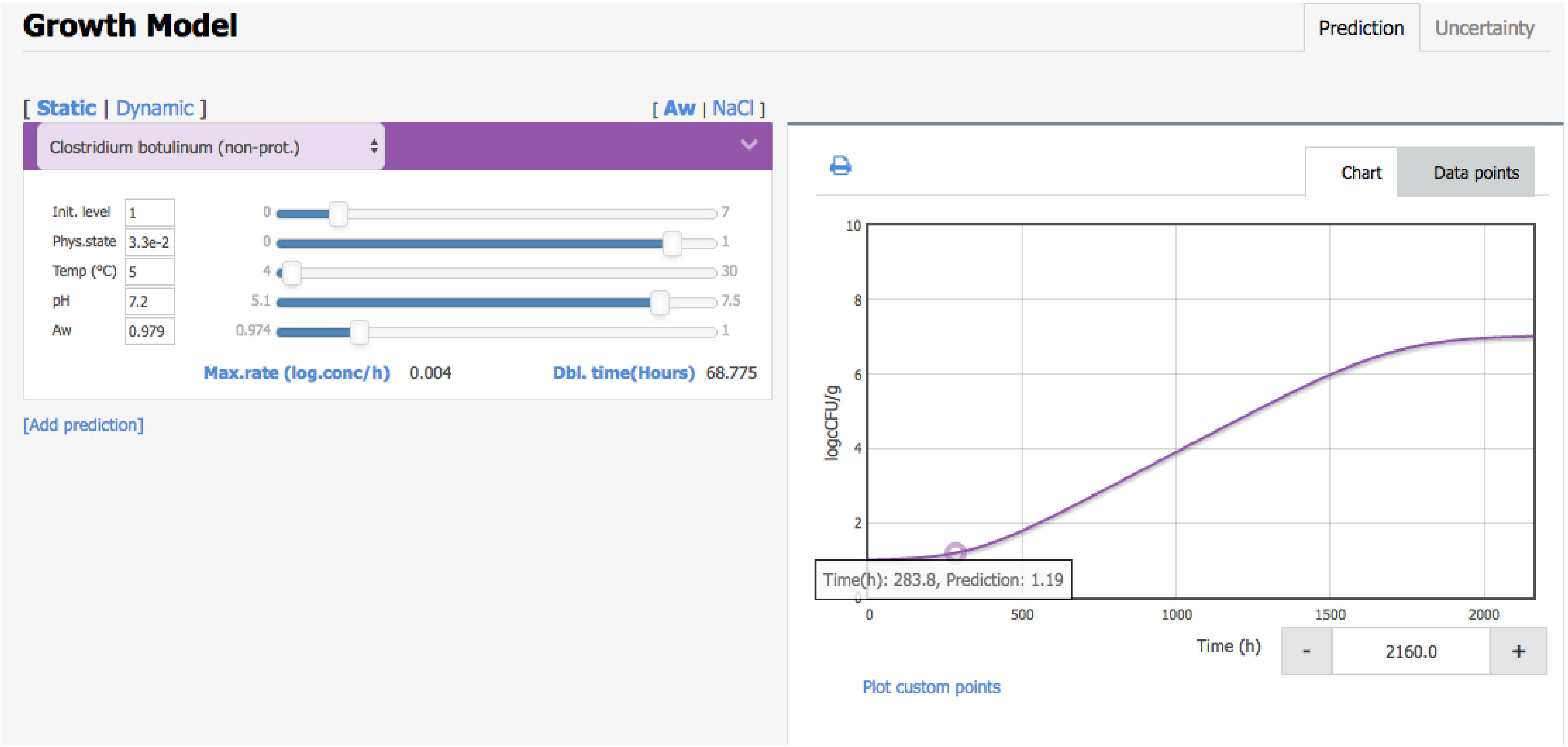
Gumbo Example – Combase Shelf Life?

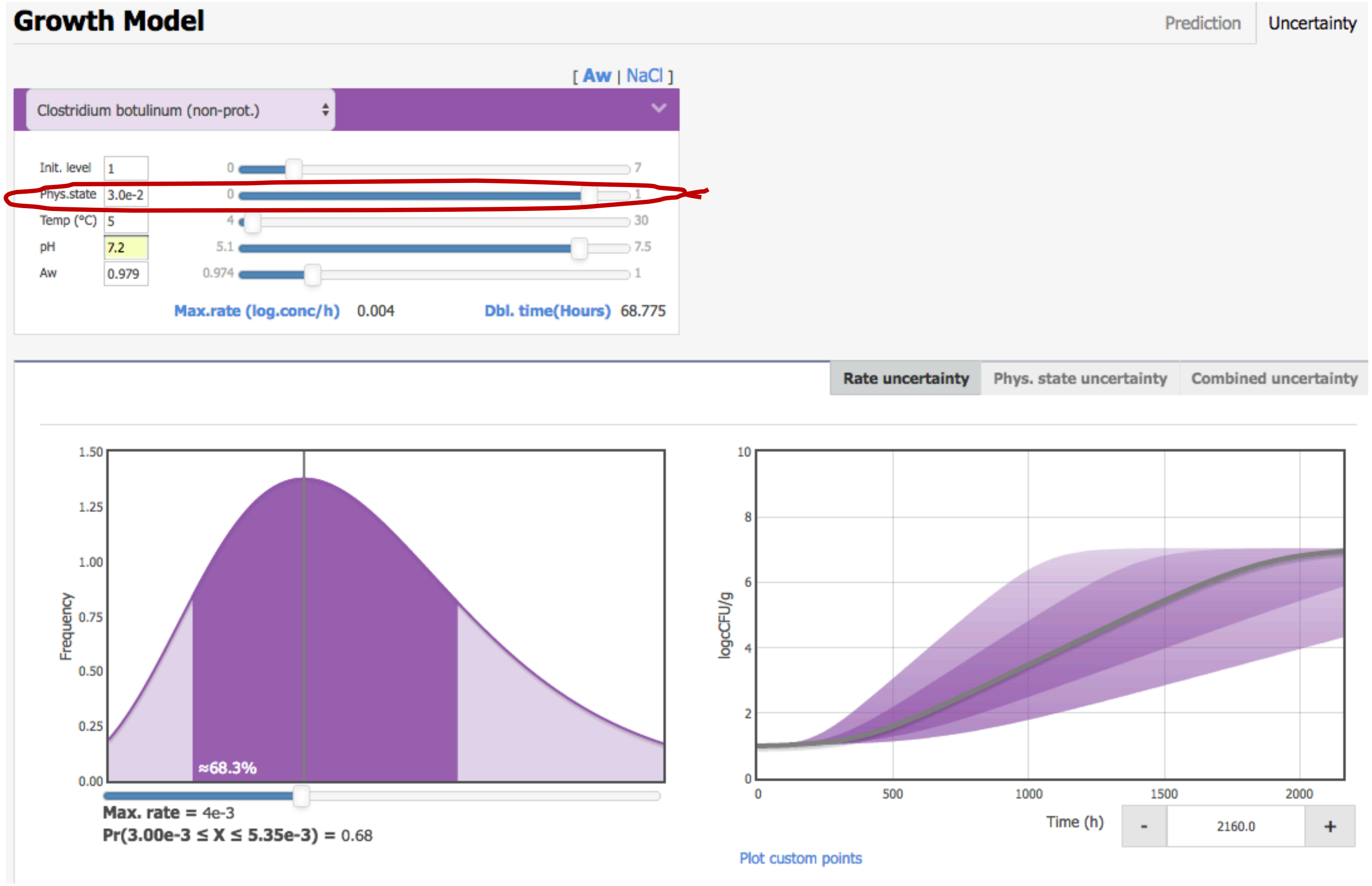


Gumbo Example – Combase Shelf Life?



Growth of non-proteolytic *C. botulinum* within about 14 days




Growth Model
Prediction
Uncertainty
[Aw | NaCl]
Clostridium botulinum (non-prot.)
Init. level 1 0 7
Phys.state 3.0e-2 0 1
Temp (°C) 5 4 30
pH 7.2 5.1 7.5
Aw 0.979 0.974 1
Max.rate (log.conc/h) 0.004
Dbl. time(Hours) 68.775
Rate uncertainty
Phys. state uncertainty
Combined uncertainty
Frequency
≈68.3%
Max. rate = 4e-3
Pr(3.00e-3 ≤ X ≤ 5.35e-3) = 0.68
logCFU/g
Time (h)
2160.0
Plot custom points

Summary

- Various Tertiary Models Exist
  - Some of which were demonstrated in this webinar
- Select Model Based Upon Your Unique Situation and Parameters
- Be Careful with Assumptions and Interpretation
  - Read and follow guidelines and disclaimers
- Validate and Verify

Dr. Betsy Booren

Dr. Tom Ross

Dr. Peter Taormina

QUESTIONS & ANSWERS

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- Dr. Yuhuan Chen
- Dr. Marcel Zwietering
- Dr. Bala Kottapalli

IAFP

- David Tharp
- Sarah Dempsey
- Tamara Ford

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  - Spring 2018