Modeling Salmonella Growth for Small and Very Small Processors with Limited Data

Moderator: Dennis Seman, DL Seman Consulting, L.L.C.

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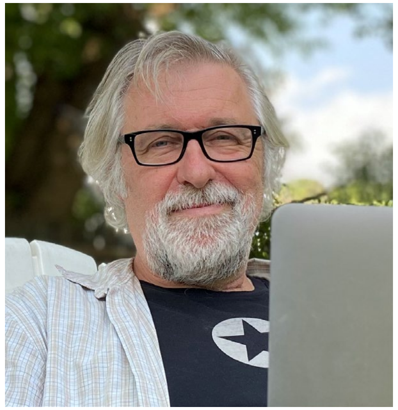
Today’s Panelists

Dr. Dickson is currently a Professor in the Department of Animal Science and the Inter-Departmental Program in Microbiology at Iowa State University. Dr. Dickson's research focuses on the control of bacteria of public health significance in foods of animal origin. Prior to his appointment at Iowa State University in 1993, he was employed by USDA-ARS as a Research Food Technologist and lead scientist of the Meat Safety Assurance Program, located at the Roman L. Hruska U.S. Meat Animal Research Center, Clay Center, NE. Dr. Dickson was employed in the food industry for three years before joining USDA-ARS. He is a Fellow in the American Academy of Microbiology, and is a Past President of the International Association for Food Protection. He is also active in the American Society for Microbiology and a Certified Food Technologist with the Institute of Food Technologists. Dr. Dickson is currently serving on the National Advisory Committee for Microbiological Specifications for Foods and chairs the U.S. mirror committee for ISO that addresses food safety standards (ISO 22000 series).



Dr. Donald W. Schaffner is Extension Specialist in Food Science and Distinguished Professor at Rutgers University. He is the current Chair of the Rutgers Department of Food Science. His research interests include handwashing, cross-contamination and quantitative microbial risk assessment. He is a Fellow of the Institute of Food Technologists, the American Academy of Microbiology, International Association for Food Protection (IAFP) and the Society for Risk Analysis. Dr. Schaffner was the president of IAFP in 2013-2014. He co-hosts the Food Safety Talk and Risky or Not podcasts.

Modeling to Determine if Cooking Cured Bone-In Ham Meets Regulatory Requirements

JIM DICKSON

DEPARTMENT OF ANIMAL SCIENCE

IOWA STATE UNIVERSITY

Lethality

- **FSIS Cooking Guideline for Meat and Poultry Products (Revised Appendix A) December, 2021**

- **https://www.fsis.usda.gov/sites/default/files/media_file/2021-12/Appendix-A.pdf**

Critical Operating Parameters

- Come Up Time (CUT)
  - An establishment must also consider the heating CUT to be a critical operating parameter unless the establishment can provide a science-based rationale why heating CUT does not need to be addressed.
  - Come-Up-Time Option: ***Total time product temperature is between 50°F and 130°F is 6 hours or less***.

- ***BUT:*** USDA FSIS recognizes that large diameter products may have longer come up times (CUT)

Predictive Microbial Modeling to Support CUT

- Alternatively, **establishments may use predictive microbiology modeling to develop custom critical operating parameters**. Predictive food microbiology uses models (i.e., mathematical equations) to describe the growth, survival, or inactivation of microbes in food systems from knowledge of the intrinsic and extrinsic factors of the food over time.

Cooking Deviations
Long Heating Come Up Time (CUT)

- **If modeling estimates the growth of vegetative pathogens to be 1-Log or less, *<u>modeling is adequate to show that the process prevented vegetative pathogen outgrowth</u>***

What do we need to model?

- Physical properties of the food (pH, NaCl or A_w, nitrite, etc.)
- Elapsed time - the time, in hours, between temperatures
- Temperature

Cooked Cured Ham
Elapsed Time and Linear Model

- Starting temperature and time
  - 50°F, 7:40AM (0 hours)
- Final temperature and time
  - 130°F, 3:30PM (? hours)

Elapsed Time Example - 01

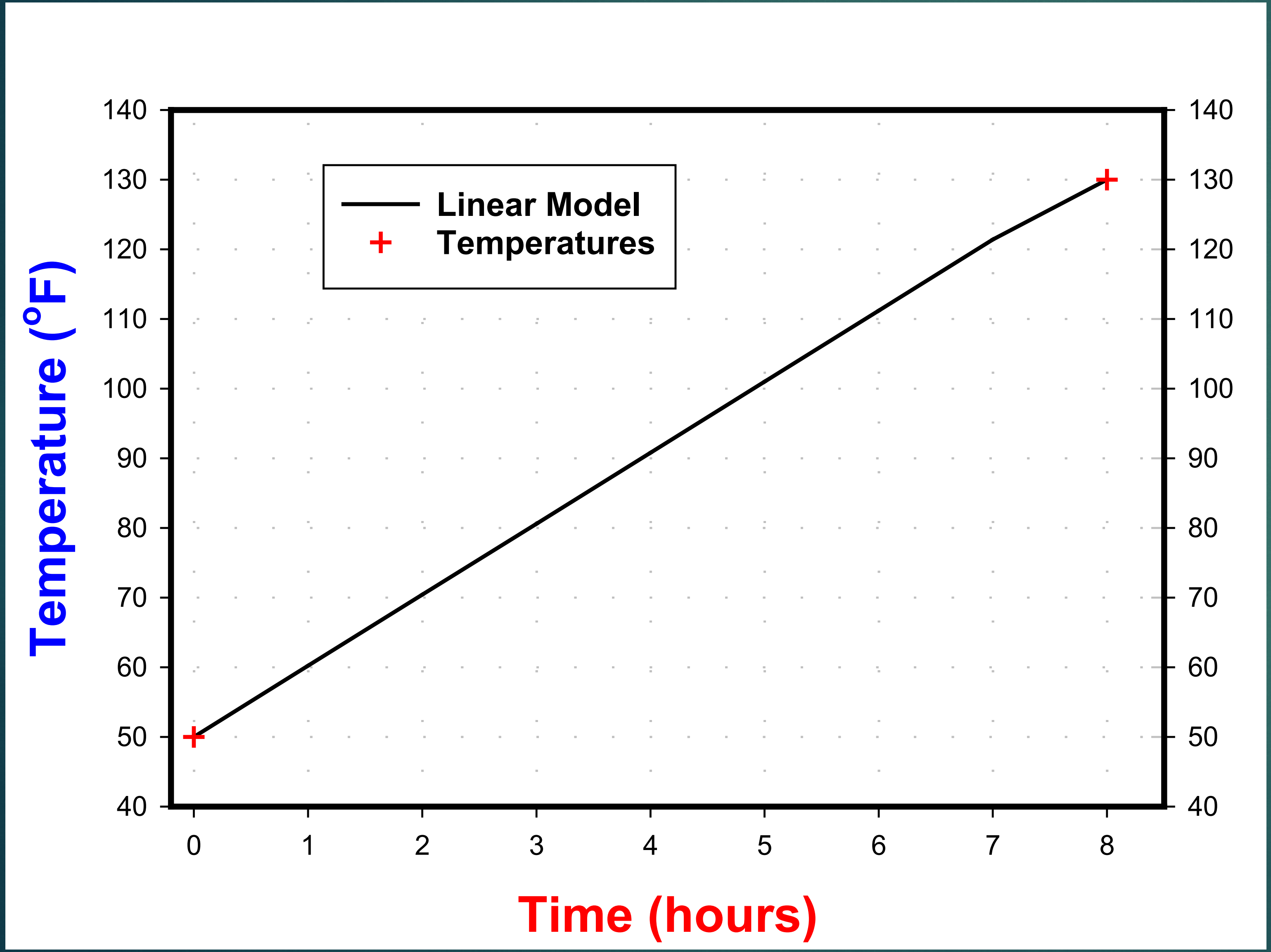
- Start: 7:40AM 50°F; End : 3:30PM 130°F
  - 7:40 to 8:00 = 20 min
  - 8:00 to 9:00 = 60 min
  - 9:00 to 10:00 = 60 min
  - 10:00 to 11:00 = 60 min
  - 11:00 to 12:00 = 60 min
  - 12:00 to1:00 = 60 min
  - 1:00 to 2:00 = 60 min
  - 2:00 to 3:00 = 60 min
  - 3:00 to 3:30 = 30 min

- 20 + 60 + 60 + 60 + 60 + 60 + 60 + 60 + 30 = 470 minutes
- 470 minutes/ 60 minutes per hour = 7.83 hours

Linear Modeling

- **Drawing a straight line between two points**

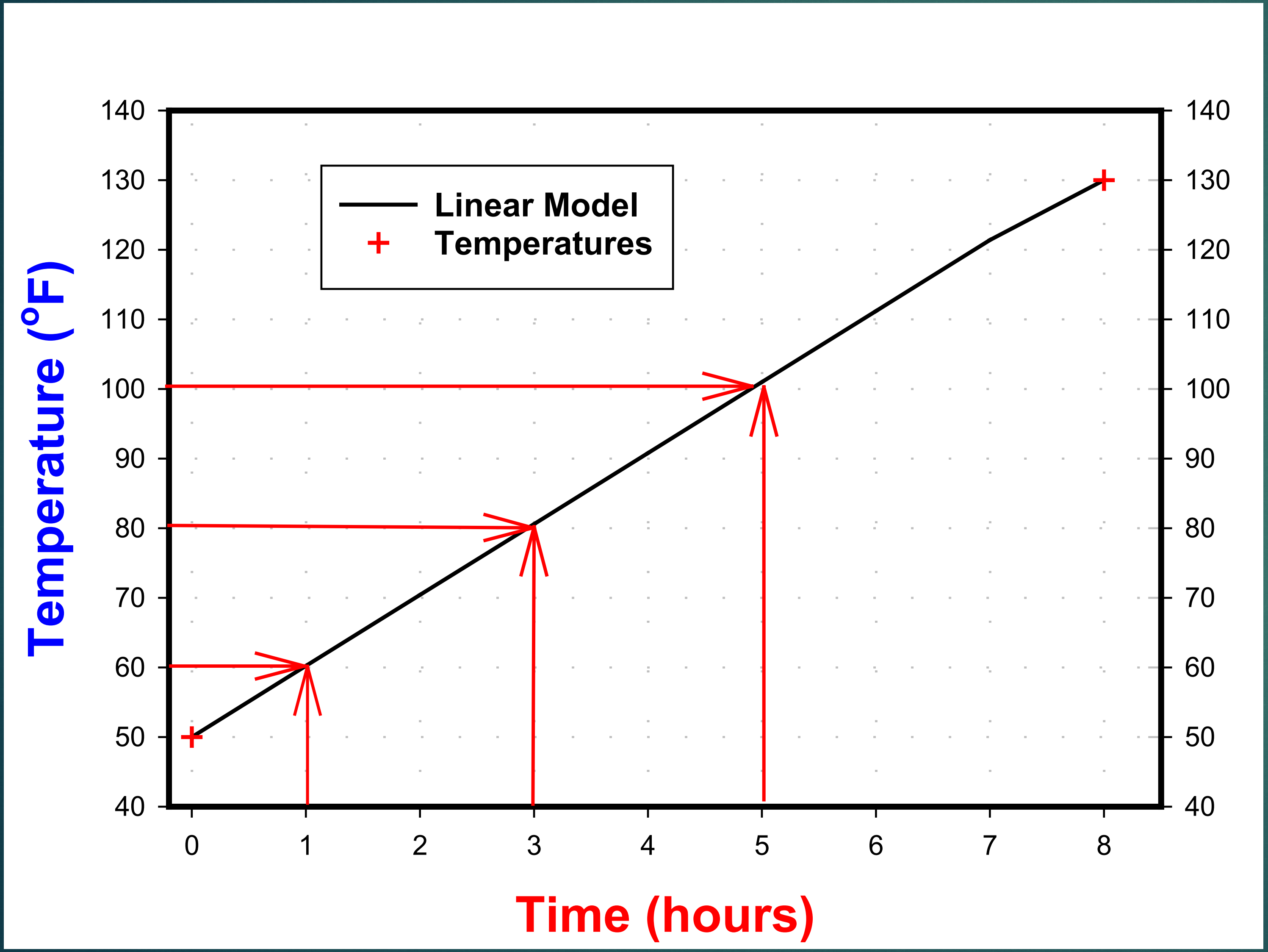
Linear Model



Time between 50°F and 130°F = ~ 8 hours

This process is not in compliance

Linear Model



Read 3 additional temperature and time points from the graph

That will give 5 points: start, finish and additional points

Linear Model – Example 01

$$\frac{\text{Temperature(2)} - \text{Temperature(1)}}{\text{Time(2)} - \text{Time(1)}}$$

Linear Model

- $\underline{130^{o}F - 50^{o}F}$
- 7.83 – 0
- Or
- $\underline{80^{o}F}$
- 7.83 hours

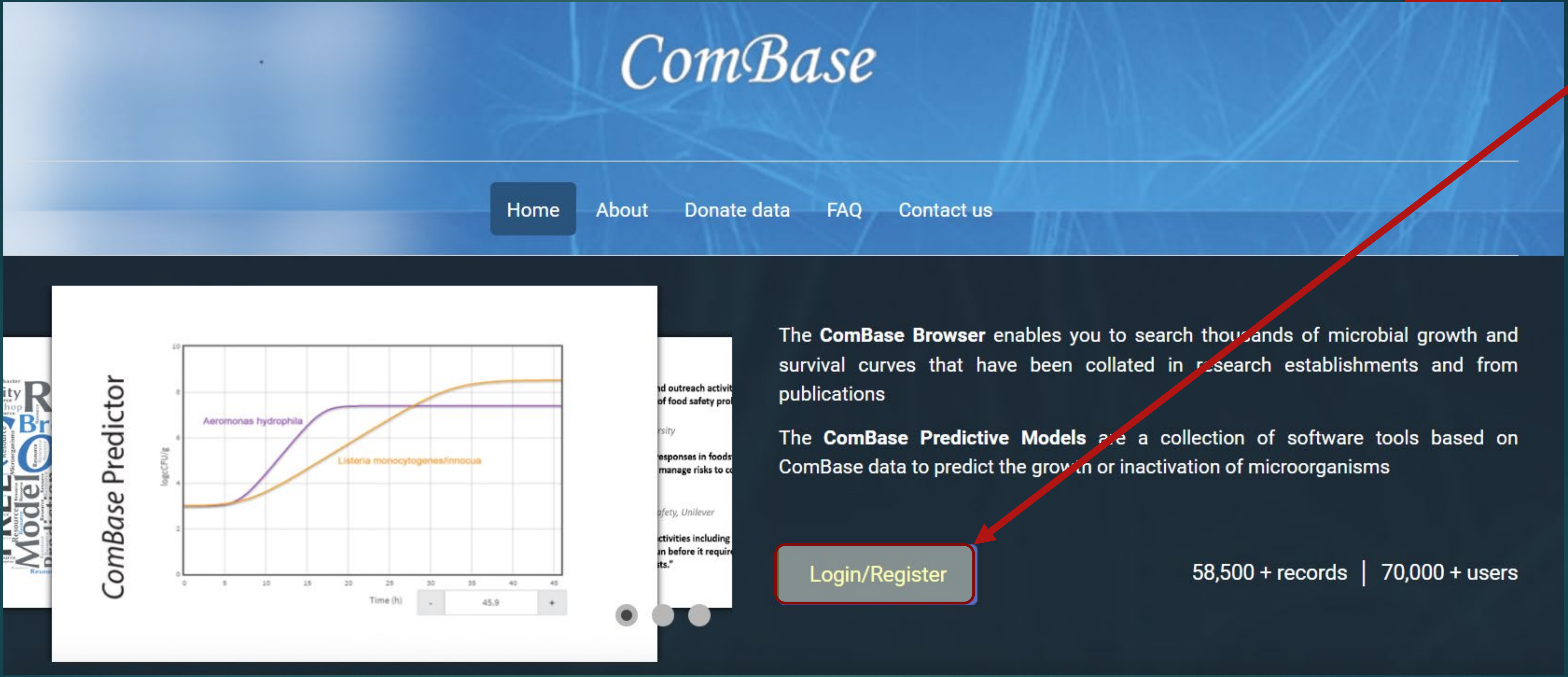
- $10.2^{o}F/hour$

Linear Model - Example - 01

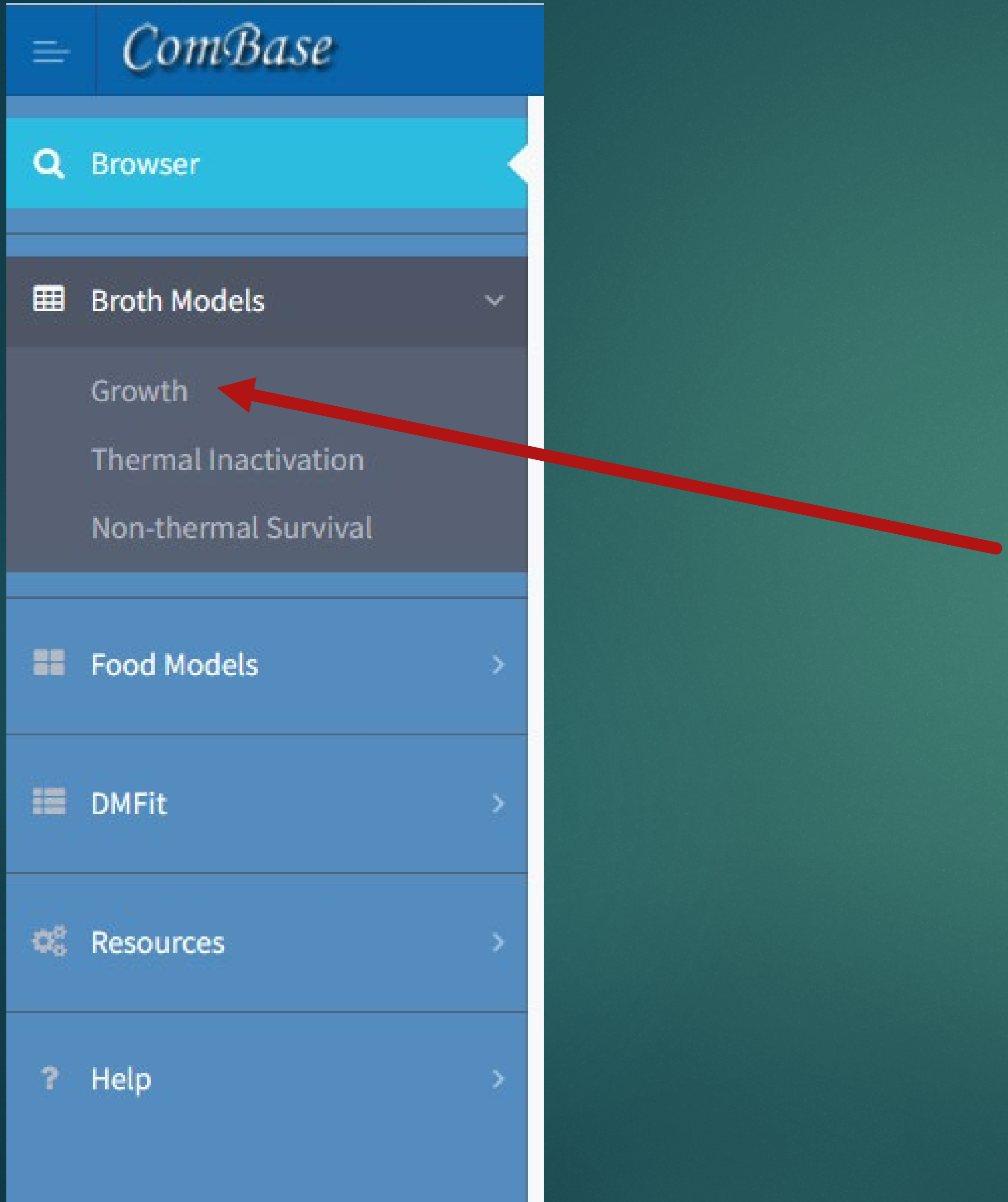
Time (hours)	Temperature (°F)
0	50
1	60.2
2	70.4
3	80.6
4	90.8
5	101
6	111.2
7	121.4
8	130

Linear Modeling

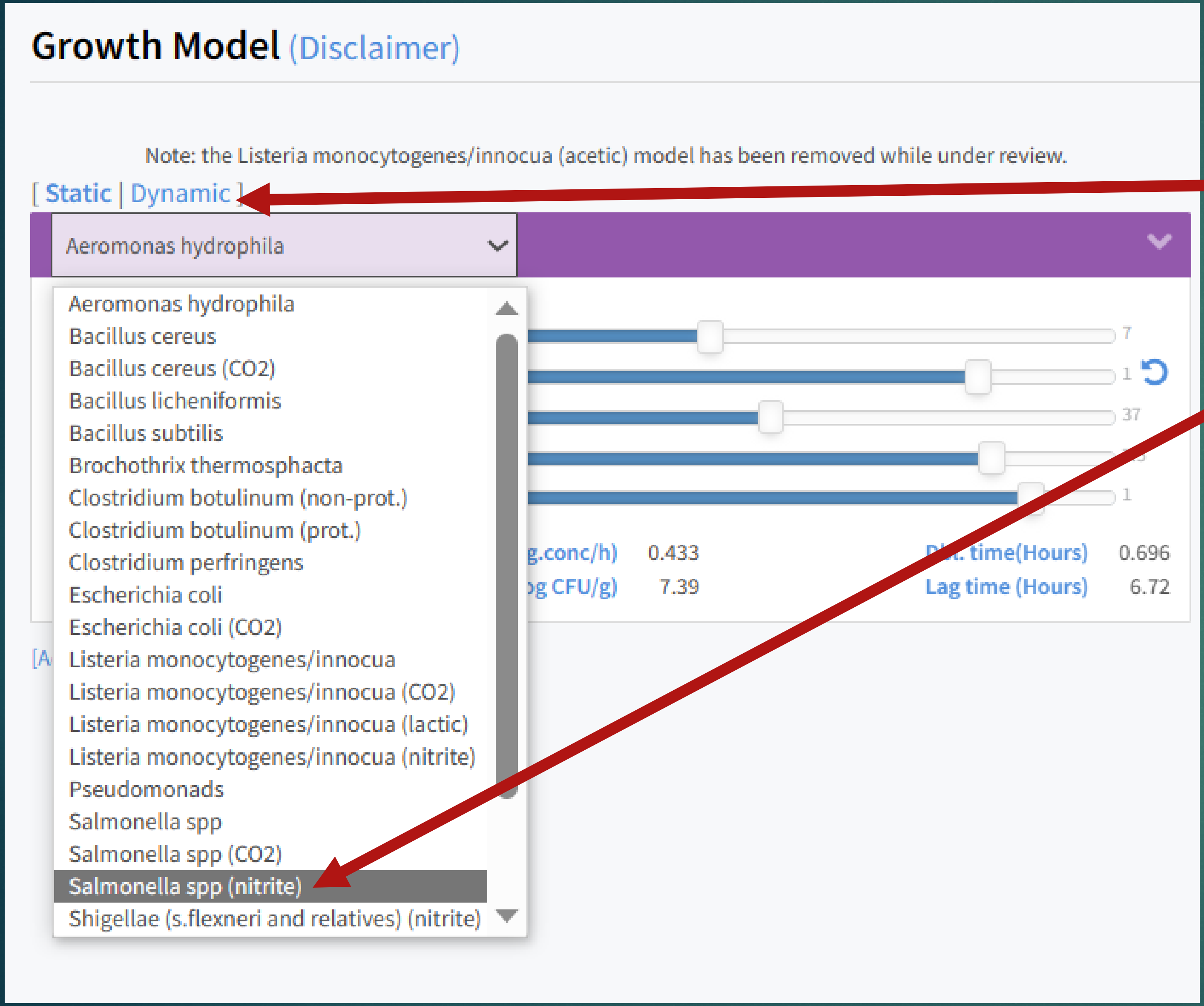
- Linear modeling –
  - overestimates pathogen growth during the cooling
  - overestimates pathogen growth
- FSIS considers this modeling result fail-safe
- Therefore – more temperature and time information provides a more accurate estimate in the model



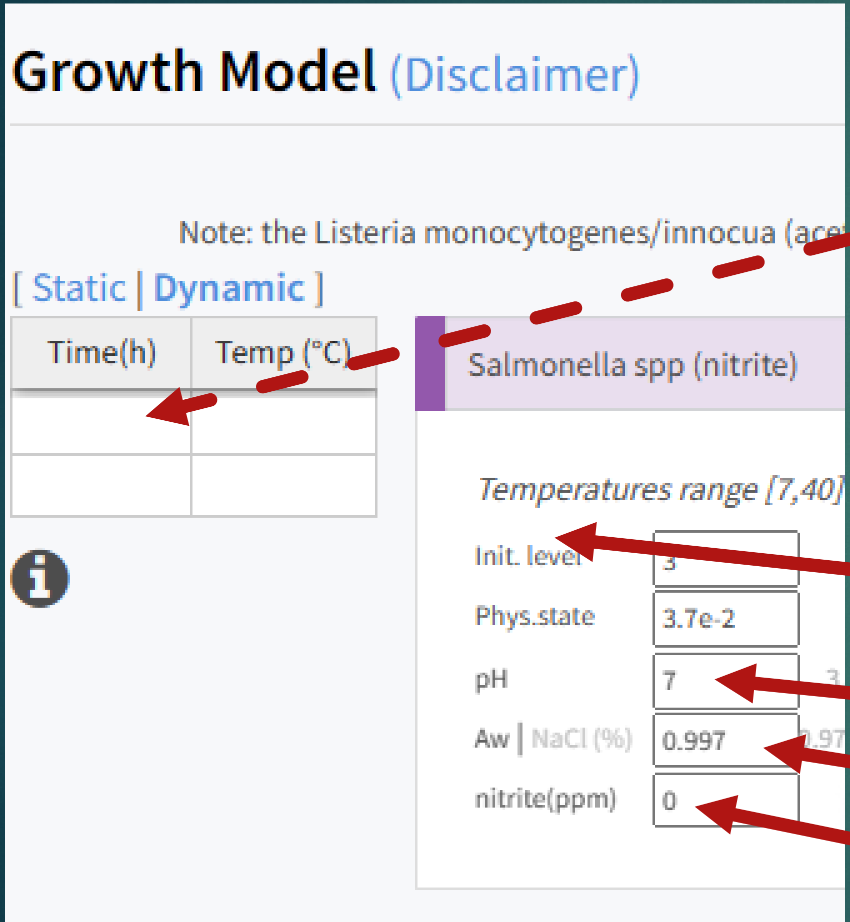
https://www.combase.cc/index.php/en/



- After log in
- Upper left corner
- “Growth” in the “Broth Models” tab



- Dynamic
- Select organism



- Time and Temperature ***(°C!!)***
- ***At least 5 time and temperature points***
- ***Range 7°C to 40°C***
- Inputs
- Initial population
- pH
- Water activity (a_w) or NaCl
- Nitrite

Fahrenheit to Celsius Temperature conversion

- 128^oF = ??^oC

- $(128^oF – 32^oF) * (5/9) = 53.3^oC$

- $212^oF = 100^oC$
- $32^oF = 0^oC$

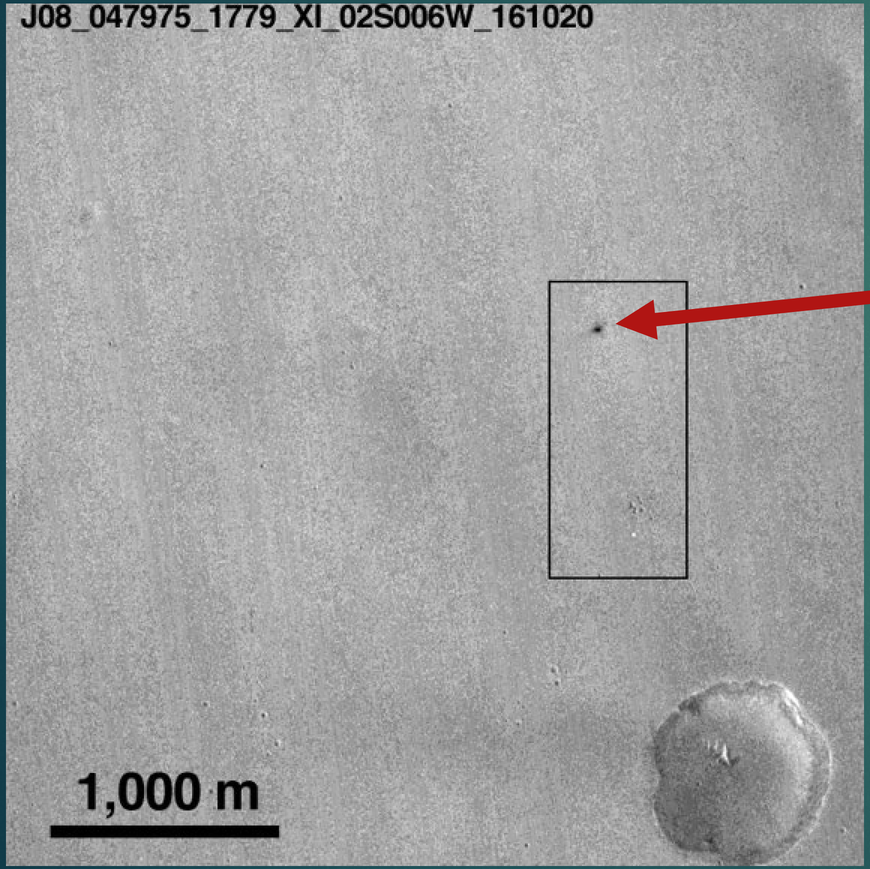
Fahrenheit to Celsius Temperature conversion

- In MS-Excel
- Covert temperature “from” “to”

Temp F	-	Temp C	-	Formula
50		10.0		=CONVERT (A3,"F","C")
60		15.6		=CONVERT (A4,"F","C")
70		21.1		=CONVERT (A5,"F","C")
80		26.7		=CONVERT (A6,"F","C")
90		32.2		=CONVERT (A7,"F","C")
100		37.8		=CONVERT (A8,"F","C")
110		43.3		=CONVERT (A9,"F","C")
120		48.9		=CONVERT (A10,"F","C")
130		54.4		=CONVERT (A11,"F","C")

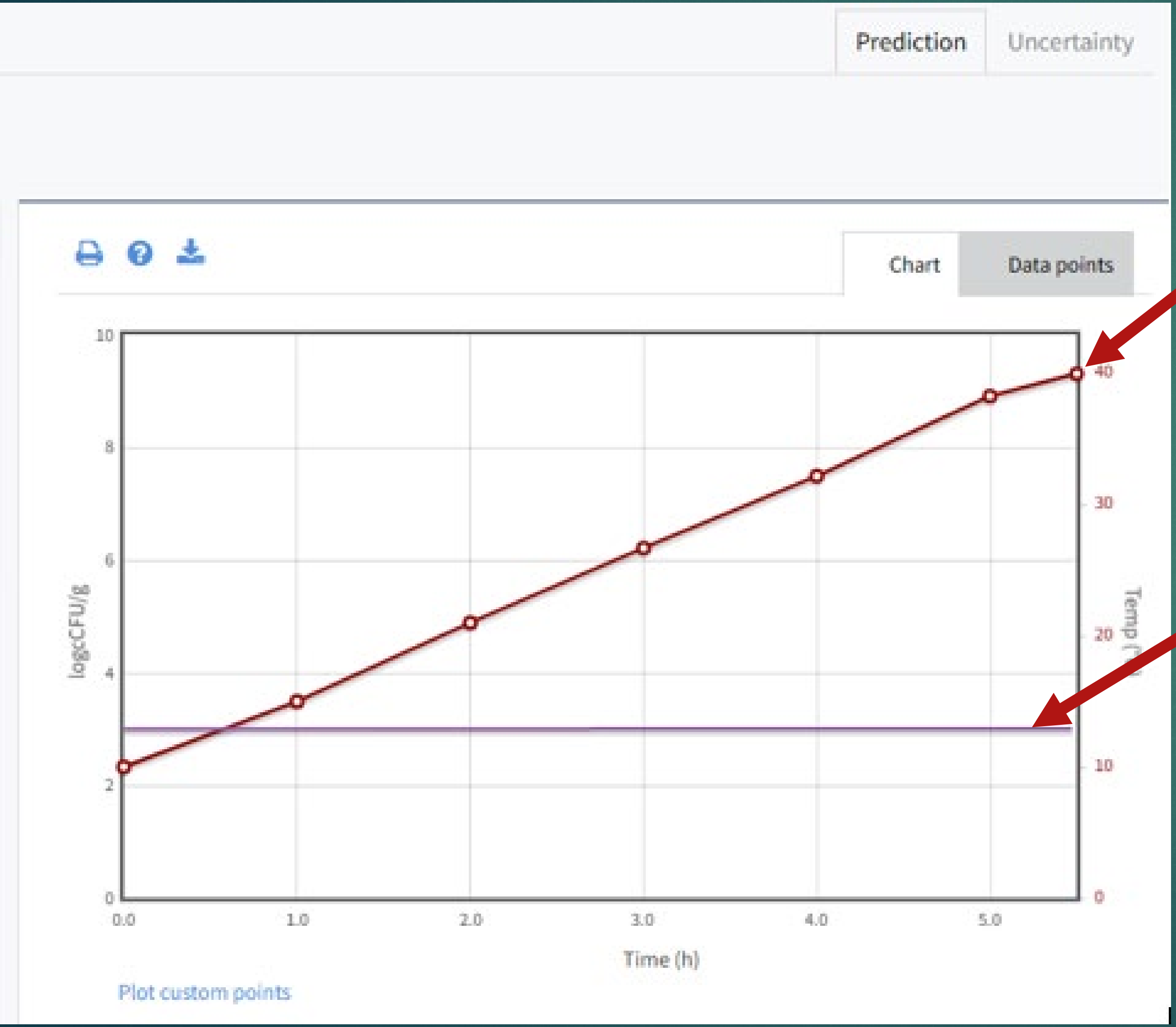
=CONVERT(temp,"F","C")

Fahrenheit to Celsius Temperature conversion



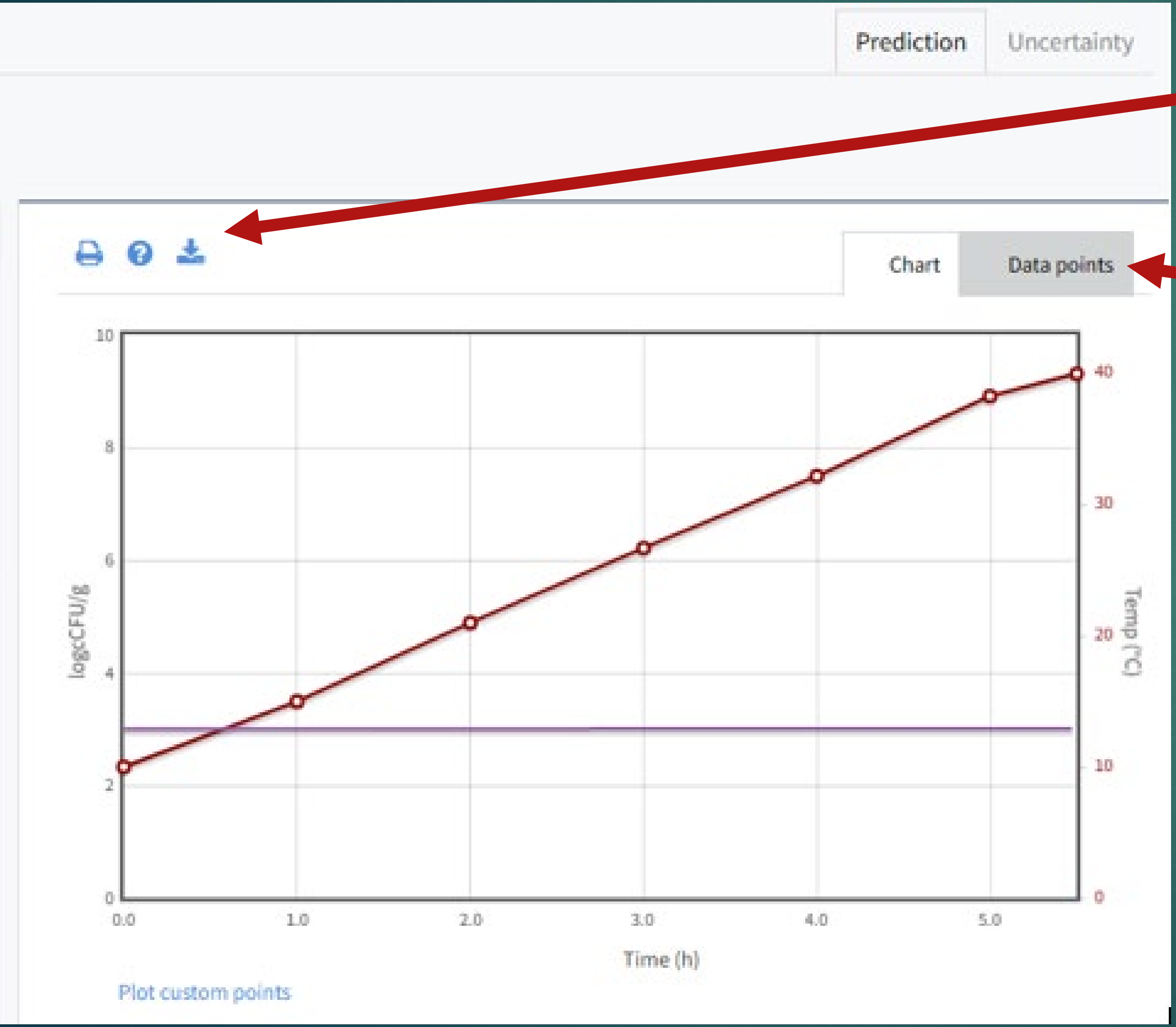
- **Mars Probe Lost Due to Simple Math Error (01 Oct 1999)**
- **NASA lost its $125-million Mars Climate Orbiter because spacecraft engineers failed to convert from Imperial to Metric measurements when exchanging vital data before the craft was launched, space agency officials said Thursday.**
- **As a result, JPL engineers *mistook acceleration readings measured in Imperial units of pound-seconds for a metric measure of force called newton-seconds*.**
- https://www.latimes.com/archives/la-xpm-1999-oct-01-mn-17288-story.html

ComBase Output



- Temperature
- Predicted Growth

Output



- Print or download
- Data Points

Output

Chart | Data points

Temp (°C)	Time(h)	Conc (Log10 cells/g)
10	0	3
10.14	0.028	3
10.28	0.055	3
10.41	0.083	3
10.55	0.111	3
10.69	0.138	3
10.83	0.166	3
10.97	0.193	3
11.11	0.221	3
11.24	0.249	3
11.38	0.276	3

- Print or download
- Predicted Population
- Temperature and Time

What does it mean?
Long Heating Come Up Time (CUT)

- "If modeling estimates the growth of vegetative pathogens to be 1-Log or less, ***modeling is adequate to show that the process prevented vegetative pathogen outgrowth***"

- ComBase growth model predicts < 1 $\log_{10}$ increase in population

Documentation

- **Physical parameters of the product (pH, Nitrite, NaCl or A_w)**
- **Available temperature and time information**
- **Model results**

- ***All parameters should represent the "worst case" scenario***

RUTGERS
New Jersey Agricultural Experiment Station

Modeling below the limits of the model and cooking deviations

Don Schaffner, PhD
Distinguished Professor and Extension Specialist
Chair, Department of Food Science

Outline

- Modeling below the limits of the model
  - The limits of a model are often inside the limits of the growth of the organism
  - There are different solutions to the problem
- Cooking deviations with limited data
  - Modeling cooking deviations requires use of D and z values
  - My preferred tool is the NAMI spreadsheet

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Limits of the organism

- Limits to growth (NACMCF 2010)
  - ICMSF v 5 (1996)
  - FDA (2011) Fish and Fisheries Products Hazards and Controls Guidance. Appendix 4.

Pathogen		Temp (°C)		pH		a_w	Water Phase NaCl (%)
		Min	Max	Min	Max	Min	Max
B. cereus	FDA	4	55	4.3	9.3	0.92	10
	ICMSF	4	55	5.0	8.8	0.93	
C. bot (growth only)	FDA	10	48	4.6	9	0.93	10
(Proteolytic)	ICMSF	10-12		4.6		0.93	10
C. bot (growth only)	FDA	3.3	45	5	9	0.97	5
(Non-proteolytic)	ICMSF	3.3		5.0		0.97	5
C. perfringens	FDA	10	52	5	9	0.93	7
	ICMSF	12	50	5.5	9.0	0.97	
Pathogenic *E. coli*	FDA	6.5	49.4	4	9	0.95	6.5
	ICMSF	7-8	44-46	4.4	9.0	0.95	
E. coli O157:H7	ICMSF	8	44-45	4.5			Slow at 6.5 NG at 8.5
L. monocytogenes	FDA	-0.4	45	4.4	9.4	0.92	10
	ICMSF	-0.4	45	4.39	9.4	0.92	
S. aureus (growth only)	FDA	7	50	4	10	0.83	20
Aerobic conditions	ICMSF	7	48	4	10	0.83	
Anaerobic conditions	ICMSF			5.0		0.90	
Salmonella	FDA	5.2	46.2	3.7	9.5	0.94	8
	ICMSF	5.2	46.2	3.8	9.5	0.94	

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Limits of the model

- Also from NACMCF (2010)

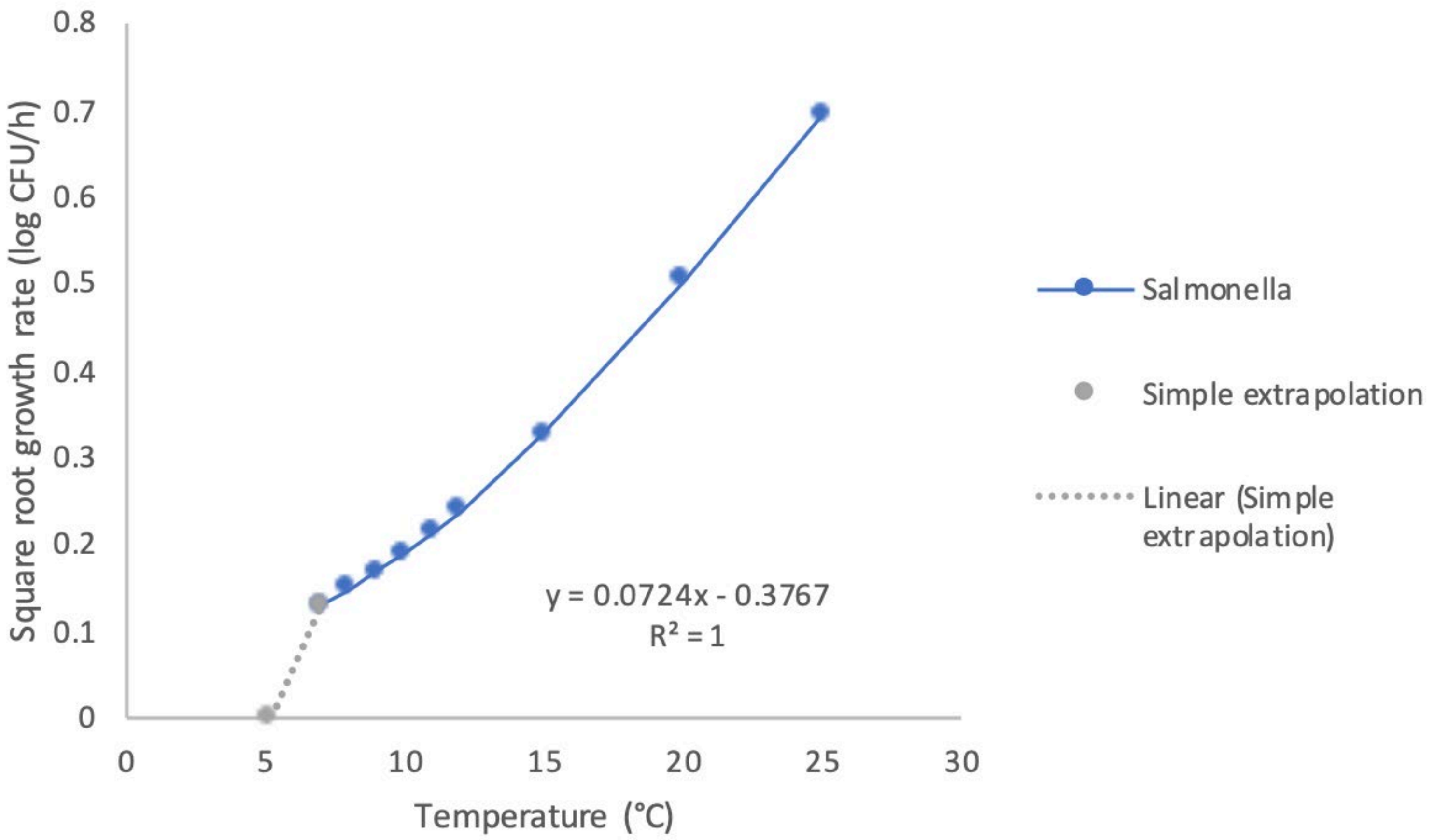
	ComBase[2]					PMP[3]				
	Temperature (°C)		pH		a_w	Temperature (°C)		pH		a_w
	Min	Max	Min	Max	Min	Min	Max	Min	Max	Min
B. cereus										
with CO_2	5	34	4.9	7.5	0.974					
aerobic						5	42	4.7	7.5	0.97
anaerobic						10	42	5.0	9.0	0.97
C. botulinum (growth only)										
proteolytic	14	40	4.7	7.2	0.954	15	34	5.0	7.2	0.977
non-proteolytic	4	30	5.1	7.5	0.974	5	28	5.0	7.0	0.977
C. perfringens	15	52	5	8	0.971	19	37	6.0	6.5	0.983
E. coli O157:H7										
with CO_2	10	30	4.5	7	0.961					
aerobic						5	42	4.5	8.5	0.97
anaerobic						5	42	4.5	8.5	0.97
L. monocytogenes										
with CO_2	1	35	4.4	7.5	0.934					
aerobic						4	37	4.5	7.5	0.928
anaerobic						4	37	4.5	8.0	0.97
S. aureus (growth only)										
not specified	7.5	30	4.4	7.1	0.907					
aerobic						10	42	4.5	9.0	0.911
anaerobic						12	42	5.3	9.0	0.872
Salmonella spp.										
with CO_2	7	30	3.9	7.4	0.973					
aerobic						10	30	5.6	6.8	0.974

Three solutions, one wrong

- If the temperature is below the limit of the model, assume the temperature is at the limit of the model
- If the temperature is below the limit of the model, interpolate between the limit of the model and the temperature
- ~~If the temperature is below the limit of the model, the growth rate of the organism is zero~~

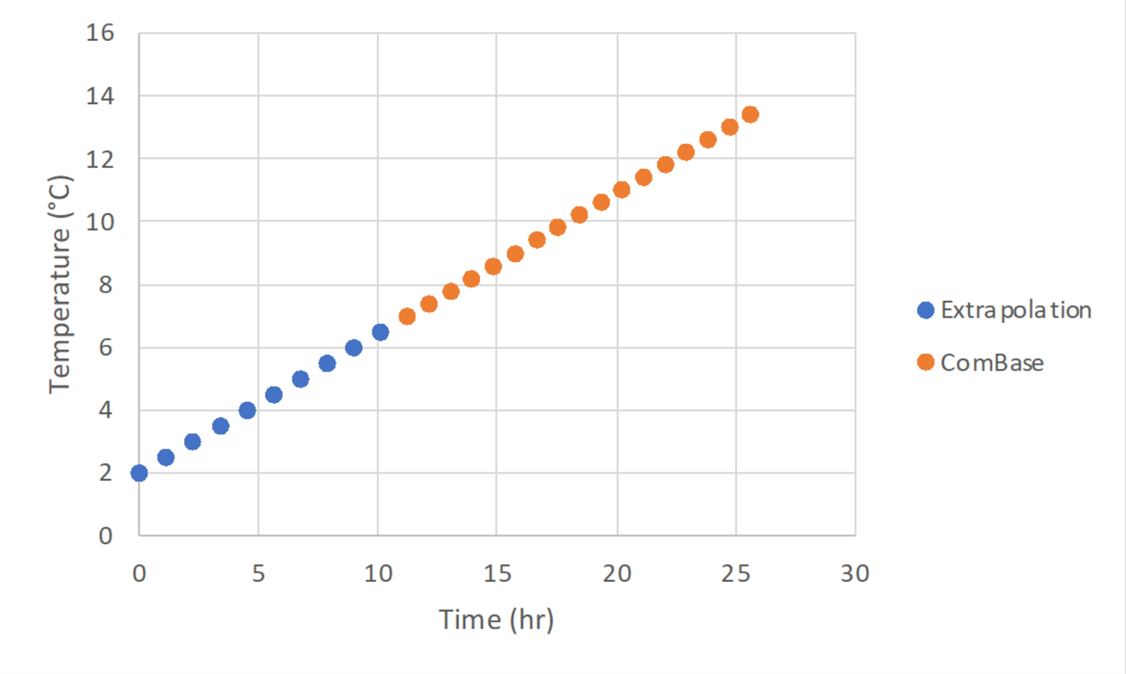
Extrapolating below the model limit

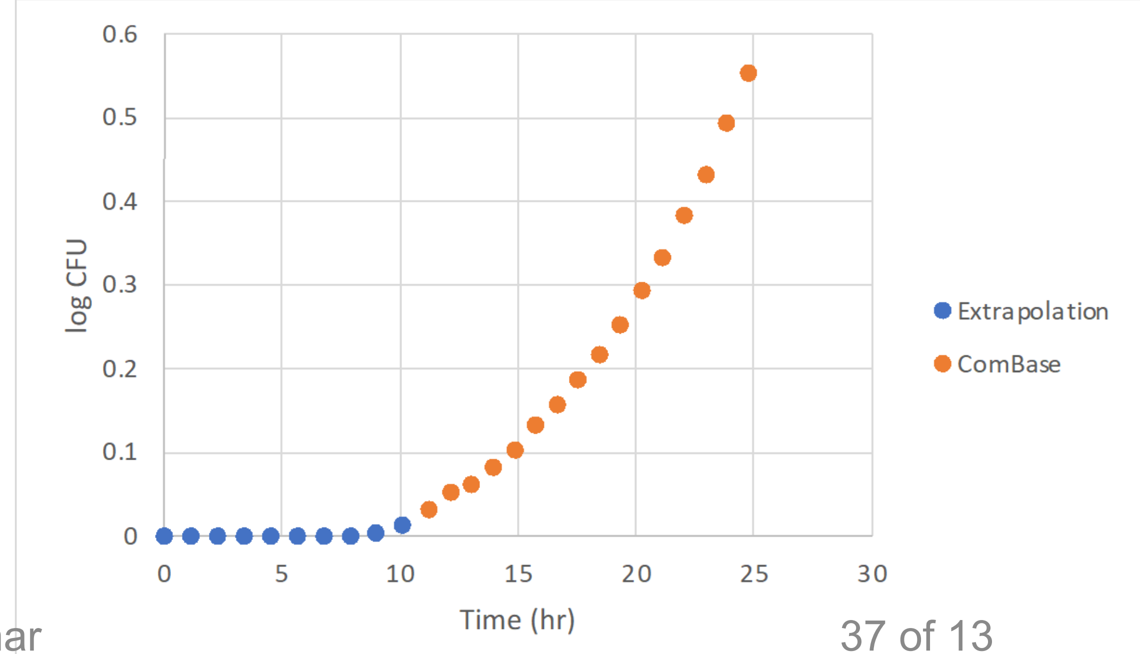
- Vol 29, No 55 (2021), Revista Alimentos Hoy



Example

- *Salmonella* growth under constant temperature increase
- A little growth up to 12 hours





Example

- Company was using 1999 USDA Appendix A
- Cook to 159 °F (instantaneous)
- What to do if 159 °F is not reached?
  - Drop down to lower time and temperature
  - Integrated lethality

Guidelines for Cooked Beef, Roast Beef, and Cooked Corned Beef

1. Cooked beef and roast beef, including sectioned and formed roasts, chunked and formed roasts, and cooked corned beef can be prepared using one of the following time and temperature combinations to meet either a 6.5-log_{10} or 7-log_{10} reduction of Salmonella. The stated temperature is the minimum that must be achieved and maintained in all parts of each piece of meat for a least the stated time:

Minimum Internal Temperature		Minimum processing time in minutes or seconds after minimum temperature is reached	
Degrees Fahrenheit	Degrees Centigrade	6.5-log_{10} Lethality	7-log_{10} Lethality
130	54.4	112 min.	121 min.
131	55.0	89 min.	97 min.
132	55.6	71 min.	77 min.
133	56.1	56 min.	62 min.
134	56.7	45 min.	47 min.
135	57.2	36 min.	37 min.
136	57.8	28 min.	32 min.
137	58.4	23 min.	24 min.
138	58.9	18 min.	19 min.
139	59.5	15 min.	15 min.
140	60.0	12 min.	12 min.
141	60.6	9 min.	10 min.
142	61.1	8 min.	8 min.
143	61.7	6 min.	6 min.
144	62.2	5 min.	5 min.
145	62.8	4 min.*	4 min.*
146	63.3	169 sec.	182 sec.
147	63.9	134 sec.	144 sec.
148	64.4	107 sec.	115 sec.
149	65.0	85 sec.	91 sec.
150	65.6	67 sec.	72 sec.
151	66.1	54 sec.	58 sec.
152	66.7	43 sec.	46 sec.
153	67.2	34 sec.	37 sec.
154	67.8	27 sec.	29 sec.
155	68.3	22 sec.	23 sec.
156	68.9	17 sec.	19 sec.
157	69.4	14 sec.	15 sec.
158	70.0	0 sec.**	0 sec.**
159	70.6	0 sec.**	0 sec.**
160	71.1	0 sec **	0 sec.**

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Cooking deviations with limited data

- NAMI spreadsheet
- http://www.amif.org/process-lethality/
- Choice of D and z are important

Date:________________________
Organism:______________________
Product name:___________________

User Must:
1. Identify organism and product of concern
2. Provide at least 20 time/temp data points

Instructions:

1 Select the organism and product of concern and identify corresponding T ref (Temperature reference), z, and D values and create a similar table to Table 1. These values should be obtained from your own companies challenge study data, from scientific literature, or other reliable sources. These values need to be relevant and appropriate for the type of product and the organism of concern.

Note: *The data in Table 1 has been selected as examples of the type of data that should be collected and extracted from your own companies challenge study data, scientific literature, safe harbor documents, or other relieable sources. The data in Table 1* ***SHOULD NOT BE USED EXCLUSIVELY AS SUPPORT DATA.***

2 Enter the T ref, z, and D values into the appropriate labeled cells below the table that contains the lethality data from literature.
3 Clear and enter at least 20 time/temperature data points into the data table.

Note: *This model* ***MUST*** *contain a* ***MINIMUM*** *of 20 time/temperature data points. The model is not accurate if less than 20 data time/temperature data points are used.*

4 Once the table is completed, a cumulative F value will be given as the very last number in the right hand column of the data table. This number adds up the lethality values for each time interval and calculates an approximation of the area under the lethal rate curve.

5 After the data is entered, a core temperature and lethality curve are produced.
6 The total log reduction of the process is automatically determined by dividing the cumulative F value by the D value that was entered into the appropriate labeled cell. The resulting value equals the total log reduction of the process.
7 By using these estimates, you or a process authority should determine if the process meets regulatory requirements as safe.
The USDA's FSIS Appendix A Compliance Guidelines For Meeting Lethality Performance Standards For Certain Meat And Poultry Products that addresses desired log reductions should also be considered when evaluating a lethality process.

Definitions:
D-value: The time (in minutes) at an associated T ref required to kill 90% of the selected microorganism, a one log reduction.
z-value: The number of degrees F to change the D-value by a factor of ten.

F-value: The process lethality. The equivalent time of heating at a reference temperature. Total lethality will be the final computed cumulative F value.

TABLE 1: EXAMPLE - Lethality Data from Literature		Microbial Heat Tolerance		
Organism	Product	T ref (°F)	z (°F)	D (min)
Salmonella	Meat Patty (Scott and Weddig, 1998)	150.0	10	0.172
	Gr. Beef (25% fat) (Juneja, 2003)	140.0	14.5	4.72
	van Asselt and Zwietering (2006) mean	158.0	16.38	0.15
	van Asselt and Zwietering (2006) 95%ile	158.0	16.38	3.89
E. coli O157:H7	Lean Gr. Beef (2% fat) (Line et al., 1991)	145.0	8.3	0.30
	Gr. Beef (25% fat) (Juneja, 2003)	140.0	11.4	3.39
	Lean Gr. Turkey (Juneja and Marmer, 1999)	149.0	11.7	0.29
	Lean Gr. Lamb (Juneja and Marmer, 1999)	149.0	12.4	0.38
	Lean Gr. Pork (Juneja and Marmer, 1999)	149.0	11.7	0.30
Listeria monocytogenes	Lean Gr. Beef (2% fat) (Fain, et al., 1991)	145.0	9.3	0.6
	Gr. Beef (25% fat) (Juneja, 2003)	140.0	12.0	4.18
	Hot Dog Batter (30% fat) (Mazzotta and Gombas, 2001)	144.0	10.8	3.3

Note: This model is a tool for calculating F-values. To ensure correct results, the proper z, T-ref, and D-values for each product and organism must be used.

Useful reference

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INTERNATIONAL JOURNAL OF Food Microbiology

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A systematic approach to determine global thermal inactivation parameters for various food pathogens

Esther D. van Asselt [1], Marcel H. Zwietering *

Wageningen University, Laboratory of Food Microbiology, P.O. Box 8129, 6700 EV Wageningen, The Netherlands

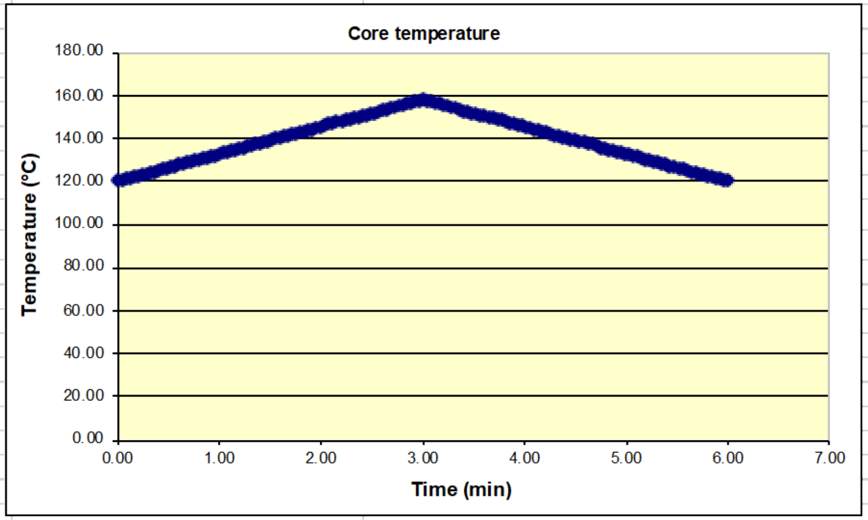
Received 19 February 2005; received in revised form 3 August 2005; accepted 7 August 2005

Using NAMI spreadsheet

- 20 data points are needed, so interpolate

PROCESS LETHALITY DETERMINATION

User Must:
1. Identify organism and product of concern
2. Provide at least 20 time/temp data points



T ref = 158 °F
z = 16.38 °F
D = 0.15 min

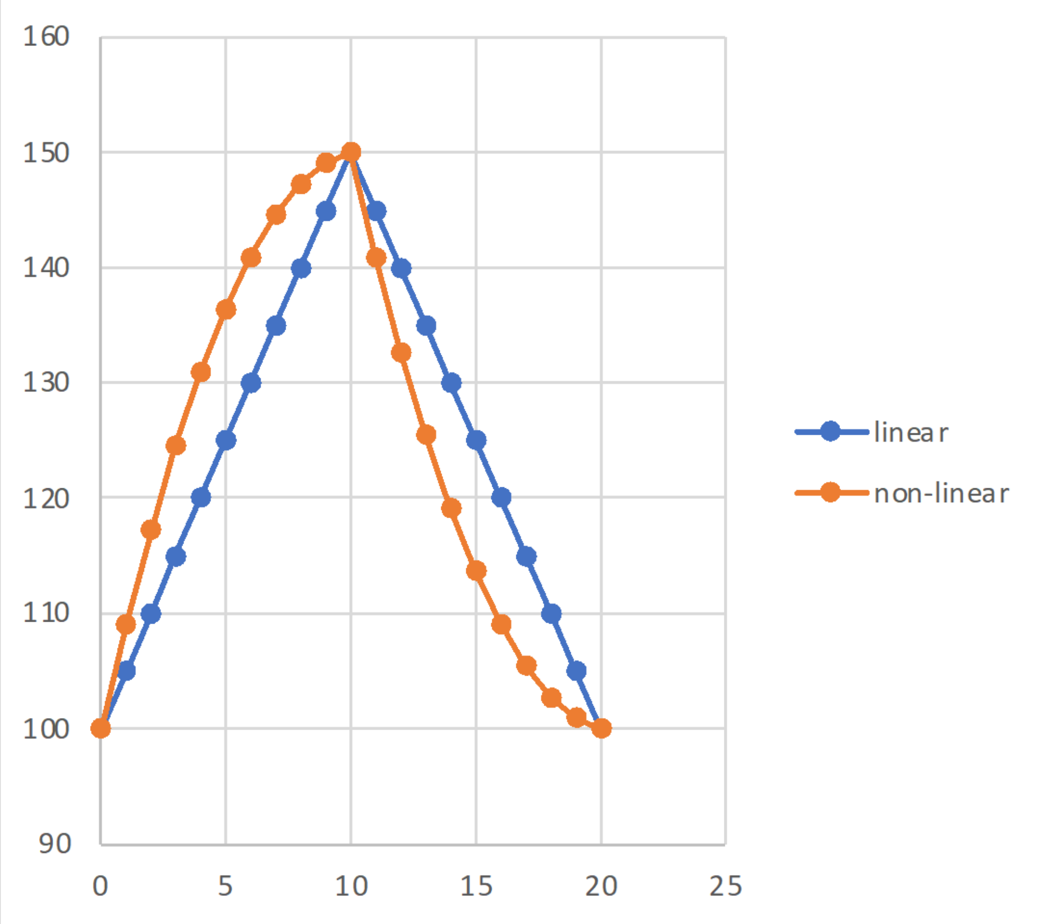
Log Reduction of Process
7.46

Data Table

Time (min)	Core Temp (°F)	F-value (min)	time	D value	time (min)	temp
0.00	120.00	0.000	0.0	0.0	0.00	120
0.04	120.51	0.000	0.0	0.0	3.00	158
0.08	121.01	0.000	0.1	0.0	6.00	120
0.12	121.52	0.001	0.1	0.0		
0.16	122.03	0.001	0.2	0.0		
0.20	122.53	0.001	0.2	0.0		
0.24	123.04	0.001	0.2	0.0		
0.28	123.55	0.002	0.3	0.0		

Straight line interpolation

- May be close to observation
- Under-estimates lethality on rise
- Over-estimates lethality on decline
- Overall underestimation (fail safe) with linear



Summary

- Two examples today
  - Modeling below the limits of the model
  - Cooking deviations with limited data
- Many problems can be solved with off-the-shelf modeling tools and Excel
- The key is to make fail safe assumptions, and justify them

Contact Info

James Dickson, Speaker	jdickson@iastate.edu
Don Schaffner, Speaker	don.schaffner@rutgers.edu
Dennis Seman	dlseman@hotmail.com

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