Determining the Thermal Resistance of Microorganisms in Low Moisture Foods

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April 4, 2012

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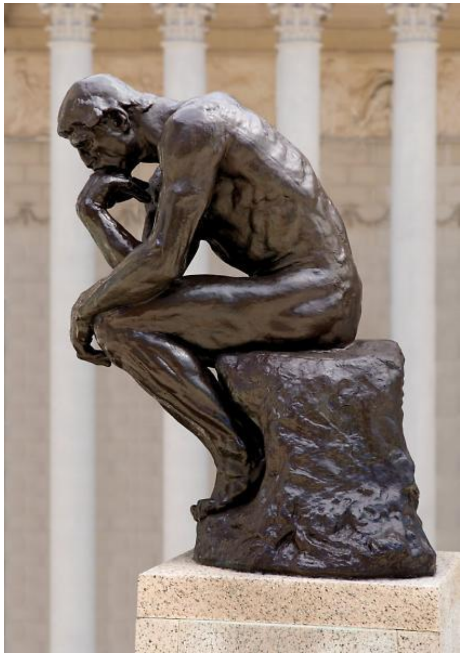
Presentation Overview

- Food Safety and Low Moisture Foods
- Behavior of Microorganisms in Low Moisture Foods
- Thermal Process Validations – A Microbiologist's Perspective
  - Phase I: Process/Product Review
  - Phase II: Microbial Kinetics Studies
  - Phase III: In-Process Validation
- Questions

Food Safety and Low Moisture Foods

- Dehydration as a preservation method
- Inhibits microbial growth
- Extension of shelf life

Does this apply to Food Safety?

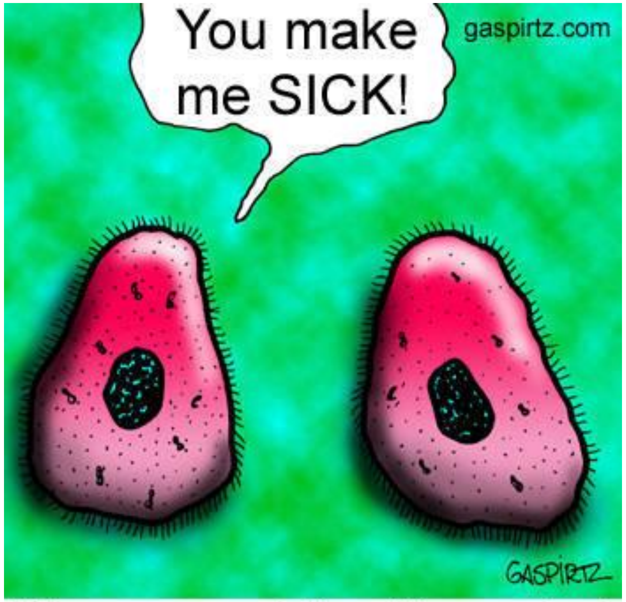


Food Safety and Low Moisture Foods – Outbreaks

Organism	Product	Year
E. coli **O157:H7**	**Salami**	**1994**
E. coli **O111:NM**	**Semidry Sausage**	**1995**
E. coli **O157:H7**	**Venison Jerky**	**1995**
Salmonella **Saint-Paul, Javiana, Rubislaw**	**Paprika Chips**	**1993**
Salmonella **Senftenberg**	**Infant Cereals**	**1995**
Salmonella **Mbandaka**	**Peanut Butter**	**1996**
Salmonella **Agona**	**Toasted Oat Cereal**	**1998**
Salmonella **spp.**	**Dried Squid**	**1999**
Salmonella **Oranienburg, Chester**	**Cuttlefish Chips**	**1999**
Salmonella **Stanley, Newport**	**Peanuts**	**2001**
Salmonella **Oranienburg**	**Chocolate**	**2001**
Salmonella **Enteritidis**	**Raw Almonds**	**2003-2004**
Salmonella **Montevideo**	**Chocolate**	**2006**
Salmonella **Tennessee**	**Peanut Butter**	**2006-2007**
Salmonella **Agona**	**Puffed Cereals**	**2008**
Salmonella **Give**	**Powdered Infant Formula**	**2008**
Salmonella **Typhimurium**	**Peanut Butter, Peanut Butter Containing Products**	**2008-2009**

Behavior of Microorganisms in Low Moisture Foods

- Low water activity limits growth of microorganisms
- Pathogens can survive in this environment
- Pathogens demonstrate higher thermal resistance in low water activity environments
- Fat/oil, solids, and other intrinsic properties of a food product can protect/shield microorganisms from thermal treatment
- Pathogens with low infective dose can survive thermal processing "kill" steps to cause infection



When germ relationships go bad

Behavior of Microorganisms in Low Moisture Foods

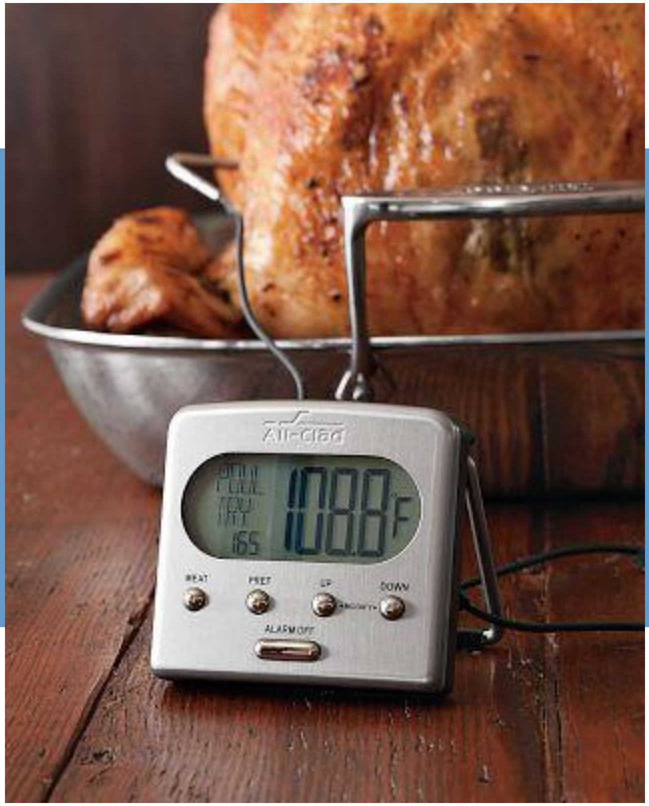
Knowledge of thermal resistance of bacteria can help to determine proper thermal treatment parameters for a **given food product**

Food Safety Goals

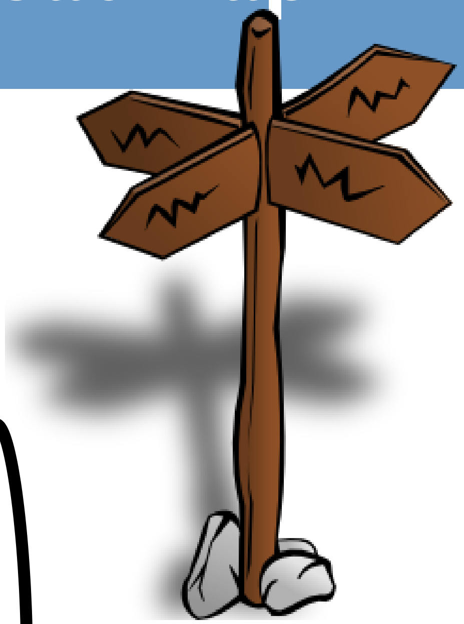
- Understanding the food safety risks associated with your product
- Understanding how the composition of your product influences bacterial behavior
- Understanding how a process implemented as a kill step influences the survival of bacteria in the product

How is this done?

Thermal Process Validations



Thermal Process Validation Roadmap



Phase I: Process/ Product Review

Phase II: Microbial Kinetics (TDT)

Phase III: In-Process Validation

Final Result:

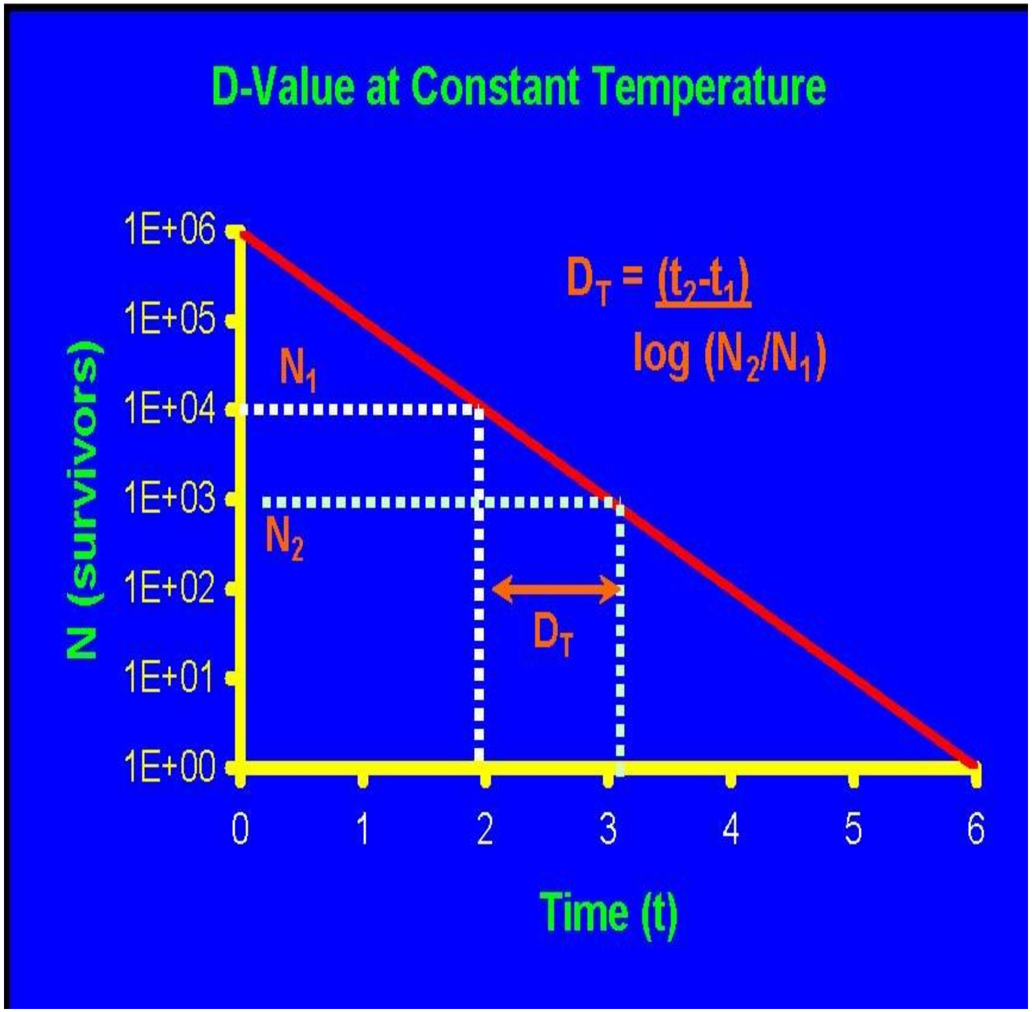
Determination of the level of reduction of the target organism delivered by the thermal process

Food Safety Vocabulary

- Target Organism – Pathogenic organism(s) of significance in a given food product.
- Surrogate Organism – Non-pathogenic organism which mimics process resistance of target organism and is suitable for use in validation work.
- Kill-Step – Process step which results in sufficient destruction of the target organism.
- Kill-Ratio – Mathematical correlation between the destruction of surrogate and target organisms.
- Process Lethality – Measure of process' ability to destroy the target organism, normally expressed as "log reduction" for the target organism.

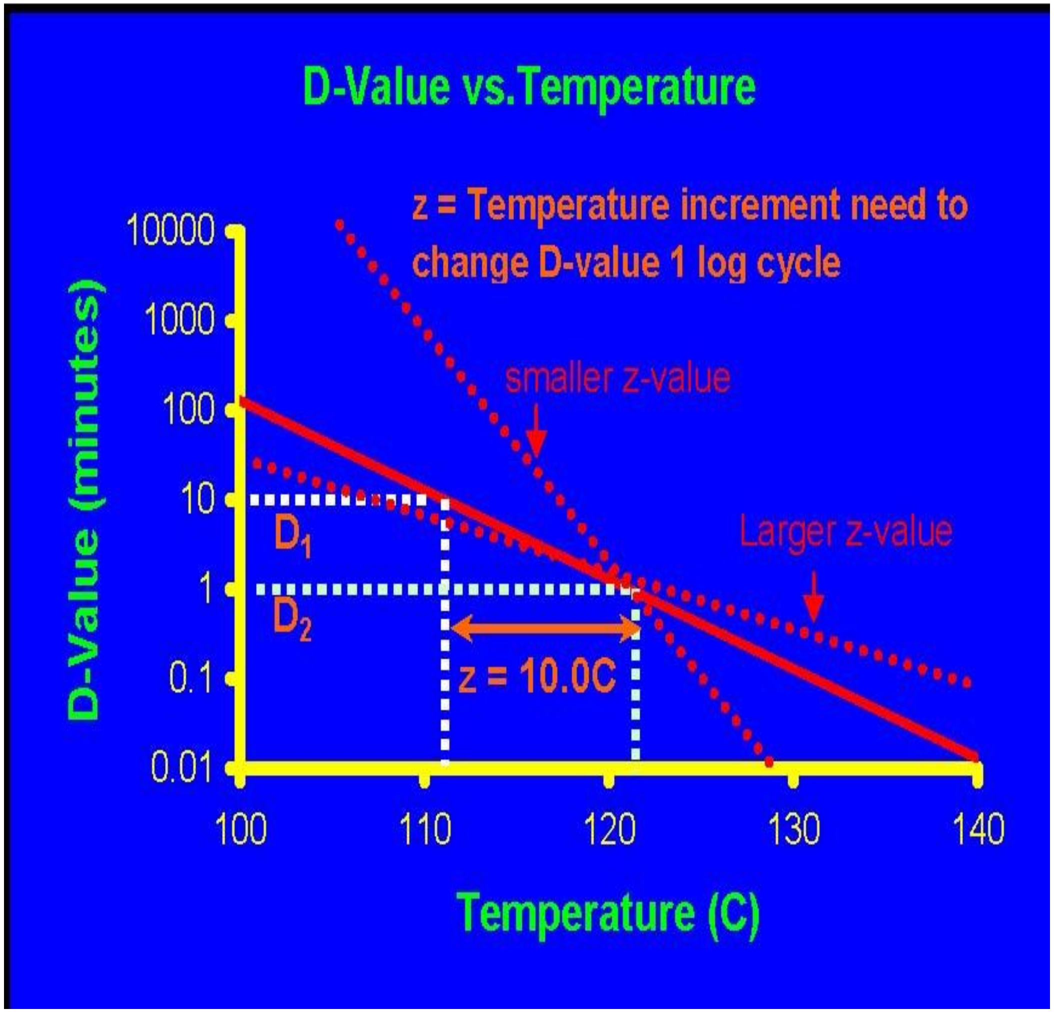
Food Safety Vocabulary

- <u>D value</u> – The time required at a constant temperature to destroy 90% of the microorganisms present.
  - It can be determined experimentally by conducting TDT studies for a given organism in a specific product.



Food Safety Vocabulary

- z value – The change in temperature necessary to bring about a 10-fold (1-log) change in the D value.
  - It can be determined experimentally by conducting TDT studies for a given organism in a specific product



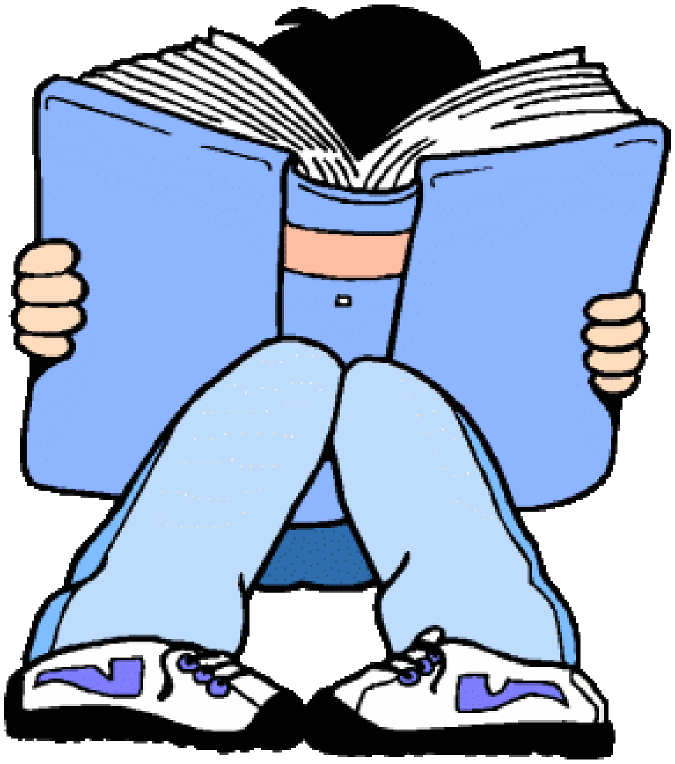
Phase I: Process/Product Review

Process/Product Review

- Understand the process:
  - Equipment being validated
  - Manner of heat application
  - Temperature and time (equipment settings and actual of product)
- Understand the product:
  - Intrinsic properties (pH, a_w, moisture, fat/oil, solids)
  - Physical properties (piece size, shape, surface structure, surface area)

Process/Product Review

- Review the scientific literature to:
  - Understand the impact of process and product properties on bacterial survival
  - Help to select the worst case scenario for subsequent work
  - Help to select appropriate strains for validation work



Process/Product Review

Example:

Product Entering Dryer →

Zone 1	Zone 2	Zone 3
160-170ºF; 30 min	180-190ºF; 60 min	170-180ºF; 60 min

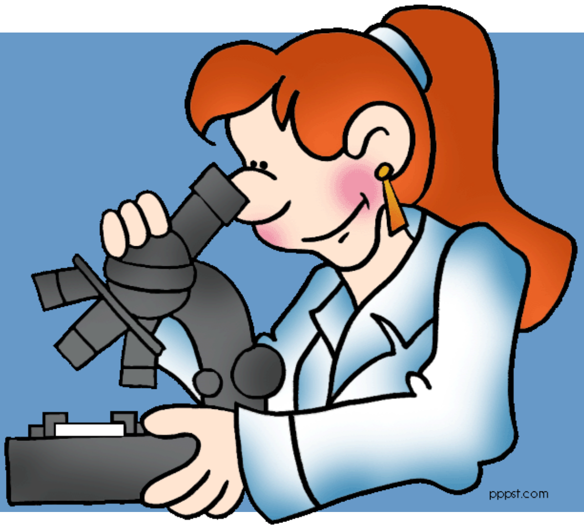
→ Product Exiting Dryer

$a_w = 0.9$

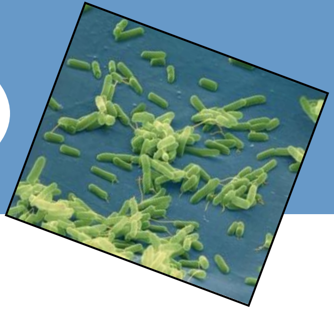
Note: Heat resistance of *Salmonella* is greater at lower water activities.

$a_w = 0.4$

Phase II: Microbial Kinetics Studies – TDT's and D and z values



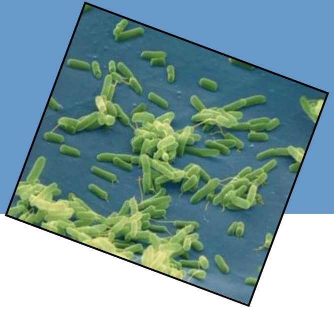
Phase II: Microbial Kinetics (TDT)



What is a Thermal Death Time (TDT) Study?

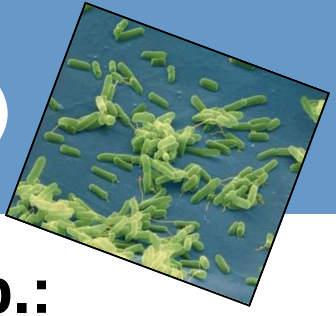
Study designed to determine the thermal resistance of a specific bacteria in a defined product

Phase II: Microbial Kinetics (TDT)



- Defined Product
  - Primarily based on most conservative a_w
  - Consideration also for other intrinsic and physical factors
- Target Organisms
  - Appropriate for product
  - *Salmonella, Escherichia coli* O157:H7
- Surrogate Organism
  - *Enterococcus faecium* (NRRL B-2354) is a common surrogate used for *Salmonella* for the evaluation of thermal processes applied to low moisture foods
  - For a thermal process, surrogate must demonstrate similar or greater resistance compared to the target organism before it can be used

Phase II: Microbial Kinetics (TDT)

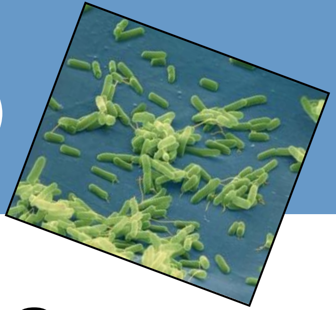


Surrogate microorganisms for *Salmonella* spp.:

Organism	Food	Reference
B. stearothermophilus spores, *B. stearothermophilus* 12980	Animal feed, Poultry feed	Okelo et al, 2006 Okelo et al, 2008
*Enterococcus faecium NRRL B-2354**	Almonds	ABC, 2007b
Pantoea agglomerans SPS2F1	Dry roast almonds	ABC, 2007d
Pediococcus spp. and *Pediococcus acidilactici* “Saga 200” and “Biosource”	Ground, formed beef jerky	Borowski et al, 2009
Pediococcus spp.	Whole-muscle turkey jerky	Williams et al, 2010

Never use pathogens in a food process environment.

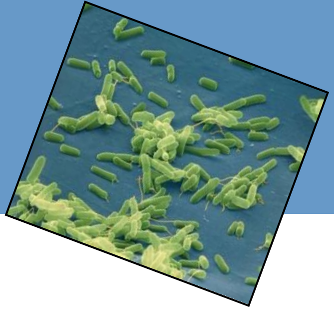
Phase II: Microbial Kinetics (TDT)



TDT Protocol Development Process:

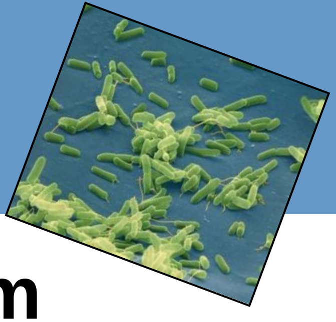
- Preparation of organism(s)
  - Growth conditions can impact thermal resistance
- Inoculation method for selected product
  - Prevent changing intrinsic product parameters (pH, a_w, etc.)
  - Use of sand, chalk, spray (atomizer), freeze-dried culture
- Heat treatment method
  - Water bath, Oil bath, Oven
- Recovery / enumeration method for target and surrogate organisms

Phase II: Microbial Kinetics (TDT)

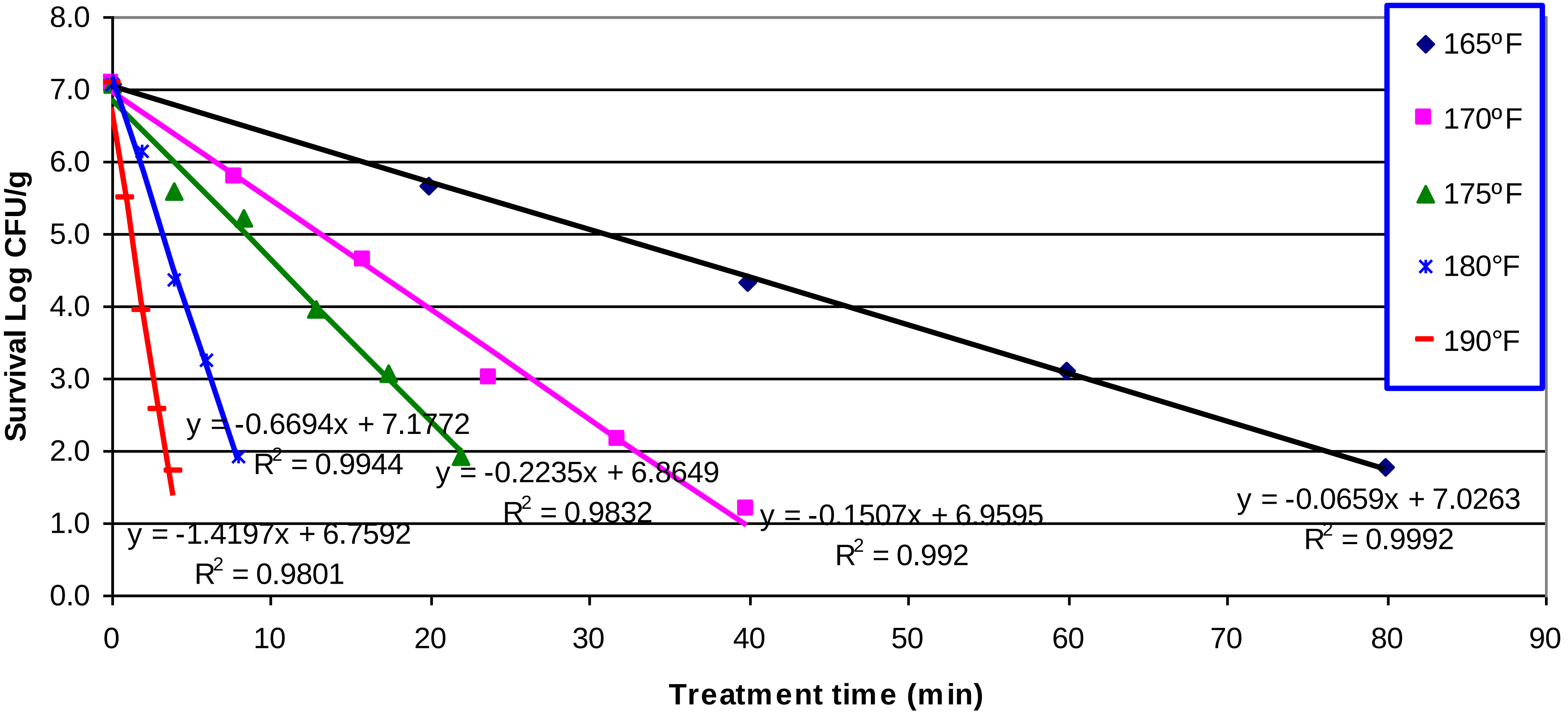


- Conduct thermal death time (TDT) studies on target and surrogate organisms in selected "worst case" product

  - Preliminary studies to determine the appropriate heat application method, packaging, temperature monitoring of product during thermal treatment
  - Screening studies to determine the appropriate temperature range, time
  - Final TDT study: 5-6 time intervals, 5 temperatures, triplicate samples

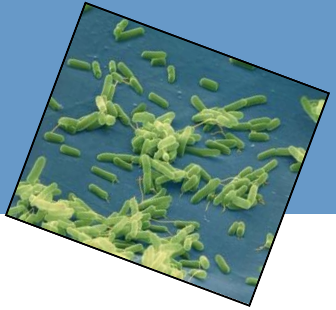


Example Survival Graph: Results from One TDT Study



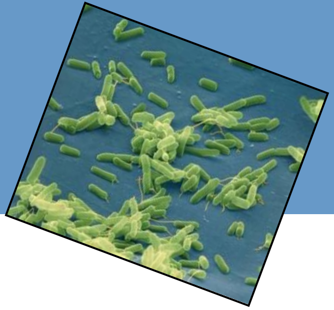
This is an example graph and is for illustration only.

Phase II: Microbial Kinetics (TDT)



- Generate D and z values for target and surrogate organisms in the product
- Determine correlation ("kill-ratio") between target and surrogate organisms at selected time/temp
  - Log reduction should be ≥1:1 for target:surrogate
- Estimate the theoretical log reduction of target organisms in the product during the process based upon thermal process data (time/temperature)

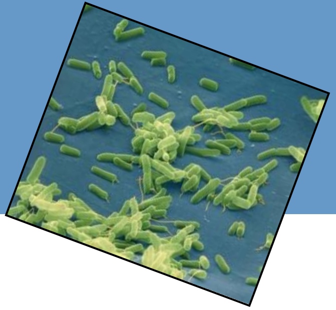
Phase II: Microbial Kinetics (TDT)



Benefits of Determining D and z values

- Allows for assessment of effectiveness of process as a "kill step" for target organisms
- Allows for accurate quantification of "kill ratio" between surrogate and target organisms
- D and z values will allow for process adjustments to optimize the process, if needed
- D and z values will allow you to address process deviations

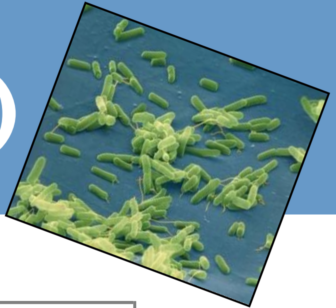
Phase II: Microbial Kinetics (TDT)

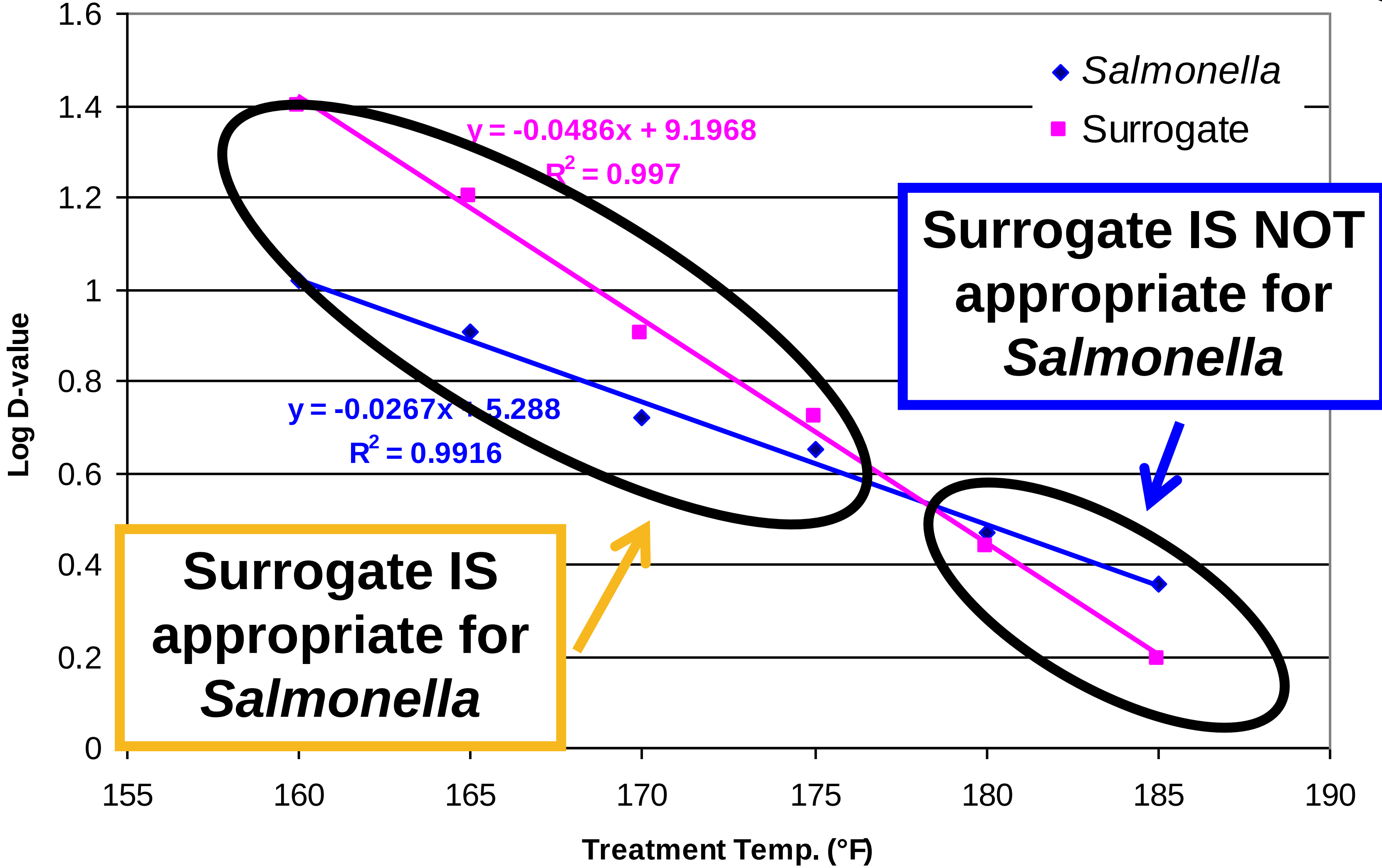


<u>Risk of Not Completing Kinetics Studies Prior to On-Site Validation Work</u>

Surrogate may not be appropriate for target organisms

Phase II: Microbial Kinetics (TDT)

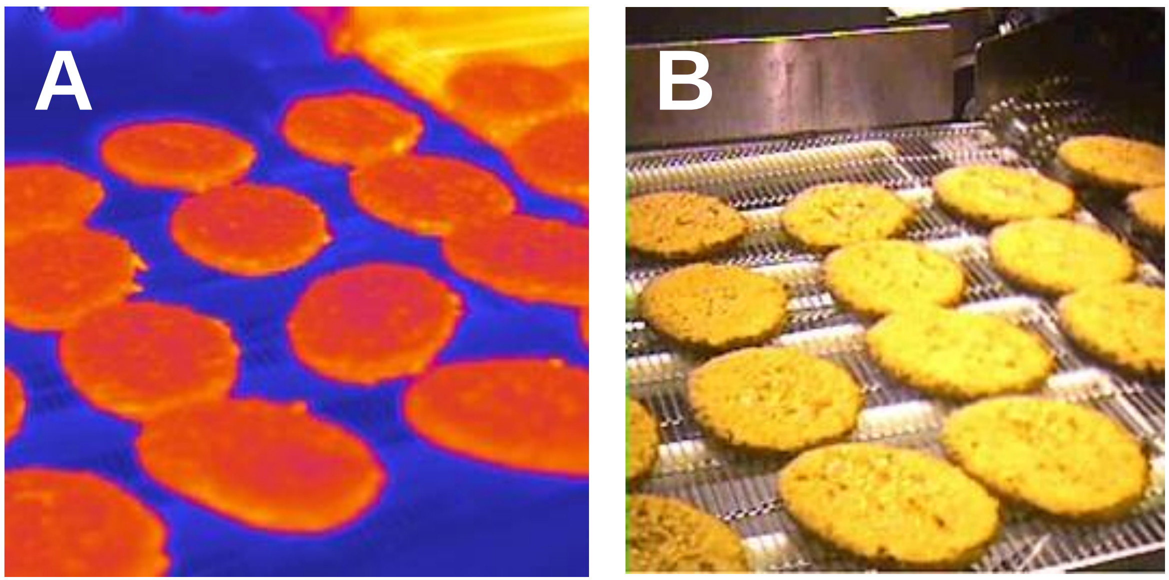




Phase III: In-Process Validation

Phase III: In-Process Validation

- Temperature distribution testing in the product on the process line (finding the cold spot)



Thermal image of chicken patties during processing (A), and actual appearance of chicken patties during processing (B).

Thermal imagery example from the website: http://www.testequipmentdepot.com/flir/index.htm

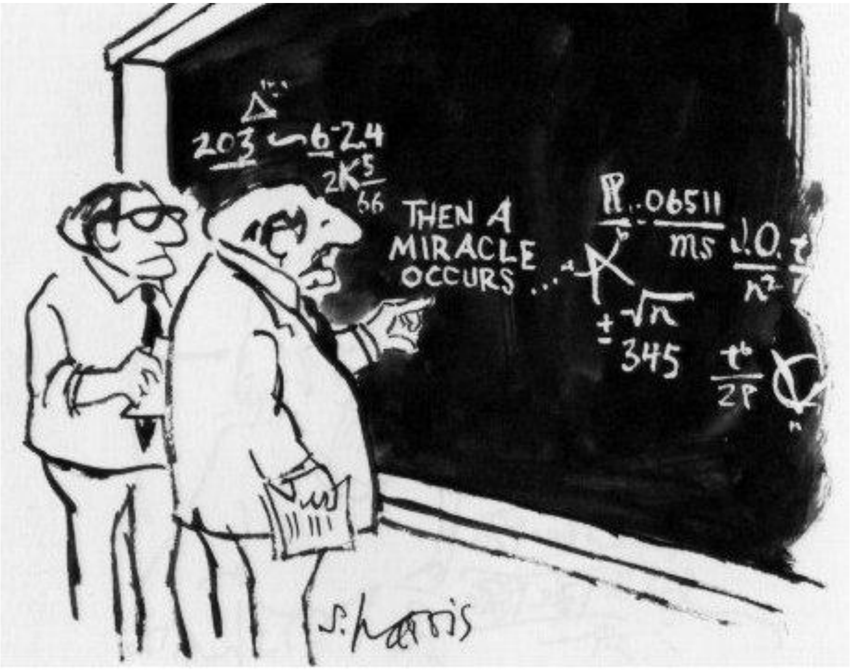
Phase III: In-Process Validation

- Preparation of inoculated products with surrogate organism (w/o changing intrinsic properties)
- On-site process validation using inoculated product
  - Inoculated product is subjected to the process
  - Insertion and recovery of inoculated samples from process is critical
- Lab analysis of on-site validation samples

Phase III: In-Process Validation

Final Result:

- Determination of the log reduction of surrogate during the production process
- Calculation of log reduction of the target organism, based upon the kill ratio between the target and surrogate organisms
  - This will be compared to the calculated kill using D and z values



"I think you should be more explicit here in step two."

from *What's so Funny about Science?* by Sidney Harris (1977)

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Thank you!!

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