

2022

The logo for 'Field to Fork' is centered within the zero of the year '2022'. It features the words 'field' and 'FORK' in a dark grey, sans-serif font. A light blue fork is positioned diagonally across the text, with its tines pointing towards the bottom left. A red tomato with green leaves is placed at the bottom left of the fork's tines. The word 'to' is written in a smaller, lowercase font between 'field' and 'FORK'.

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Upcoming Webinars

April 6

Attracting Pollinators to Your Garden – Janet Knodel, professor and Extension entomologist, NDSU

April 13

Farm to School: Getting Started and Best Practices - Londa Nwadike, Extension associate professor and food safety specialist, Kansas State University and the University of Missouri, and Anna Barr, South Dakota State University Extension farm to school nutrition field specialist



2022

field to FORK

Presenter

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Audio Settings



Chat



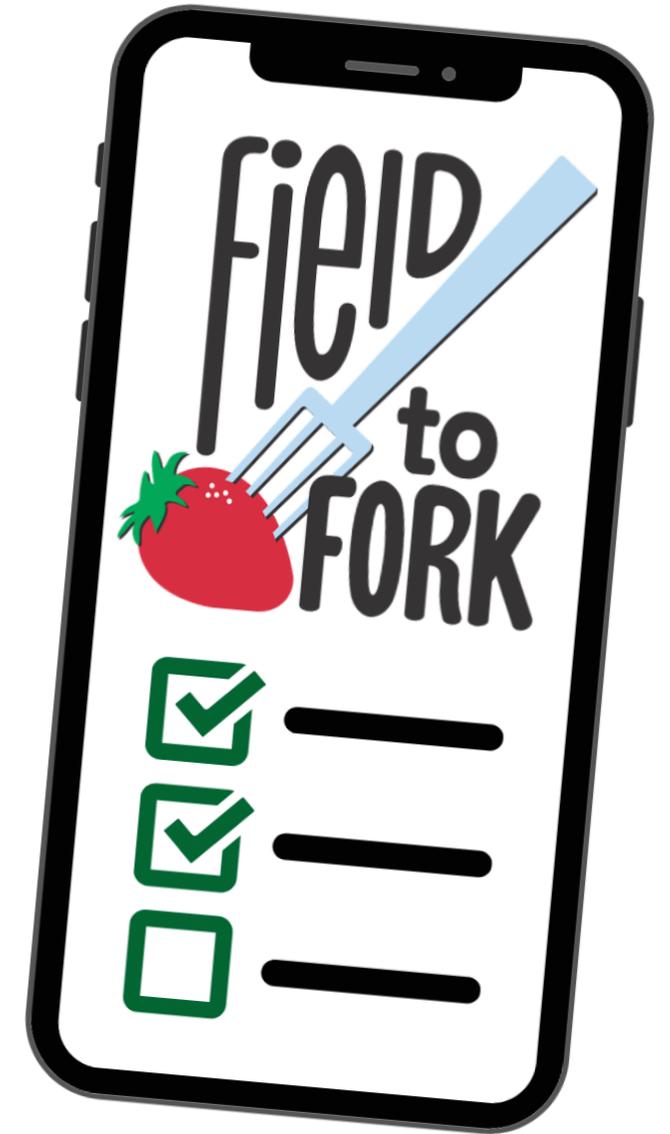
Raise Hand



Q&A

Leave

- **Please complete the short online survey** that will be emailed to you after today's webinar. It will take just a couple minutes!
- Be sure to sign up for an opportunity to win a prize in the drawing. After submitting the survey, a form to fill out with your name/address will appear.
- *Acknowledgement: This project was supported by the U.S. Department of Agriculture's (USDA) Agricultural Marketing Service through AM190100XXXG028. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.*





March 30

Developing Safe Food Products

**Byron D. Chaves, Assistant Professor and Food Safety Extension Specialist,
University of Nebraska-Lincoln**

DEVELOPING SAFE FOOD PRODUCTS

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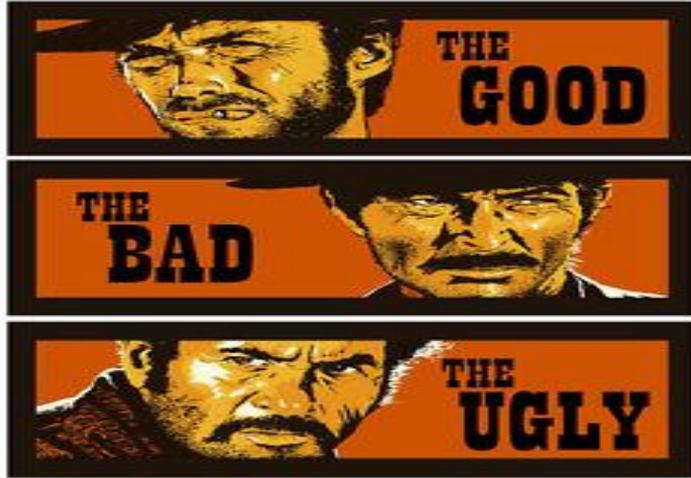
University of Nebraska-Lincoln



NDSU Extension “Field to Fork”

March 30, 2022

Microbiology of Food Processing



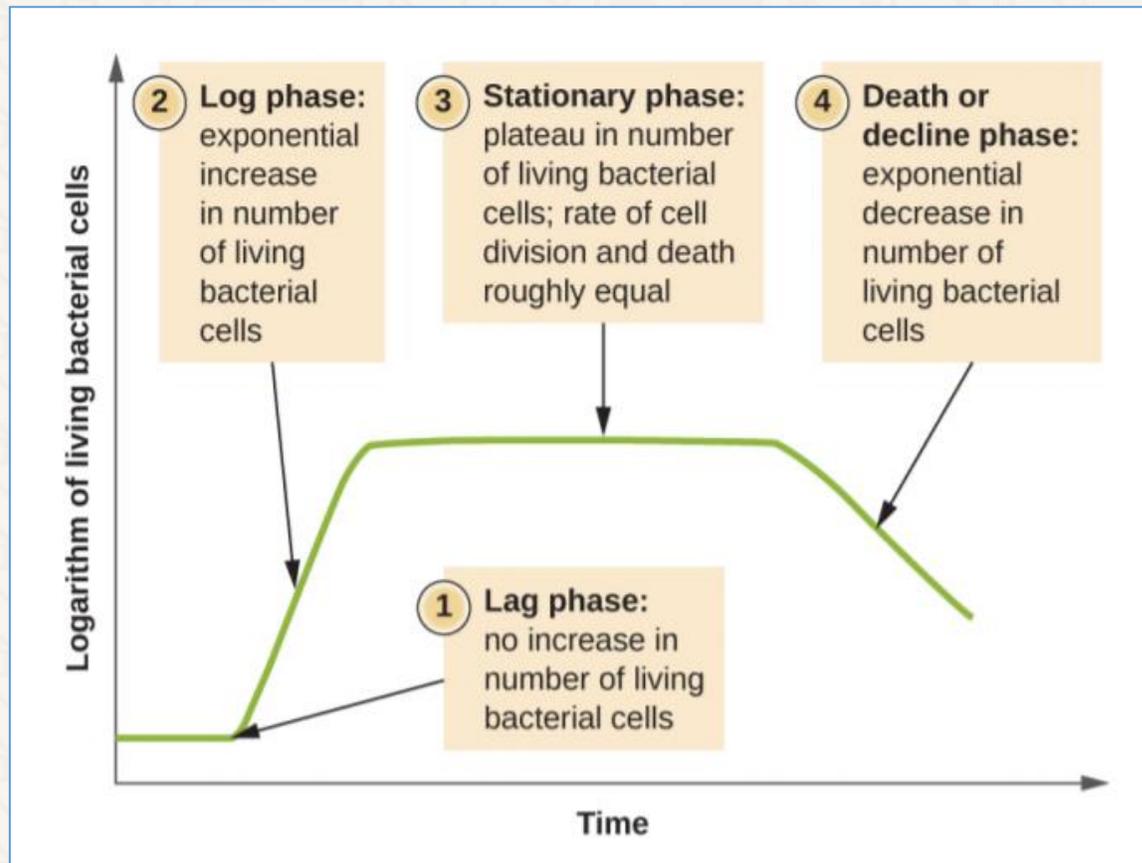
- **BIOPROCESSING**
- **SPOILAGE**
- **PATHOGENS**

- Foods are complex and dynamic microbial ecosystems.
 - Bacteria, yeasts and filamentous fungi cohabitate, interact, and communicate in mixed microbial populations.
- The microbial profile will be determined by the properties of the food, its storage environment, properties of the organisms, and the effects of processing.
- Microbes can be introduced at any point during the food production chain.

Microbial Growth in Food

1. Physicochemical properties of the food matrix
 - Intrinsic Factors – a_w , chemical composition, pH
2. Conditions of the packaging and storage environment
 - Extrinsic factors – temperature, gaseous atmosphere, RH
3. Microbial phenotypes and ecological interactions
 - Implicit factors – physiological state, microbial community
4. Antimicrobial and other interventions
 - Process factors – physical and chemical antimicrobial treatments

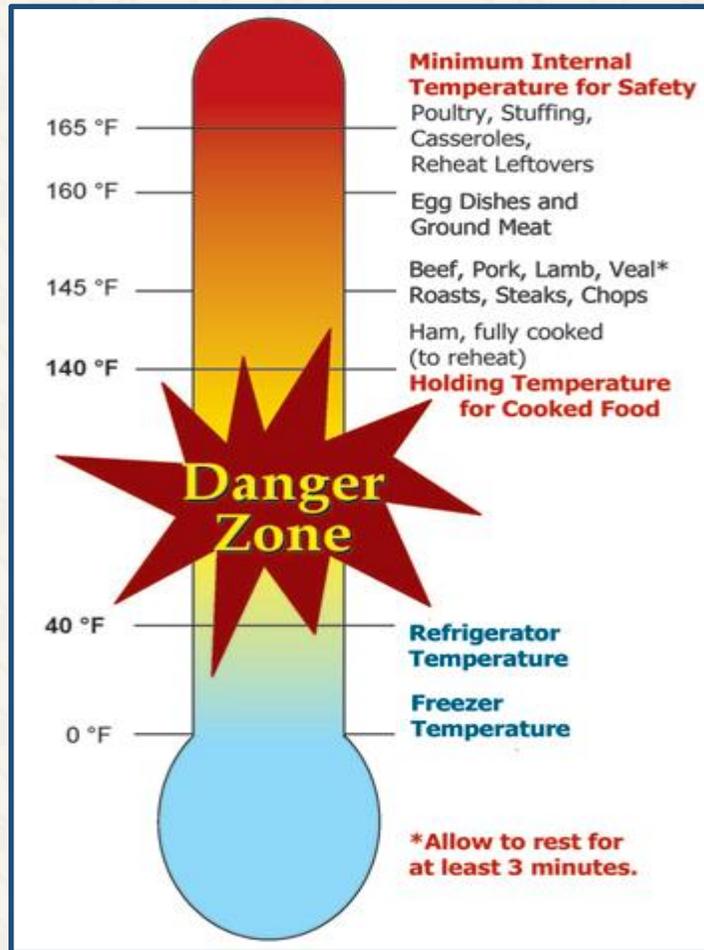
Microbial Growth in Food (cont.)



Adam & Moss. (2008). Food Microbiology. 3 Ed. RSC Publishing, p 21.

Nutrients
pH/Acidity
 a_w /Moisture
Temperature
Gaseous atmosphere
Time

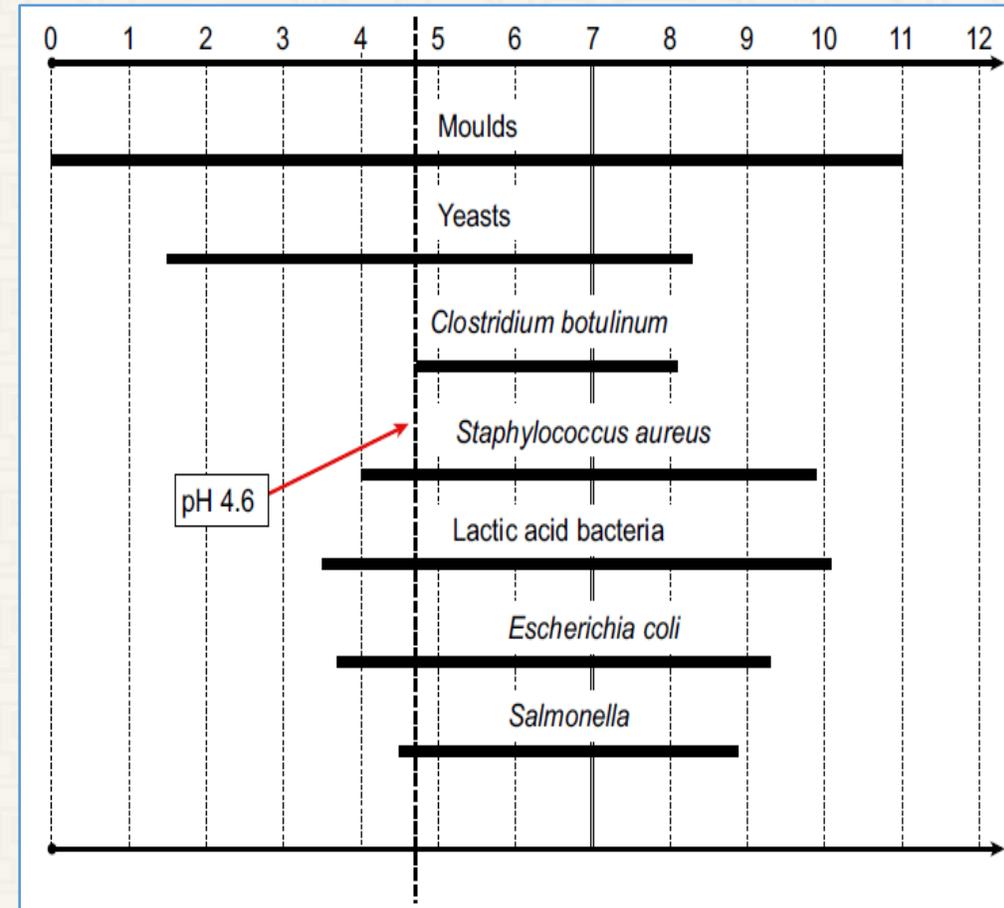
Temperature Danger Zone



- What is temperature abuse?
 - Temperature/time combination that allows growth of pathogenic microorganism in the food matrix.
 - 40-140 °F (4-60 °C)
- What is the effect on microbial growth?
 - Increase in growth rate
 - Decrease in doubling time

Microbial Growth – pH

- Acid foods: natural $\text{pH} \leq 4.6$
- Acidified foods: foods to which acid(s) or acid food(s) are added $\text{pH} \leq 4.6$ and $a_w > 0.85$
- Low-acid foods: $\text{pH} > 4.6$ AND $a_w > 0.85$.
 - Alcoholic beverages excluded
 - Tomatoes and tomato products with $\text{pH} < 4.7$ are not classified as low-acid foods.

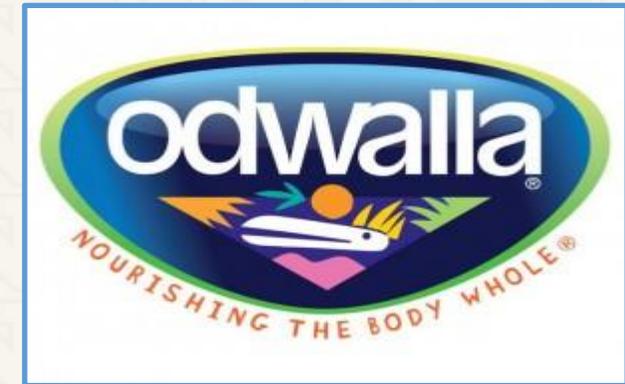


Microbiology of Canned Foods (2015). In A Complete Course in Canning and Related Processes. 14th ed. Woodhead Publishing p 13.

<http://dx.doi.org/10.1016/B978-0-85709-678-4.00001-4>

Microbial Growth – pH (cont.)

Microorganism	Minimum	Optimum	Maximum
<i>Clostridium perfringens</i>	5.5 to 5.8	7.2	8.0 to 9.0
<i>Vibrio vulnificus</i>	5.0	7.8	10.2
<i>Bacillus cereus</i>	4.9	6.0 to 7.0	8.8
<i>Campylobacter</i> spp.	4.9	6.5 to 7.5	9.0
<i>Shigella</i> spp.	4.9	9.3	
<i>Vibrio parahaemolyticus</i>	4.8	7.8 to 8.6	11.0
<i>Clostridium botulinum</i> toxin	4.6	8.5	
growth	4.6	8.5	
<i>Staphylococcus aureus</i> growth	4.0	6.0 to 7.0	10.0
toxin	4.5	7.0 to 8.0	9.6
Enterohemorrhagic <i>Escherichia coli</i>	4.4	6.0 to 7.0	9.0
<i>Listeria monocytogenes</i>	4.39	7.0	9.4
<i>Salmonella</i> spp.	4.2 ¹	7.0 to 7.5	9.5
<i>Yersinia enterocolitica</i>	4.2	7.2	9.6



21 CFR 120 – Juice HACCP



Microbial Growth – a_w

- Available water for chemical, enzymatic, and biochemical reactions.
 - Bacteria require a high a_w (0.91-0.99) to **grow**, while fungi can tolerate 0.80 to 0.75.
 - Bacteria and fungi can **survive** in much lower a_w for prolonged time
 - **GROWTH \neq SURVIVAL**

Table 3-2—Approximate a_w values for growth of selected pathogens in food

Organism	Minimum	Optimum	Maximum
<i>Campylobacter spp.</i>	0.98	0.99	
<i>Clostridium botulinum</i> type E*	0.97		
<i>Shigella spp.</i>	0.97		
<i>Yersinia enterocolitica</i>	0.97		
<i>Vibrio vulnificus</i>	0.96	0.98	0.99
Enterohemorrhagic <i>Escherichia coli</i>	0.95	0.99	
<i>Salmonella spp.</i>	0.94	0.99	>0.99
<i>Vibrio parahaemolyticus</i>	0.94	0.98	0.99
<i>Bacillus cereus</i>	0.93		
<i>Clostridium botulinum</i> types A & B**	0.93		
<i>Clostridium perfringens</i>	0.943	0.95 to 0.96	0.97
<i>Listeria monocytogenes</i>	0.92		
<i>Staphylococcus aureus</i> growth	0.83	0.98	0.99
toxin	0.88	0.98	0.99

ICMSF 1996.
**proteolytic
*nonproteolytic

Microbial Growth – a_w (cont.)

- Control of microbial growth via a_w
 - Individual unit operations:
 - Crystallization, dehydration, drying, encapsulation, evaporation, extrusion, freezing, puffing, etc.
 - Product formulation:
 - Increase in osmotic pressure – salt, sugar, curing agents
- Low water activity foods:
 - $a_w < 0.70$
 - Also known as low moisture foods

Microbial Growth – a_w (cont.)

- Low water activity is a barrier for microbial growth.
 - Dry foods are **not** inherently safe.
 - *Cronobacter sakazakii*, *Salmonella*, STEC, etc.
 - **GROWTH \neq SURVIVAL**
- When other environmental conditions are optimal, most bacteria do not exhibit growth below a_w 0.91.
 - *S. aureus* can grow as low as 0.83 water activity depending upon the other growth conditions, particularly if oxygen is present.



Microbial Growth – Biological Structures

- Biological structures can prevent entry and growth of pathogens
 - Skin of fruits and vegetables; shell of nuts; animal hide; egg cuticle, shell, and membranes.
- During the preparation of foods, processes such as slicing, chopping, grinding, and shucking will compromise the physical barriers.



Microbial Growth – Temperature

- Most pathogenic bacteria grow at moderate temperatures.
- Some foodborne pathogens are capable of growing at refrigeration temperatures: $\leq 5^{\circ}\text{C}$ / $\leq 41^{\circ}\text{F}$
 - *Listeria monocytogenes*, *Clostridium botulinum* type E
- Freezing generally prevents growth or multiplication of most bacterial pathogens but does not kill them.
- Control of microbial growth via temperature:
 - Refrigeration, cooling, chilling, freezing
 - Thermal treatment: pasteurization, canning, etc.

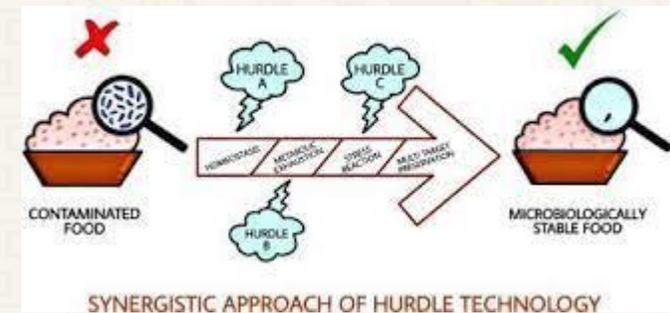
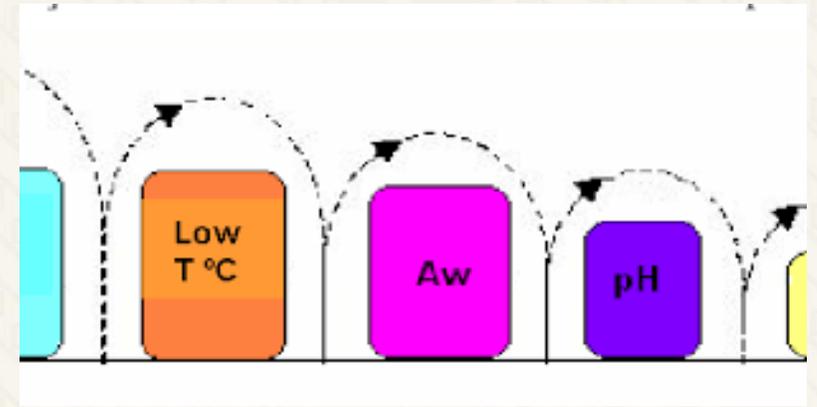
Microbial Growth – Packaging Atmosphere

- Certain gases, like carbon dioxide, ozone, and oxygen, are directly toxic to certain microorganisms.
- By modifying the gas composition around the product, we can inhibit growth.
 - Technologies include modified atmosphere packaging (MAP), controlled atmosphere packaging (CAP), controlled oxygen storage (CAS), and vacuum packaging.



Interaction of Factors

- Foods have combinations of pH, aw, atmosphere, preservatives, and other inhibitory factors.
- There can be an interactive effect between these intrinsic and extrinsic factors to inhibit growth.



Interaction of Factors - Example

- Growth of *Clostridium botulinum*:
 - Temperature 68°F: good for growth
 - pH of 7: good for growth
 - But if $a_w < 0.96$: no growth is observed.

Table 3-12—Incubation period, in days, before growth of proteolytic *Clostridium botulinum* type B was observed at various levels of temperature, pH, and a_w .

Temperature	pH	a_w						
		0.997	0.99	0.98	0.97	0.96	0.95	0.94
20 °C (68 °F)	5	—	—	—	—	—	—	—
	6	49	9	—	—	—	—	—
	7	2	2	4	9	—	—	—
	8	2	2	4	14	—	—	—
	9	—	—	—	—	—	—	—
30 °C (86 °F)	5	—	—	—	—	—	—	—
	6	2	2	3	9	—	—	—
	7	1	1	2	3	9	14	—
	8	1	1	2	4	14	—	—
	9	—	—	—	—	—	—	—
40 °C (104 °F)	5	—	—	—	—	—	—	—
	6	1	2	2	3	14	—	—
	7	1	1	1	2	3	9	17
	8	1	1	1	2	9	14	—
	9	—	—	—	—	—	—	—

No growth observed at any pH or a_w level at 10 °C (50 °F).
Source: Table 6 in FDA 1986

Time/Temperature Control for Safety

- These are foods that require time/temperature control for safety (TCS) to limit pathogenic microorganism growth or toxin formation.
- Maintaining these foods at a proper temperature reduces the possibility of foodborne illnesses.



Time/Temperature Control for Safety Food

- (a) An animal food that is raw or heat-treated; a plant food that is heat-treated or consists of raw seed sprouts, cut melons, cut leafy greens, cut tomatoes or mixtures of cut tomatoes that are not modified in a way so that they are unable to support pathogenic microorganism growth or toxin formation, or garlic-in-oil mixtures that are not modified in a way so that they are unable to support pathogenic microorganism growth or toxin formation; and
- (b) a food that because of the interaction of its a_w and pH values is designated as Product Assessment Required (PA)

TCS Foods (cont.)

Table A. Interaction of PH and A_w for control of spores in FOOD heat-treated to destroy vegetative cells and subsequently PACKAGED

A_w values	PH values		
	4.6 or less	> 4.6 - 5.6	> 5.6
≤ 0.92	non-TCS FOOD*	non-TCS FOOD	non-TCS FOOD
>0.92 - .95	non-TCS FOOD	non-TCS FOOD	PA**
>0.95	non-TCS FOOD	PA	PA

* TCS FOOD means TIME/TEMPERATURE CONTROL FOR SAFETY FOOD

** PA means Product Assessment required

TCS Foods (cont.)

Table B. Interaction of PH and A_w for control of vegetative cells and spores in FOOD not heat-treated or heat-treated but not PACKAGED

A_w values	PH values			
	<4.2	4.2 - 4.6	>4.6 - 5.0	>5.0
<0.88	non-TCS food*	non-TCS food	non-TCS food	non-TCS food
0.88 - 0.90	non-TCS food	non-TCS food	non-TCS food	PA**
>0.90 - 0.92	non-TCS food	non-TCS food	PA	PA
>0.92	non-TCS food	PA	PA	PA

* TCS FOOD means TIME/TEMPERATURE CONTROL FOR SAFETY FOOD

** PA means Product Assessment required

Examples of TCS Foods

- Meat and poultry products, raw and ready to eat, including meat salads and meat pastries
- Most seafood, including cooked seafood and sushi
- Most fresh fruits and vegetables and fresh-cut produce
- Boiled or steamed cereal products, such as rice
- Meat and vegetable-filled cereal products
- Fresh milk and most milk products, including some cheeses

TCS Foods (cont.)

- The following operations should follow required temperatures and times, according to the US FDA Food Code:
 - Refrigerated storage: 41 °F or less
 - Hot holding: 140 °F or above
 - Cooling: from 140 to 70 °F within two hours and from 70 to 41 °F within and additional 4 hours
 - Reheating: to 165 °F for 15 seconds

TCS Foods (cont.)

- TCS are time and temperature abused any time they are in the temperature danger zone (41 to 140°F).
- This happens when food is:
 - Not cooked to the recommended minimum internal temperature.
 - Not held at the proper temperature.
 - Not cooled or reheated properly.

Examples of Non-TCS Foods

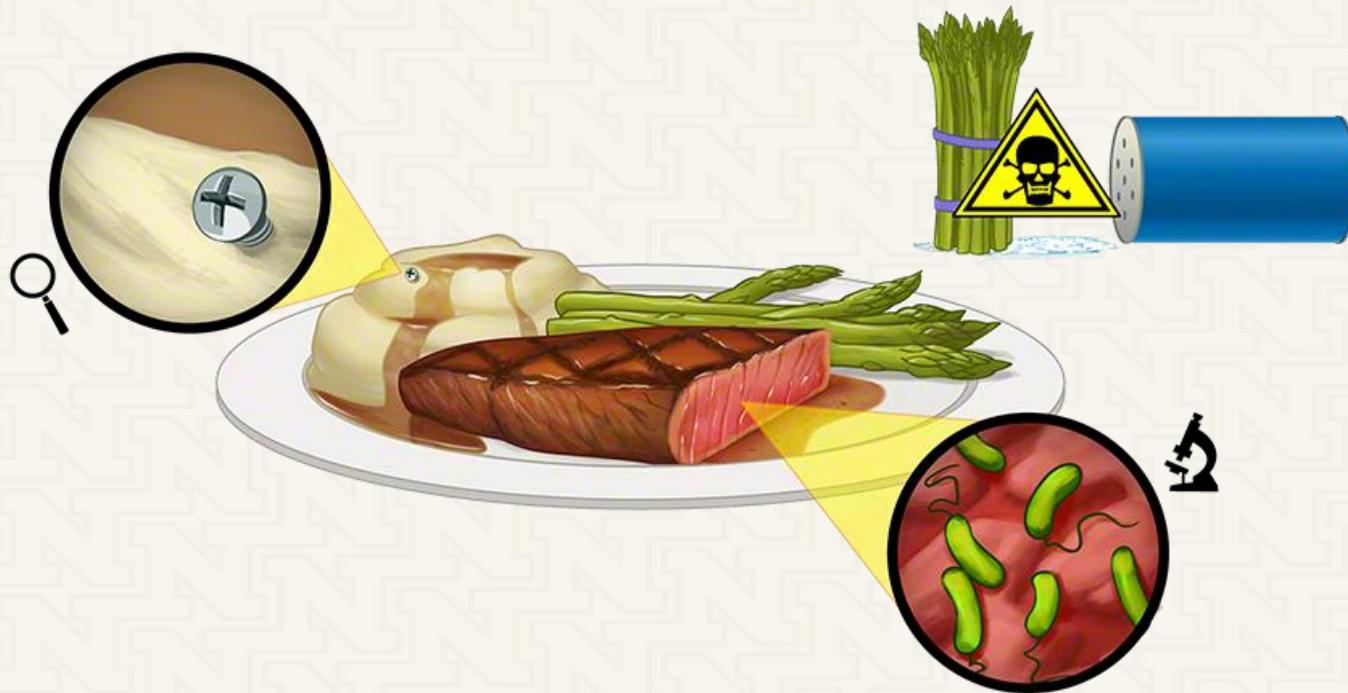
- Fully retorted and fully dried and salted seafood
- Processed fruit and vegetable products (frozen, canned, dried, fermented, or acidified)
- Most baked goods, without a filling
- Salad dressings with pH less than 4.0
- Traditional sugars and syrups
- Canned milks and dried milk
- Traditional hard cheeses
- Hard boiled eggs with intact shell

Cottage Foods

- Cottage food laws allow **small**-time producers to use appliances in their homes to bake, cook, can, pickle, dry, or candy certain **low-risk** foods for sale.
- By contrast, state laws require all other food producers to process foods in licensed kitchens.
- If a consumer buys food from a neighbor, friend, or even an acquaintance, then that consumer presumably knows enough about the operation to make an **informed decision**.

Food Safety Hazard

- A biological, chemical or physical agent that is reasonably likely to cause illness or injury in the absence of its control.



Hazard vs. Risk

HAZARD

Any physical, chemical, or biological agent capable of causing illness or injury in the consumer

CONTROL, REDUCE, ELIMINATE

RISK

A probability function of the incidence of occurrence of a hazard and the severity of the illness/injury caused by that hazard

MINIMIZE

Growth vs Survival

- Microorganisms can survive under harsh conditions, even if they can't grow.
- For some microorganisms, as little as one cell is enough to cause foodborne illness.
- Multiple outbreaks have been associated with foods in which no microbial growth is expected, e.g. *Salmonella* in peanut butter.
- Therefore, control of pathogen growth is only ONE of the multiple strategies required to make safe foods.



Regulatory Oversight for Food Safety

- USDA-FSIS and U.S. FDA – primary federal agencies
 - Regulatory inspection and enforcement
 - Adulteration and misbranding
 - Interstate commerce
- State inspection – Intrastate commerce
- City, municipal, tribal agencies
 - Always check with Health/Ag Department

THANK YOU!

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EXTENSION

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