HEAT TREATMENT APPLICATIONS IN THE FOOD INDUSTRY
AND
MICROWAVE PASTEURIZATION AS AN EXAMPLE

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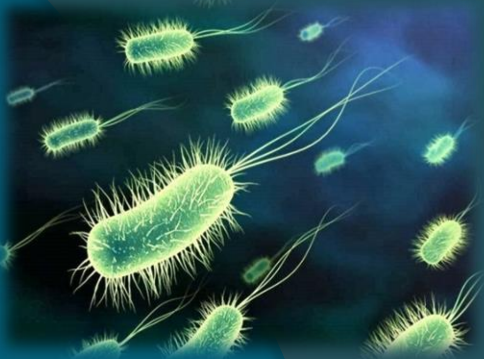
GUIDELINES FOR CONDUCTING THERMAL PROCESSING STUDIES

The following recommendations are to be considered voluntary guidelines. These recommendations do not preclude the application of other methods and equipment for conducting thermal processing studies. These guidelines have been developed by consensus of the Institute for Thermal Processing Specialists and should be given serious consideration for adoption as methodology by individuals performing thermal processing studies.

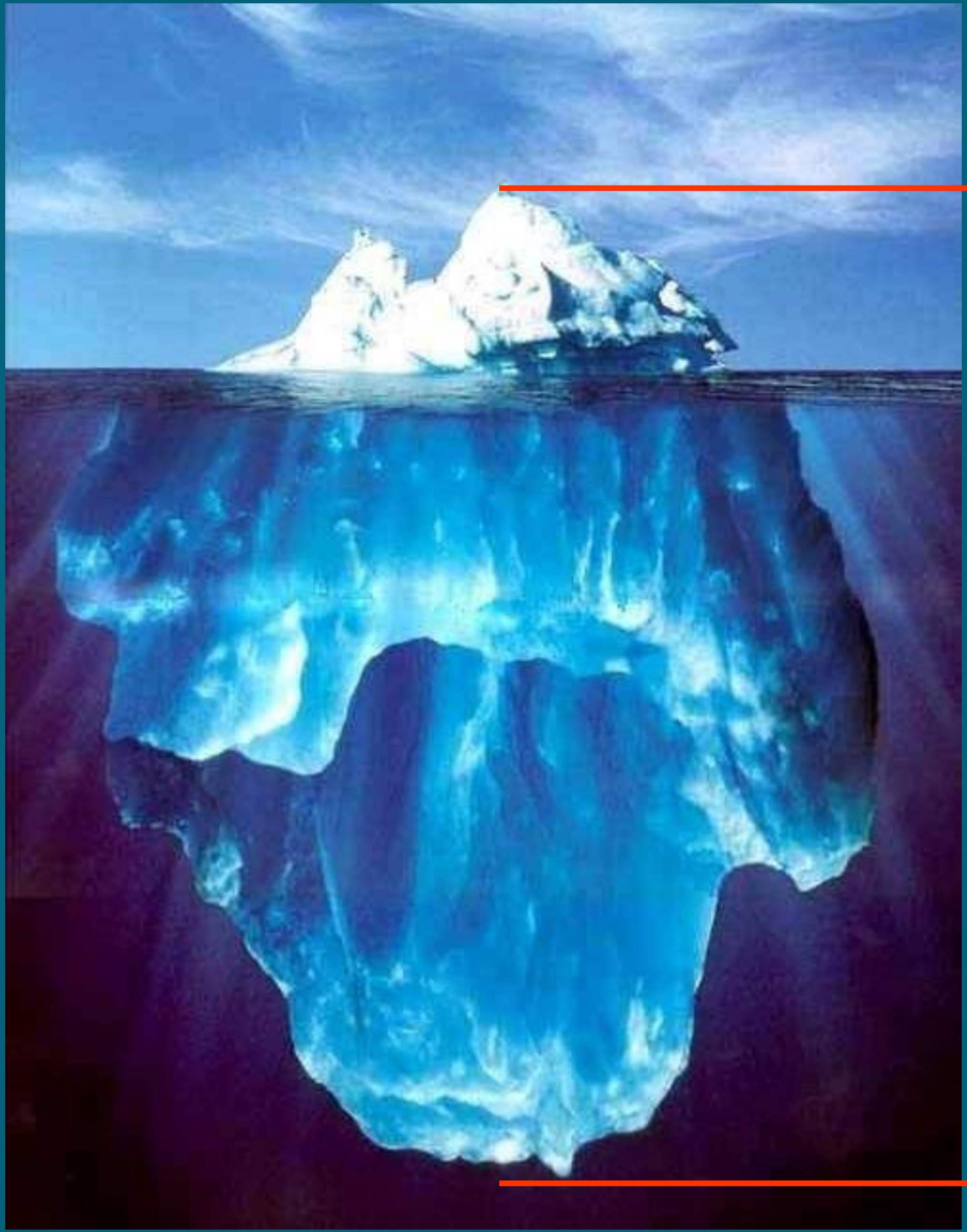
HOW ARE FOODS DETERIORATE ?



Enzymes

Other factors:
Oxygen, Light,
Metals,…etc.

Microorganisms



Reported
Foodborne disease

Not Reported
Foodborne disease

Foodborne disease

HOW WE EXTEND THE SHELF LIFE ?

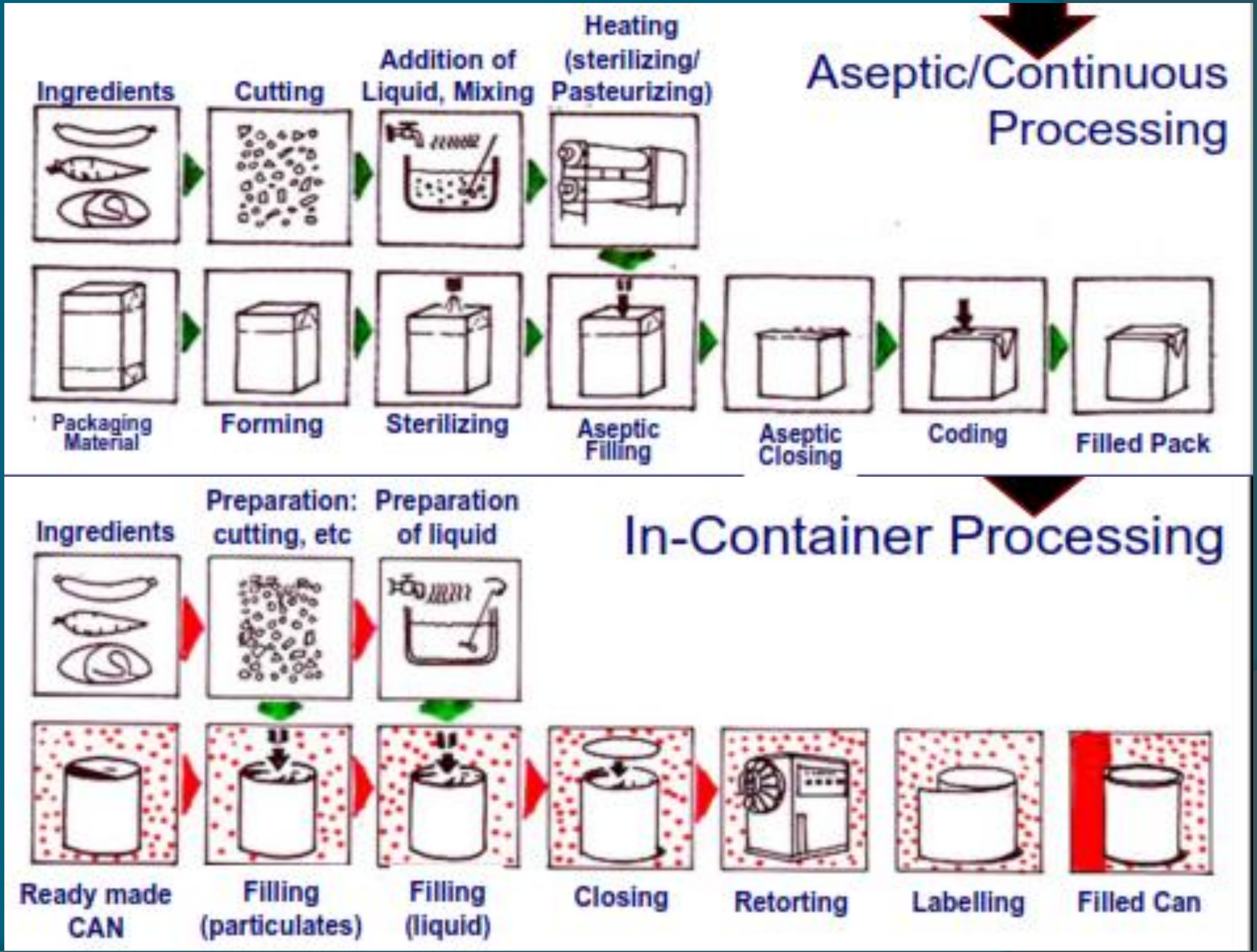
- Drying
- Packaging
- Heat treatment
- Fermantation
- Freezing

WHAT ARE HEAT TREATMENT APPLICATIONS ?

Pasteurization

Hot filled

Sterilization

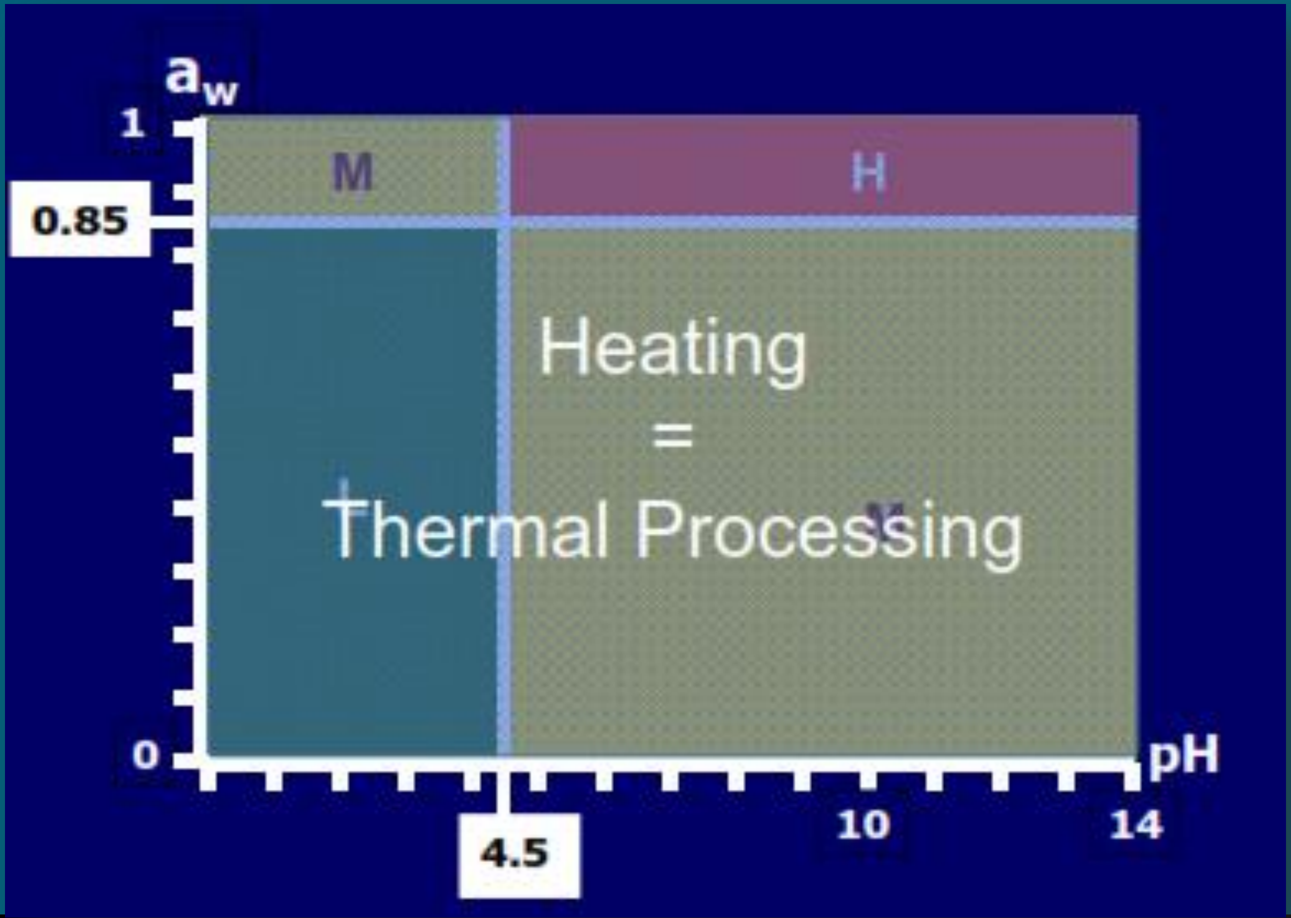


PASTEURIZATION OR STERILIZATION ?

pH < 4.6
e.g. fruits and tomato based products
< 100ºC
Target: pathogens
Pressure: **atmospheric**

pH > 4.6
e.g. vegetables
> 100ºC
Target:all micororganisms
under pressure in closed conditions

Pasteurization	Sterilization
Streptecoccus feacalis	*Clostridium botulinum*
Reference temperature=70°C	Reference temperature=121°C
Number desired in final product $N=1/10^6 g= 10^{-6}/g$	Number desired in final product $N=1/10^{12} g= 10^{-12}/g$



Equlibrium pH Value	Water activity (aw)	Low acid (21 CFR 108.35/113)	Acidified (21 CFR 108.25/114)
≤ 4.6	≤ 0.85	No	No
≤ 4.6	> 0.85	No	Yes
> 4.6	≤ 0.85	No	No
> 4.6	> 0.85	Yes	No

WHAT IS HEAT TREATMENT DESIGN ?

Creating the conditions that prevents the activity of spoilage bacteria to a spesific survivor level.

✓ The aim is reduce the **target microorganism** (most serious and heat resistance)

- which is ***Clostridium botulinum*** **in sterilization** to a survivor probability level of 1 to 12

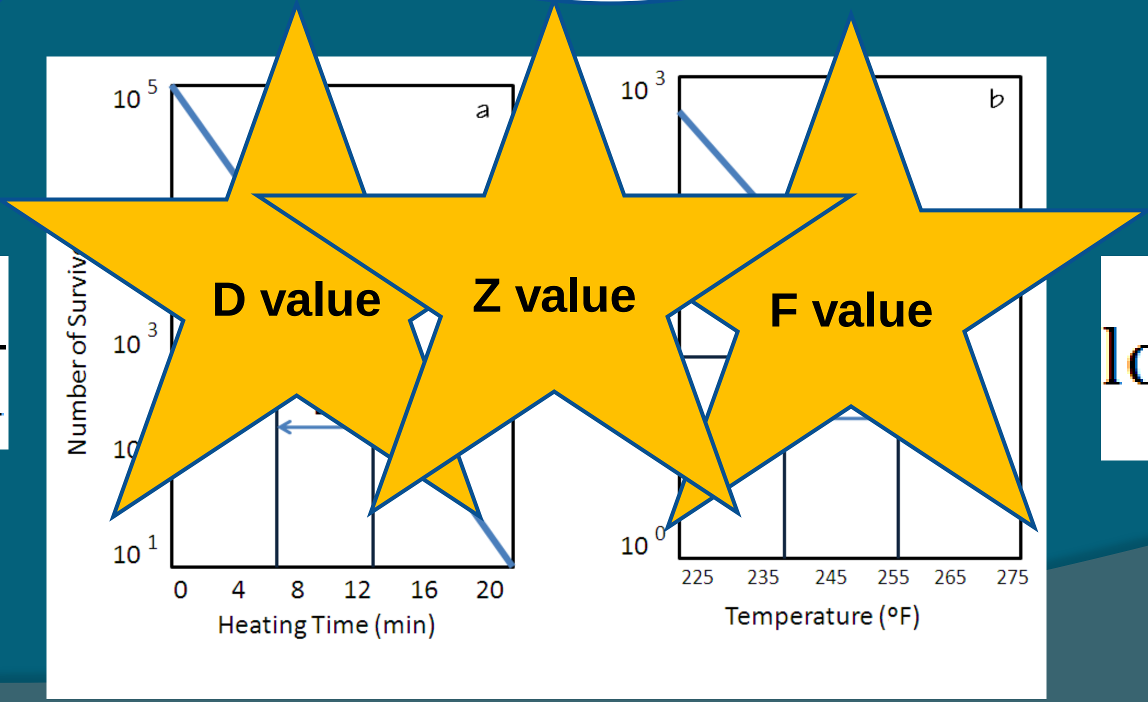
- In pasteurization the target microorganism **changes to the type of food.**

WHAT IS THE IMPORTANCE OF D AND Z VALUES ?

In order to calculate the efficiency of a heat treatment → thermal resistance characteristics of microorganism

should be determined

$$Z = \frac{T1 - T2}{logD2 - logD1}$$



$$\log\left(\frac{No}{N}\right) = \frac{t}{D} = Sd$$

$F_T^D = t * 10^{(T-121.1)/z}$

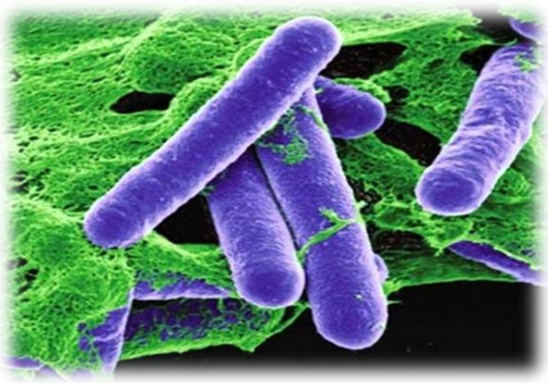
STERILIZATION or PASTEURIZATION

$L = 10^{(T-TRef)}/z$

Target microorganism is ***Clostridium botulinum*** for the sterilization at 121.1°C

Class of Food	Type of Microorganism	Microorganism(s)	Reference Temperature (°F)	D-Value (minutes)	Z-Value (°F)
Low-acid food (pH > 4.6)	Thermophiles[a] (spores)	Flat-sour group (*B. stearothermophilus*)	250	4.0 – 5.0	14-22
	Mesophiles[b] (spores)	Putrefactive anaerobes (*C. botulinum* types A and B)	250	0.10 – 0.20	14-18
		C. sporogenes group (including P.A. 3679)	250	0.10 - 1.5	14-18
Acid food and acidified food (pH 4.0 – 4.6)	Thermophiles (spores)	*B. coagulans* (facultatively mesophilic[c])	250	0.01 – 0.07	14-18
	Mesophiles (spores)	*B. polymyxa* and *B. macerans*	212	0.10 – 0.50	12-16
		Butyric anaerobes (*C. pasteurianum*)	212	0.10 – 0.50	12-16
		B. licheniformis[d]	200	4.5	27
Acid food and acidified food (pH < 4.0)	Yeasts, molds, and mesophilic non-spore-bearing bacteria	*Lactobacillus* species, *Leuconostoc* species	150	0.50 – 1.00	8-10

[a] A thermophilic microorganism is one that thrives at a relatively high temperature, such as 50 °C or above.
[b] A mesophilic microorganism is one that thrives at a moderate temperature, such as 37 °C.
[c] A facultative microorganism is one that can live under more than one set of environmental conditions.
[d] Ref. 18.



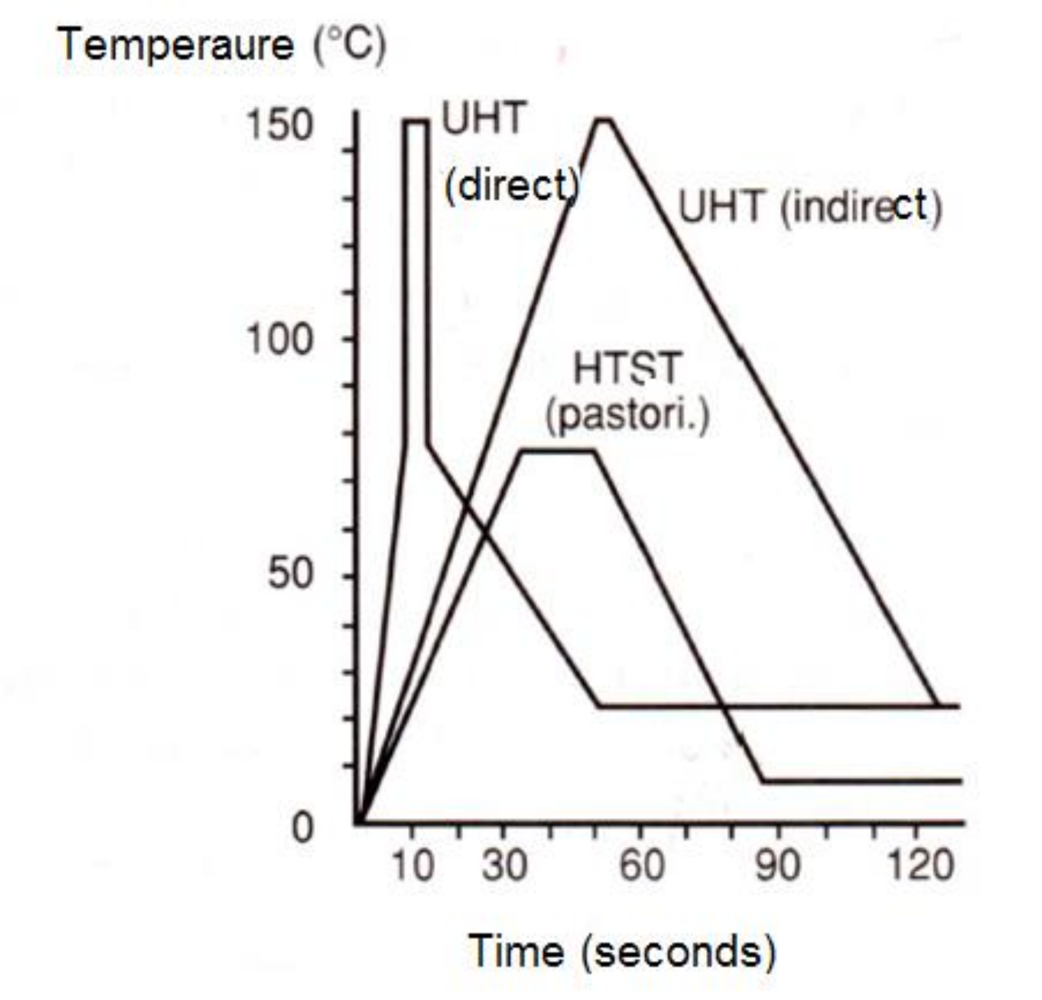
$D_{121.1}$=0,2-1,5

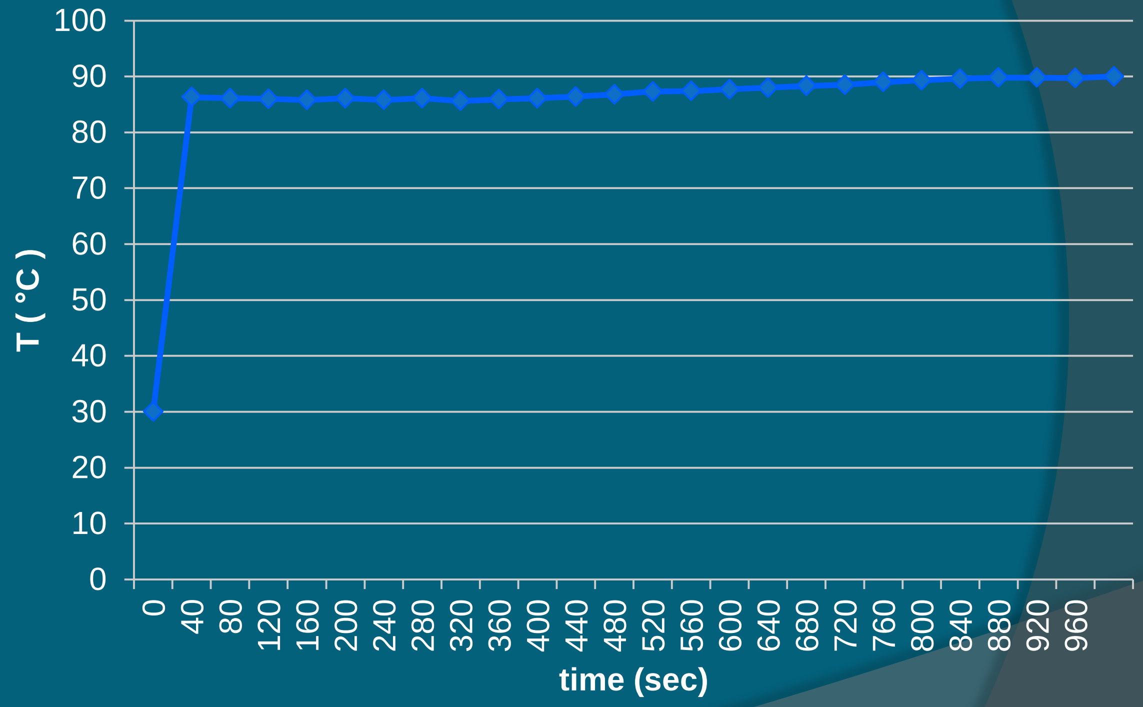
F= D x Sd

For the12D consept

(Number disered in the final porduct, $N=1/10^{12}$g)

THE DIFFICULTY OF THE HEAT TRANSFER IN PACKAGED SOLID or SEMI SOLID FOODS





(Cemeroğlu, 1990)

HOW SHOULD BE FOR FDA ?

- Deciding spoilage microorganisms and heat treatment application
- Determining and reporting the heat distribution in the autoclave
- Specifying the cold point in the package
- Heat treatment design by measuring heat penetration

Determining the total lethality with the time and temperature in the heat process

Critical factors for the food material needs to be determined

WHAT IS THE MEANING OF «INVESTIGATING THE CRITICAL FACTORS FOR THE FOOD MATERIAL» ?

Thermal resistance of microrganisms affected from the **formulation of food material**

- pH
- Protein
- Sugar
- Fat
- Salt
- Aroma compounds and chemical preservatives
- Growth phase of microorganisms

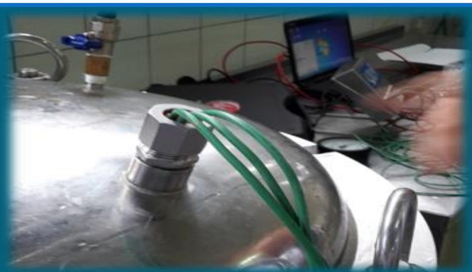
WHAT HAPPENED IF …

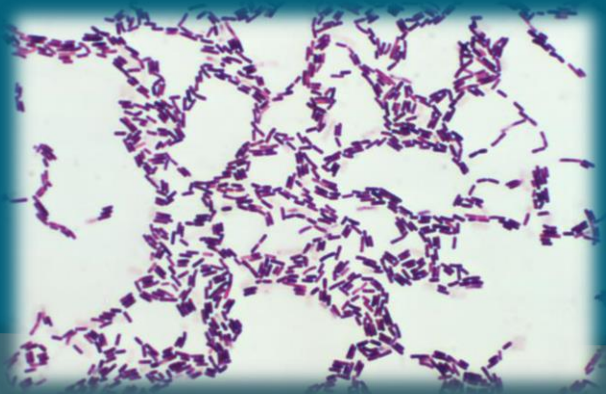
The food formulation changes?

The heating type changes?

EORESIN ENRICHED TOMATO SAUC

The inhibitory effects of oleoresins **thyme, basil and garlic** on the thermal resistance of the target microorganism *Bacillus coagulans* were determined in tomato sauce.





1. Sauce which has the pH value of 4.2 and °Brix of 10 was produced with tomato and red pepper pulp.

2. Oleroesins were added to sauces with the amount of MICs (minumum inhibition content) and thermal process was applied.

3. The thermal resistance of *B. coagulans* in the sauce media enriched with oleoresins was calculated.

After the thermal tretments at different temperatures 80, 90 and 100°C,

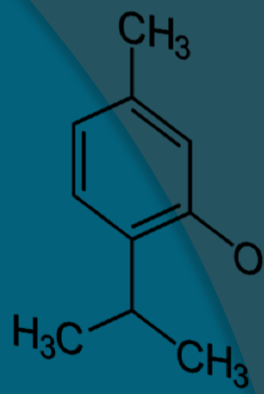
D and Z values were determined for the bacteria.

$$\log\left(\frac{No}{N}\right) = \frac{t}{D} = Sd$$

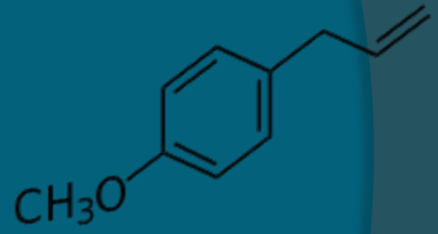
$$Z = \frac{T1 - T2}{logD2 - logD1}$$

Oleoresin	MIC value (ml/100ml sauce)
Thymol	2.5
Basil	1.25
Garlic	1.25

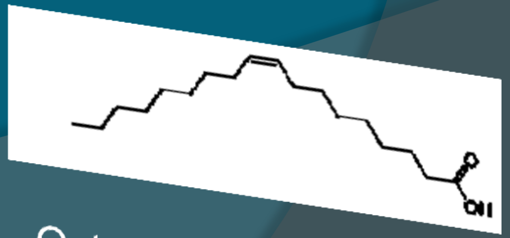
Basil and garlic have the **same** inhibitory effects against this bacteria and were **more effective than thyme** in the tomato based sauce.



Tyhmol



Estragol



Octadec-9 enoik acid

$$\log\left(\frac{No}{N}\right) = \frac{t}{D} = Sd$$

RESULTS

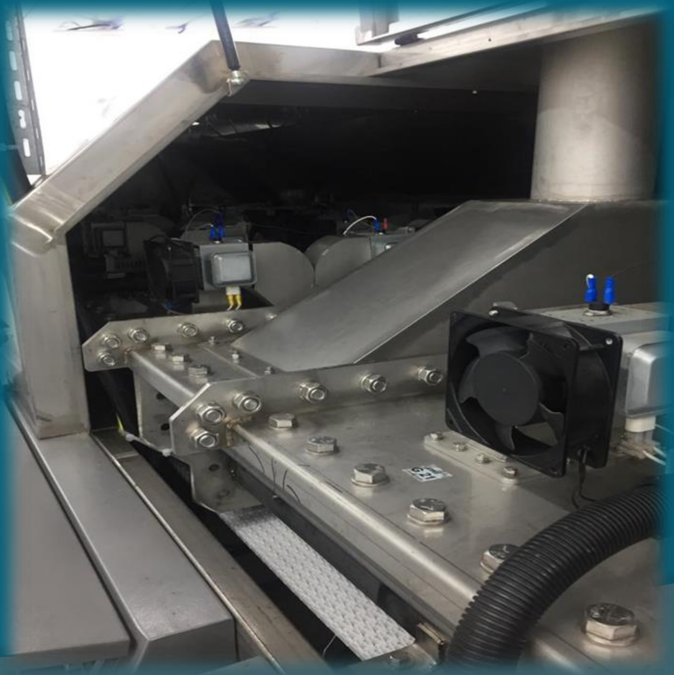
D_{90} values for sauce groups	
90°C	**D (dk)**
Sauce	14.79
Thyme	6.28
Basil	17.03
Garlic	13.52

Z values for the sauce groups	
80 – 100 °C	**Z (℃)**
Sauce	24.9
Thyme	23.7
Basil	22.7
Garlic	20.1

F values for the 4 log reduction	
90 °C	**F (dk)**
Sauce	59.16
Thyme	25.12
Basil	68.12
Garlic	54.08

MICROWAVE PASTEURIZED ORGANIC INTERMADIATE MOISTURE RAISIN

Microwave pasteurizator was designed and produced for the organic intermadiate moisture fruits (raisin, apricot and fig). (TÜBİTAK-TEYDEB 1505).



WHY ORGANIC INTERMADIATE MOISTURE FRUITS ?

- Easy to deteoriate without any chemicals
- Difficult heat conduction without brine/ syrup
- Long process time
- Long time to reach come up time
- Plastic packages need more space so High cost
- Sensory and nutritive losses

MECHANISM OF MW HEATING

- Microwaves have fluctuating electric fields
- Water molecules orient back and forth
- Liquid water heats due to molecular “friction”
- Ice doesn’t heat due to orientational stiffness
- Steam doesn’t heat due to lack of “friction”
- Food’s liquid water content heats the food

DECIDING THE HEAT TREATMENT TYPE AND TARGET MICROORGANISM

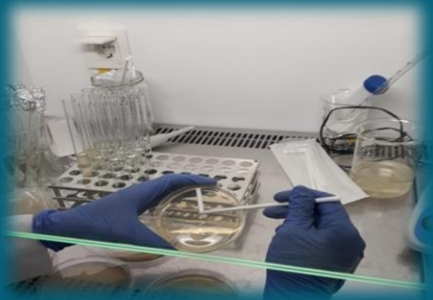
Sample	pH	Water activity	Moisture (%)
Organic intermadiate moisture raisin	4.20±0.06	0.72	25.24

pH < 4.5

aw<0.85

→ Pasteurization

Target yeast → *Zygosaccharomyces rouxii*



1. Inoculation of yeast to raisins

2. Heat treatment at traditional and with microwaves at different temperatures with different time intervals

60 ˚C	½. 1. 2. 4. 6. 8 min.
70 ˚C	½. 1. 2. 3. 4. 5 min.
80 ˚C	½. 1. 1.5. 2. 2.5. 3. 3.5 min.

3. Calculation of heat resisstance characteristics of the yeast.

4. Determinig the Ft for 85°C

5. Confirmation with practical results.

COME UP TIME FOR PASTUERIZATION

Temperature (˚C)	Traditional method (min)	Microwave (min)
60 °C	34.5±0.70	5.17±1.66
70°C	40.5±2.12	10±0
80 °C	44.5±2.1	11.75±0.35

	Raisin (traditional method)	Raisin (microwave)
D_{60} (min)	6.50±0.49	3.46±0.31
D_{70} (min)	2.96±0.02	2.02±0.14
D_{80} (min)	1.91±0.007	1±0.014
z (^{0}C)	37.7	37.03

Raisin (traditional method)	
D_{85}	1.4 min
F=5*D	7.06 min

Raisin (microwave)	
D_{85}	0.73 min
F=5*D	3.65 min.

Raisin (traditional method)	
D_{85}	1.4 min.
F=5*D	7.06 min.

Calculation of **theoric** heat treatment conditions

F1	0.24	1*10^((70-93.3)/37.7)
F2	0.53	F1+1*10^((72.8-93.3)/37.7)
F3	0.83	F2+1*10^((73.5-93.3)/37.7)
F4	1.15	F3+1*10^((75-93.3)/37.7)
F5	1.51	F4+1*10^((76.4-93.3)/37.7)
F6	1.9	F5+1*10^((77.8-93.3)/37.7)
F7	2.3	F6+1*10^((77.9-93.3)/37.7)
F8	2.74	F7+1*10^((79.7-93.3)/37.7)
F9	3.24	F8+1*10^((80-93.3)/37.7)
F10	3.84	F9+1*10^((81.4-93.3)/37.7)
F11	4.36	F10+1*10^((82.6-93.3)/37.7)
F12	4.9	F11+1*10^((83.5-93.3)/37.7)
F13	5.5	F12+1*10^((85-93.3)/37.7)
F14	6.1	F13+1*10^((85-93.3)/37.7)
F15	6.7	F14+1*10^((85-93.3)/37.7)
F16	7.3	F14+1*10^((85-93.3)/37.7)

$F_= t*10^{(T-70/z)}$

Ft=D*5

Calculation of **experimental** heat treatment conditions

Raisin (microwave)	
D_{85}	0.73 min.
F=5*D	3.65 min.

Calculation of **theoric** heat treatment conditions

F1	0.25	1*10^((70.7-93.3)/37.03)
F2	0.58	F1+1*10^((75.3-93.3)/37.03)
F3	0.93	F2+1*10^((76.4-93.3)/37.03)
F4	1.31	F3+1*10^((77.9-93.3)/37.03)
F5	1.82	F4+1*10^((82.6-93.3)/37.03)
F6	2.43	F5+1*10^((85.3-93.3)/37.03)
F7	3.04	F6+1*10^((85.3-93.3)/37.03)
F8	3.65	F7+1*10^((85.3-93.3)/37.03)

Calculation of **experimentally**

RESULT

↑ Temperature ↓ Resistance of m.o.

D value

↓ C.U.T.

D values with microwave heating.

Critical factors for heat design;

1. High temperature and/or long process time causes quality losses,
   Insufficient heat process causes unsafe food production for the human health.

2. D and z values changes with the conditions (temperature, time, process and formulation…etc.)

3. Heat treatment needs to be designed for every specific food.

THANK YOU FOR YOUR KIND ATTENTION