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Foundations of Pasteurization for Regular and Non-Alcohol Beers

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Beer Is Safe
UNTIL IT’S NOT

- Making low or non-alcohol beer?
- Know what you are doing…
- DO IT RIGHT!

Non-Alcohol Beer on Draught: Risks, Considerations, and Resources

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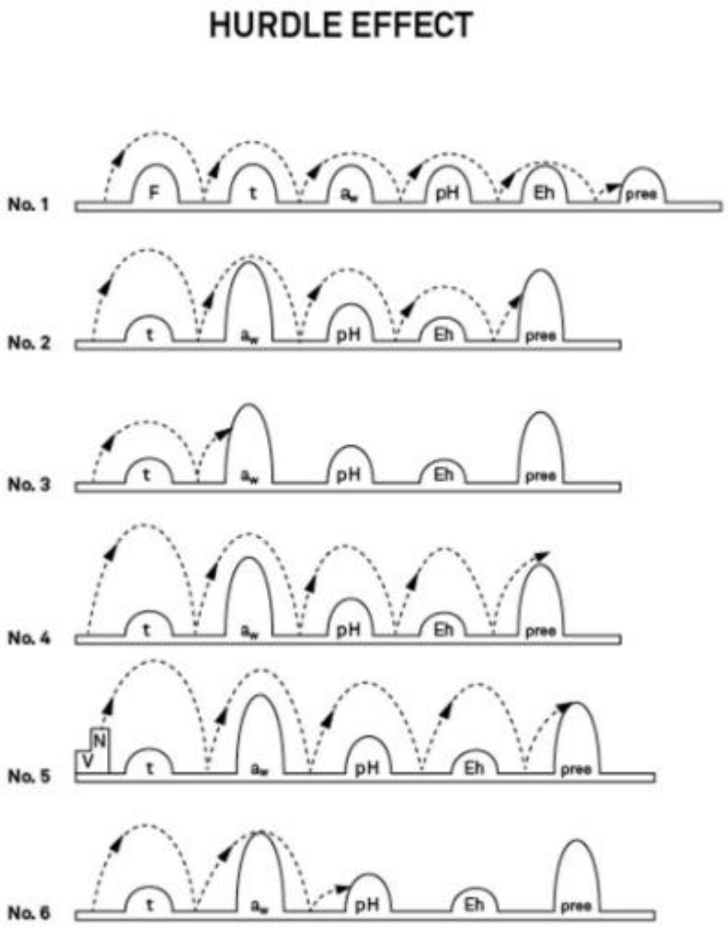
There are challenges to not just producing and packaging food-safe non-alcohol (NA) beer, but extra considerations crucial to NA on draught.

Outline

- Definition
- Factors
- Thermal Bacteriology D, z, PU
- Traditional Design
- Other Methods
- Review

Hurdles



SYMBOLS

F = Heating

t = Refrigeration

aw = Water activity

pH = Acidification

Eh = Redox potential

pres. = Preservatives

K-F = Competitive organisms

V = Vitamins

N = Nutrients

Leistner, L. 1992, "Food preservation by combined methods." Food Research International, 25:151-158.

Bacteriology

- Common beer spoilage microorganisms
  - Wild yeast – various species
  - Gram positive lactic acid bacteria
    - *Lactobacillus sp. (rods) (brevis, pasturianus, delbruckii, etc.)*
    - *Pedicoccus sp. (cocci) (damnosus* esp.)
  - Gram negative – not as common
      - *Obesumbacterium Proteus (rod)*
      - *Acetobacter and gluconobacter – acetic acid bacteria (rods)*
      - *Zymomonas (rod)*
      - *Pectinatus (rod)*
      - *Megasphaera (rod)*

Definition

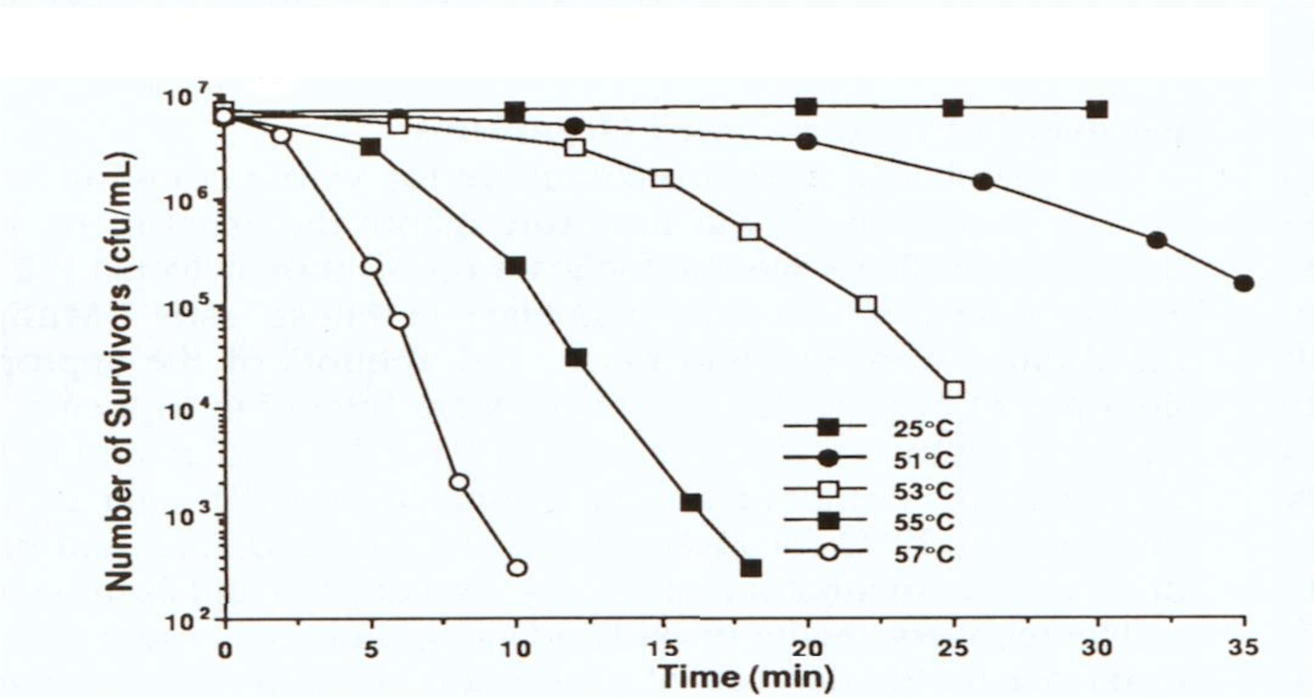
- Application of heat to food products in order to prolong shelf-life (i.e., extend the biological stability of the product)
- Pasteurization IS NOT sterilization – It is a means of reducing the risk of microbial growth
- Considered to reduce the risk of pathogens to near zero

Factors

- D, z, PUs used to predict microbe death
- Container type and size
- Chemical qualities of suspending beer
  - pH
  - CO_2
  - Bitterness Units
  - Alcohol level
- Time and temperature regime
- Number and health of microbes
- Degree of pasteurization required

Thermal Bacteriology

- Decimal Reduction Time
  - "D" time (min) for 10-fold reduction in bacterial numbers – negative inverse of slope of curve
  - $-1/D=\{\log(N_o)-\log(N_1)\}/(t_o-t_1)$
  - $D=-(t_o-t_1)$



Thermal Bacteriology

Temperature

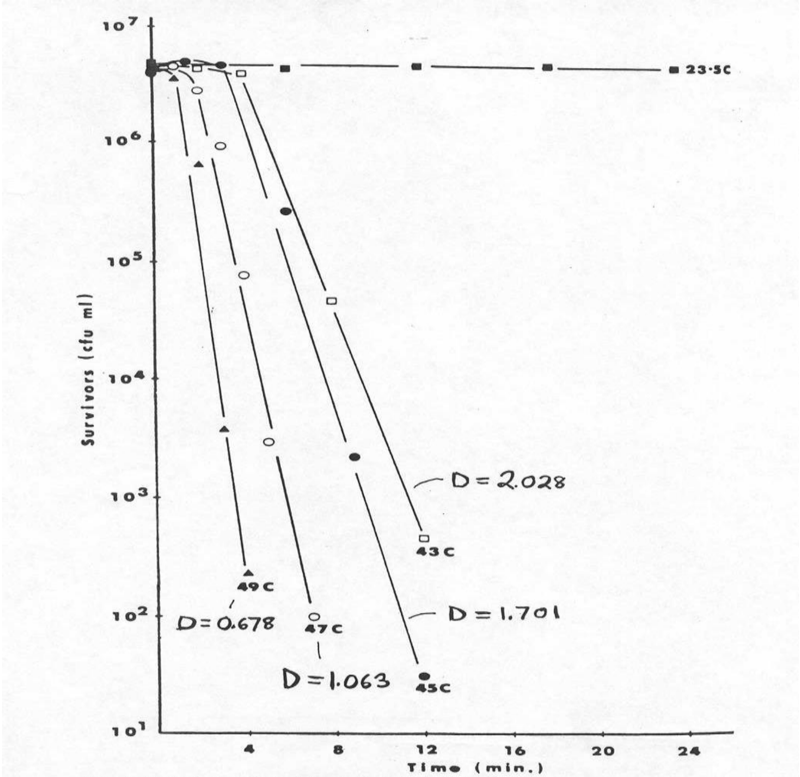


Fig. 3. Survival curve of *Lactobacillus delbrueckii*.

Alcohol

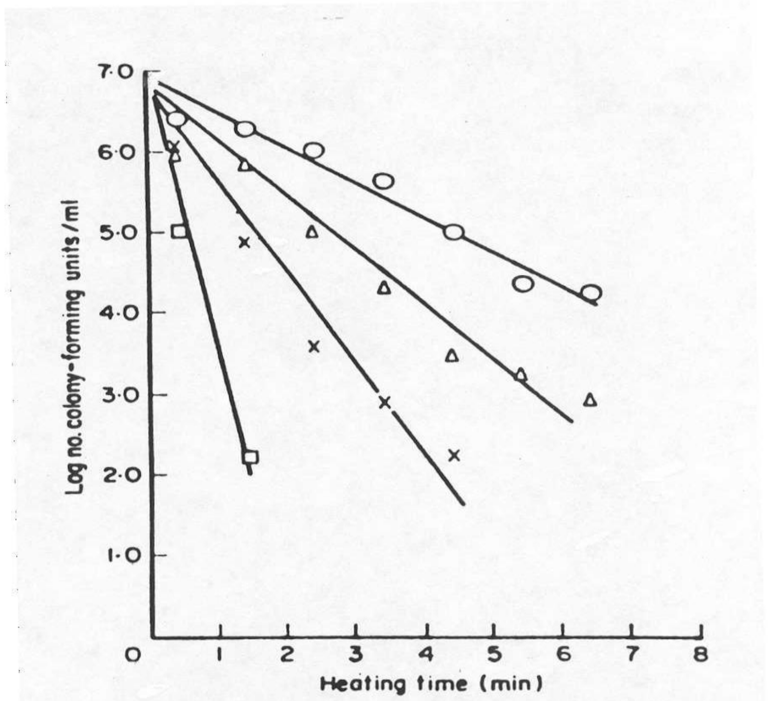


Fig. 1. The survival of *Lactobacillus* E93 at 60°C in 0·05% (○), 0·9% (△), 3·3% (×) and 4·4% (□) alcohol larger.

Thermal Bacteriology

z value = ***time to reduce D 10-fold***

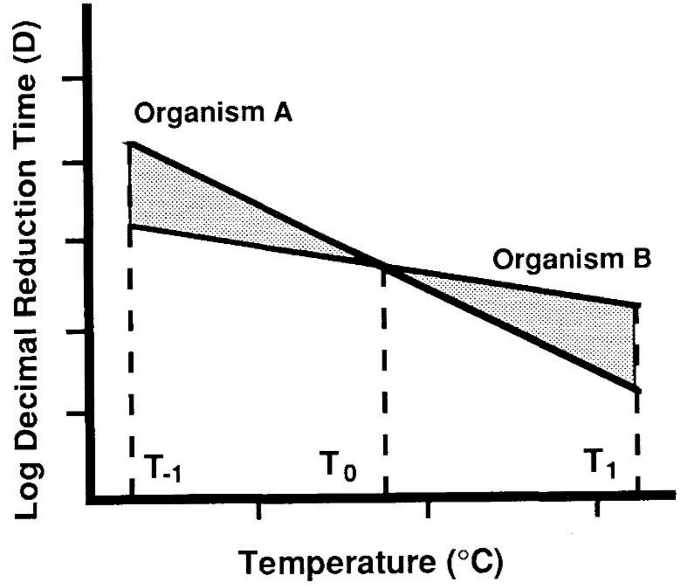
$1/z=\log(D_1/D_o)/(T_1-T_o)$

$z=-(T_1-T_o)$

Units in C° NOT °C

Set z for organism!

Some sensors and presentations fix z



Don't assume z is constant! THIS IS WRONG

z Values for Different Beer Spoilers

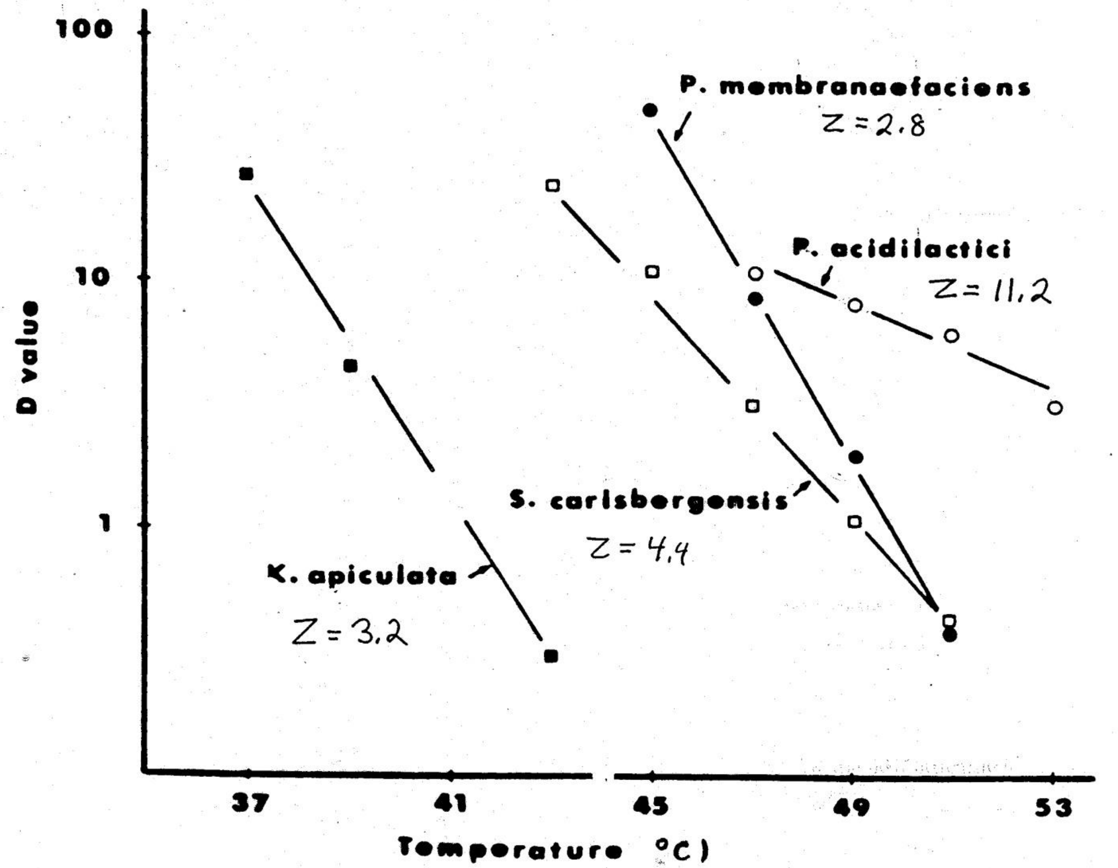
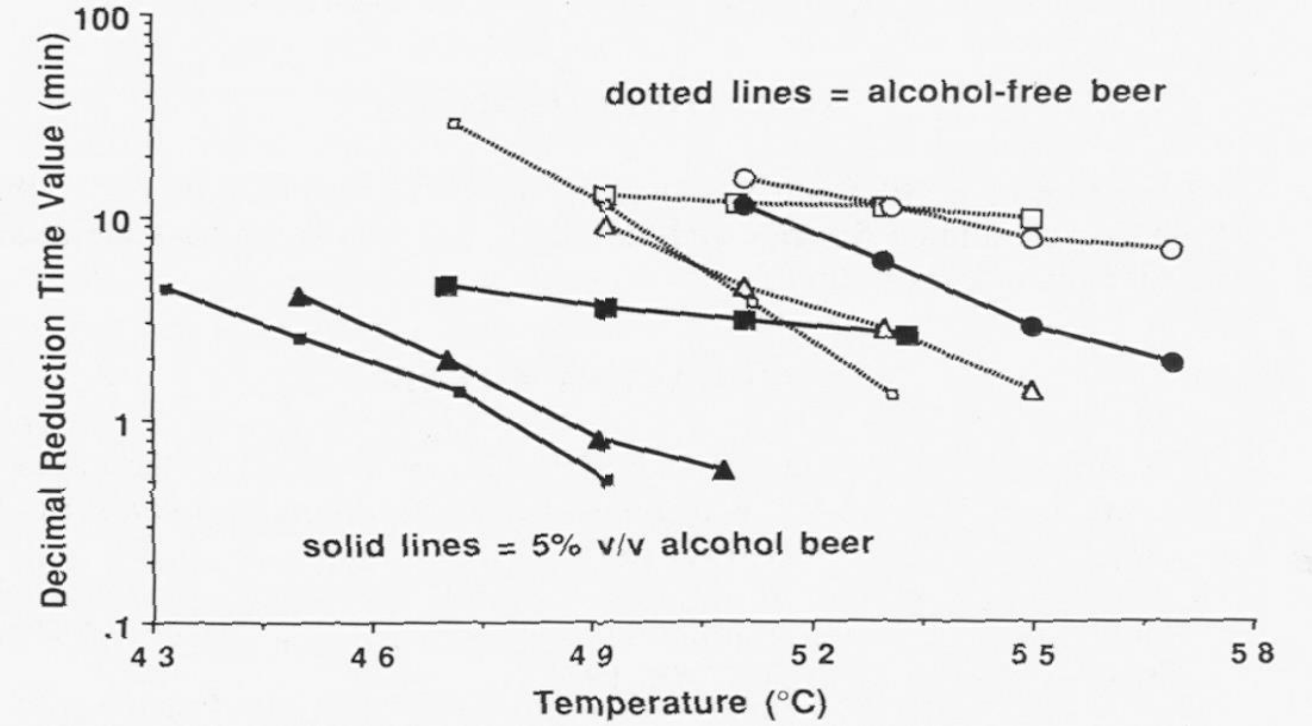


Fig. 5. Phantom thermal death time curves for some of the organisms with normal survival curves.

Thermal Bacteriology

Both D and z values depend on media and culture history



Some Existing D Values

Yeast	D	z	OH	ph	IBU
S. carlsbergensis	0.004	4.4	5	4	
S. cerevisiae	0.35		0	5.5	0
S. carlsbergensis	0.01	4.6	4.97	4.28	20.5
S. XY66	0.2	8	3.7	*	*
S. XY66	0.5	5.5	<.05	*	*
Zygosaccharomyces Bailii	0.7	4	4.55	*	Beer
Z. Bailii	0.83	8.35	2	3.1	*
Z. Bailii	0.94	7.78	<0.05	4.26	Beer

From R.A. Speers, 2022. A review of Pasteurisation literature for alcohol and non-alcohol beers. MBAA TQ 59:129-135.

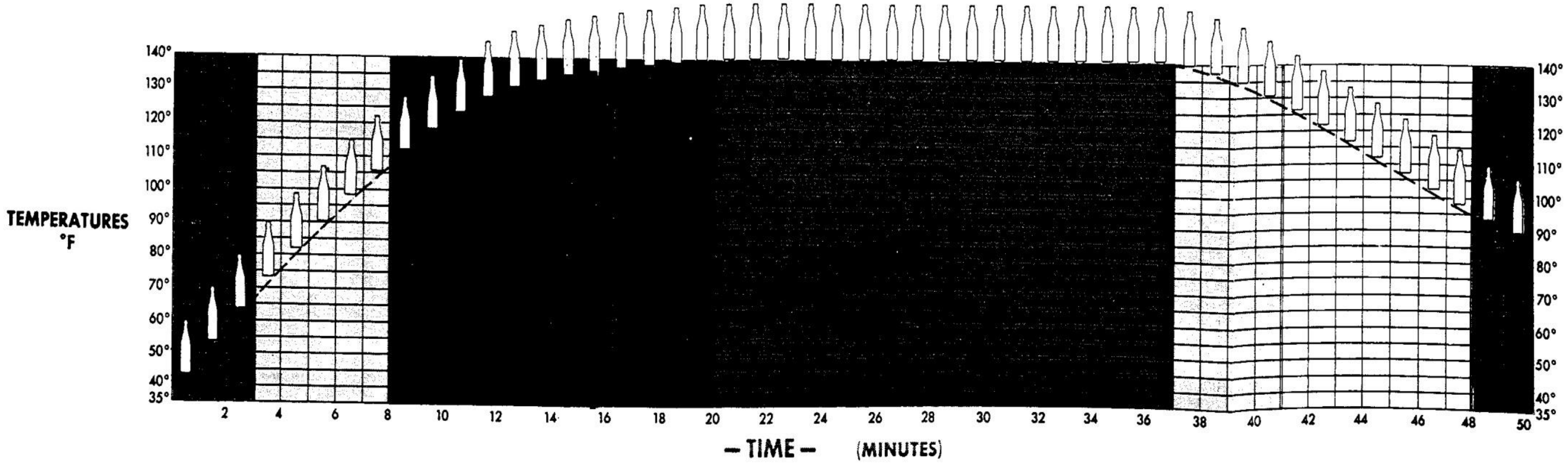
Pasteurization Units

- Known as PU's
- Equivalent time at 140ºF or 60ºC
- Typically 5-15 min used by breweries

  Sum time (t) & temperature (T) profile

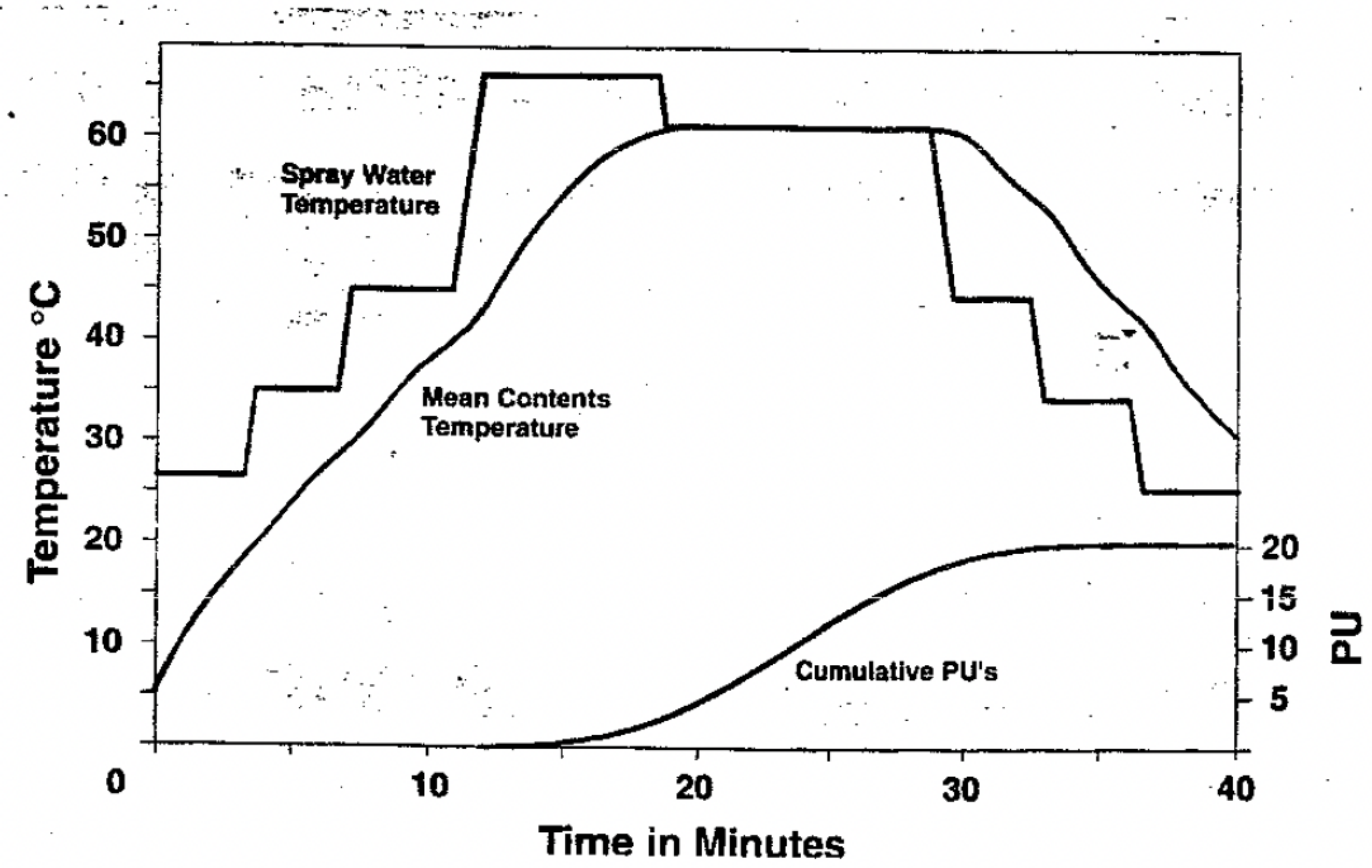
  Lethality $L=10^{(T-60)/z}$

  $PU= \Sigma(L *t)$



Pasteurization Units

Temp (°C)	Lethality
55	0.190
56	0.265
57	0.369
58	0.515
59	0.717
60	1.000
61	1.393
62	1.941



Pasteurization Units

- Determine initial load - N_0
  - (say 10 cell/mL or 3550/can)
- Determine final load - N_t
  - (say 1 cell/10^6cans)
- Determine D_{60} - 0.867 min
  - From typical heat resistant organism say Pediocococcus acidilactici
- Then:
  - $PU = D_{60} \times (\log N_0 - \log N_t)$
  - PU= 0.867 min x (log 3550-log 0.000001)
  - PU=8.28 min

Thermal Bacteriology

- Traditionally set by wild yeast – Very high PU=15 min, z=12.5 F^{o} , 6.9 C^{o}
- One has to pick a D and z specific to brewery
- E.G. *Lactobacillus delbrueckii*
  - D_{60}= 0.637 min
  - z= 7.23 C^{o}

With low alcohol, be careful!

Alcohol? Hops? pH <4.0?

Low/Non-Alcohol Pasteurization

Low/Non-Alcohol Pasteurization?

- Odwalla 1996 *E coli* outbreak
- Not supposed to happen in apple juice!
- 1 death and 70 illnesses…Potential Bankruptcy

CAN this happen in Low/Non-Alcohol beer?

Low/Non-Alcohol Pasteurization

- Data for pathogens in low non-alcohol beer

- With IBU of 15, G+ pathogens (L. monocytogenes and S. aureus) were rapidly inactivated in alcohol-free beer

- G- pathogens in low/non-alcohol beers
- E. coli 0157:H7 D_{60}=.285 min
- S. Typhimurium D_{60}=.035 min

- Beware in low/non-alcohol draft beer! See J. Applied Microbiol. 2022. 133:3728–3740. 2021
- Others?

- This needs research!

Low/Non-Alcohol Pasteurization

First:

- Keep pH WELL BELOW 4.6!!! Preferably 4.0…check with government requirements
    - Consider personnel – hire outside company?
- Consider worst/most prevalent pathogen – D and z
- Drop to 1 cell in 10^6 cans for spoilers (which microbe? tricky at present)

Or second:

- Set PU and screen for heat resistant pathogens and adjust as needed

Or third:

- Follow EU Low/No OH guide of 60-120 PU's….really!!!!!? Burst containers?

Or…use a flash pasteurizer.

- All these options need research as opined by Mike Ingledew in the last century!

Pasteurization

- Important to use the most heat resistant beer spoilage microorganism to set the amount of pasteurization required to make a product microbiologically stable.

- Generally enough heat should be applied to effectively kill 6 logs (6 D reduction) microorganisms. Note: For human pathogens 12 D reduction is typically recommended.

- Important to realize that different beers require different amounts of pasteurization. Alcohol content, pH, Hops and CO_2 all affect the amount of pasteurization required.

Pasteurization Review

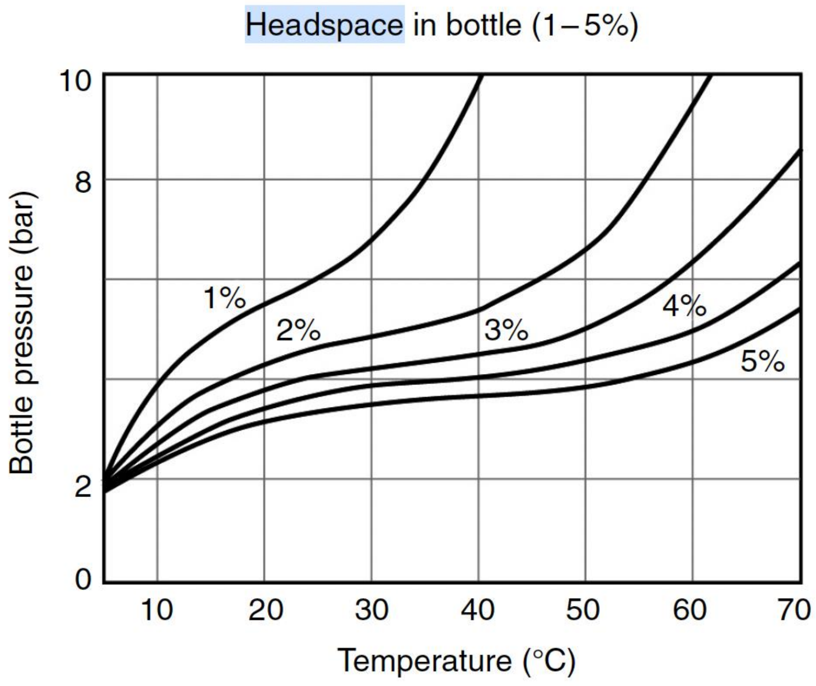
- Objective is to eliminate all microorganisms that can affect the product with minimal effect on flavor and shelf-life stability.
- Definition of a pasteurization unit (PU): 1 PU = the amount of heat applied by holding the product at 140°F (60°C) for 1 minute.
- Definition of D value (decimal reduction time) = the amount of time required (at a specific T) to reduce a microbial population by one log.
- D_{60} values (D value at 60° C) translate directly into PU's (e.g. If a beer spoiler has a D_{60} value of 2, it requires 2 minutes at 60° C (2 PU's) to kill 90% - one log).

Traditional Design

- Verification
  - By inserting trip recorder
  - Microorganism culture
  - Detection of invertase or melibiase

Traditional Design

- Problems (Continued)
  - Line stoppages can cause “burnt” flavor as product held in holding zone
  - High temperatures and low head space can cause container failure
  - Glass breakage/ removal
    - Below 1%
  - Spray fouling



Other Methods

- Flash Pasteurization (Continued)
  - Due to high heating both burnt and oxidized flavors must be controlled. Thus:
    - keep O_2 low - below 0.3 mg/L
    - control flow rate or use surge tank
    - Consider package sterility
  - When done right results in:
    - low bottle breakage
    - low labor inputs
    - energy costs low 8-10 x's lower than tunnel pasteurizers

Flash Pasteurization

- Plate heat exchanger
  - Heated to 70-75^{o}C cooled to 5^{o}C before packaging in keg, bottle or can
  - Packaging MUST BE STERILE!
  - Up to 95% energy efficient

Other Methods

- Advantages of Flash Pasteurization (Continued)
  - Small footprint
  - Quick
  - PU's up to 220 min with no flavor effects
  - No bottle breakages
  - Relatively inexpensive (daily operation)

- Disadvantages
  - MUST sterile fill
  - Over-pasteurization risk

The Bottom Line for Beer Pasteurization?

- Full strength beers and normal light beers require around 10 PU’s to achieve a 6 log reduction of the most heat resistant beer spoiler (*Pediococcus acidilactici* or *Lactobacillus delbrueckii*?).
- For low other beers, one has to do the math:
  - Extra-light products (1.8 % alcohol) require >18-20 PU’s for 6 log reduction.
  - Non-alcoholic beers (<0.5 % alcohol) require >40 PU’s for a 6 log reduction.

Key References

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THANK YOU!

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