



The Pasteurization Primer: Starting Out and Scaling Up

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First, An Overview of Stability

- Why?
- What is it?

Why?

After you've made great cider, how do you keep it that way and help ensure your customers experience it at its best?

Customer Satisfaction

- Consistency
- No Off-Flavors
- Longer Shelf Life

Safety

- No Exploding Cans or Bottles!

What Is Stability?

Microbial/Spoilage Prevention

- MLF
- Bacteria

Prolonging Freshness

- Oxidation

Refermentation Prevention

- In-package fermentation by yeast, for ciders packaged with > 0% residual sugar

Overview of Options

Microbial/Spoilage Prevention

- **Method / Style:** clean, low O₂, low nutrient, high ABV, low pH
- **Additives:** SO₂, sorbate, chitosan, lysozyme, Velcorin, etc.
- **Processes:** sterile filtration, pasteurization

Overview of Options

Prolonging Freshness

- **Method / Style:** low O₂, higher tannin
- **Additives:** SO₂, tannins, etc.
- **Processes:** CO₂ and/or N₂ sparging, counterpressure packaging

Overview of Options

Refermentation Prevention

- **Method / Style:** low %RS, low O₂, low nutrient, high ABV
 - **Additives:** SO₂ + sorbate (*not good for cans*), Velcorin
 - **Processes:** sterile filtration, pasteurization
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- **NOTE:** For higher %RS, modern-style ciders typically Velcorin or in-package pasteurization are recommended.
 - **NOTE 2:** A good QC process is important to validate and monitor your refermentation prevention!

What happens during pasteurization?

Let's look at this from 3 perspectives:

- Biological
- Chemical
- Sensory Analysis

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

Variables = Organism, Medium, Temperature and Time

General equation for
all pasteurization:
(the equation specific for
cider is on the next slide)

$$PU = t \cdot 10^{\left(\frac{T - T_{ref}}{Z}\right)}$$

PU: Pasteurization Unit

t : Time (in minutes)

T: Temperature (In Celsius)

T_{ref}: Reference Temperature (In Celsius)

Z: Coefficient of thermal resistance (In Celsius)

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

$$PU = t \cdot 10^{\left(\frac{T - T_{ref}}{Z}\right)}$$

- Organisms have different thermal resistance and thus different values for T_{ref} and Z .
- The constants $T_{ref} = 60^{\circ}\text{C}$ (140°F) and $Z = 6.94$ are used in fermented beverages because we know which organisms can survive at the level of alcohol and pH of our product, and what their heat resistance typically is.
- Practically, many yeast strains begin to die sooner, but the most heat resistant organisms typically experience logarithmic death (10x reduction per minute) by 60°C .
- In unfermented juice, higher temperatures are required for pasteurization and a Z value 10°C is often used.
- So the equation we use can be simplified to the following:

$$PU = t * 1.393^{(T-60)}$$

PU = Pasteurization Units

t = time

T = Temperature in Celsius

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

$$PU = t * 1.393^{(T-60)}$$

- A pasteurization unit (PU) is a measure of the heat received during pasteurization.
- 1 PU is 1 min at 60° C (140°F), or the equivalent time-temperature effect on organisms, and generally refers to a logarithmic reduction of organisms.
 - For example, at 1 PU, 351 cells dies off to 35 cells. 35 cells to 3, 3 cells to 0
- With constant temperature, the rate of PU accumulation scales up linearly with time.
 - For example: at 60°C, 1 min = 1 PU, 2 min = 2 PU, 3 min = 3 PU, etc.
- For the same amount of time, this speed scales up exponentially with temperature (10x PU/min for every 7 degrees C increased)
 - For example: for 1 min, 60°C = 1 PU, at 67°C = 10 PU, at 74°C = 100 PU

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

$$PU = t * 1.393^{(T-60)}$$

Same temperature, different amount of time.

t (time, minutes)	T (temperature)	PU (log reduction)	Size of microbial load PUs are theoretically effective against (CFUs)
1.0	60.0	1	9
2.0	60.0	2	99
3.0	60.0	3	999
4.0	60.0	4	9999
5.0	60.0	5	99999
6.0	60.0	6	999999
10.0	60.0	10	9999999999

Amount of time required for 10 PUs
at different temperatures.

t (time, minutes)	T (temperature)	PU (log reduction)
1.0	67.0	10
1.4	66.0	10
2.0	65.0	10
2.7	64.0	10
3.7	63.0	10
5.0	62.0	10
7.0	61.0	10

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

- To maximize speed, you can maximize temperature, BUT...
 - Too much temperature under pressure can be dangerous!
 - Containers will explode or deform under too much pressure
 - Good test of seam integrity
 - Sounds like popcorn
 - Overfilled cans pop early
 - 2% max overflow is a good goal
 - Test CO₂ levels!

Recommended limits for properly filled cans

Carbonation Level		Max Product Temperature	
Volumes	g/L	°C	°F
2.0	3.91	79	175
2.1	4.11	77	170
2.2	4.30	74	165
2.3	4.50	71	160
2.4	4.69	68	155
2.5	4.89	66	150
2.6	5.08	63	145
2.7	5.28	60	140
2.8	5.48	58	137
2.9	5.67	56	134
3.0	5.87	54	130

What happens during pasteurization?

From a Biological Perspective: Logarithmic death of microbes

- Fermenting cider can have as many as 10 million cells of yeast per mL.
- Filtration and fining can remove most of this, but often not all.
- The exact microbial load remaining after fining and filtration will vary from product to product and batch to batch, so do some lab testing for yeast, bacteria, and spores on your typical product to establish a baseline.
- After baseline minimum levels are established, build some safeguards/overkill into your pasteurization methods.
- Theoretical minimums and labs will help figure out the starting point, but real world data logging has some uncertainty built in (you can't put a temperature probe in every can of cider).
- When in doubt, go for overkill.
- When you aren't sure if your data is 100% accurate, go a little overboard.
- It doesn't hurt much to just make sure everything is good and give it a little more time.
- When in doubt, go for overkill.
- When in doubt, go for overkill.

What happens during pasteurization?

From a Chemical Perspective:

- Oxidation
 - Depends on DO level
 - Ideally, it will only oxidize sacrificial tannins
- Enzymatic activity
 - Rapid function of some enzymes – They function very quickly when hot.
 - Denaturing of some enzymes – Or they break down and don't function anymore.
- Other chemical reactions and chemical breakdown

What happens during pasteurization?

From a Sensory Perspective:

- Brief, Rapid Aging
 - Melding/Marriage of Flavors
 - Immediately after blending, layers of flavors are perceived individually. After pasteurization and aging, flavors tend to meld into one instantaneous flavor.
 - Length of finish tends to shorten.
 - Oxidation (D.O. dependent) – Can highlight off-flavors and oxidative faults, or smooth out harsh tannins.
 - Thermal Degradation Units (TDUs) – See next slide
- Locked-in flavor and long-term stability
 - Knowing your customers will taste what you intended for them to taste without spoilage.

What happens during pasteurization?

From a Sensory Perspective: Thermal Degradation Units

- TDUs give a measure of the amount of flavor change that has been caused by pasteurization or aging.
- It is generally accepted that chemical reactions occur twice as fast for each increase of 10°C.
- From the sensory perspective, it is better to achieve the PU target by using a higher temperature for a shorter time.
- The formula for TDUs is normally shown like this:

$$\text{TDU} = t * 2^{(T-20)/10}$$

Note: TDUs aren't accumulated below 20°C (68°F).

A Roadmap to Pasteurization

Practical Advice, Tips, Tricks, and Pitfalls

Always start by asking questions: your best resources are:

- Sales reps & service technicians
- Fellow cidermakers, brewers, winemakers, etc

A Roadmap to Pasteurization

Big Questions

- What is your packaging format?
- How quickly and how often do you need to pasteurize?
- How clean is your product?
- What's your plan for growth and flexibility?

A Roadmap to Pasteurization

Big Questions

- What is your packaging format?
 - Cans – Bath, Batch, or Tunnel
 - Bottles – Bath, Batch, or Tunnel
 - Kegs – Flash (kegs should be sterilized, not just sanitized)

A Roadmap to Pasteurization

Big Questions

- How quickly and how often do you need to pasteurize?
 - OPTION 1: Match Daily Rate – Pasteurize in-line with packaging
 - Requires extra labor and extends time of packaging runs
 - Eliminates the need for cold storage
 - OPTION 2: Match Weekly Rate – Space for cold storage until pasteurization?
 - If packaging schedule has large gaps between packaging runs, this method can utilize labor during off-peak times for more consistent work schedules
 - Requires more cold storage space (walk-in coolers) to keep product from spoiling until it can be pasteurized.

A Roadmap to Pasteurization

Big Questions

- How clean is your product?
 - Get lab work done before and after pasteurization
- How many PUs do you need?
 - Do you have consistent fining/filtration practice prior to packaging?
 - Validate results with lab analysis and DIY methods (stress tests)
 - Consider packaging line cleanliness (downstream contamination)
 - Once again, overkill.

A Roadmap to Pasteurization

Invest in robust data logging, temperature probes, real time monitoring and processing, etc.

Some cideries estimate PUs by using a thermometer and a timer alone. This introduces operator error, and doesn't correctly account for fluctuations in water temperature, starting product temperature, or less-than-full pasteurizer loads. Data logging bath/reservoir temperature takes these variables into account, producing consistent results every time.

A Roadmap to Pasteurization

Invest in robust data logging, temperature probes, real time monitoring and processing, etc.

In addition to measuring in can probe, use a water temperature probe. This isn't required constantly, but is a great way to monitor the bath water temperature to know when your pasteurizer is ready for use and to avoid overheating product while maximizing rate of pasteurization.

A Roadmap to Pasteurization

DIY data logging, temperature probes, real time monitoring and processing, etc.

Raspberry Pi 4 Model B - 1 GB RAM

Product ID: 4295

\$35.00



High Temp Waterproof DS18B20 Digital temperature sensor + extras

Product ID: 642

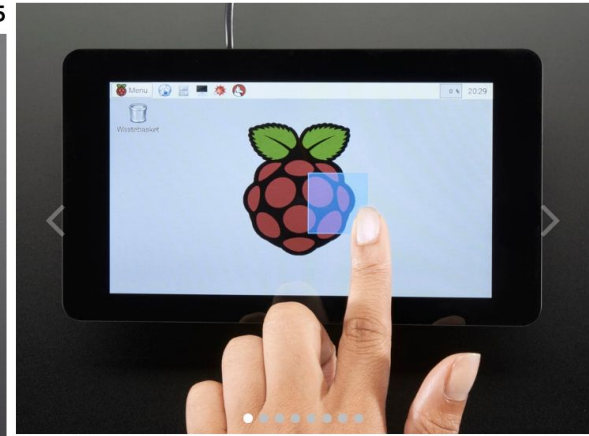
\$14.95



Pi Foundation Display - 7" Touchscreen Display for Raspberry Pi

Product ID: 2718

\$79.95



A Roadmap to Pasteurization

Ready-to-use data logging, temperature probes, real time monitoring and processing, etc.



Craft Metrics



PASTEURIZATION COMPUTER



\$394.00



Bung

Can ▾



Probe Length

2m ▾



Madgetech
Temp1000IS I.S....

\$239.00

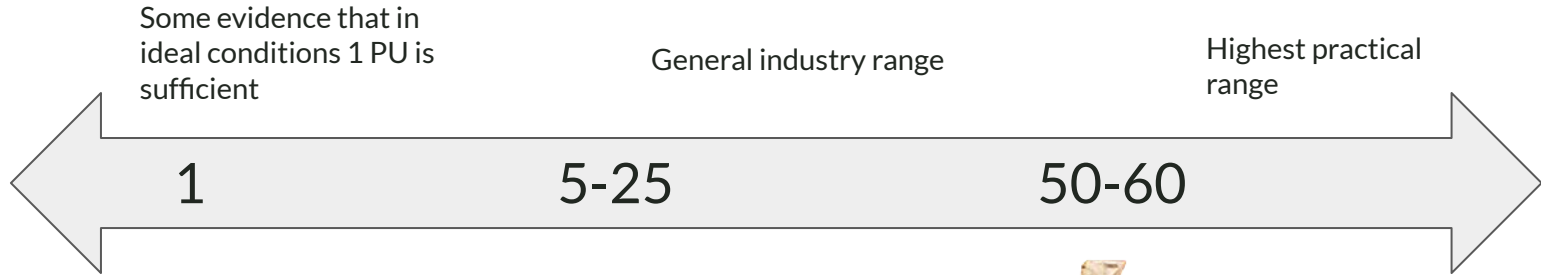
Global Test Supply
Free shipping

How many PU do I need?

CREDIT: This slide copied from
Steve Trussler's CINA
Bootcamp presentation

You need more PUs when your cider has:

- a high microbial load (GMPs and cellar hygiene)
- sediment or is very cloudy (filtering)
- lower alcohol (nature of the cider itself)
- high sugar content (nutrient desert)



A Roadmap to Pasteurization

Big Questions

- What's your plan for growth and flexibility?
 - Growth will not be a steady curve. There will be many ups and downs, so take a zoomed-out view of your packaging program.
 - A consistent and unspoiled product will cause growth in all aspects of production! Plan your next steps on a timeline.

A Roadmap to Pasteurization

Big Questions

- Is your maintenance program ready?
 - Always plan preventative maintenance schedules for your machines and your people (pasteurization is intense in terms of labor, time, heat and mechanical stress!).
 - Check/calibrate all instruments on a schedule! Your methods are only as reliable as your data is accurate.

A Roadmap to Pasteurization

The Big Questions

- How will you check your work? Always validate data.
 - Data collection and analysis
 - DIY methods (stress tests, QA library)
 - Labs (in-house or at a laboratory)
 - Customer satisfaction (Untappd reviews, Instagram comments, account visits)

A Roadmap to Pasteurization

A video of our first day of pasteurization – learning amidst chaos!



A Roadmap to Pasteurization

Our first over-pressure can pops (high fill & high temperature)



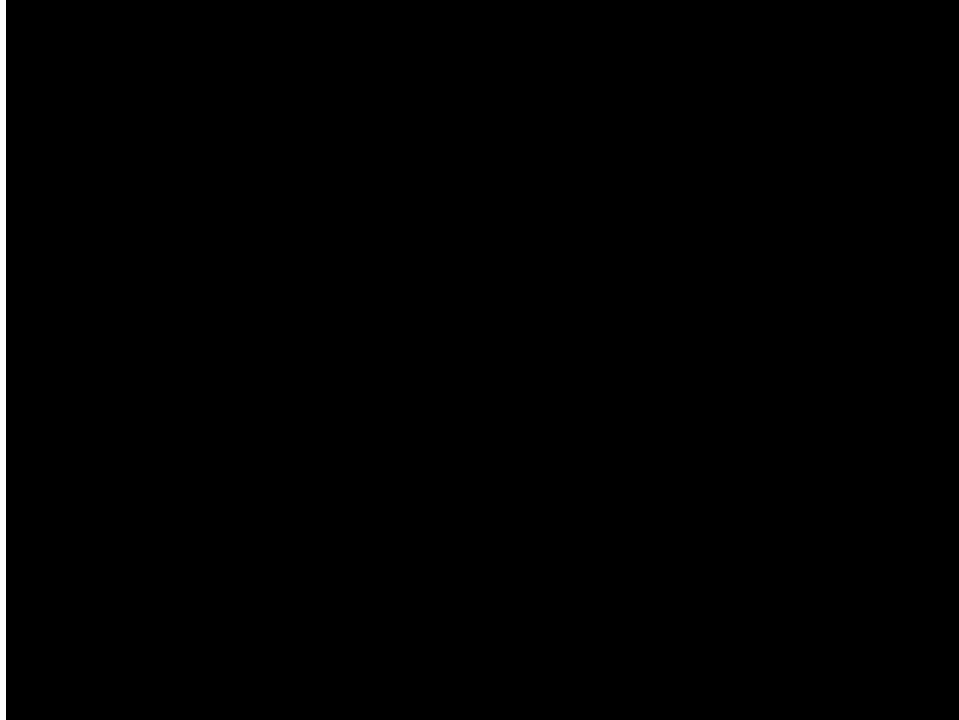
A Roadmap to Pasteurization

A video of our bath setup after a few years of optimization



A Roadmap to Pasteurization

A video of our current pasteurization setup using a Jenrey “Craft Can Pasteurizer”



A short list of additional resources

A good resource on pasteurization science and data:

<https://www.redpostltd.com/support/science>

The outside laboratory I have experience with:

<https://www.etslabs.com/analyses/all-analyses>

Contact me, Joseph Kilbourn, Head Cidermaker @ Ash & Elm Cider Co. with questions!

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