AMERICAN CIDER ASSOCIATION

-2025-
CIDERCON®
CHICAGO

Unique Stability Considerations for Fruited Ciders

PRESENTED BY:

Dr. Nichola Hall, Scott Laboratories

AGENDA

1. A quick look at stability and instability
2. A review of apple chemistry
3. Fruited cider
4. Minimizing instabilities risks
5. Take home message

01 Stability & Instabilities

Stability

WHY DO WE CARE?

The goal of (most) producers is to produce a product where there are no changes in:

- Visual quality
- Aroma
- Flavor
- Texture
- Color
- Acceptable shelf-life

The customer experiences what you intended!

Common cider instabilities

Unwanted haziness and carbonation

Changes in color (straw > nut brown)

Changes in aroma, flavor, and mouthfeel (vinegar)

Changes in aroma (sulfur off-odors)

How do we prevent instability?

By understanding the matrix

(base chemistry)

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02
Apple chemistry

Understanding the base material

Understanding apple juice chemistry

Sugar: ~95-130 g/L

TA: 1.5-15 g/L

pH: 3-4.5

Primary acid: Malic acid

Protein, pectin, etc

Apple juice composition is impacted by:

- **Apple variety**
- **Growing/storage conditions**
- **Processing decisions**
- **Chosen inputs**

Understanding apple juice chemistry

Sugar: ~95-130 g/L

TA: 1.5-15 g/L

pH: 3-4.5

Primary acid: Malic acid

Protein, pectin, etc

Apple juice composition is perishable!

Understanding apple juice chemistry

Sugar: ~95-130 g/L

TA: 1.5-15 g/L

pH: 3-4.5

Primary acid: Malic acid

Protein, pectin, etc

The biochemical transformation of apple juice into cider is a way of turning a perishable, unstable product into a non-perishable, stable(ish) product….

Stability in apple-based ciders

THE OBVIOUS

Compound to stabilize	Potential instability	How to stabilize
Fructose, glucose, sucrose	**Refermentation** of residual sugar. Can cause changes in appearance, aroma, flavor, and mouthfeel	Ferment to dryness. Incorporate good cellar practices post fermentation
Cellulose, pectin	Incomplete degradation of carbohydrates incl. pectin. Can lead to **clarification and filtration issues**	Use a pectinase enzyme (with cellulase side-activities if needed) to break down the pectin net
Malic acid	Metabolism of malic acid. Can cause microbial **haze**, **off-aromas, off-flavors, unintended reduction in acidity**	Stylistic choice….generally want to inhibit its degradation. Appropriate use of anti-microbial agents
Aroma compounds: esters, fatty acids, carbonyls, alcohols	**Off-aromas:** Dull, muted, aroma-less ciders, or ciders with heavy, honey, sherry-like aromas	Protect from oxidation and degradation. Incorporate good cellar practices post fermentation and sensible use of antioxidants

Stability in apple-based ciders

THE LESS OBVIOUS

Compound to stabilize	Potential instability	How to stabilize
Organic acids: citric acid, hydroxycinnamic acid	Metabolism of citric acid >VA and diacetyl HCA > brett taint	Appropriate use of anti-microbial agents
Polyphenolics/tannins	Precipitation	Induce polymerization, or fine to remove
Minerals	Can lead to metal casse	Good fermentation practices
Protein	Upon heating may lead to changes in appearance	Remove (the unstable ones) with a sodium-based bentonite

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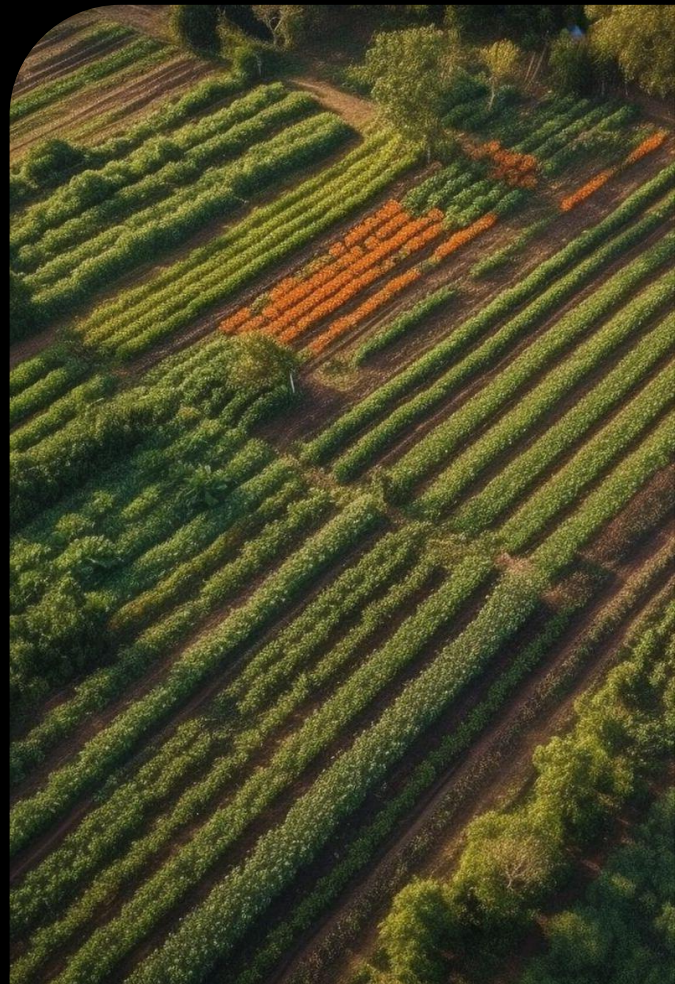
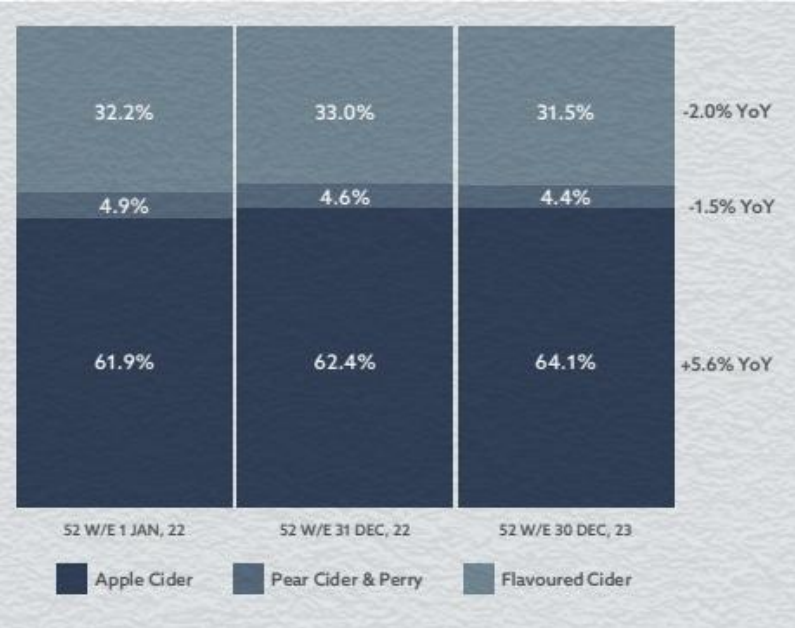
03

Fruited ciders

Understanding a new matrix



Fruited ciders: Market share flavor and options



Weston Cider Report 2024

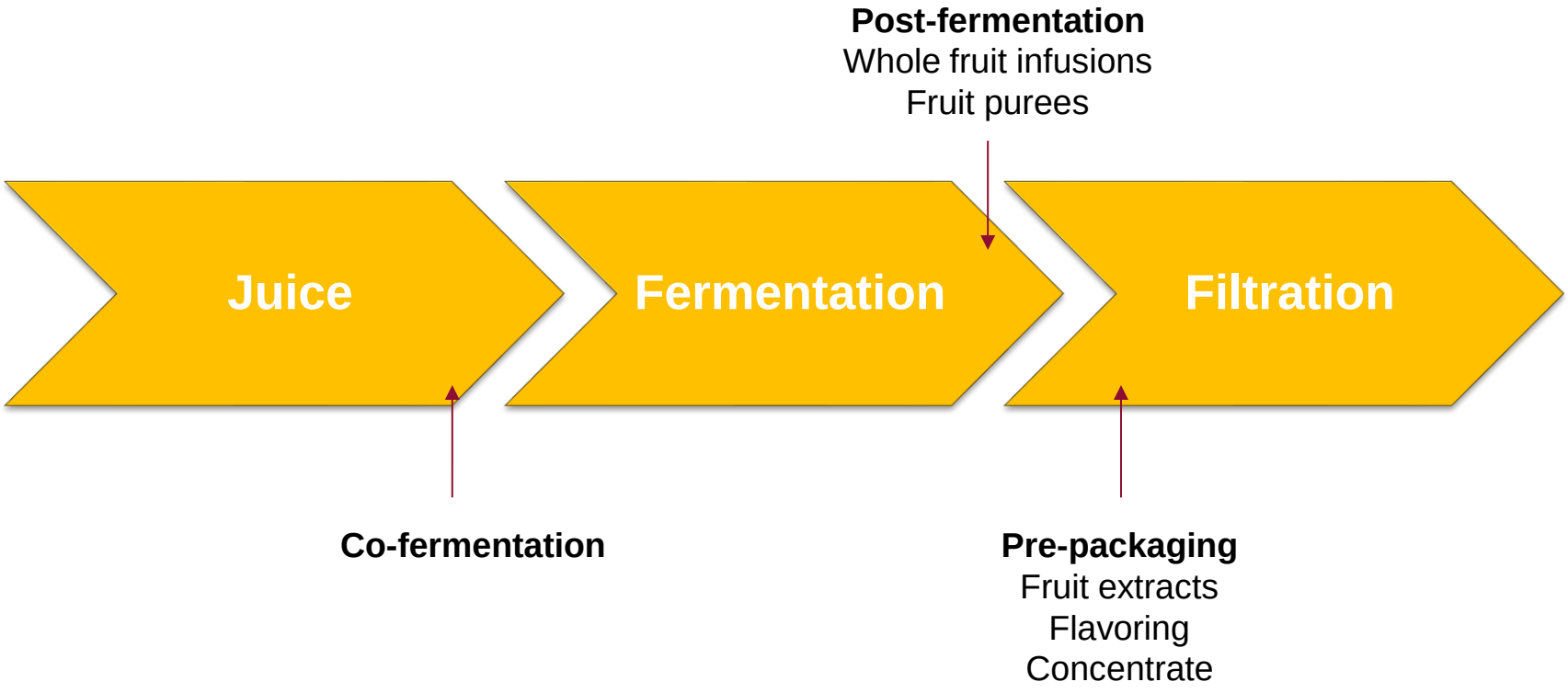
~5% market

- **Berry:** Strawberry, Raspberry, Blackberry, Blackcurrant, Blueberry
- **Citrus:** Orange, Lime
- **Tropical Fruit:** Pineapple, Kiwi

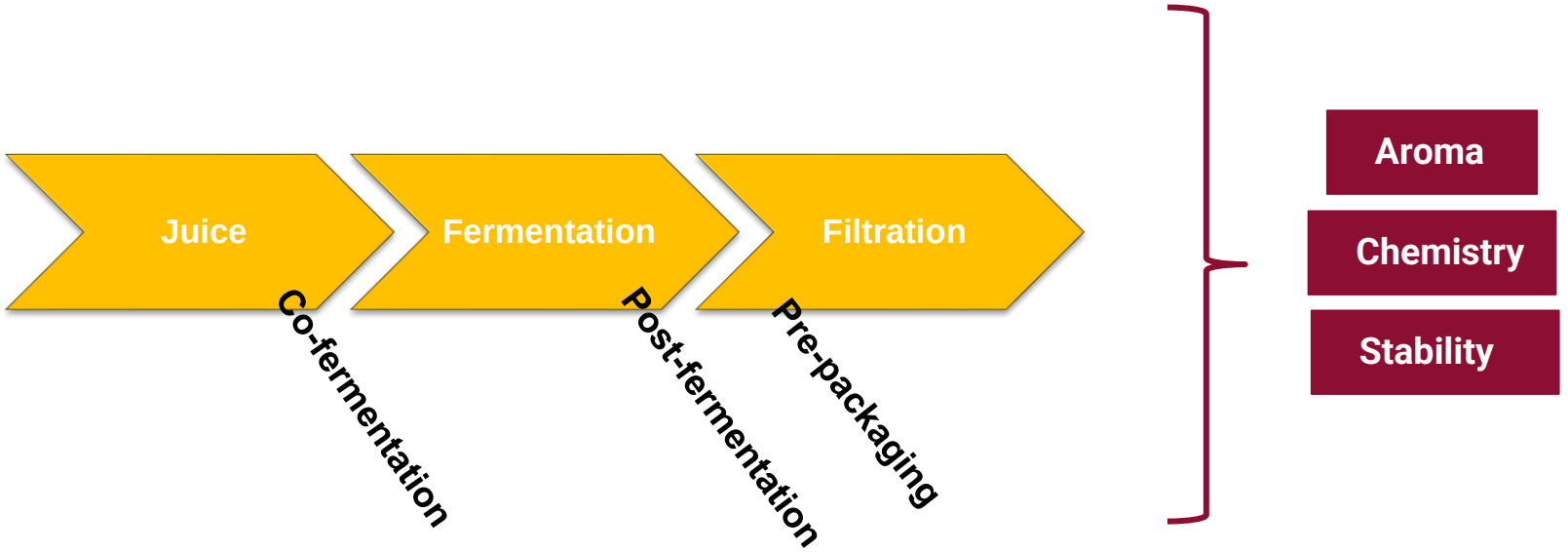
The possibilities are endless…but!

We need to understand how the addition of another source impacts chemistry and microbiology

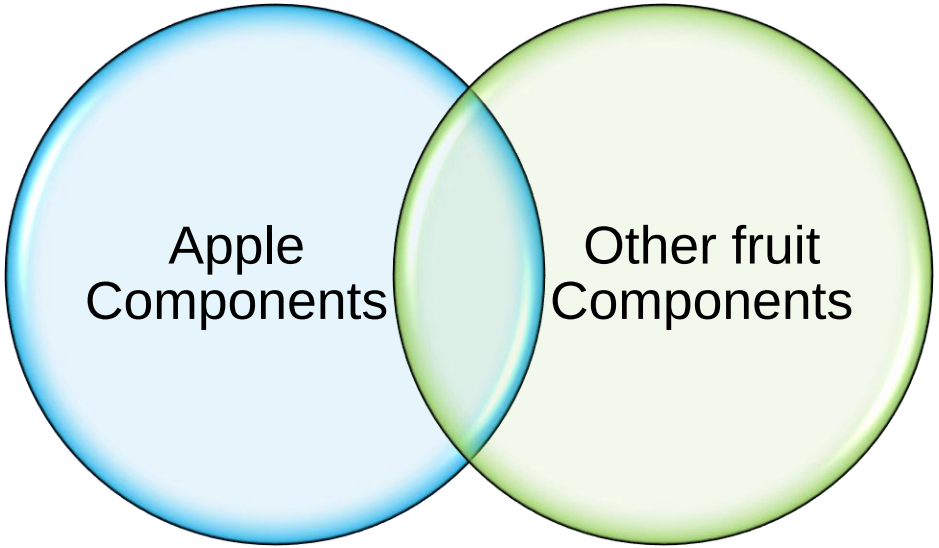
Ways to produce fruited ciders



Ways to produce fruited ciders



Implications of fruited ciders



Each fruit has its own chemical makeup. Blending fruits can impact:

- Concentration of components
- Introduce new components
- Introduce different microflora
- Introduce different challenges

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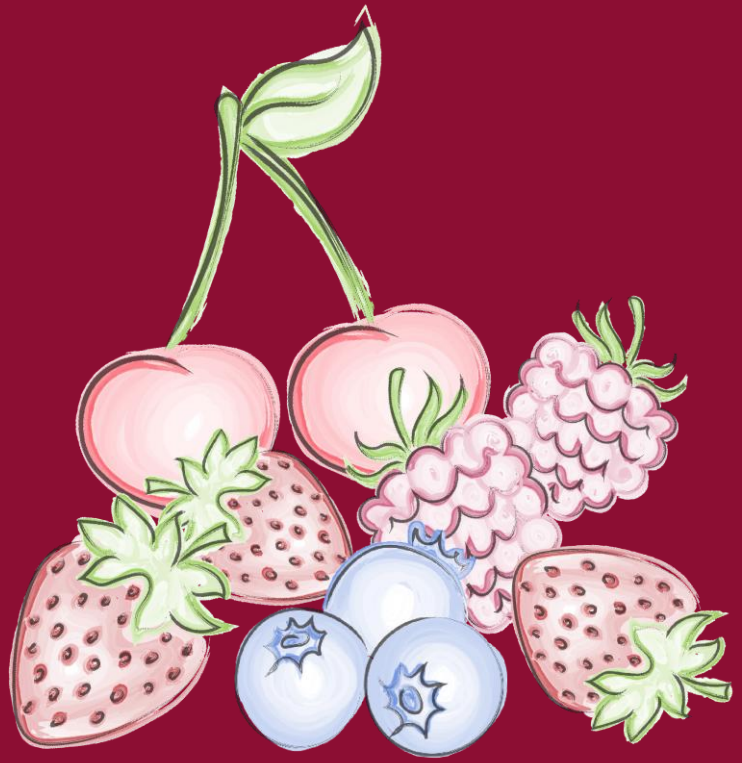
Berries



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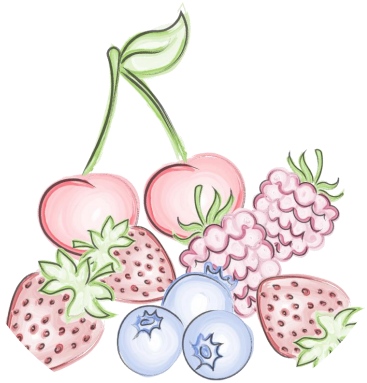
General Composition of Berries



- Sugar: 50-120 g/L (**Glucose**+Fructose)
- pH: 2.8-3.7
- TA: 3-15 g/L
- Primary acid: **citric acid**
- Secondary acids: **varied**

Strawberry, blackberry, raspberry, blueberry, black currant give a fruity flavors and aromas, sweet-tart mouthfeel, and a color impact

BERRIES

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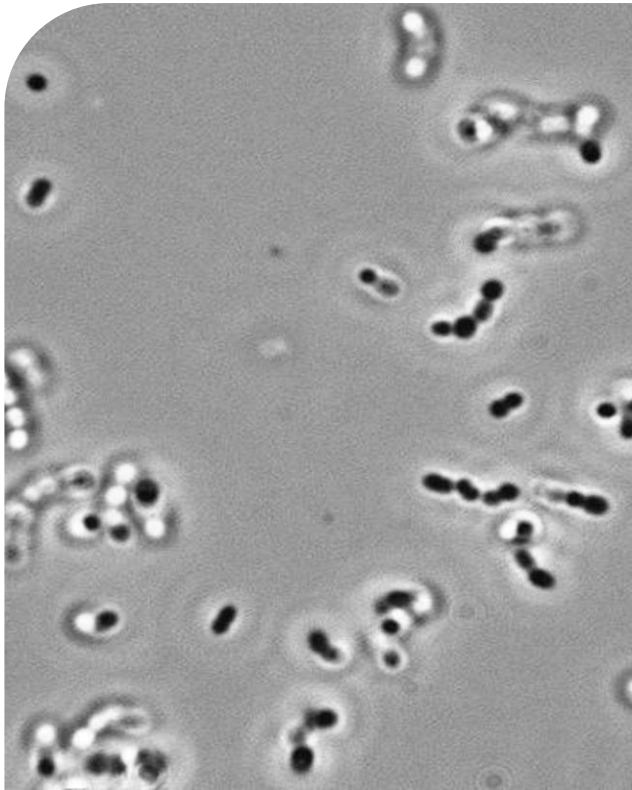
Acid Composition of Berries

Berry	Primary acid	Secondary acid(s)	% of Citric acid	% of Malic acid
Raspberry	**Citric acid**	Malic	85	5-10
Blackberry		Malic	40-80	10-50
Strawberry		Malic, quinic, succinic	88	10
Blueberry		Malic, quinic	75-85	4-11
Black currant		Malic, shikimic	43	6

Personal communication Dr. J. Fiola, U. of Maryland

A closer look at citric acid

- Weak, triprotic acid
- Tart/sour taste
- Biologically unstable…can be metabolized by LAB to form **diacetyl** and **acetic acid**



Other berry acids

Brambles (raspberry, blackberry, marionberry…) also contain **ellagic acid** and **hydroxycinnamic acids**

Personal communication Dr. J. Fiola, U. of Maryland

A closer look at ellagic acid

- Formed from the hydrolysis of ellagitannins
- Chemically unstable…is insoluble in ethanol and can precipitate
- Forms **microcrystalline deposit** associated with color pigments- rod or needle shaped

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A closer look at hydroxycinnamic acids

Hydroxycinnamic acids
(pre-cursor)

Vinyl Phenols
(intermediate)

Ethyl Phenols
(sensory active end-point)

- Compounds extracted (mainly from skins)
- Undergo an enzymatic transformation by LAB's and Brett
- Detected analytically and aromatically

Brett aromas:
Horse, barnyard, leather, earthy, medicinal, smoky, tobacco, lilac putrid, cheesy

Color impacts of berries

Berries contain color compounds known as **anthocyans.**

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Anthocyanins and Color Instability

- Anthocyanins are a sub-class of flavonoids
- Responsible for the blue, red, and purple in foods and flowers
- Found in berries (as well as cherries, grapes, black plums, pomegranates)

Anthocyanins are highly unstable

Stability impacted by pH, temperature, enzymatic activity, light, O_2, structure and concentration of compounds, the presence of other compounds (phenols, proteins…)

BERRIES

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Color considerations

Color is short lived*

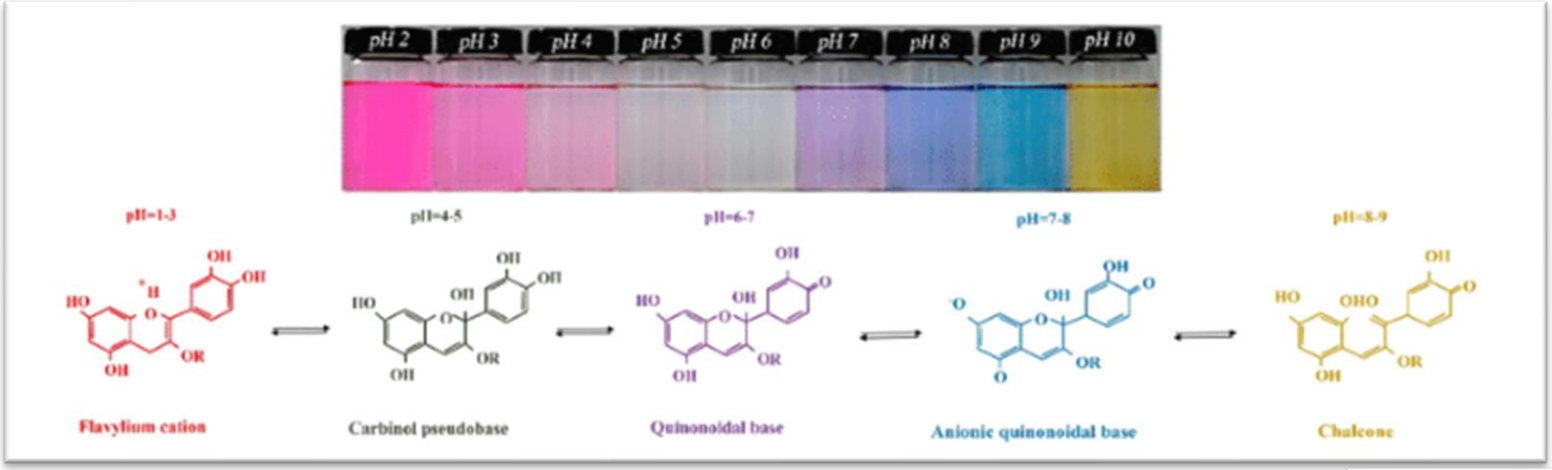
- Low levels of anthocyanins
- High browning capacity
- Chemical browning- PPO activity
- Enzymatic browning- due to high potential levels of mold/rot

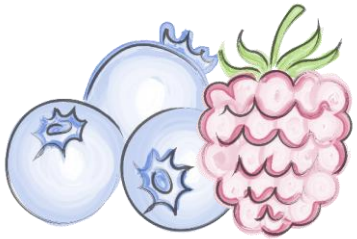
Highly impacted by chemistry/environment

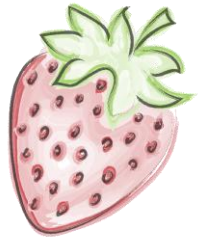
- pH
- [Tannin]
- [Polysaccharide]
- Temperature
- Light exposure

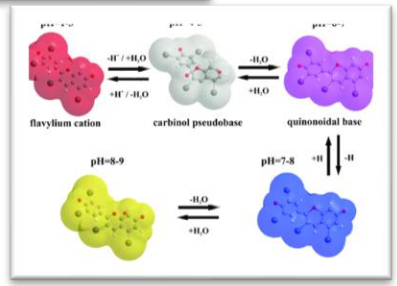
** particularly in fermented strawberries and raspberries*

Color & pH


pH 2
pH 3
pH 4
pH 5
pH 6
pH 7
pH 8
pH 9
pH 10
pH=1-3
pH=4-5
pH=6-7
pH=7-8
pH=8-9
Flavylium cation
Carbinol pseudobase
Quinonoidal base
Anionic quinonoidal base
Chalcone






flavylium cation
carbinol pseudobase
quinonoidal base
pH=8-9
pH=7-8

BERRIES

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Summary: Apple/Berry Co-ferments

Can have a positive impact on:

- Flavor
- Aroma
- Color (possibly)
- Base chemistry (possibly)
- Antioxidant strength

Can have a negative impact on:

- Aroma- freshness
- Microbial stability
- Visual quality

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Grapes

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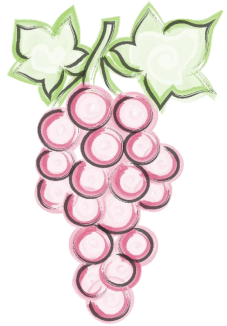
General Composition of Grapes



- Sugar: ~240 g/L
- TA: 5.5-8.5 g/L
- Primary acid: **tartaric**
- Secondary acids: malic
- **Protein**, pectin, etc

- Aromatic whites (SBL, RSL, GWT, PNG…) can impact color, aroma, flavors, freshness
- Big reds (ZIN, CSV, MER…) can impact color, aroma, and structure
- Both can impact **protein** and **tartaric acid** stabilities

A closer look at heat instability

Haze formation

Caused by **proteins**

Proteins can unravel at **high temperatures**

- Pasteurization
- Unexpected heat during transport or storage

Not all proteins can cause hazes

- Just pathogenesis related proteins (TL-P's and Chitinases)

Hazes are also impacted by pH, ionic strength, polyphenolic and polysaccharide content

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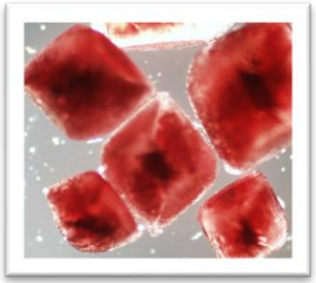
A closer look at tartrate instability



Crystal formation

- Young “wine” is a supersaturated solution of potassium bitartrate
- Depending on how much grape is added you can experience “wine diamonds” material
- Instability occurs when the concentration of K^+ and HT^- exceed the solubility of KHT and crystals form
- **Temperature (low)**, pH, potassium, HT^-, alcohol, protein, polysaccharide and [phenolic] can impact crystal formation
- CaT precipitants can also form…

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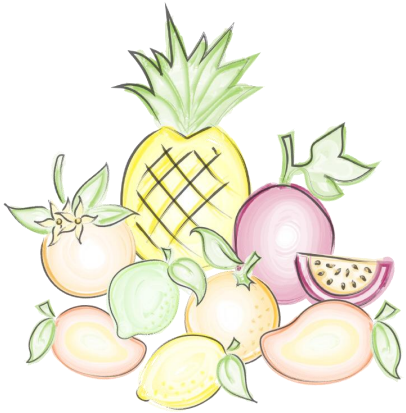
Tropical Fruits

General Composition of Tropical Fruits



- Sugar: ~60-130 g/L
- TA: 5-16 g/L
- pH: 3.5 (pineapple) - **6** (mango)
- Primary acids: Citric acid
- Secondary acids: **Lactic and acetic acid**
- Protein, carbohydrates (pectin, cellulose…), **gums, fiber**

Pineapple, mango, guava can give a refreshing, tangy, exotic component

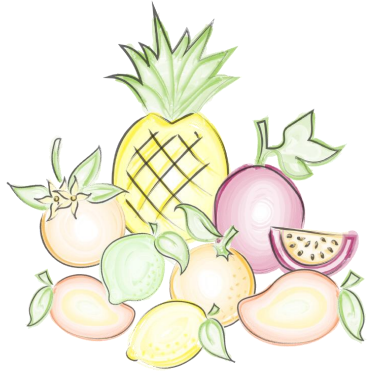
Pineapples and processing challenges

Clarification & Filtration

- Presence of galactomannan (natural gum) which can cause viscosity and foaming issues
- Presence of high levels of cellulose, hemicellulose, and lignin can lead to settling issues and clogged filters

Foaming

- High level of proteins which can lead to foaming



Pineapples and processing challenges…

Protein instability

- Pineapples contain bromelain (proteolytic enzyme) which can result in haze formation

Aroma instability

- Fermented pineapple is highly aromatic during and at the end of fermentation, but the aroma is relatively short-lived

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Citrus

General Composition of Citrus

- Sugar: ~ 10-130 g/L
- TA: 5.1- **68** g/L
- pH: **2**-4.5
- Primary acid: Citric acid
- Secondary acids: **Ascorbic acid**

Oranges, lemons, limes can give zesty and bright component

Citrus and processing challenges

Oils

- Introduced by poor juice extraction and can also be responsible for bitterness, hazy, and off-flavors over time

Clarification

- Can be a challenge due to proteins, pectin, and other polysaccharides

Bitterness

- Limonoids can be introduced from the skin/peel/zest

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Other fruits

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04

Managing Instabilities

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Instabilities can be microbiological or chemical in nature…

Microbial Instabilities

OFF-ODORS, OFF-FLAVORS, MICROBIAL HAZE, ETC.

Good fermentation practices

- Controlled fermentation, proper inoculation practices, proper nutrition management

Good cellar hygiene

- SSOP's, hygiene monitoring, avoid cross-contamination

Good cellar practices

- Temp, DO, and headspace management, appropriate clarification and filtration steps

Proper use of antimicrobial agents

- **Bactiless** (AAB and LAB), **No Brett Inside** (Brettanomyces), **Lysozyme** (LAB), **SO2**, **Velcorin®**

Heat (protein) Instability

HAZE INDUCED BY TEMPERATURE

Add (sodium-based) bentonite

- Bentonite is a negatively-charged clay with a very high surface area (post-hydration)
- Negative charged clay binds positively charged proteins, resulting in a larger particle (flocculant)
- Bentonite settles, removing the unstable proteins in the process
- Bentonite floc is removed via a racking

Amount of bentonite to add

- Determined by lab analysis

Tartrate Instability

CRYSTAL FORMATION (“Wine Diamonds” or “Glass Shards…”)

Encourage crystals to form (subtractive method)

- Involves chilling to induce crystal formation
  - Chill to ~4C (can also seed to speed up nucleation process)

Protect crystals from forming (additive method)

- Add a protective colloid to block crystals from forming
  - Mannoprotein, CMC, etc

Pectin and other Carbohydrate Instability

CLARIFICATION & FILTRATION ISSUES

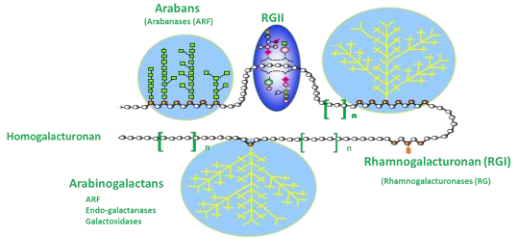
Add pectinase with appropriate **side-chain activities**

- May need cellulase/hemicellulose/protease action
- Need to add the correct enzyme, with the correct activity, at the correct dose. Ensure no negative interactions with other components

Amount and type of enzyme to add

- Determined by lab analysis (pectin test)

Other things of note:
Starched, Anthocyanase



Ellagic Tannin Instability

COLOR PRECIPITATION “Needle Crystals”

Be careful with wood contact (right before bottling)

- Since this will introduce ellagitannins to the cider, ensure cider will be consumed before hydrolysis occurs

Use protein-based fining agents

- Gelatin, Casein (and PVPP) can bind tannins, allowing for their removal via a racking

Citric acid addition

- 0.2g/L can help prevent the formation of ellagic acid by disrupting the essential chemical reactions

Bitterness

Add fining agent

- Protein-based/vegetal fining agents (gelatins, egg whites, casein) can bind and remove the bitter compound

Back sweetening

- Sugar balances out the bitter compounds and masks their perception

Color Instability

Tannin addition

- Indirectly as an anti-oxidant
- Directly as a factor in co-pigmentation

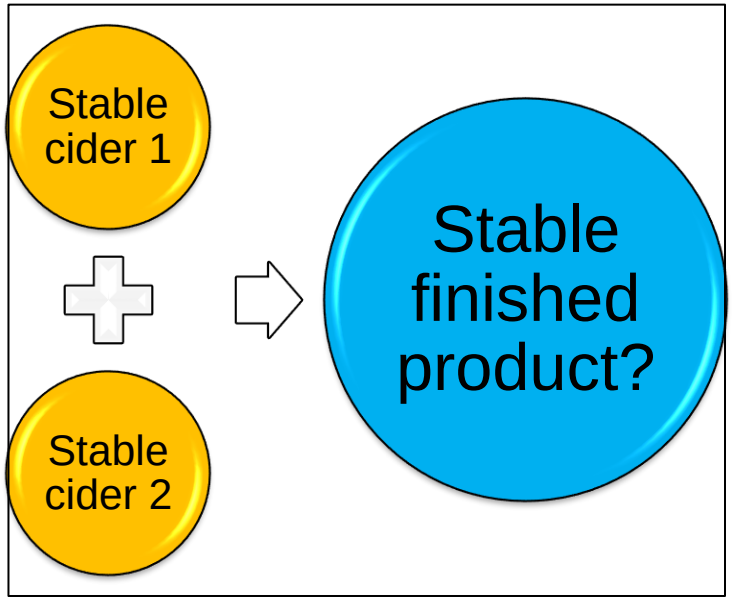
Manage pH and inputs

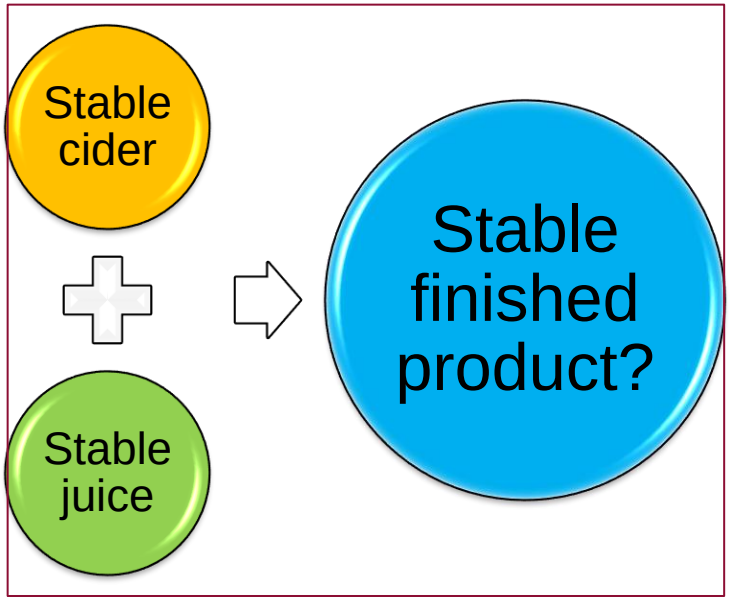
- Decrease pH to shift color compounds from color-less to colorful forms
- Protect from oxidation
- Rack as color will be absorbed onto lees
- Ensure enzyme has no anthocyanase activity

Protect form environmental degradation

- Protect from light and unsuitable temperatures

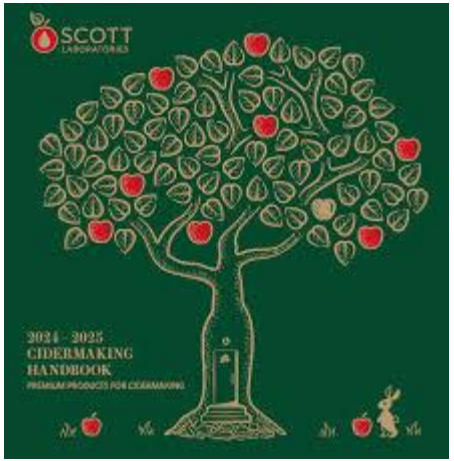
A word about blending…





Takeaways

- Understand how the added component impacts base chemistry
- Ensure no residual pectins
- Use fining agents as needed
- Ensure that color is protected/stabilized
- Manage microbial activity



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Thank you!

To you for listening
To the organizing committee for their kind invitation
To the scientific community for their continued research

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