Innovating Plant-Based Products: Pasteurization, ESL, UHT, & HTST Insights for Success

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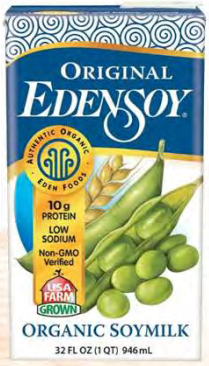
Commonalities between dairy and plant-based products

- So why don't we process plant-based products the same way we process diary products
- They see to have a lot in common!



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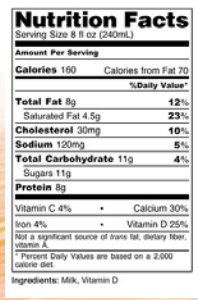
Commonalities between dairy and plant-based products

- Desire to appeal to wide range of consumers
- Desire to provide good nutrition
- Process requirements of pasteurization or sterilization prior to distribution



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In reality, they differ quite a lot!

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So we are going to look at:

- Commonly desired characteristics of plant-based products
- Types of processes used for these products
- Ingredients in plant-based products that affect actual processing conditions

- Indi… …eptic
- Temperatures
- Holding Times
- Cooling
- Up-stream Homogenization
- Down-Stream Homogenization

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For Plant-Based Products, we want similar benefits as dairy-based products

- Mother nature has a pretty robust formula in cow's milk
  (aided by homogenization and standardization)
- The majority of milk's proteins are relatively heat stable.
- It maintains its white color well throughout thermal processes.
- It can support a variety of flavors.
- Basis for many other products:
  - Fermented products like yogurt and sour cream
  - High protein shakes, and even meal replacements
- And it provides reasonably good nutrition.
- Abundantly available
- Not directly expensive to the consumer

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For Plant-Based Products, we want similar benefits as dairy-based products

- Physically stable
- Acceptable color
- Variety of Flavors
- Base for many other products:
  - Plant-Based Milks, Milk Replacements, Protein drinks
  - Smoothies, Ice cream and desserts
  - Fermented products like yogurt and sour cream,
  - High protein shakes, and even meal replacements.
- Good nutrition
- Easily available
- **PLUS**
- No Animal sourced ingredients
- Clean label
- Alterative to milk and its allergens

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Process Selection

- Process style (pasteurization, Aseptic, ESL) selection effected by:
  - Type of product
  - Product identity and quality
  - Desired shelf-life
  - Means of transportation and distribution
- Satisfying all of these requires a marriage between the product and the process.

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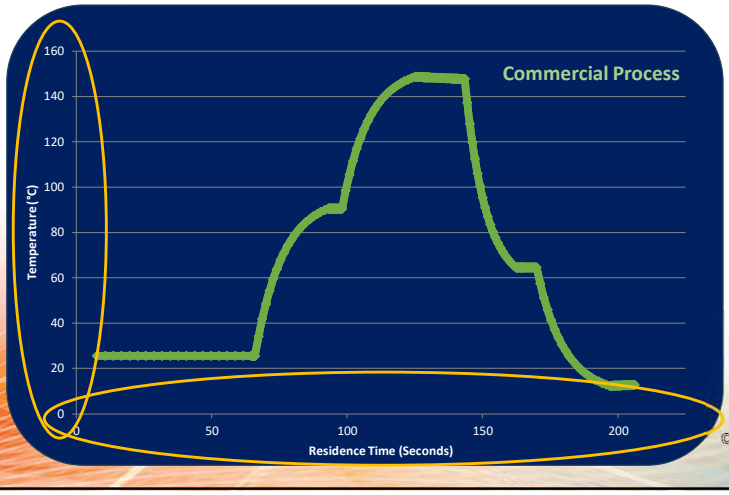
Processes

- This is a Time Temperature History (TTH)
- Graph of the product's temperature over time as it flows through a pasteurizer or sterilizer



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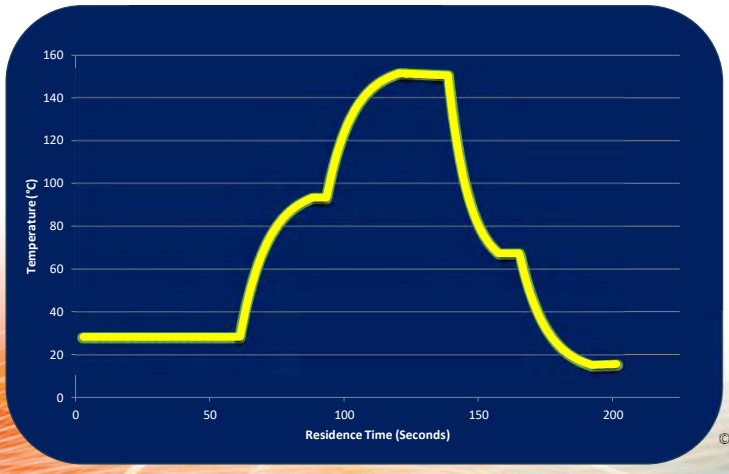
Process Time/Temperature History (TTH)

- Process goal is safety
- UHT range is 280° to 300° F, HTST range 160° to about 230° F
- Accuracy to commercial process in lab is critical to successful product development



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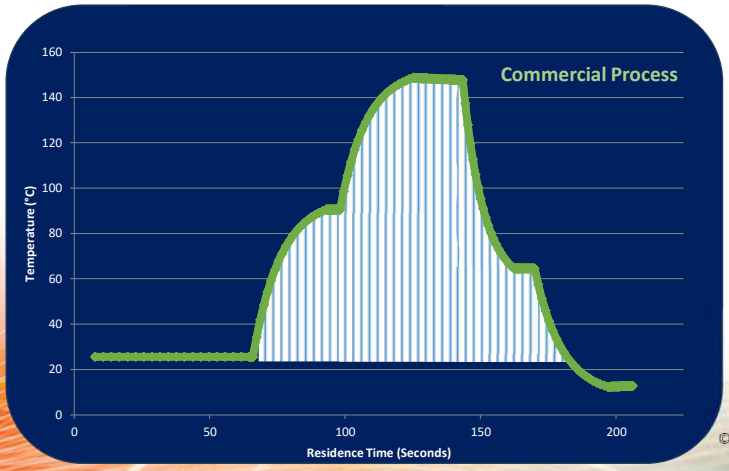
Process Time/Temperature History (TTH)

- Area under curve represents reactions occurring to the product
- Commonly used tool to understand the impact of thermal process on product



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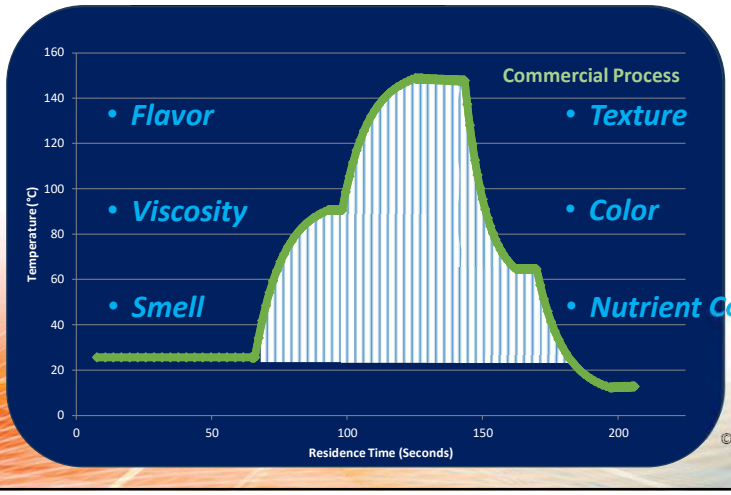
Process Time/Temperature History (TTH)

- Area under curve represents reactions occurring to the product
- Reactions literally shape the product identity



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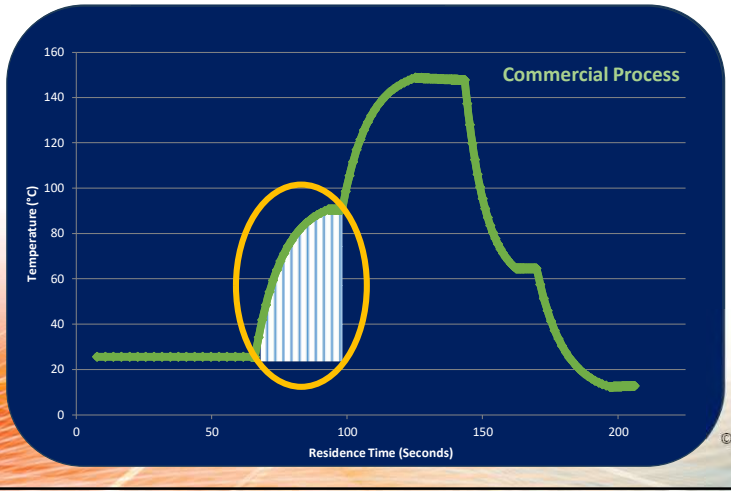
Process Time/Temperature History (TTH)

- Each part of the curve represents a part of the processor
- First part of the curve represents the preheater.
- Area under this part of the curve represents reactions fueled by the preheater



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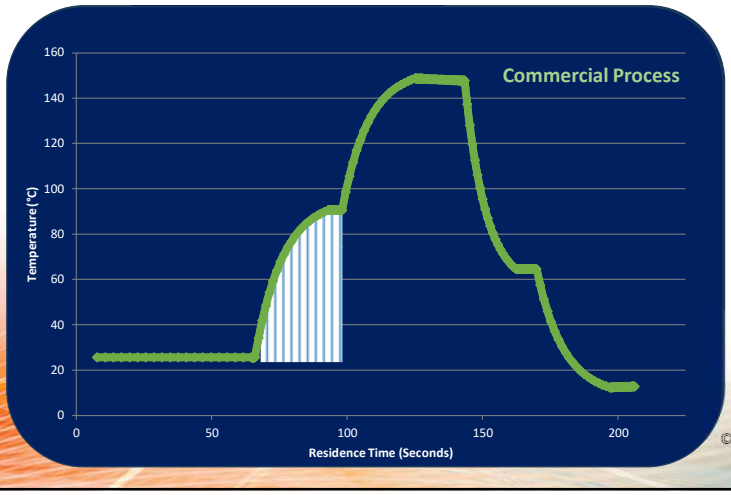
Process Time/Temperature History (TTH)

- Regenerative heating used in production
- Size of regen heaters differs from one commercial process to another
- Can have significant impact on product



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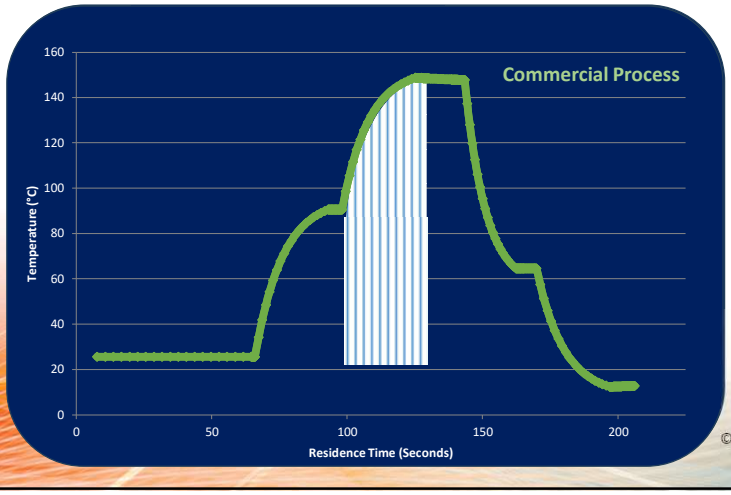
Process Time/Temperature History (TTH)

- Final heater
- Higher temperature mean much faster reaction rates
- Has major impact on product quality



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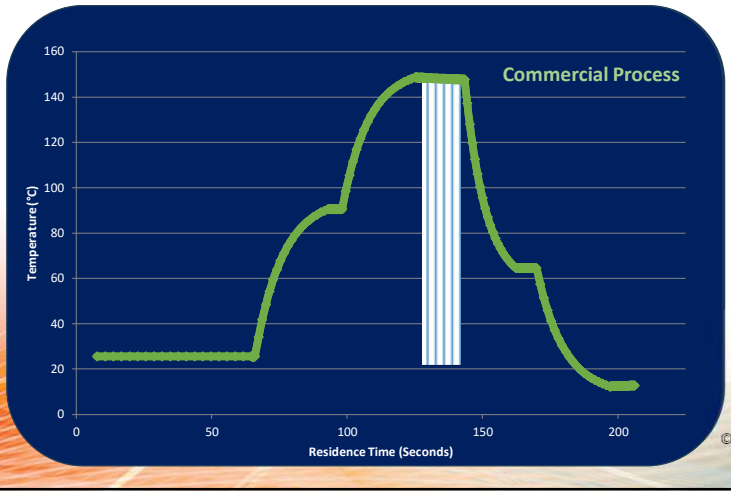
Process Time/Temperature History (TTH)

- Hold Tube
- Area represents actual reduction of bacteria and considered the "legal process"
- Also has large impact on product quality



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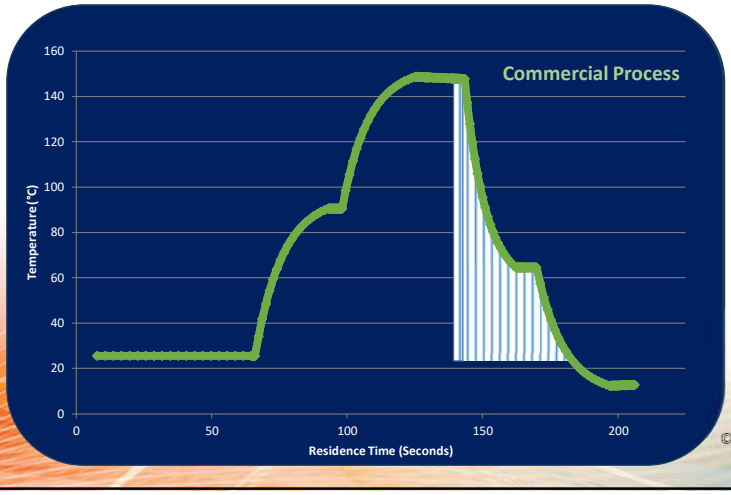
Process Time/Temperature History (TTH)

- Cooling section(s)-may have homogenizer between coolers.
- Pasteurized or ESL products cooled to refrigerated temperatures.
- Aseptic products cooled to room temperature.



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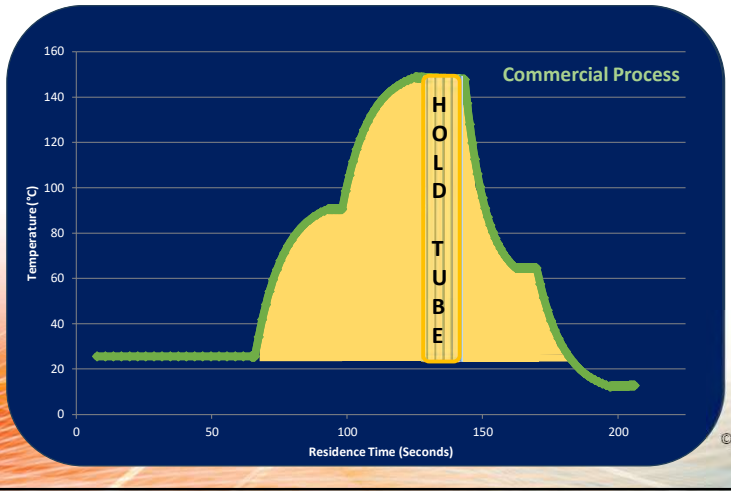
Process Time/Temperature History (TTH)

- Whole thermal process affects product quality
- Simulating only the hold tube results in sterile product that cannot be scaled to production



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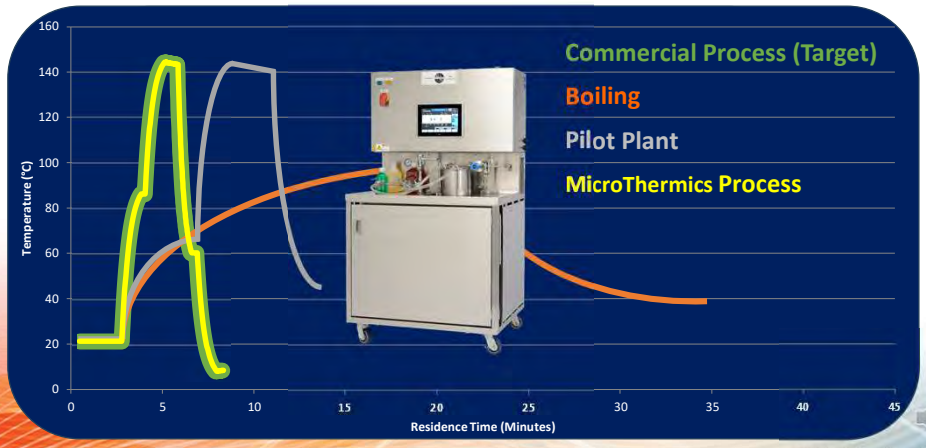

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Process Selection

- Each Process has its Pros and Cons
  - Pasteurization
  - Low Acid Aseptic (Indirect and Steam Injection)
  - High Acid Aseptic
  - Extended Shelf Life (ESL)
- Upstream or Down-Stream homogenization
  - Aseptic, pasteurization, and ESL processes

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Pasteurization

- Functional Definition
  - Products are minimally heat processed to eliminated pathogenic organisms
  - Must have a 5 log reduction of bacteria
  - Products distributed, sold, and stored by consumer refrigerated
  - 72°C for 15 seconds minimum
  - Most commercial processes are actually more severe
    - i.e. 85°C for 15 seconds
  - Refrigerated shelf-life up to about 21 days
    - Reached with conditions well above 162/15

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Pasteurization

- Benefits
  - Reduces need for preservative
  - Preserves freshness, flavor and nutrients
  - Commonly available at copackers
  - Gentle process that can be used for wide range of products
- Disadvantages
  - Refrigeration required
  - Relatively short shelf life (14-21 days)

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Pasteurization

- Example Pasteurized **Plant-Based** Products
  - Milks or Milk Replacements
  - Flavored drinks and protein drinks
  - Smoothies and shakes
  - Juices and similar drinks
  - Ice-creams
  - Yogurts
  - Puddings

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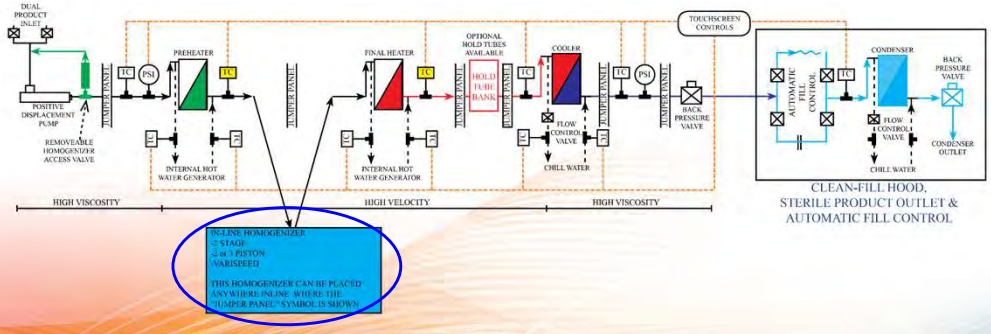
Pasteurization-Upstream Homogenization

- Process Description
  - Upstream homogenization
  - Plant-Based products homogenization conditions
    - 140-190° F and 3,000-4,000 PSI



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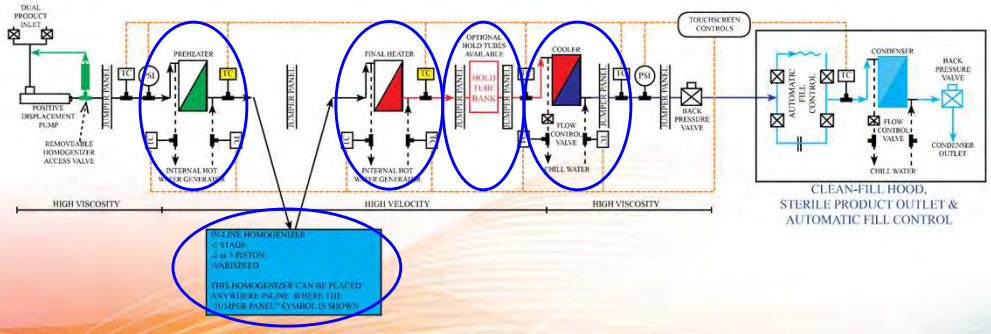
Pasteurization

- Process Description
  - Indirect Heating
  - Temperatures of 72-90C (161-196F) & hold times of 15 to 45 seconds



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Low Acid Aseptic

- Functional Definition
  - Products with pH > 4.6
  - Process (USA): >138°C (280°F), for 2-12 seconds
    - Yielding >12 log reduction of *c. bot.*
  - Plant-Based products often use more extreme conditions
    - 290° F for 6-12 seconds
  - Products sterilized and filled into sterile containers under sterile conditions

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Low Acid Aseptic

- Benefits
  - Clean label-NO PRESERVATIVES
  - Long shelf life-6+ months
  - Shelf Stable (does not require refrigeration)
  - Can preserve freshness, flavor, nutrients
  - Commonly available at co-packers
- Disadvantages
  - May cause reduction of product quality (product dependent)
  - Processing and packaging cost may be higher

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Low Acid Aseptic

- Example **Plant-Based** Products
  - Milks and milk replacements,
  - Protein drinks,
  - Meal replacements,
  - Smoothies/Shakes,
  - Ice-creams
  - Puddings and similar products

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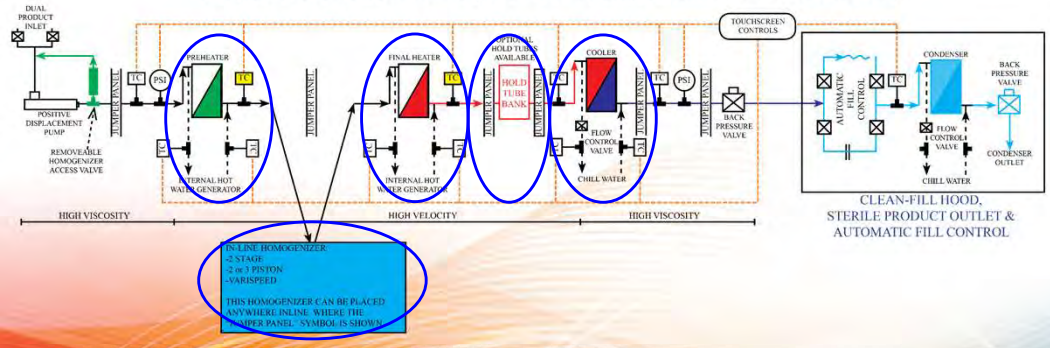
Low Acid Aseptic-Indirect

- Process Description
  - Indirect Heating
  - Upstream homogenization
  - For products with a pH>4.6, must result in a 12 log reduction of bacteria
  - Temperatures of 138-149° C (280-300° F) & hold times of 2 to 10 seconds



CLEAN-FILL HOOD,
STERILE PRODUCT OUTLET &
AUTOMATIC FILL CONTROL

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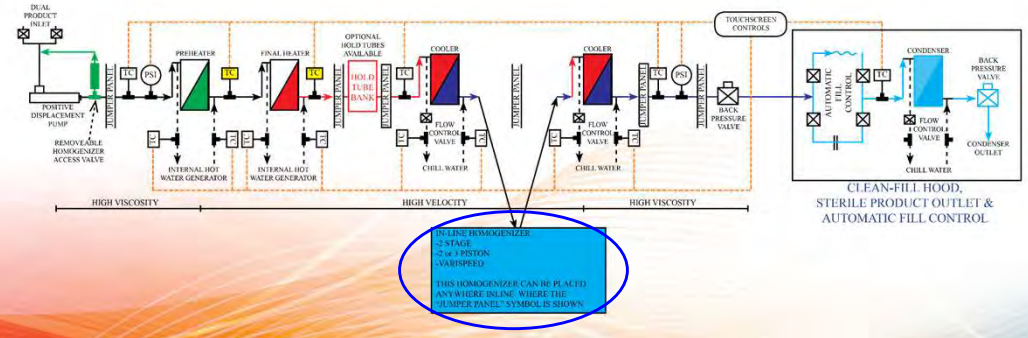
Low Acid Aseptic-Indirect-Downstream Homogenization

- Process Description
  - Plant-Based Products commonly processed at Temperatures >290° F & hold times of 2 to 10 seconds
  - Plant-Based product homogenization conditions
    - 165-190 F° and 3000 to 4000 PSI



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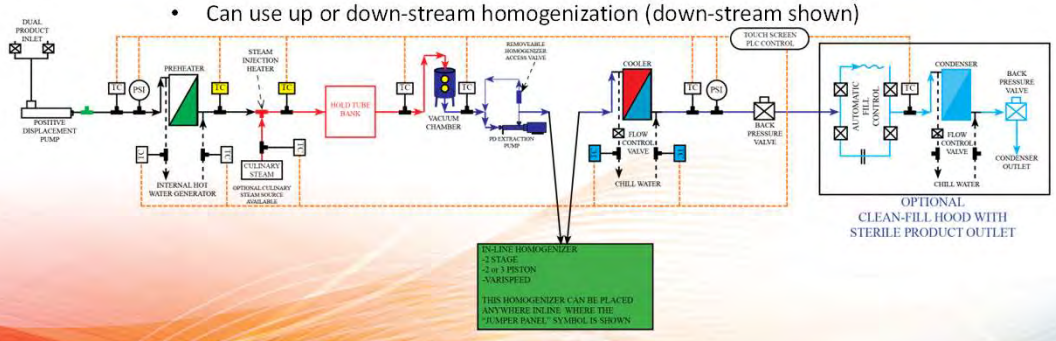
Low Acid Aseptic-Direct Steam Injection

- Steam Injection Process-common alternative UHT Process
  - Same reduction of bacteria required (12 log of *c. bot.*)
  - Avoids fouling through use of steam injection heating and vacuum cooling
  - For products with a pH>4.6
  - Also uses temperatures of 136-149C (277-300F) & hold times of 2 to 10 seconds
  - Can use up or down-stream homogenization (down-stream shown)



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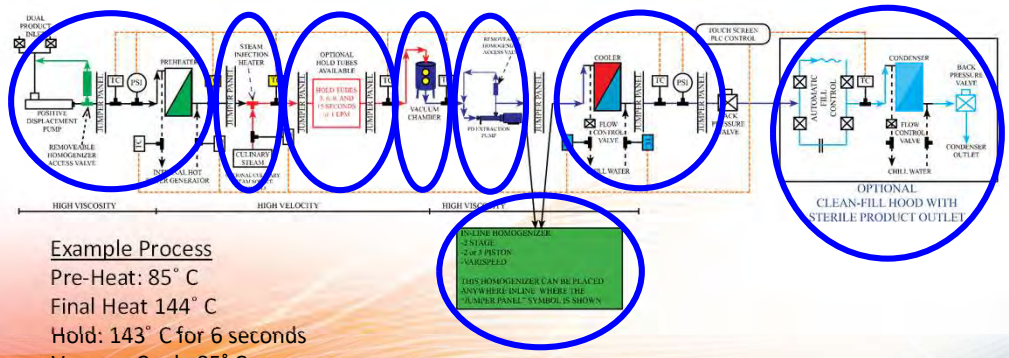
Low Acid Aseptic-Direct Steam Injection

- Steam Injection Process-common UHT Process for Plant-Based Products
  - Indirect Preheat/Regen, then steam injected into product in final heater
  - Product is held briefly, then cooled in vacuum cooler where water is also extracted
  - Downstream homogenization to address issues created by thermal process



Example Process
Pre-Heat: 85˚ C
Final Heat 144˚ C
Hold: 143˚ C for 6 seconds
Vacuum Cool: 85˚ C
Homogenize 170/35 Bar
Indirect Cool: 23˚ C

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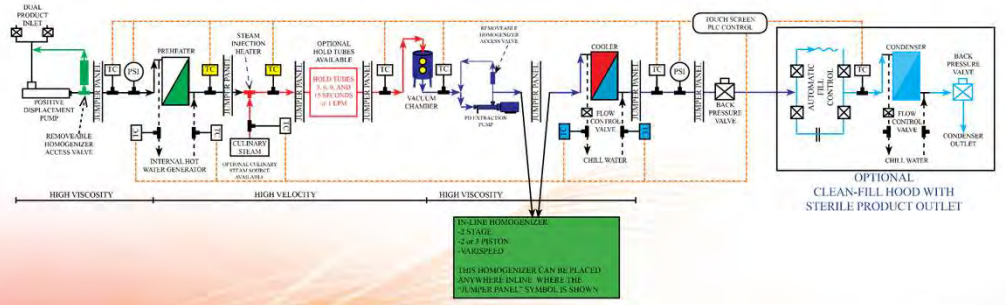
Low Acid Aseptic-Direct Steam Injection

- Steam Injection Process-common UHT Process for Plant-Based Products



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- MicroThermics Lab Direct/Indirect UHT/HTST Processing Line (DIPW)
  - Indirect UHT/HTST Processor
  - Multi-piston, 2 stage, 3 A homogenizer
  - Ultra-Clean Fill Hood
  - Can do all the indirect and direct steam injection processes and products we have discussed so far.
  - Convenient
  - Easy to Use
  - Extremely accurate & reliable

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High Acid Aseptic Processing-Indirect

- Benefits
  - Clean label-NO PRESERVATIVES
  - Long shelf life-6+ months
  - Shelf Stable (does not require refrigeration)
  - Can preserve freshness, flavor, nutrients
  - Commonly available at co-packers
- Disadvantages
  - May cause reduction of product quality of more fragile products like OJ
  - Processing and packaging cost may be higher

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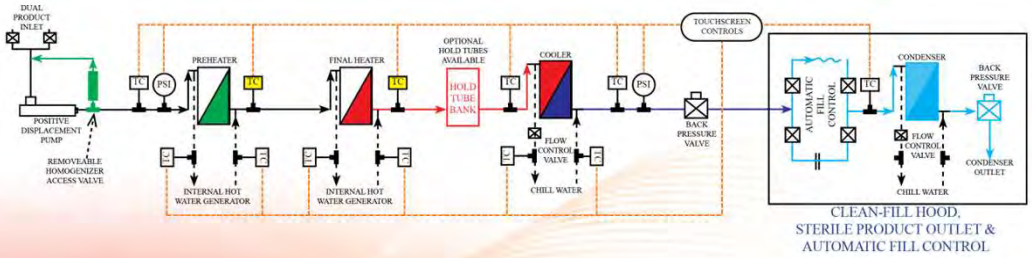
High Acid Aseptic Processing-Indirect

- Process Description
  - For products with a pH<4.6
  - Indirect Heating, often does not include homogenization, but some may.
  - Must result in a 5 log reduction of bacteria
  - Temperatures of 86-110C (187-230F) & hold times of 10 to 20 seconds



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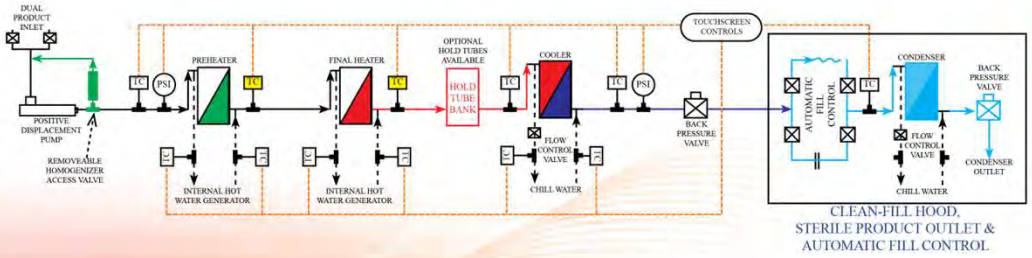
High Acid Aseptic Processing-Indirect

- Product Examples
  - Juices
  - Potentially isotonics
  - Smoothies
  - Smoothies fortified with proteins and other nutrients



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Extended Shelf-Life (ESL) Processing

- ESL Processing takes the best qualities of pasteurization and aseptic processing
- Enables very high quality products with quite long shelf lives to be produced

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Extended Shelf-Life (ESL) Processing

- ESL products are processed at or near aseptic conditions
  - Filled into non-sterile containers
- Products generally have a long refrigerated shelf life
  - 3-6 months
- Can enable products to be made without preservatives
- Fairly common process
- Can be used for wide range of high acid AND low acid products

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Extended Shelf-Life (ESL) Processing

- Example **Plant-Based** Products
  - Milks and milk replacements
  - Flavored drinks and protein shakes
  - Smoothies and juices
  - Ice creams and desserts
  - Puddings
  - Sauce and many others

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Characteristics That Effect Processing Plant-based Products

- Why don't we process plant-based products the same way we process dairy products? Because:
  - Dairy and plant-based products are actually quite different from each other.
  - Plant-based products are not even similar to one another

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Plant-based Product Characteristics That Effect Processing

- Not all Plant-based products are created equally. Comparatively,:
  - Coconut milk is often lower in proteins, but can be higher in fats
  - Rice milk can be very low in protein, but much higher in sugars and carbs
  - Almond milk may be lower in proteins, but also somewhat lower in fats and carbs
  - Hemp milk is somewhat mid-range for protein, but higher in fats and fiber
  - Soymilk is higher in proteins, and lower in fats

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Plant-based Product Characteristics That Effect Processing

- Not all Plant-based products are created equally.
- In general, physically,
  - Oat Milk is more stable than Rice Milk
  - Soy Milk is more stable than Oat Milk
  - Dairy Milk is still the most stable
    - At this time-as research evolves, this can all change

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Plant-Based Products – often based on Plant-Based Milks

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Plant-based Product Ingredients That Effect Processing

- Ingredients are processed and derived from diverse sources
  - Proteins from soy, nuts, legumes, chickpeas, hemp
  - Fats and oils from soy, canola, palm, coconut
  - Starches from grains or legumes
  - Sugars and sweeteners from corn, cane, beets, maple, stevia
  - Stabilizers from beans and seaweed
  - Flavors, vitamins, colors, minerals and other ingredients from a wide range of other sources

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Plant-based Product Characteristics That Effect Processing

- The characteristics of each type of plant-based ingredient can be affected by
  - Location,
  - Plant variety,
  - Growing conditions,
  - And upstream processing

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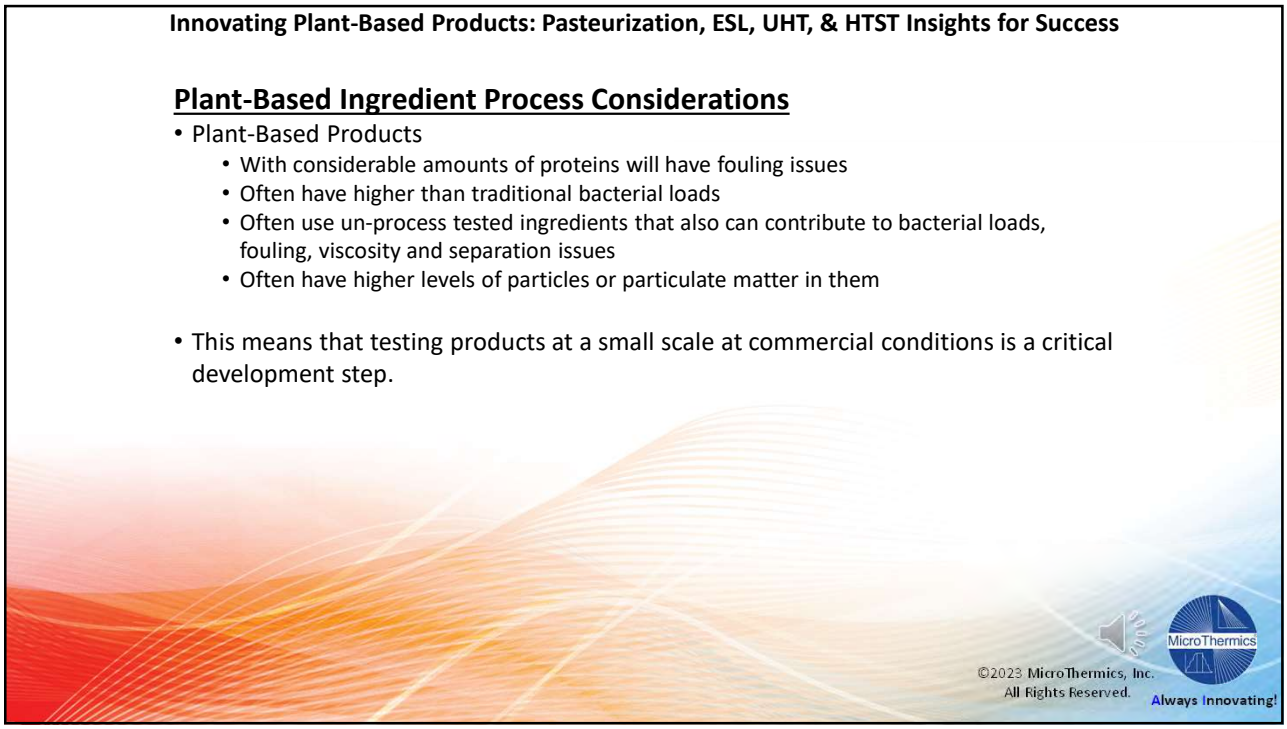

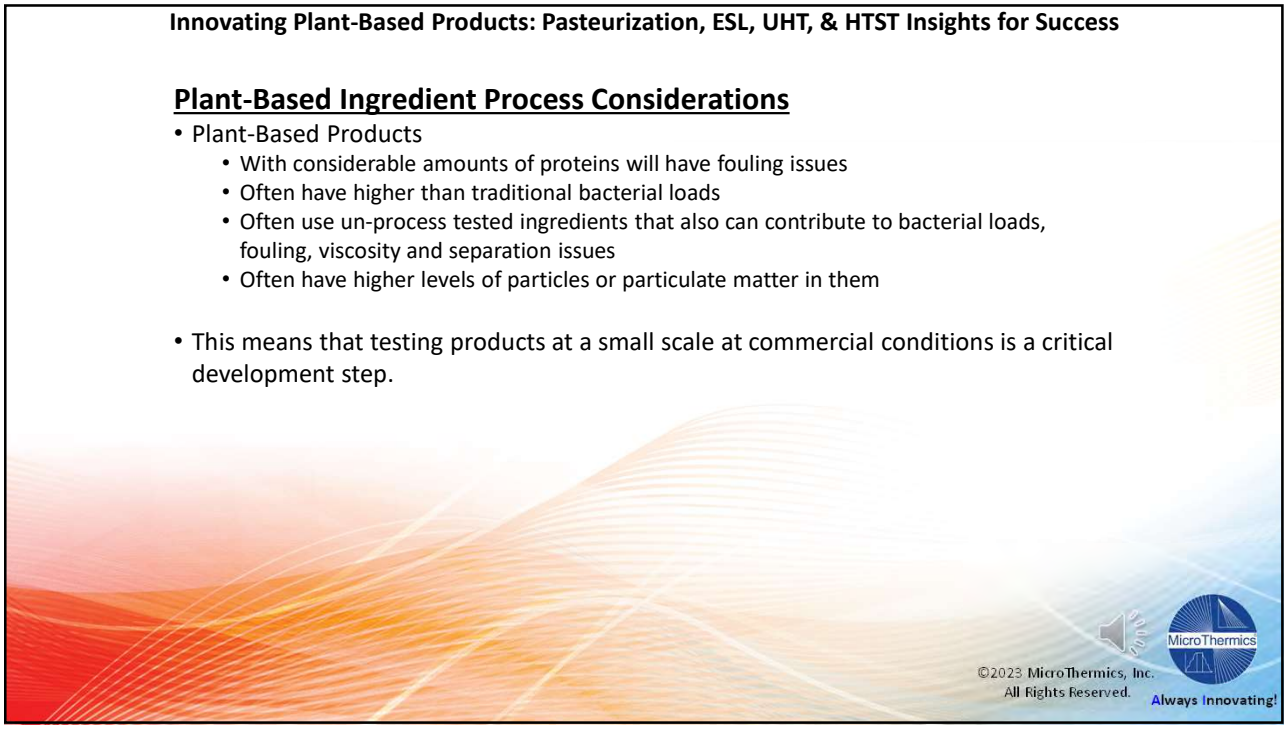

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Plant-Based Ingredient Process Considerations

- It also means that overall
  - Steam injection is preferable to reduce the risk of fouling
    - But the vacuum step removes flavors-which you may or may not want to happen
  - Indirect heating process can be used
    - But it will likely require longer heating times which may or may not be commercially available, so you may need a custom commercial process
  - Due to the additional bacterial load and particulates, conditions at the more extreme end of the thermal process ranges are likely necessary
    - 290°F+ for low-acid sterilization for both indirect and steam injection heating
  - It is more difficult to create stable emulsions in Plant-Based products due to their ingredients and susceptibility to thermal damage
    - Therefore they require higher than traditional homogenization conditions
      - 3-4000 PSI seems to be a more effective range
      - Down stream homogenization also tends to be more effective than upstream

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Plant-Based Product Process Selection Guide

Process	Pasteurization	Extended Shelf Life		Aseptic (Indirect)		Aseptic (Direct)
Acidity	Low/High	Low	High	Low	High	Low
Heating	Indirect	Indirect	Indirect	Indirect	Indirect	DSI
Fruit Drinks	X		X		X	
Smoothies	X		X		X	
Milks, Creamers, etc.	X	X		X		X
Shakes	X	X		X		X
Drinkable Yogurts	X					
Yogurts	X					
Frozen Desserts	X	X		X		Uncommon
Puddings	X	X		X		X

*Low acid pH> 4.6, High Acid pH <4.6

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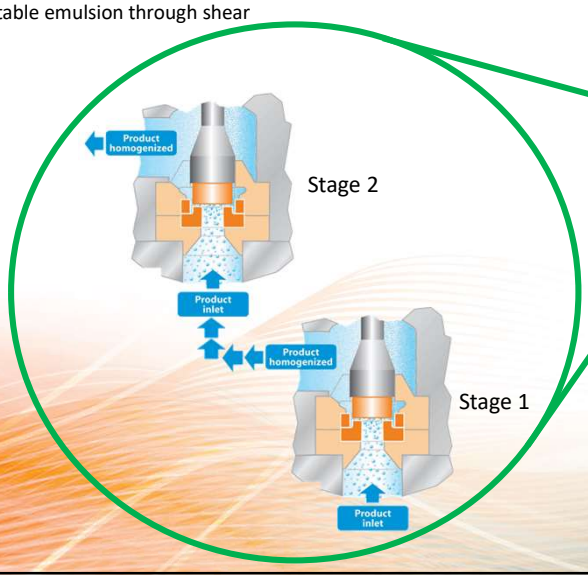
Trends in Plant-Based Product Processing

- Homogenization-
  Creation of stable emulsion through shear



Valve figures courtesy of GEA

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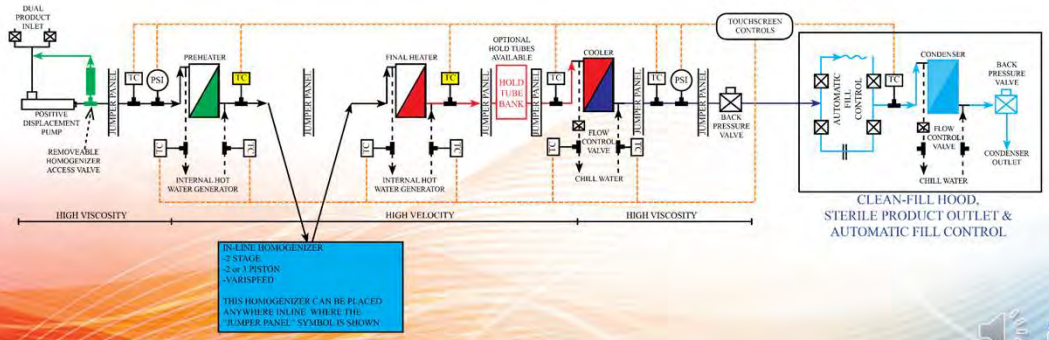
Trends in Plant-Based Product Processing

- Homogenization-
  - Upstream to specifically address fat and oil separation
  - Temp range 140° to 190° F
    - 140 for pasteurization, higher for sterilization
  - Frequently most effective at 2500 to 4000 PSI



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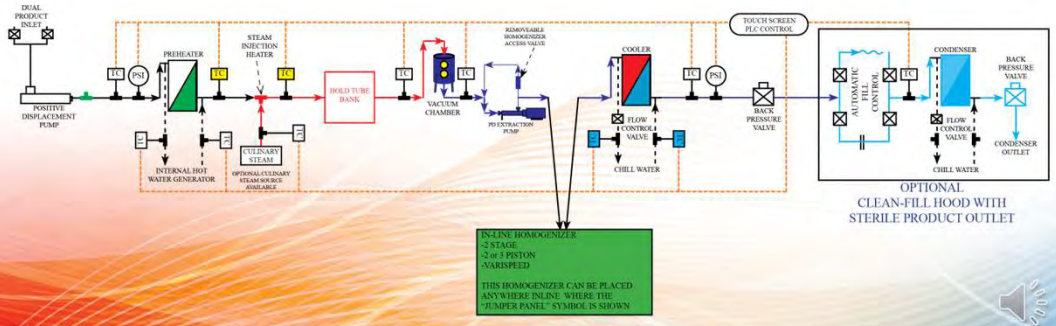
Trends in Plant-Based Product Processing

- Homogenization-
  - Downstream to address sedimentation
    - Also helps address creaming when product properly mixes
  - Temp range 165° to 190° F
    - Frequently done at 180° -190° F
  - Frequently most effective at 3000 to 4000 PSI
    - 3500 PSI seen often



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Trends in Plant-Based Product Processing

- Homogenizer Location Guide

Process	Pasteurization	Extended Shelf Life		Aseptic (Indirect)		Aseptic (Direct)
Acidity*	Low/High	Low	High	Low	High	Low
Heating	Indirect	Indirect	Indirect	Indirect	Indirect	DSI
Fruit Drinks	Up Stream		Note 1	Down Stream	Note 1	
Smoothies	Up Stream		Note 1	Down Stream	Note 1	
Milks, Creamers, etc.	Up Stream	Up or Down		Down Stream		Down stream
Shakes	Up Stream	Up or Down		Down Stream		Down stream
Drinkable Yogurts	Up Stream					
Yogurts	Up Stream					
Frozen Desserts	Up Stream	Up or Down		Down Stream		Down stream
Puddings	NO	NO	NO	NO	NO	NO

*Low acid pH> 4.6, High Acid pH <4.6
Note 1: Homogenizer occasionally placed here if product separating or gritty due to thermal process

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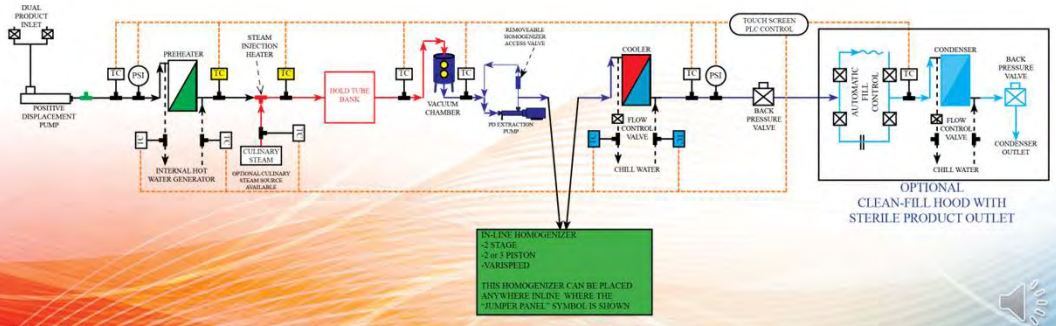
Trends in Homogenization Pressure*

- Rice Drinks: 180-250 Bar (2600-3600 PSI)
- Nut Drinks: 130-200 Bar (1900-2900 PSI)
- Grain Drinks: 180-250 Bar (2600-3600 PSI)
- Dairy Drinks: 140-170 Bar (2000-2500 PSI)

*Source: GEA



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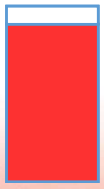
Importance of Processing in R&D

- Critical to address these issues before going to production
- Products must be sterilized or pasteurized prior to distribution
  - These processes inherently change products.
  - Your new plant-based strawberry protein smoothie is great until its commercially processed
  - Then its burned, the wrong color, gritty, it lost it nutrients and tastes terrible.
  - Products must be formulated so they have the product identity consumers want AFTER they have been processed.



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MicroThermics Lab UHT/HTST Processing Equipment And Services





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