



Dairy Processing Wastes in NYS

PROCESSED MILK PRODUCTS

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Today's discussion

- ▶ Background
 - ▶ How big is the dairy processing industry in NY?
 - ▶ What is the major waste byproduct?
- ▶ Define the problem
- ▶ Discuss the potential solutions
- ▶ Look at the economics behind each solution

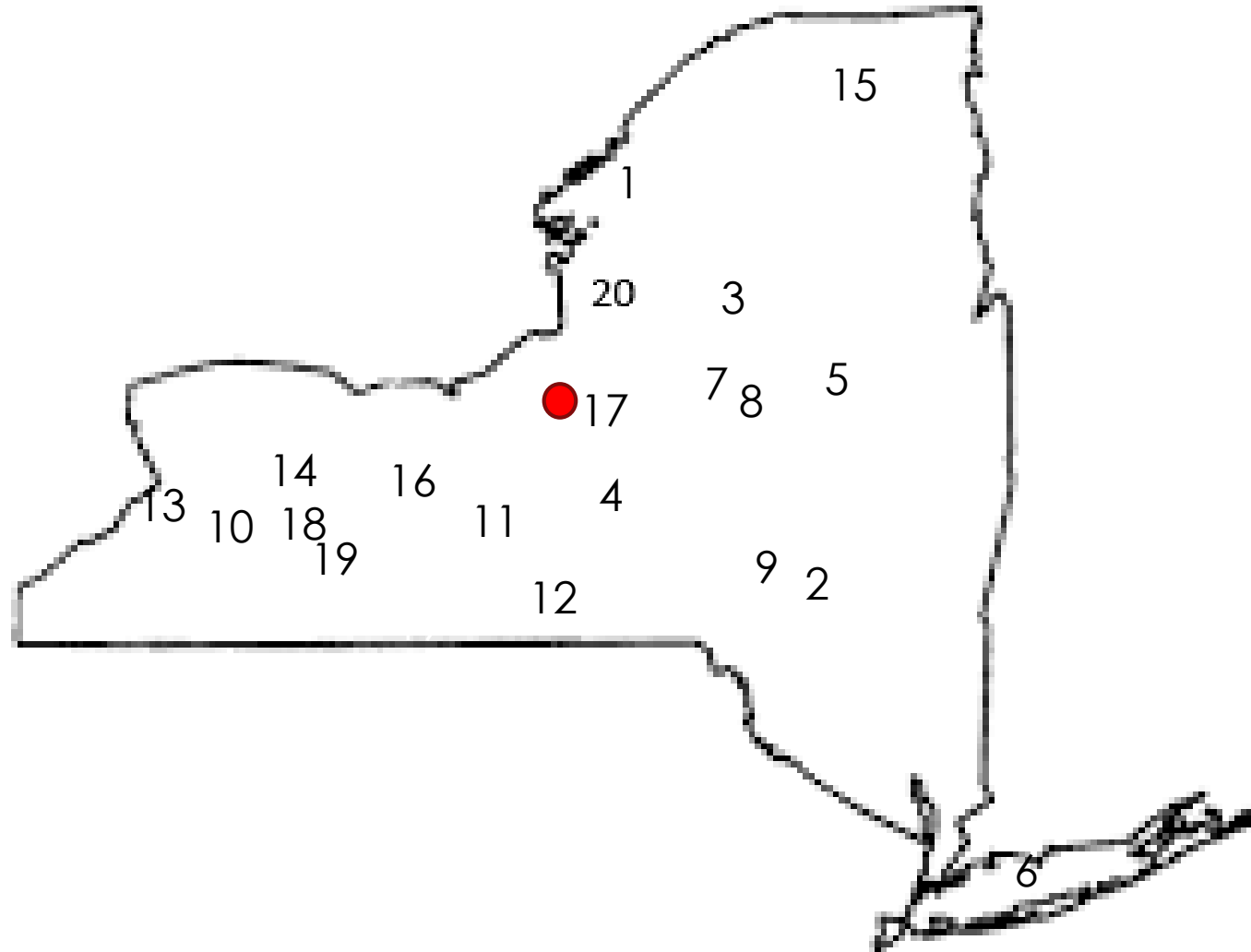
The presentation goal.....

When we are finished you should have a better understanding of the size of this industry, the challenges they face, and the engineering and science behind the potential solutions.

NYS Dairy Products *

- ▶ NY State is No. 1
 - ▶ Cream cheese production – 82,531,000 lbs/ yr
 - ▶ Cottage cheese production- 116,256,000lbs/yr
 - ▶ Yogurt production- 700,000,000 lbs/yr
- ▶ NY State is No. 2
 - ▶ Sour cream production- 281,871,000lbs/ yr
- ▶ NY state is No. 3 in milk and total cheese production.

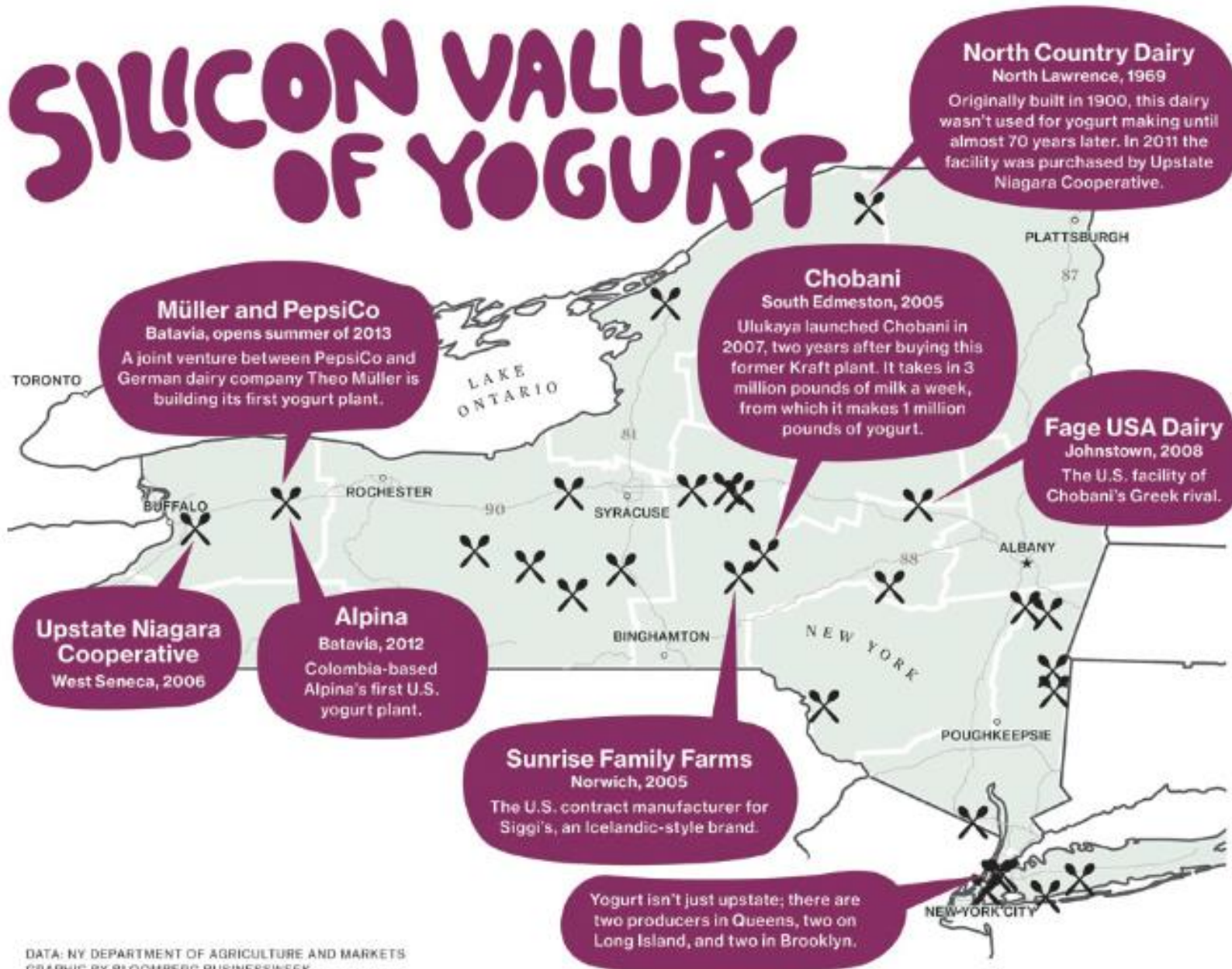
* From 2014 USDA Dairy Products Report



Where are these milk processors?

1. Crowley (Hood), Lafargeville
2. Chobani, New Berlin
3. Kraft, Lowville
4. Byrne, Cortlandville
5. Faye, Gloversville
6. Friendship Dairy, Jerico
7. Hood, Vernon
8. Hood, Oneida
9. Kraft, Walton
10. Hood, Arkport
11. Cayuga Milk Ingredients, Auburn
12. Kraft, Campbell
13. Upstate Niagara Group, West Seneca
14. Kraft, Avon
15. Upstate Niagara Group, North Lawrence
16. Summit Milk, Waterloo
17. Byrne Ultra Dairy, Syracuse
18. Alpina Foods Inc.
19. Muller Quaker Dairy (Pepsico)
20. Great Lakes Cheese, Adams NY

SILICON VALLEY OF YOGURT



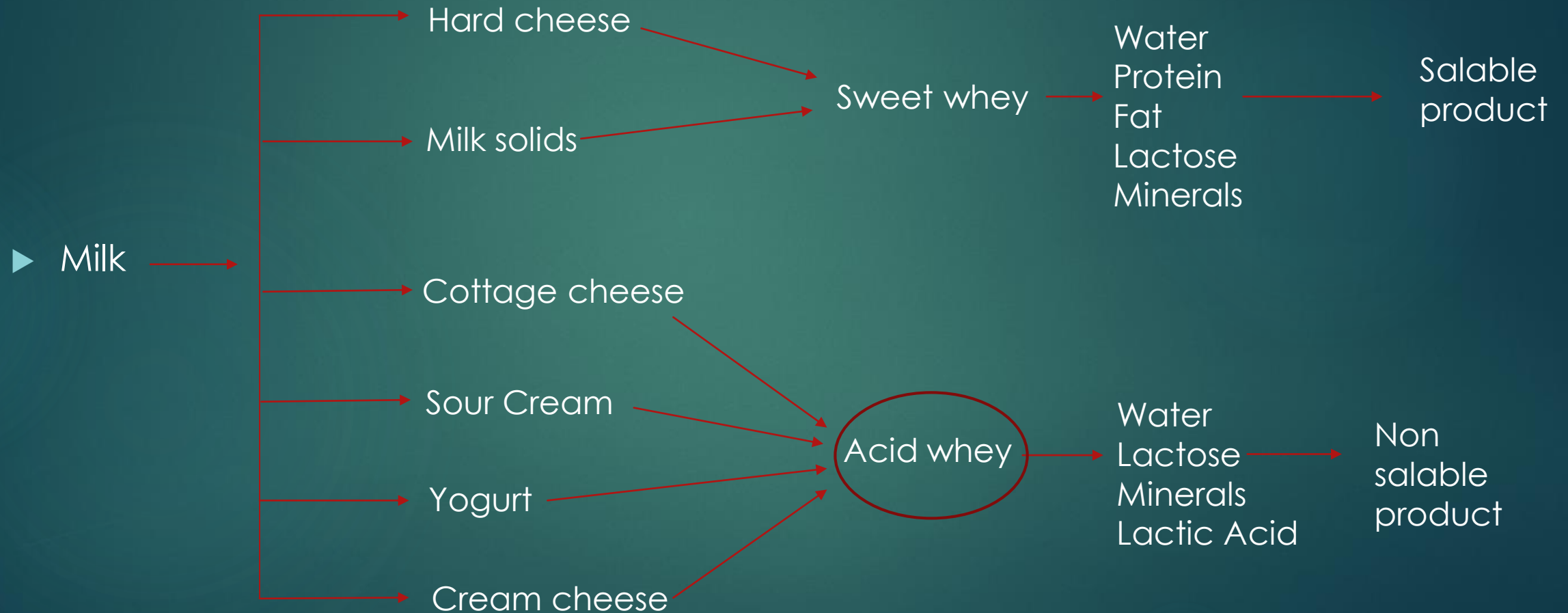
There are now 29 yogurt processing plants in NYS

Industry Challenge

What do we do with the byproduct of these industries.....the whey?

For every lb of dairy product you get 3 to 4 lbs of whey byproduct

Whey production



How is whey treated by the dairy industry

- ▶ Sweet whey is concentrated via reverse osmosis, evaporated and spray dried into a storable powder.
 - ▶ Used as an ingredient in baby formula, snack foods, animal feed or sold as a health food supplement
- ▶ Acid whey is either shipped off site as raw whey, concentrated via RO and then shipped offsite.
 - ▶ Disposal is either land apply, limited animal feed or as feed stock to an anaerobic digester
 - ▶ It has little value as human consumption compared to sweet whey

Acid Whey Facts

- ▶ Raw acid whey is dilute
 - ▶ > 92% water
 - ▶ 4-6 % lactose
 - ▶ 0.5-1% lactic acid
 - ▶ 1% minerals
 - ▶ Very little fat or protein content
- ▶ pH around 5 which makes it environmentally unfriendly
- ▶ Raw whey has short shelf life.

- ▶ Some whey producers are having to spend \$\$ treating or getting rid of the acid whey

Is there any value in acid whey

- ▶ The high BOD waste can be digested and the methane recovered
- ▶ The lactose can be fermented to a biofuel- ie ethanol or butanol
- ▶ The lactic acid has some value as a precursor for bioplastics production

- ▶ Raw acid whey does not have enough value to make separation of the components economically viable.

- ▶ The value is in really in the **lactose** content

How much acid whey lactose in NYS

- ▶ Yogurt 140MMlbs/yr lactose
- ▶ Cottage cheese 23Mlbs/yr lactose
- ▶ Cream cheese- 16.5MMlbs/yr lactose
- ▶ Sour cream- 56MMlbs/ yr lactose
- ▶ **Total available 235.5 MMlbs/yr lactose***

* Based on 2013 research paper Program on Dairy Markets and Policy Paper by Cornell University. *Milk solids is not included in these numbers.*

The problem....acid whey disposal

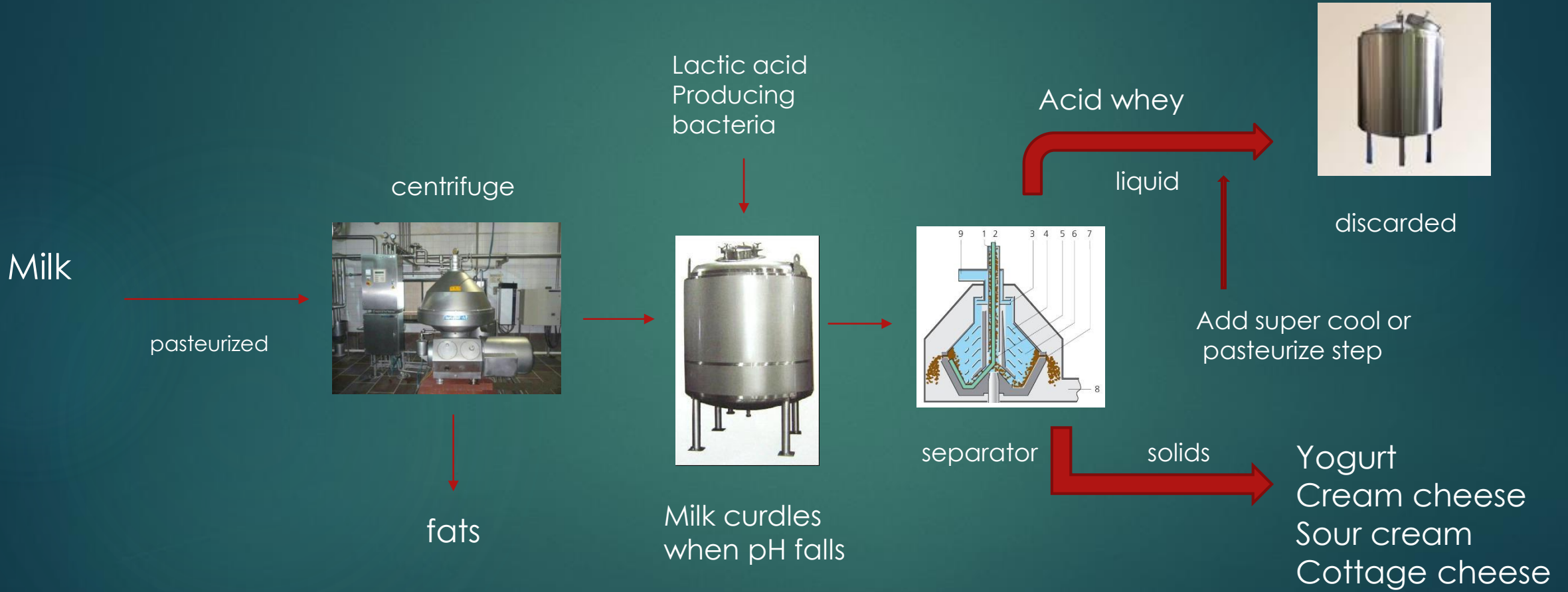
- ▶ The acid whey is dilute making transportation costs expensive.
- ▶ The high BOD in acid whey makes it challenging to plant sewage treatment plants.
- ▶ **Value** on the open market is mainly a **cost avoidance** for the dairy industry
- ▶ NYS DEC has concerns about land application
- ▶ The lactic acid makes whey
 - ▶ Poor feed stock for animals
 - ▶ Poor candidate for land application- runoff contamination
 - ▶ Not worth much as a salable product
 - ▶ Inhibits fermentation

Potential Solutions

1. Find a way to make less lactic acid during dairy product production and increase its salable value- as an animal feed
2. Make use of existing digesters and convert the whey to methane
3. Make biofuel from the waste
4. Isolate the lactic acid and use it for bioplastics production

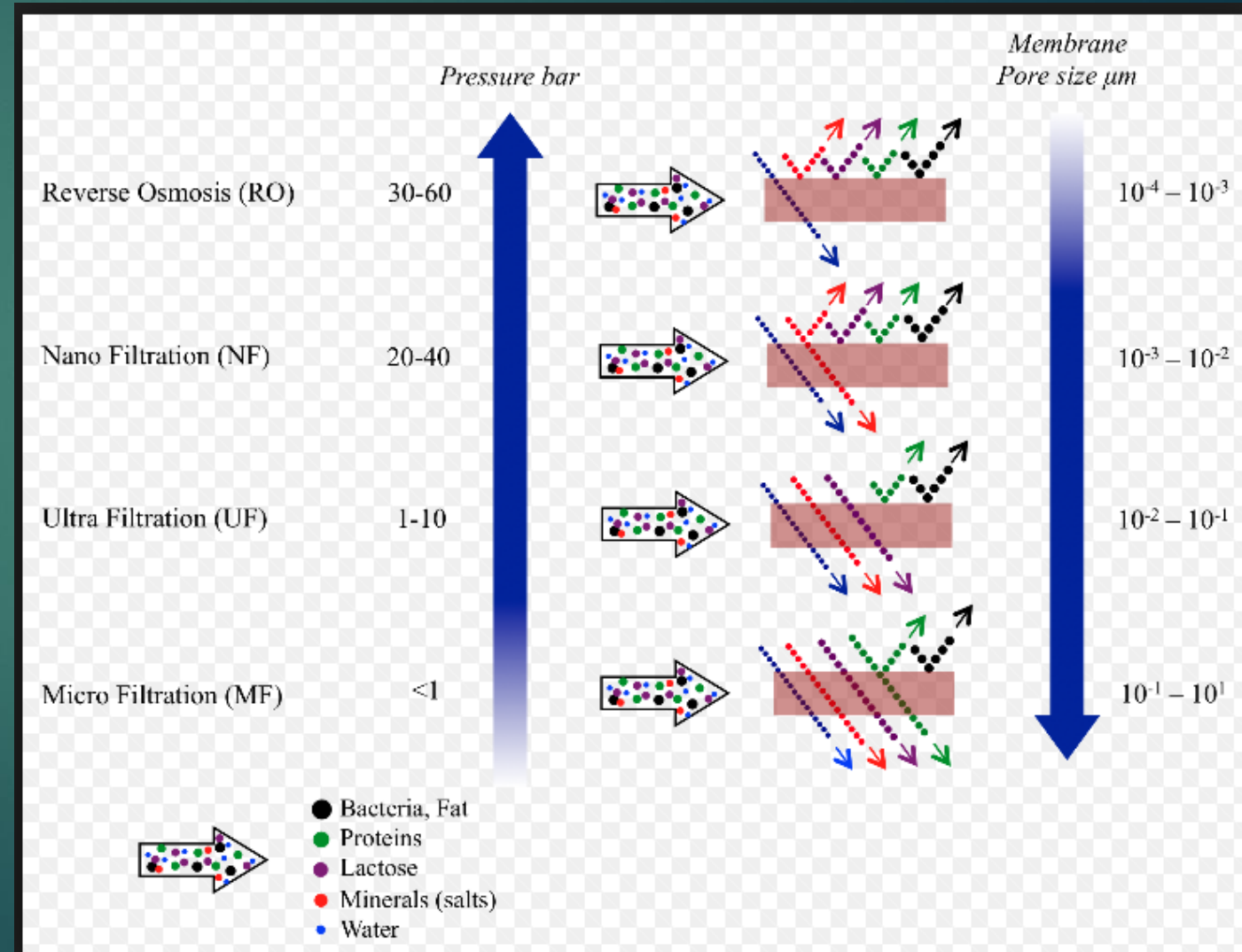
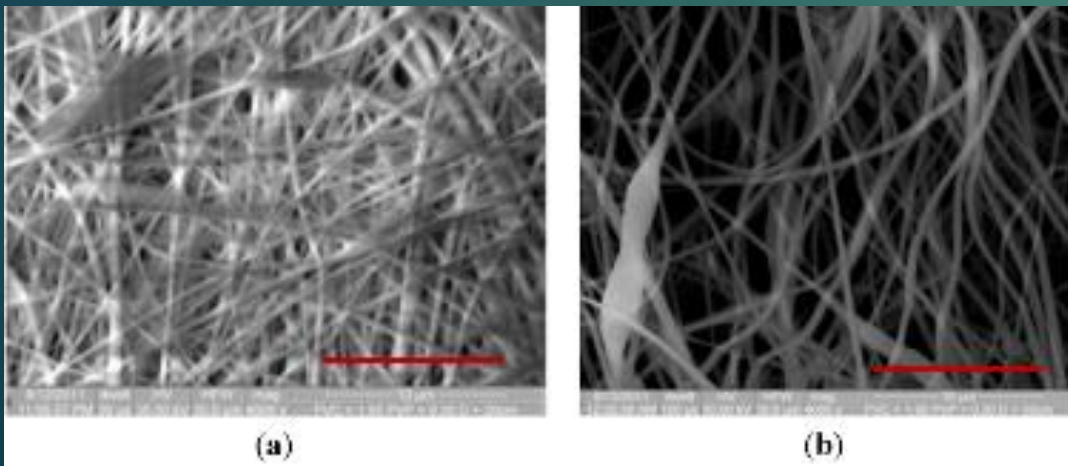
Option #1 Reduce the lactic acid generation

- ▶ Super cool or pasteurize after curdling takes place may reduce LA generation



Remove lactic acid in the whey and concentrate the lactose

- ▶ Membrane technology can accomplish this.

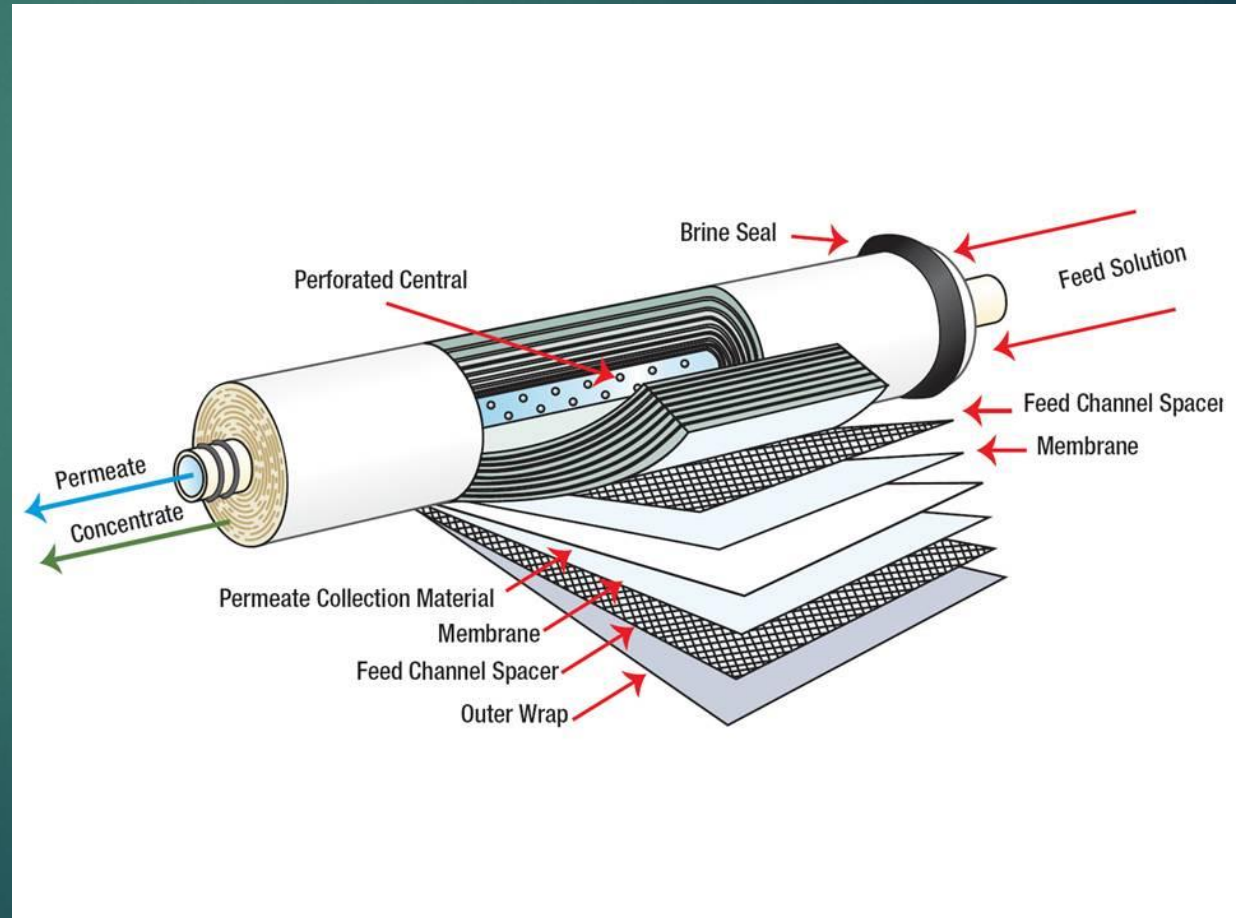


Nano-filtration



Water , minerals and lactic acid

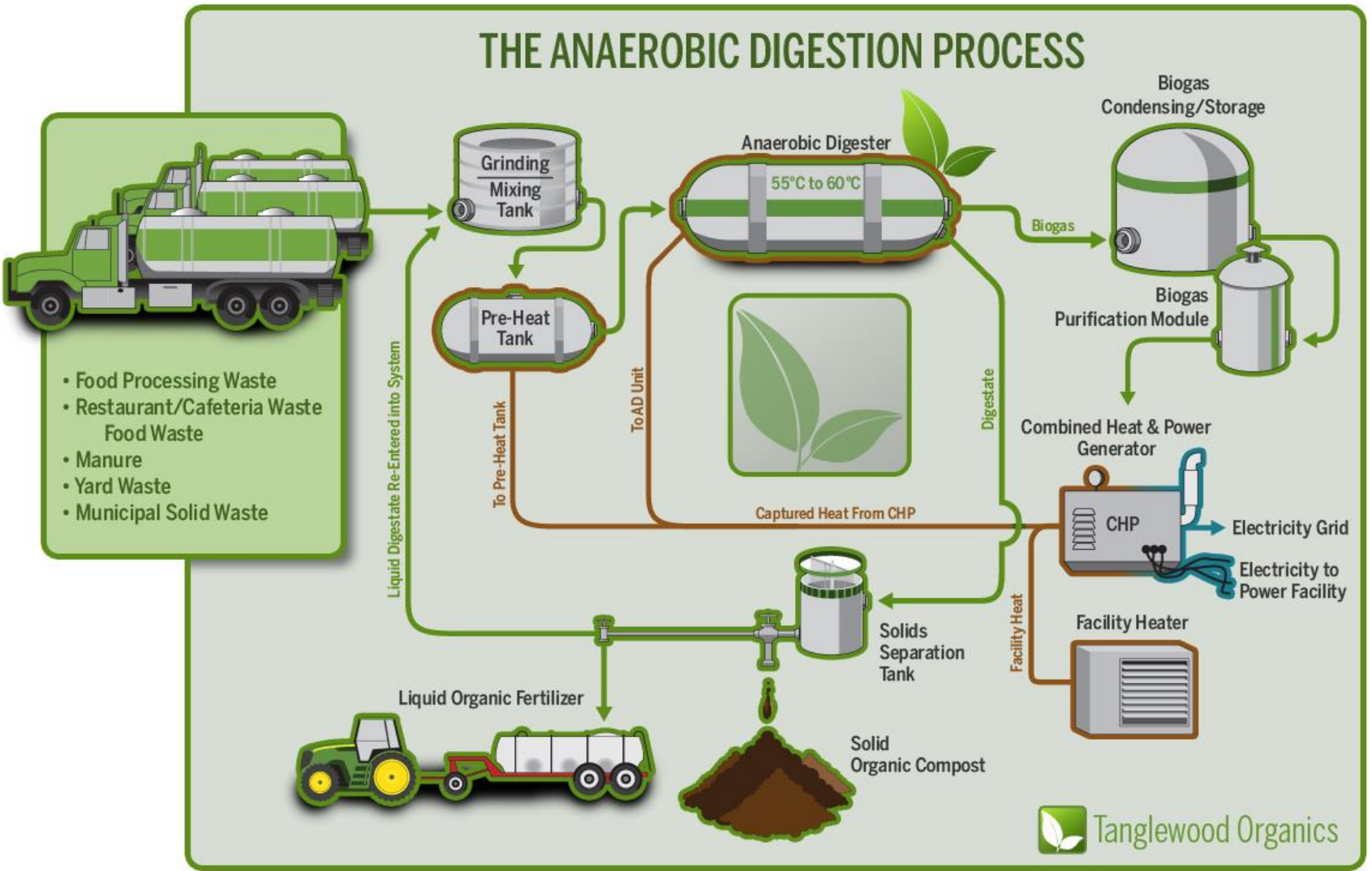
Water, Lactose, plus
any fats and protein

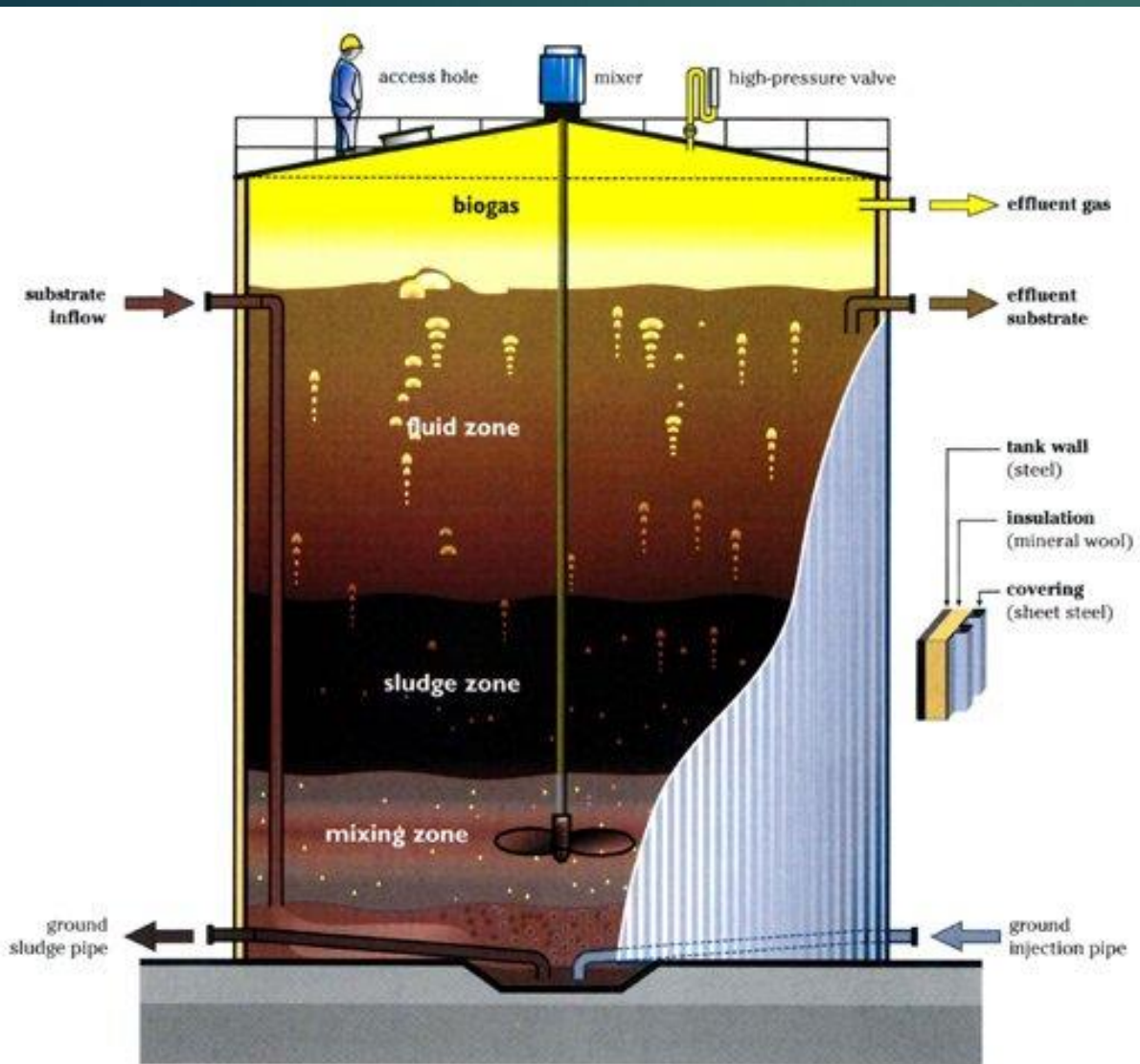


Raw
whey



Option #2 Convert whey to methane





Digestion Challenges

- ▶ Large capital costs (Ex. Chobani plant would require \$30MM investment)
- ▶ Lots of large tanks and real estate needed
- ▶ Gas produced is **low pressure 60% methane and 40 % CO₂**....so btu content is much less than natural gas
- ▶ Gas usually contains H₂S which is very corrosive.....requires removal.
- ▶ Bugs are finicky little devils....temperature, pH, nutrients need to be ideal
- ▶ Viable if enough gas can be used to generate electricity or to operate a boiler

Digestion Economics

- If we perform a carbon balance, we should be able to predict conversion of lactose/lactic acid to methane (CH₄)
- We know that lactose is about 5% of the whey, so
- A 11,000 tanker truck will contain about $11,000 \text{ g} \times 8.3 \text{ lbs/g} \times 5\% = 4,565 \text{ lbs}$ or 2,072 kg Lactose
- The Lactose has a molecular weight of 342 kg/kmol. So we have $2,072\text{kg} / 342\text{kg/kmol} = 6.1$ kilomoles of lactose
- Lactose is a 12 carbon compound and the conversion is 60% methane and 40% CO₂
- So, 6.1Kmol of lactose will produce $6.1\text{kmol} \times 12 \text{ C/mol} \times .6$ or **43.9Kmol of CH₄**

The value of the digester gas

And we know that 1 mol of gas occupies 22.4 liters at Standard Temperature and Pressure

Therefore the 43.9 Kmol will have a volume of $(43,900\text{mol} \times 22.4\text{l/mol}) \times .0353 \text{ l/ ft}^3 =$

34,712 ft³ CH₄

If methane (NG) has 1000 btu/ft³ and the digester CH₄ is worth \$5/ MM btu then each truck has a value of $34,712 \text{ ft}^3 \times 1000\text{btu/ft}^3 \times \$5/ \text{MM btu} =$ **\$174**

Note: If the whey is concentrated to 15% lactose the value of the truck becomes **\$522**

Option #3 Convert the whey to biofuel

- ▶ Fermentation can be used to convert the lactose to **ethanol** or **butanol**
 - ▶ Facts: Lactic acid inhibits fermentation
 - ▶ Lactose ferments slower than corn sugar
 - ▶ Fermentation requires time, temperature, and nutrient control
 - ▶ Yeast and Bacteria available may need to be genetically altered



Fermentation challenges

- ▶ To make fermentation viable we would need
 - ▶ Reduce the lactic acid levels in the whey
 - ▶ Find the optimal fermentation conditions- pH, temperature, nutrient level, duration and the right yeast or bacteria
 - ▶ May have to use lactase enzyme to break down the lactose
 - ▶ Fermentation times need to be <48 hours and we need to get to ferment biofuel concentrations of 10- 12%

Biofuel from whey production facts

- ▶ Dairy industry has no interest in on site biofuel production
- ▶ Considerations for offsite biofuel production
 - ▶ The whey will need to be concentrated to make transport viable
 - ▶ Lactase or genetically altered yeasts can be expensive
 - ▶ Distillation construction is very expensive
 - ▶ Make use of the synergy of an existing ethanol/ butanol plant
- ▶ There are two biofuel plants with existing distillation systems in NYS
Western NY Energy in Medina and Sunoco Inc. in Fulton
- ▶ Some interest in NYS to make spirits from the whey.

Biofuel production economics

- ▶ 235,000,000lbs/ year lactose would be converted to how much ethanol?
 - ▶ We know from lab scale experiments that about 13lbs of lactose will produce 1 gallon of pure ethanol under ideal fermentation conditions.
 - ▶ This would result in $235\text{MM lb/year} / 13 = \mathbf{18.1\ MM\ GPY}$ ethanol production
 - ▶ At \$1.50/gal for ethanol how much would an 11,000 gallon tanker truck be worth carrying 15% lactose?
 - ▶ $(11,000\ \text{gals} \times 8.3\ \text{lbs/gal} \times 15\%) / 13\text{lbs lactose / gal of ethanol} \times \$1.5/\ \text{gal} = \mathbf{\$1,580}$
 - ▶ But you need to subtract the cost of evaporating the water, so
 - ▶ $(11,000\ \text{gals} \times 8.3\ \text{lbs/gal} \times 90\% \times 1100\text{btu/gal}) / \$5\ \text{per million btu} = \mathbf{\$452}$, so this truck is actually only worth
- $\$1,580 - \452 or **\$1,128**

Note: Raw whey at 5% lactose would have a value at only **$\$526 - \$489 = \$37$**

How much whey do we need to replace 10% of the corn for a typical ethanol plant?

- ▶ 32 million bushels of corn will yield 86,000,000 gallons of ethanol, and 13 lbs of lactose can be converted into 1 gallon of ethanol
- ▶ To make 8,600,000 gallons / yr ethanol from lactose, we would need $8,600,000 \times 13 =$ **111.8 MMlbs lactose/yr**

$111.8 / 235.5 \times 100\% =$ **47%** of available lactose

Option 4: Isolate the Lactic acid

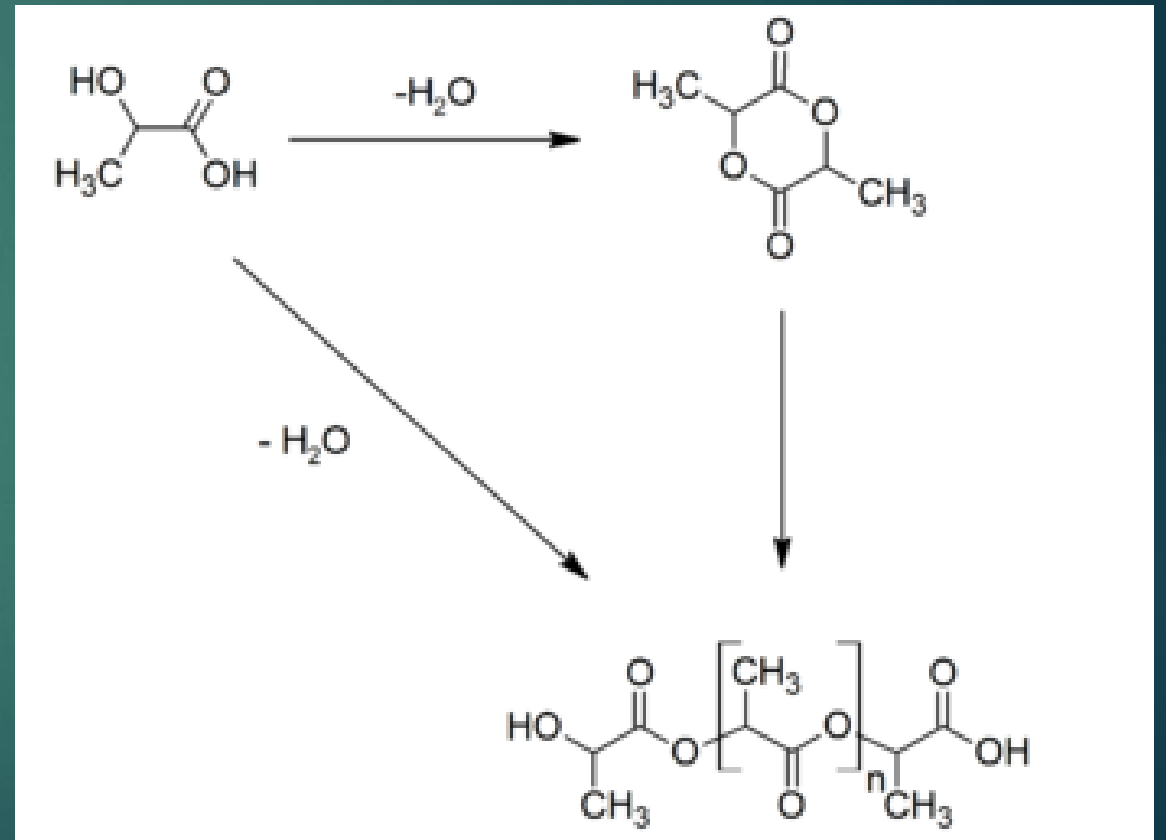
- ▶ Lactic acid can be used to make bio-plastics
- ▶ It is dilute in whey (<1% in raw whey)
- ▶ It has a charge (-) so it can be separated via ion exchange
- ▶ The separation costs out weigh the economic benefits
- ▶ More research is needed to find more efficient ways to purify

Polylactic acid or Polylactide (PLA)

- Formed by direct condensation of lactic acid
- A biodegradable thermoplastic polyester



Biodegradable PLA cups in use at a restaurant



Keys to solving the problem

1. Reduce or remove the lactic acid from the whey
2. Concentrate the whey and reduce the trucking costs
3. Partnerships of dairy industry and owners of the digesters where feasible
4. Find the right fermentation reactor
5. Partnership with the ethanol plants for distillation economics
6. Find a way to efficiently recover the lactic acid- refined membrane technology

Current Status

- ▶ The whey producers are looking for an answer - now
- ▶ There seems to be a lot of interest in the state to move forward.
- ▶ We should have a fermentation reactor designed for production by early 2016.

Questions

1. Where does NYS rank with regards to dairy products production?
2. what are the major dairy products creating the waste?
3. What is the problem waste?
4. What make the problem waste a problem?
5. What two methods of waste treatment are the most viable?