Production of fermented cucumbers with $CaCl_2$ and without NaCl

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Rationale of the project:

- Waste water containing high levels of NaCl from cucumber fermentation tank yards is a continuing problem for the pickled vegetable industry.
- A major reduction in waste salt could be achieved if NaCl was eliminated from the cucumber fermentation process.
- Thus the objective is to ferment cucumbers in cover brines containing $CaCl_2$ as the only salt.
- And to compare firmness retention of cucumbers fermented in $CaCl_2$ brine during subsequent storage to cucumbers fermented in brines containing NaCl.

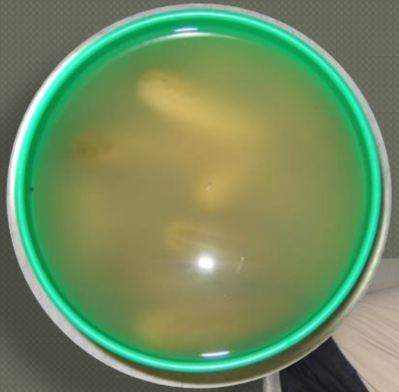
Laboratory scale evaluation of salt-free cucumber fermentation

- $CaCl_2$ fermentations were similar to NaCl fermentations
  - in the chemical changes caused by the fermentative microorganisms
  - and in the retention of firmness in the fermented cucumbers
  - $CaCl_2$ fermentations were also stable (in jars, in the absence of air)
- However, post-fermentation pH was lower in the presence of $CaCl_2$ than in the presence of sodium chloride (~3.0)

McFeeters RF, Pérez-Díaz IM. 2010. Fermentation of cucumbers brined with calcium chloride instead of sodium chloride. J Food Sci 75(3):C291-C296.

Initial trials at the commercial scale

- Trials at B&G Foods, MD in open top tanks
  - Primary fermentation proceeded successfully, however a secondary fermentation developed after 4 months of storage



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Observations from the trials in barrels

- It was observed that a key factor in doing fermentations without salt is to limit purging only to what is needed to prevent bloating, though the minimum required is not completely clear.

- Sorbic acid is effective in limiting yeast growth, but we wanted to also look at other preservatives such as benzoate and AITC to see if we had multiple options.

Observations from the trials in barrels

- Aromas from the fermentation barrels were clean, although some film yeast formed on the surfaces of the cover brines.
- Finally there was the question of whether post-fermentation spoilage would occur over extended periods of storage; and whether preservatives added to the cover solution before or after fermentation would prevent it.

Initial commercial tanks of 3,000 gallons were packed

Control Tanks

6% NaCl
1.1% $CaCl_2$
0.05% acetic acid

Experimental Tanks

1.1% $CaCl_2$
0.09% potassium sorbate
starter culture (*L. plantarum*)

0.32% fumaric acid (3 weeks later)

Air Purging Routine

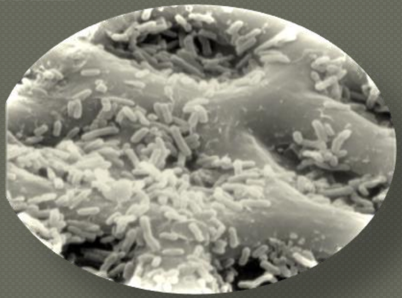
- Initiated the morning after the tanking day
- 4 hours on and 4 hours off for 7 days
- purged on that same schedule on days 9, 11, 13 and then stopped the purging

Rationale of the cover brine formulation

- $CaCl_2$: firmness retention with time
- Potassium sorbate and the minimized air purging routine: prevention of the proliferation of yeasts during fermentation and storage
- Fumaric acid: to prevent the growth of spoilage associated lactic acid bacteria during storage
- Removal of acetic acid: to reduce the extent and/or probability of secondary cucumber fermentation or spoilage
- Starter culture: outcompete the natural microbiota

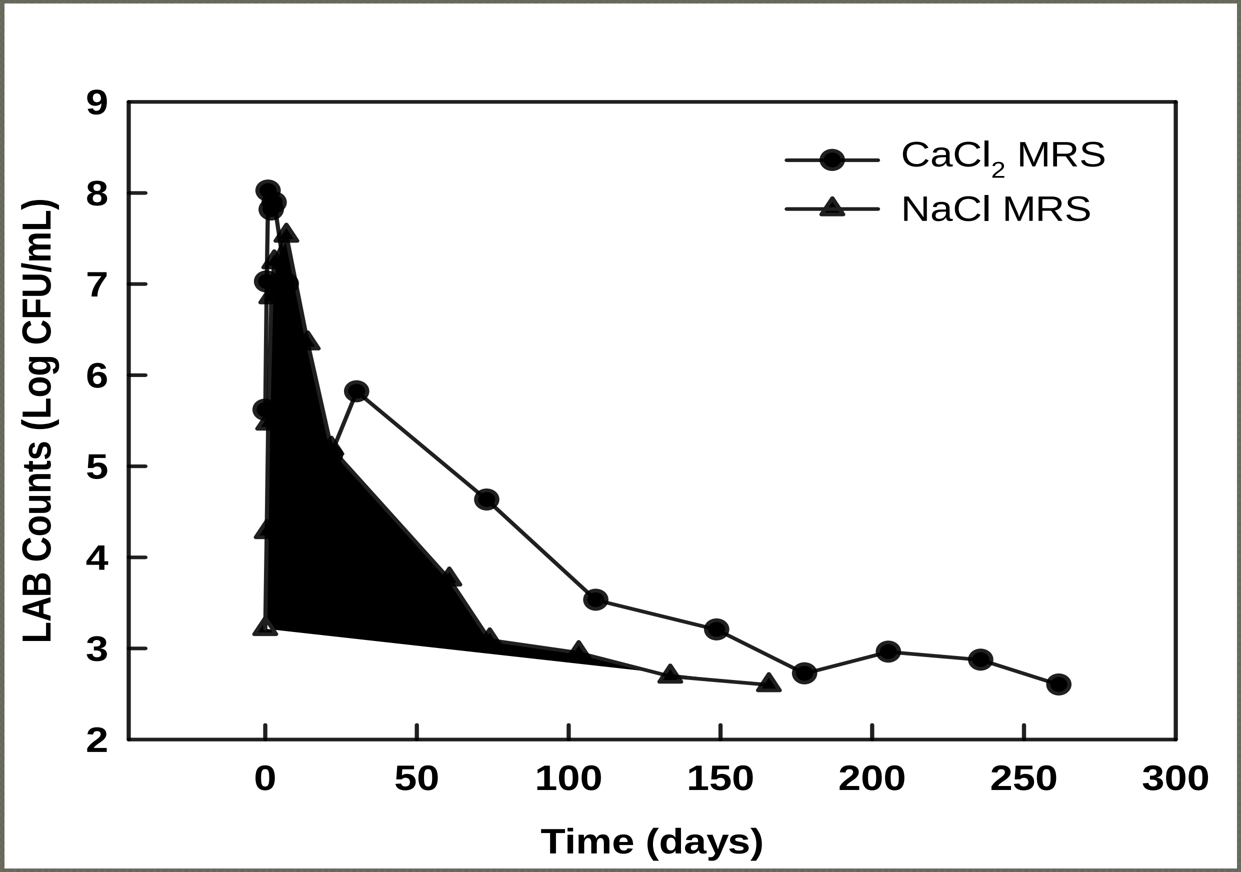
Initial Microbial Counts

- Fresh Cucumbers: 5.22 ± 0.93 Log of CFU/mL
- Fresh $CaCl_2$ Brines: 1.44 ± 1.89 Log of CFU/mL
- Fresh NaCl Brines: below detection level



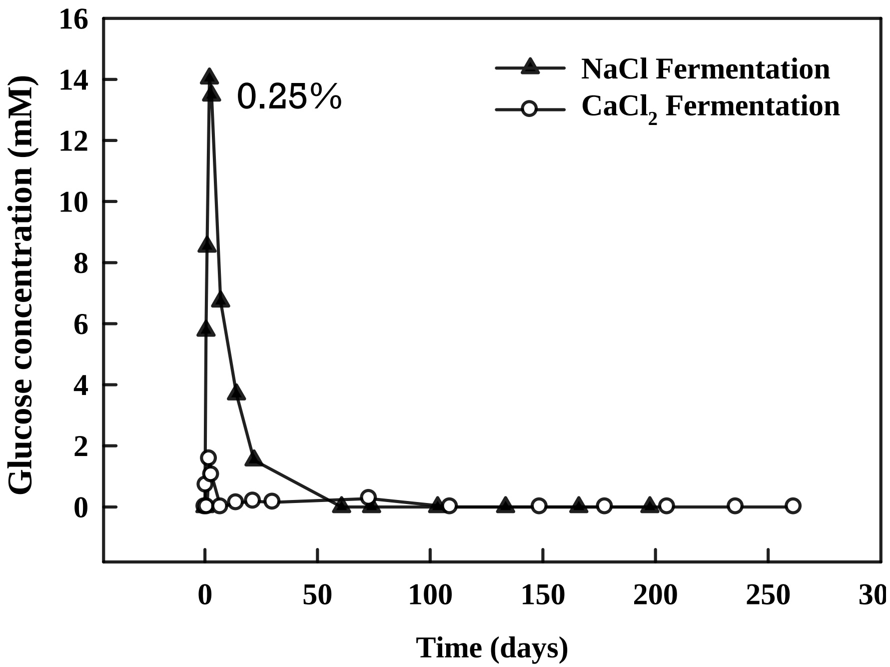
- Inocula: 8.17 ± 0.55 Log of CFU/mL
  - Preliminary data suggest that Starter Cultures used as inocula prior to reaching maximum cell density (9 Log of CFU/mL) grow faster in the commercial fermentation.
- Initial LAB Counts: 5.88 ± 0.59 Log of CFU/mL

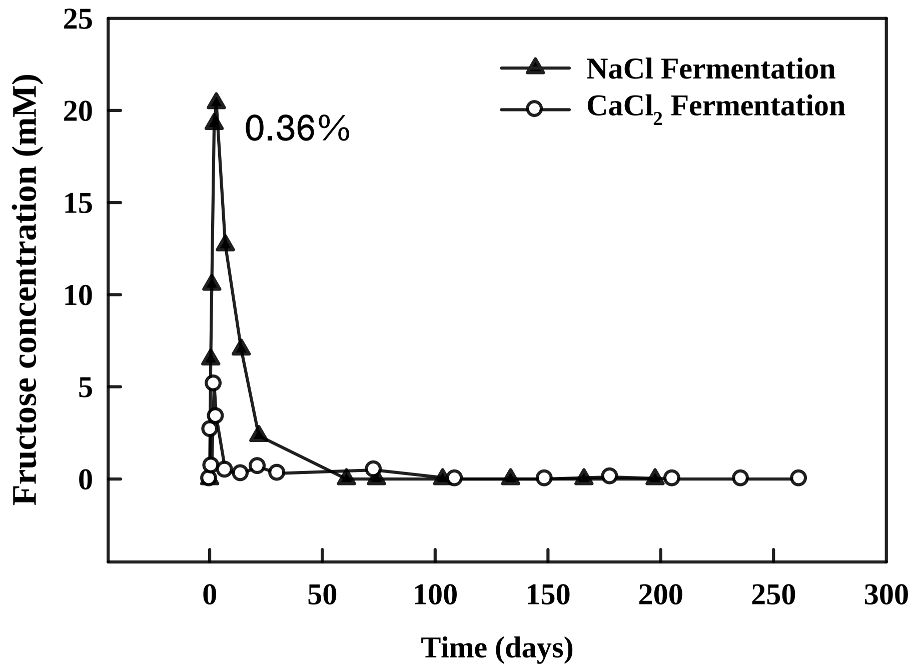
Commercial scale NaCl and $CaCl_2$ fermentations



Counts of lactic acid bacteria reached a maximum after 0.75 days in the $CaCl_2$ fermentations as compared to 4 days in the NaCl fermentation.

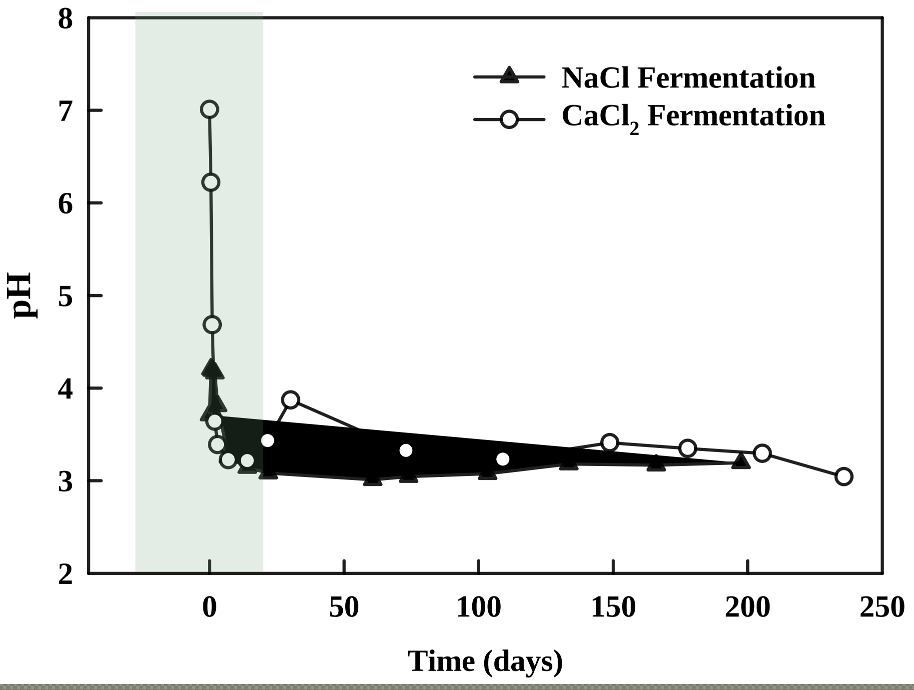
Glucose utilization in $CaCl_2$ fermentation

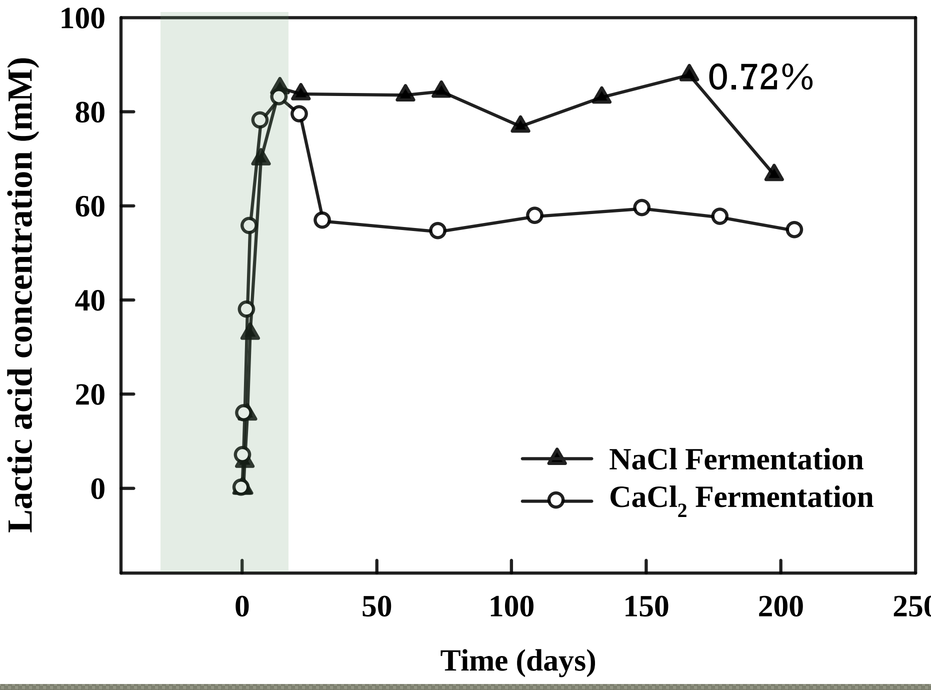




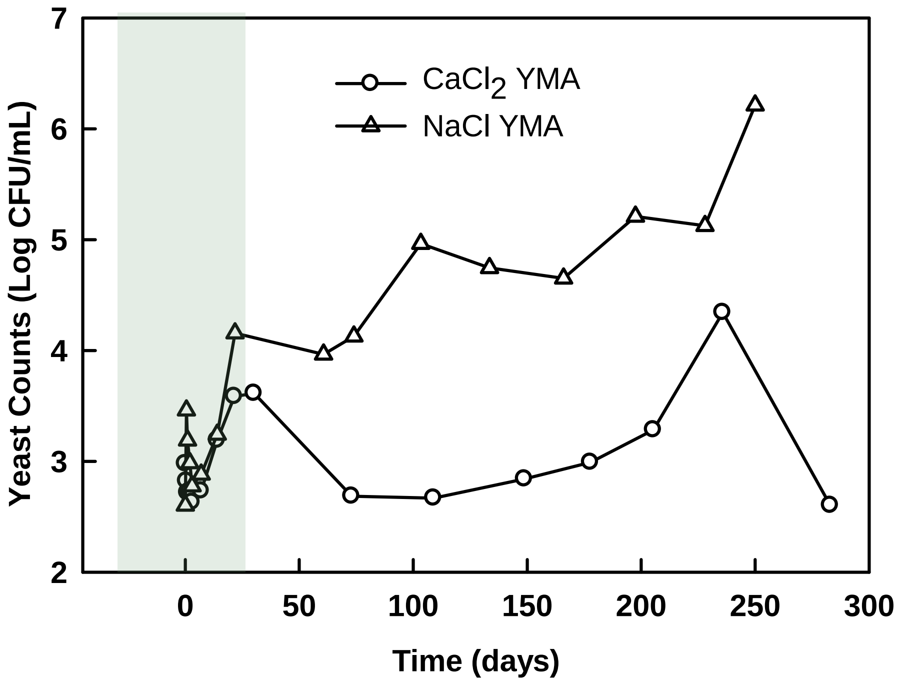
Carbohydrate utilization proceeds faster in $CaCl_2$ fermentations as compared to NaCl fermentations

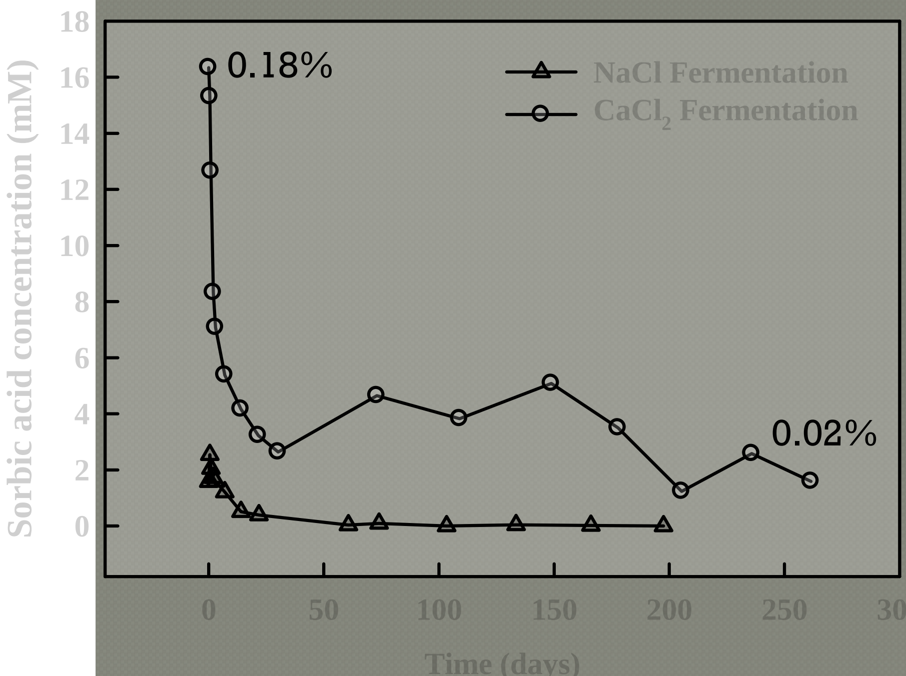
Increases in pH and decreases in lactic acid were observed in the $CaCl_2$ fermentation





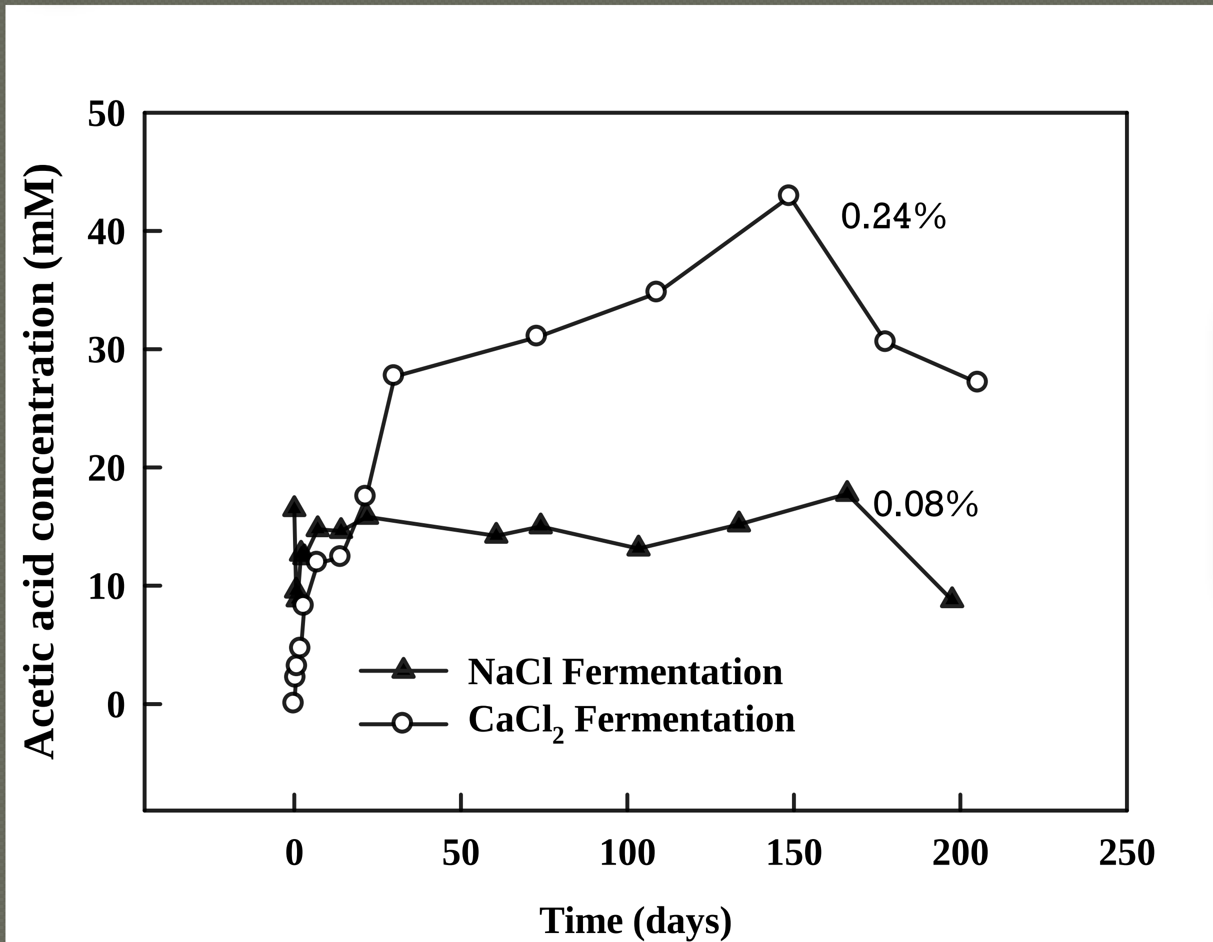
Yeast counts in the commercial scale $CaCl_2$ fermentation

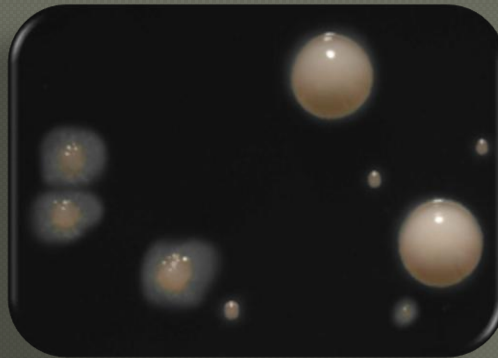




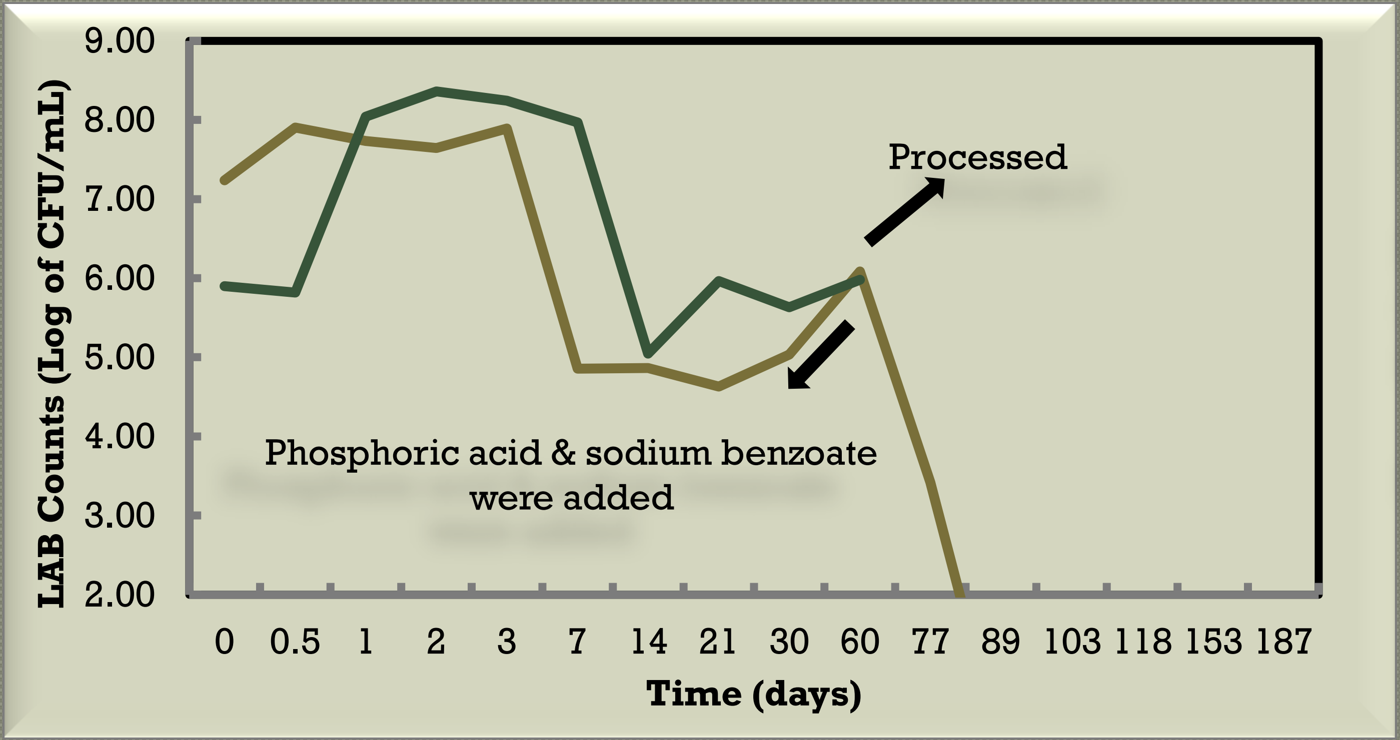
Yeasts proliferated immediately after the primary fermentation, presumably deriving energy from the residual carbohydrates or from lactic acid.

Acetic acid production was detected in the $CaCl_2$ fermentation





Some spoiling tanks were rescued by adding preservative and acidifying with phosphoric acid



Potassium sorbate
Sodium benzoate
Fumaric acid

Phosphoric Acid

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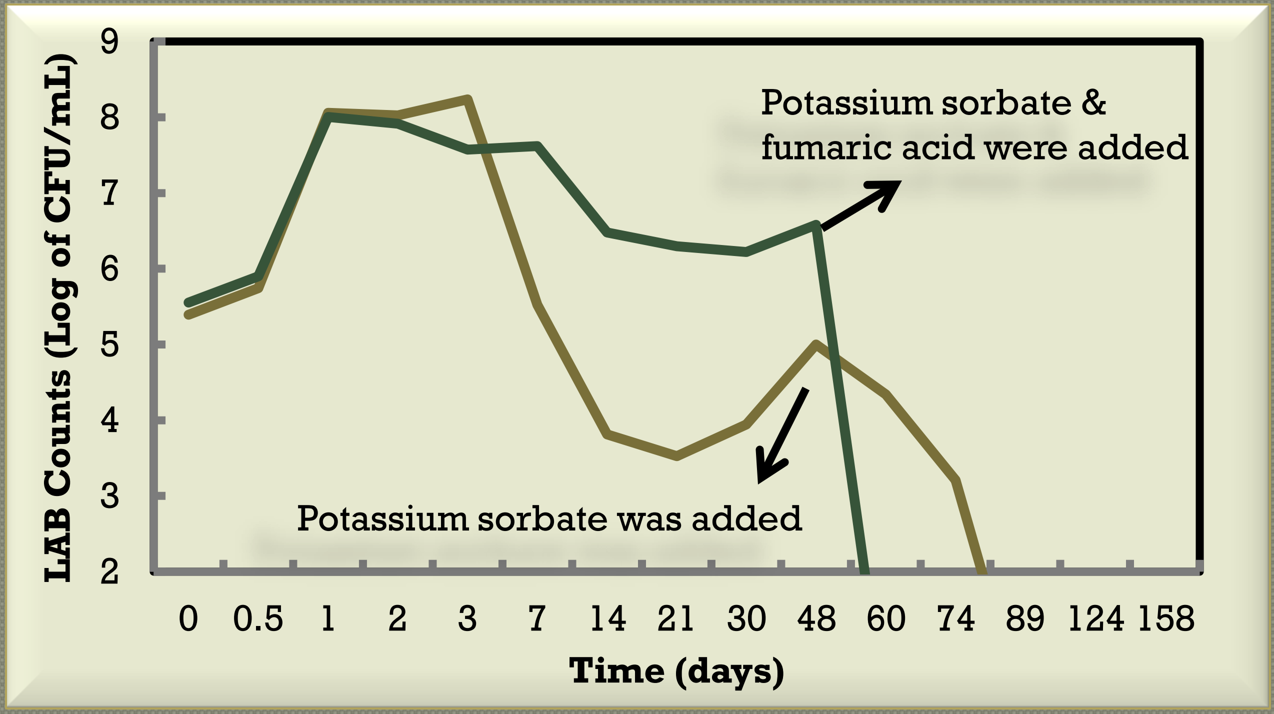
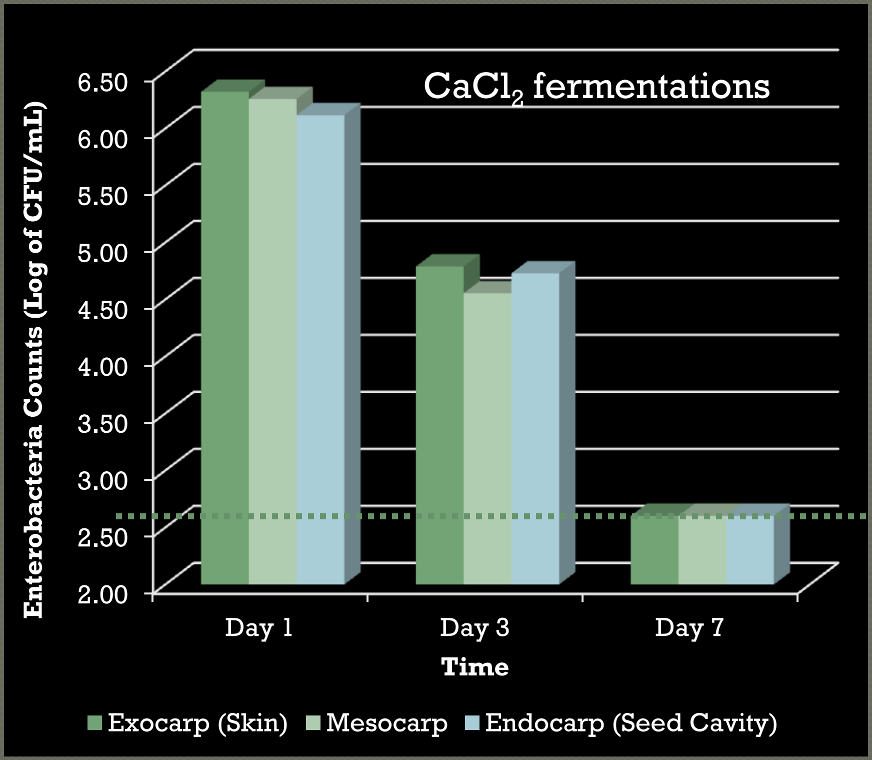
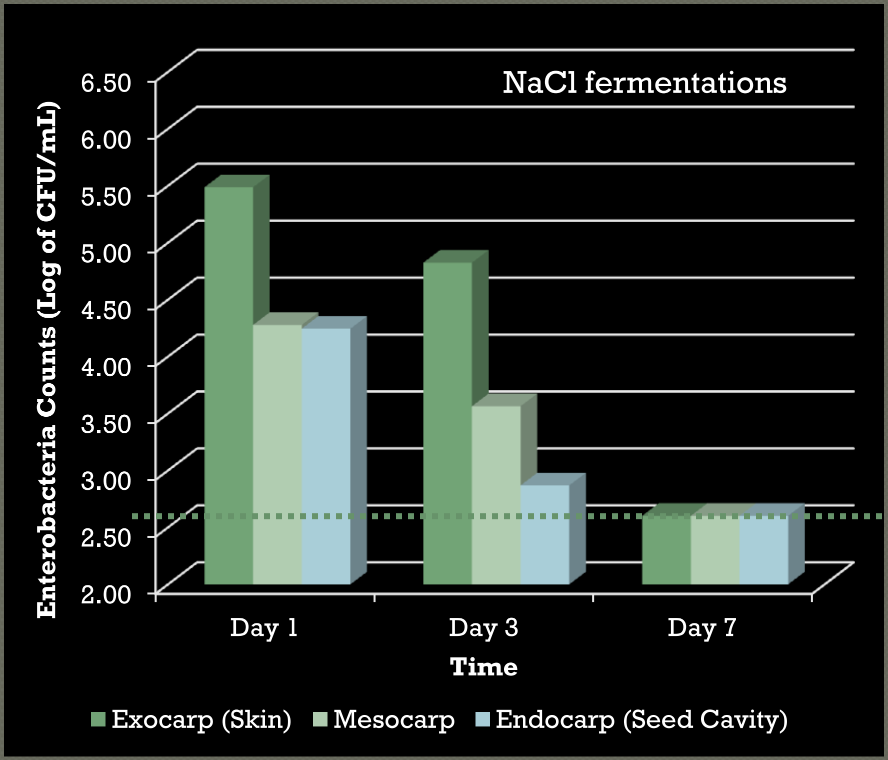
Fumaric acid induced a faster decrease in the counts of lactic acid bacteria



Counts of enterobacteriacea after culture enrichment

Fresh $CaCl_2$ Brine: 2.55 ± 1.17 Log of CFU/mL
Fresh NaCl Brine: Below Detection Level
Fresh Cucumbers: 5.67 ± 0.82 Log of CFU/mL





Second trial of the $CaCl_2$ fermentation

1.1% $CaCl_2$
0.09% potassium sorbate
starter culture (*L. plantarum*)

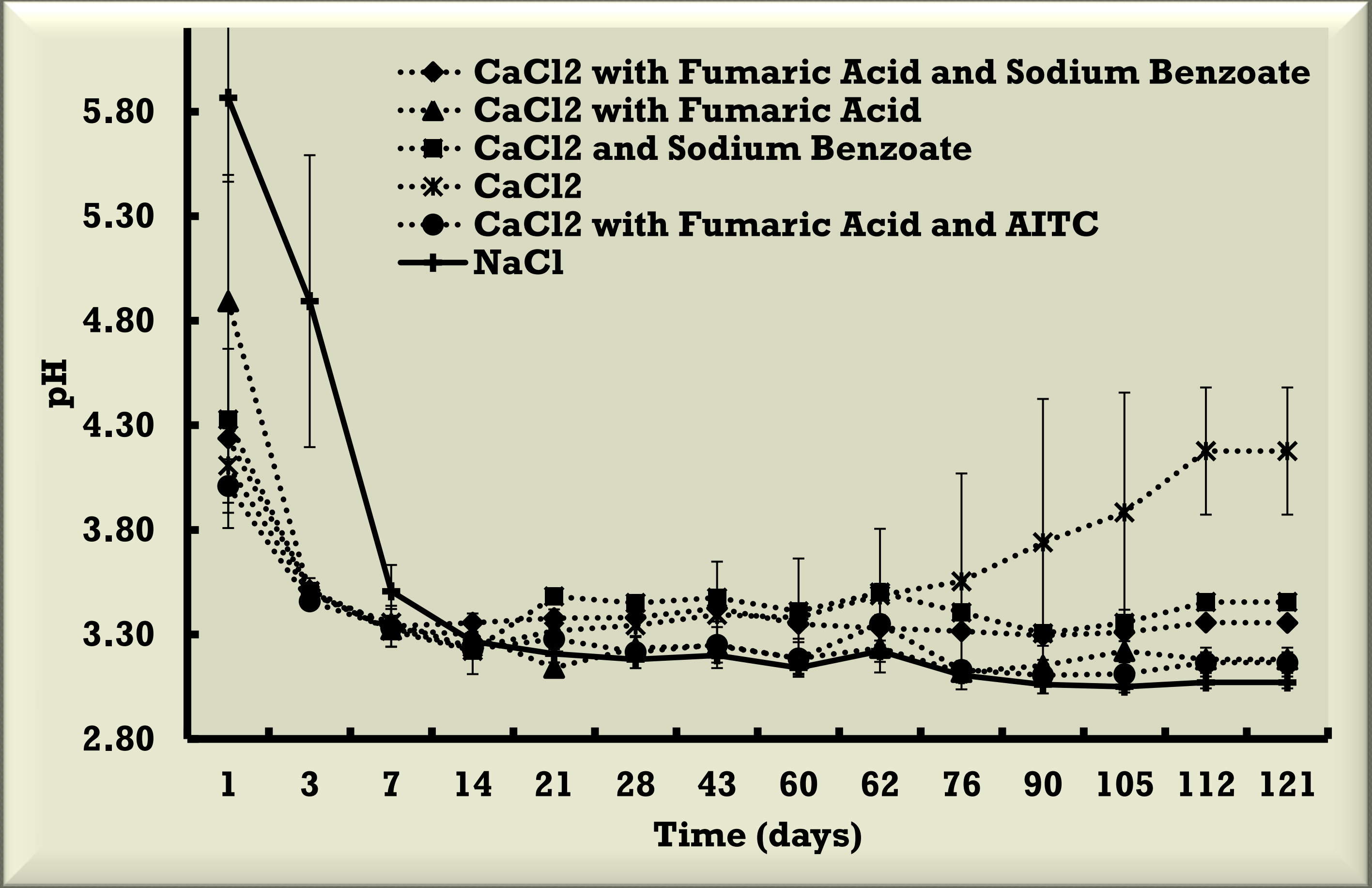
2 weeks post-tanking

0.32% fumaric acid, **0.17% sodium benzoate, 200 ppm AITC**
or
combinations of these preservatives

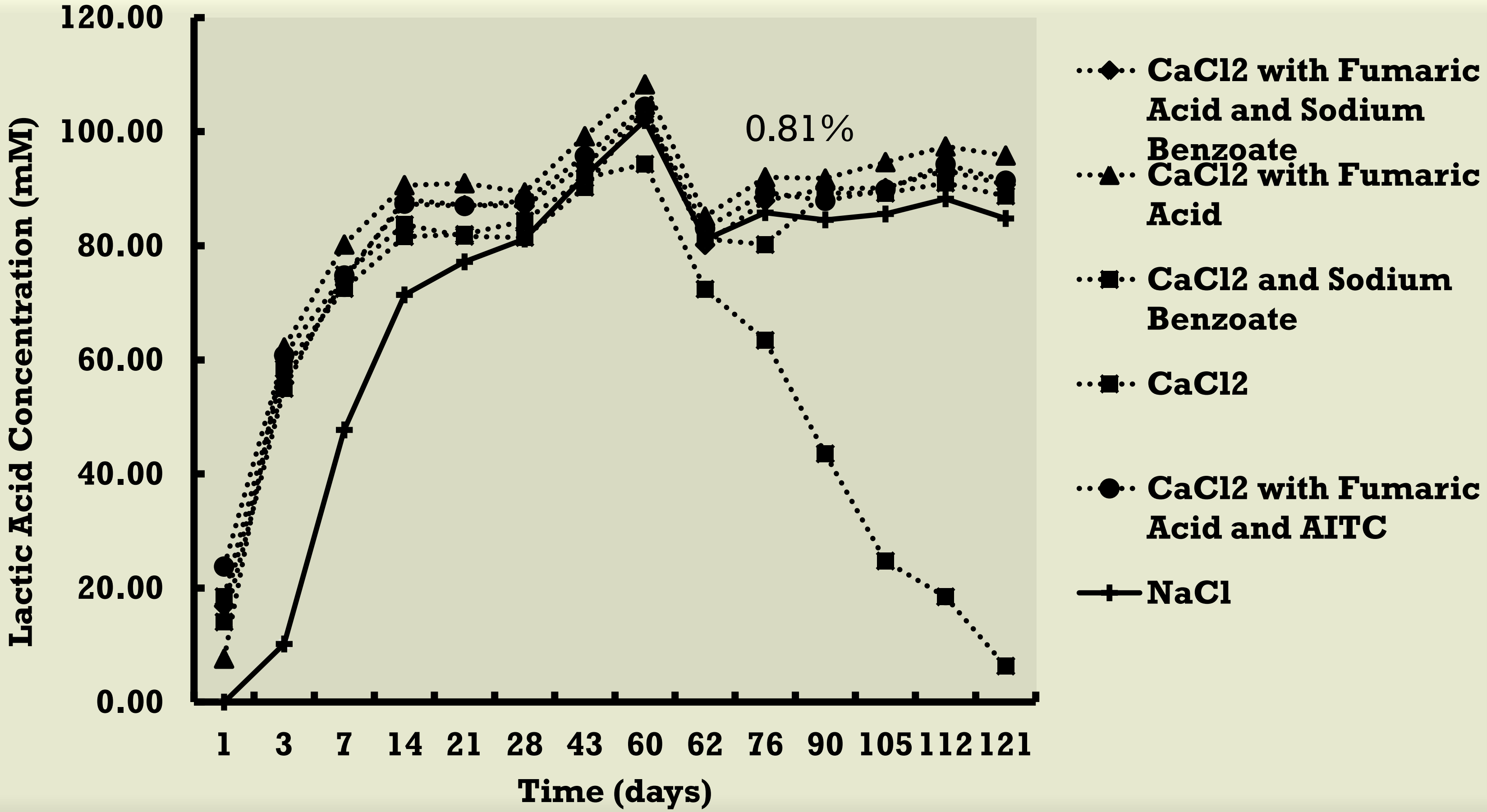
Air Purging Routine

- Initiated the morning after the tanking day
- 4 hours on and 4 hours off for 7 days
- purged on that same schedule on days 9, 11, 13 and then stopped the purging

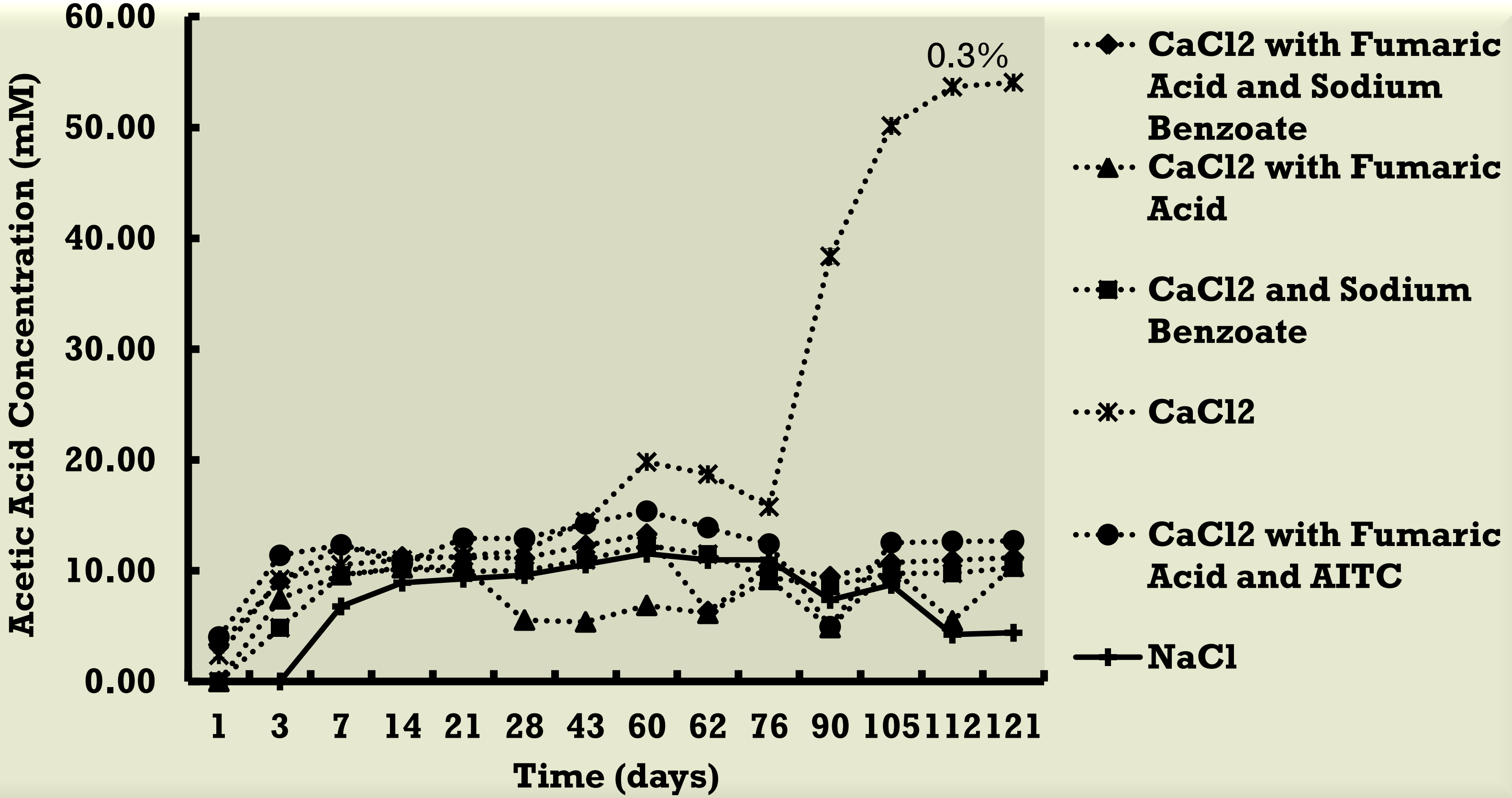
pH values as a function of time



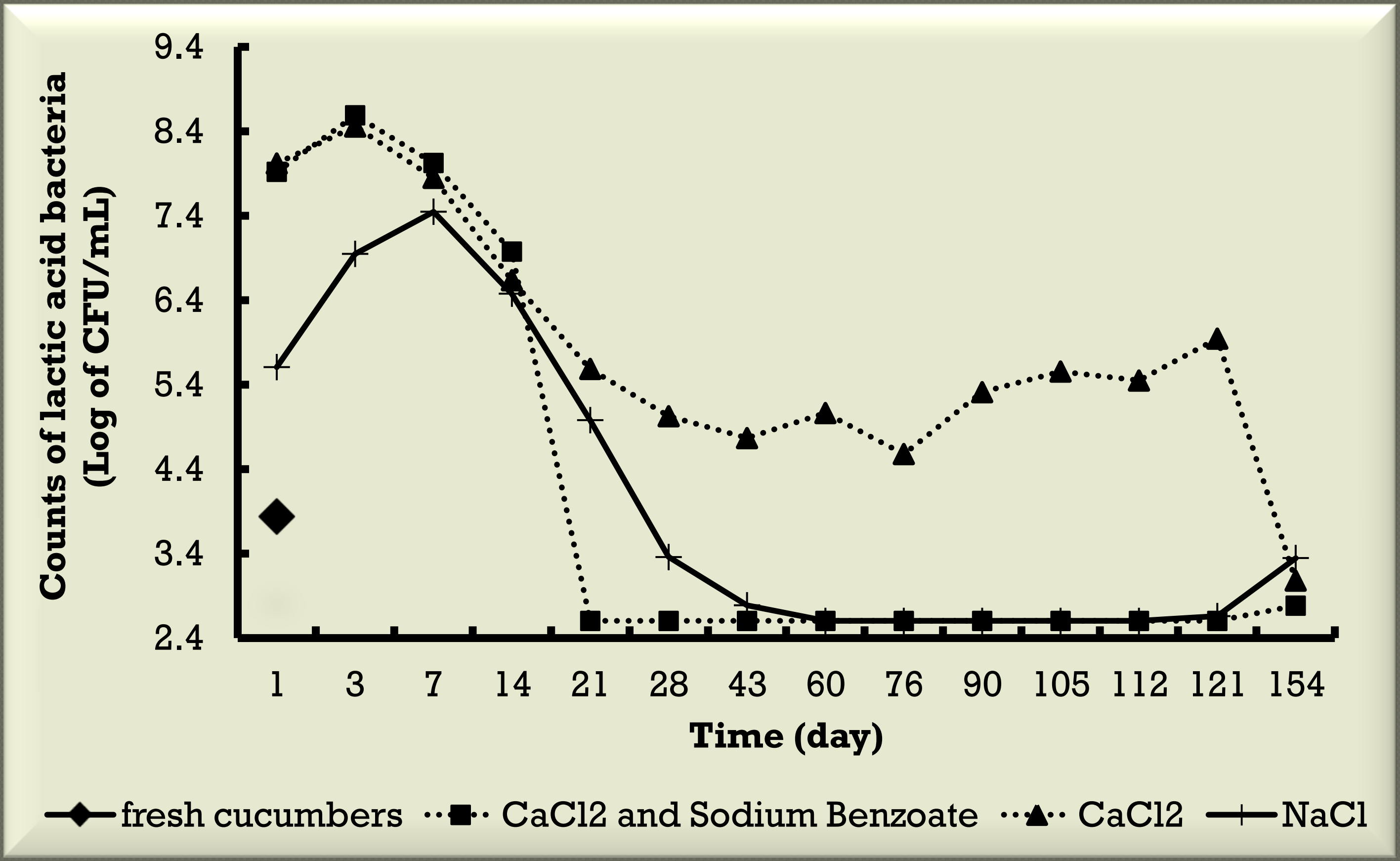
Trends in lactic acid concentration as a function of time



Trends in acetic acid concentration as a function of time



Counts of lactic acid bacteria during primary fermentation



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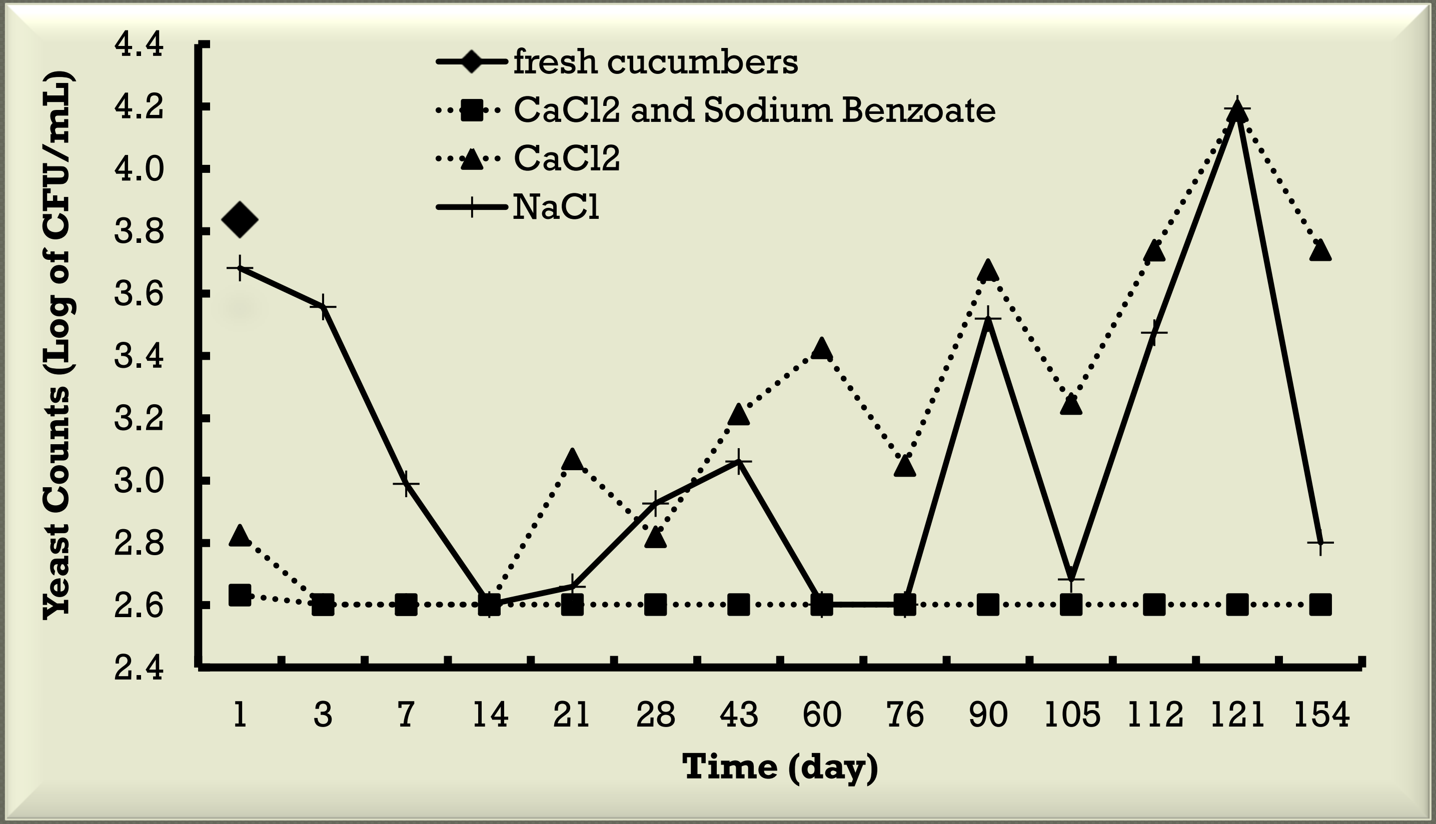
Yeast counts during primary fermentation and storage



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Observations from the second trial in commercial tanks

- The temperature fluctuated between 68 and 90 degree F
- Fumaric acid and benzoic acid concentrations were stable thru time.
- Sorbic acid concentrations were unstable thru time.
- Sodium benzoate was the most robust preservative in preventing microbial growth.

Product Comparisons

NaCl Fermented

- pH 3.49 ± 0.11
- Calcium 22 ± 5.5 mM
- Slightly darker appearance
- Differences in texture varied in independent trials

CaCl2 Fermented

- pH 3.30 ± 0.02
- Calcium 22 ± 2.8 mM
- Brighter in appearance, especially as observed in jars

All products were within the range of a normal hamburger dill chip product

No significant off-flavors were associated with either treatment

Conclusions

- It is possible to ferment cucumbers and stored them for six months in a cover brine without NaCl.
- The proposed $CaCl_2$ system has the potential to reduce the high salt wastes from vegetable fermentations.
- Hamburger dill chips prepared from calcium chloride fermentations were nearly identical in sensory quality after 6 months storage in glass jars

Salt-free cover brine solution for cucumber fermentations

- **Disadvantages:**

  (1) new process, uncertainty
  (2) freshly made fermentation cover brines cannot be stored for extended periods of time
  (3) need to add a preservative post-fermentation
  (4) need to generate large volumes of starter cultures in-house
  (5) water usage;
  however a lot of water is used today with the purpose of diluting chlorides in waste waters

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Salt-free cover brine solution for cucumber fermentations

Advantages:

(1) reduces pollution from the disposal of high salt brines

(2) presents an opportunity for the manufacture of low-sodium products

(3) create opportunities for new flavors in finished products

(4) eliminates the need to recycle cover brines

(5) no carry-over of undesired flavors, enzymes, an high acid levels from the recycled brines

Salt-free cover brine solution for cucumber fermentations

Advantages:
(more)

(6) reduces cost of labor and equipment operation
(7) minimizes the need for pumps on the platforms
(8) reduces energy demands
(9) eliminates the need to store used cover brines
(10) more consistent end-product
(11) less air purging
(12) the $CaCl_2$ containing brines can be sprayed on landfills

Questions

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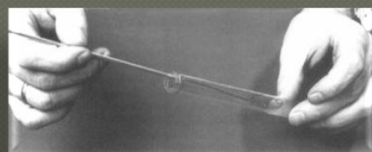
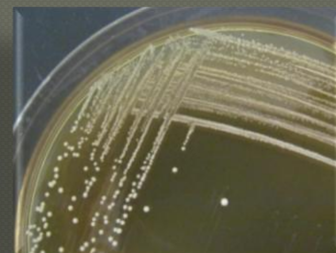
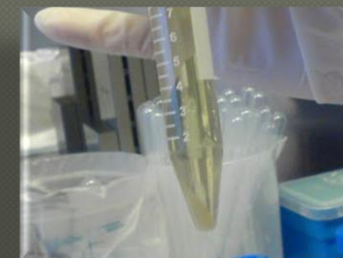
Preparation of a Kosher starter culture for vegetable fermentations



Step 6: As needed a small piece of ice from the frozen bacterial culture is transferred to fresh and sterile 1 ml MRS broth. Here the MRS broth can be substituted by cucumber juice.





Step 7: The tube containing the 1 ml cucumber juice and the bacterial cells is incubated at 30 °C for 48 hours to encourage growth (multiplication of the bacterial cells).

Step 8: Jars are inoculated and incubated for 3 days at 30°C

Step 9: A portion of the brine from this jar is pour off onto a 1-gallon Kosher dill spears.

Step 10: The 1-gallon jar is maintained at room temperature until turbidity develops.

Step 11: The total content of 4 turbid 1-gallon jars , is pour off into a tank of (6000-10000 gallons).