Thursday Concurrent Session: Hot Topics in Quality Cheesemaking

Three Common Quality Challenges Impacting Consistent Production of High-Quality Cheese.

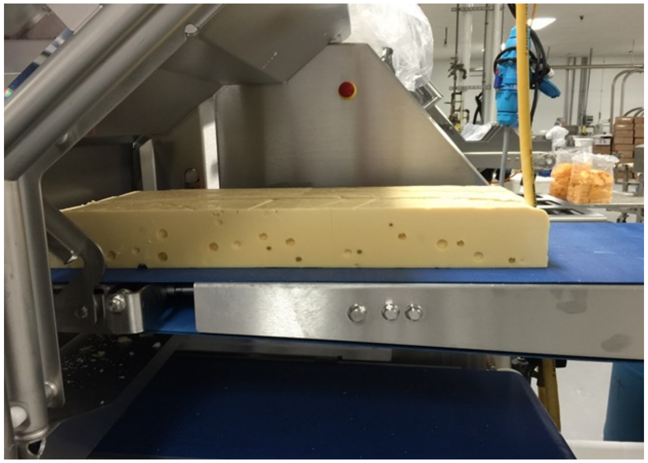
John Jaeggi – Coordinator
Cheese Industry and Applications Group

What is a "Defect"?

The *meaning* of *DEFECT* is an imperfection or abnormality that impairs quality, function, or utility : shortcoming, flaw.

- Appearance/Surface Finish/Rind/Color
- Odor
- Body and Texture
- Flavor
- Functionality

Where Did the Defect Start?



Cheese Defects

According to Dr. Mark Johnson, most cheese defects are related to 6 areas:

- Improper moisture content- usually too much moisture which leads to soft bodied cheese.
- Improper rate and extent of acid development.
- Improper type, use rate, or quality of ingredients (flavor and body).
- Microbiological contamination (flavor, gas formation).
- Improper aging conditions (retail: usually too long of pull dates).
- Transit and/or Retail abuse (light, temperature, shelf life, packaging, contamination).

Due to Time…Here Are THREE Common Defects (Amongst the dozens we see!)

- Bitterness
- Acidity
- Calcium Lactate Crystals

Bitterness

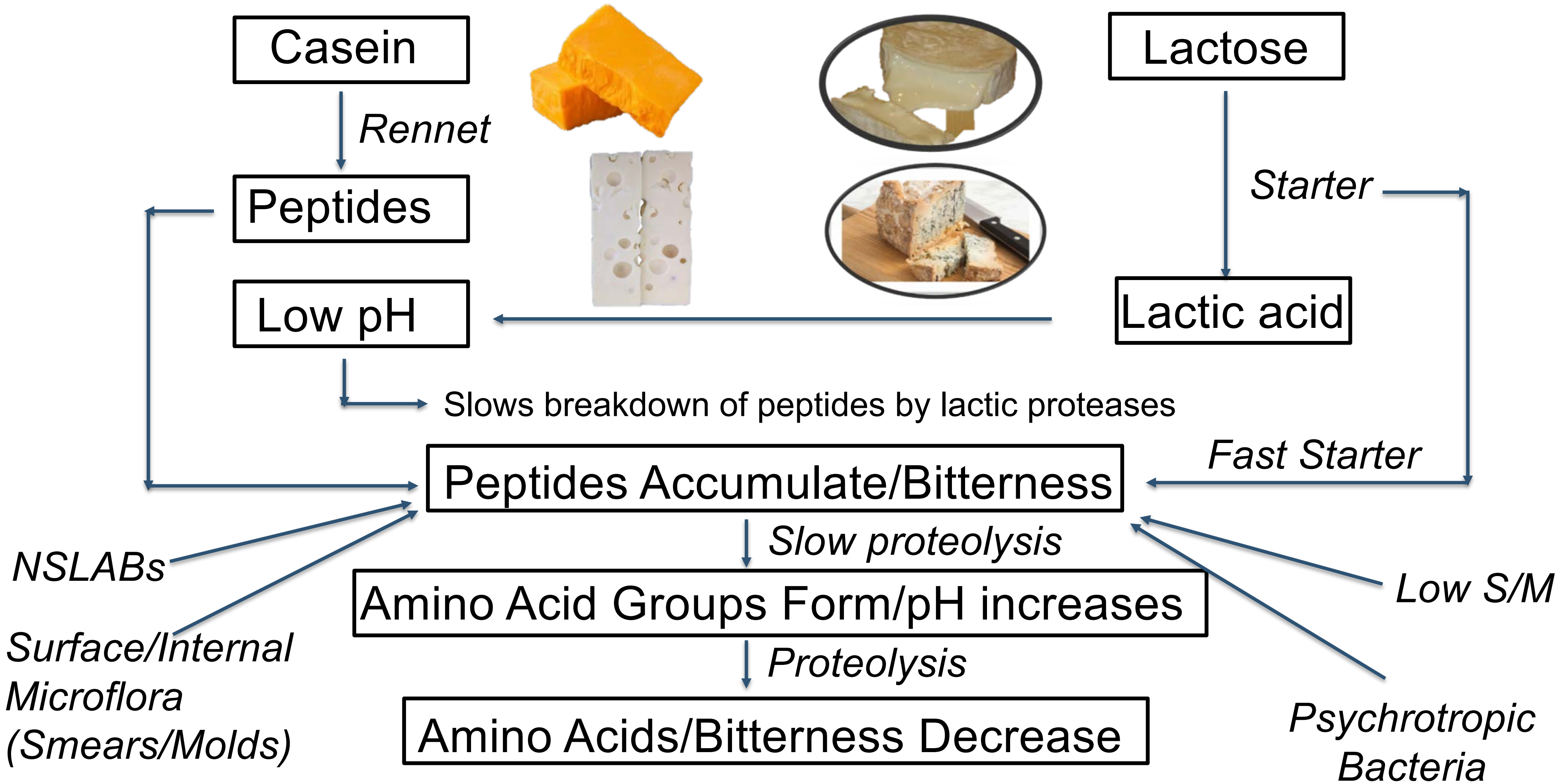
- Bitterness is a study of interest to health researchers as **many bitter compounds** are known to be ***toxic***.
- The **threshold** for stimulation of **bitter taste** by quinine averages a concentration of **8 μM (micromolar)**.
- Common bitter foods and beverages include coffee, unsweetened cocoa, citrus peel, some cheese, and hops in beer.
- Roughly 25% of the population is considered bitter blind!

Bitterness in Cheese

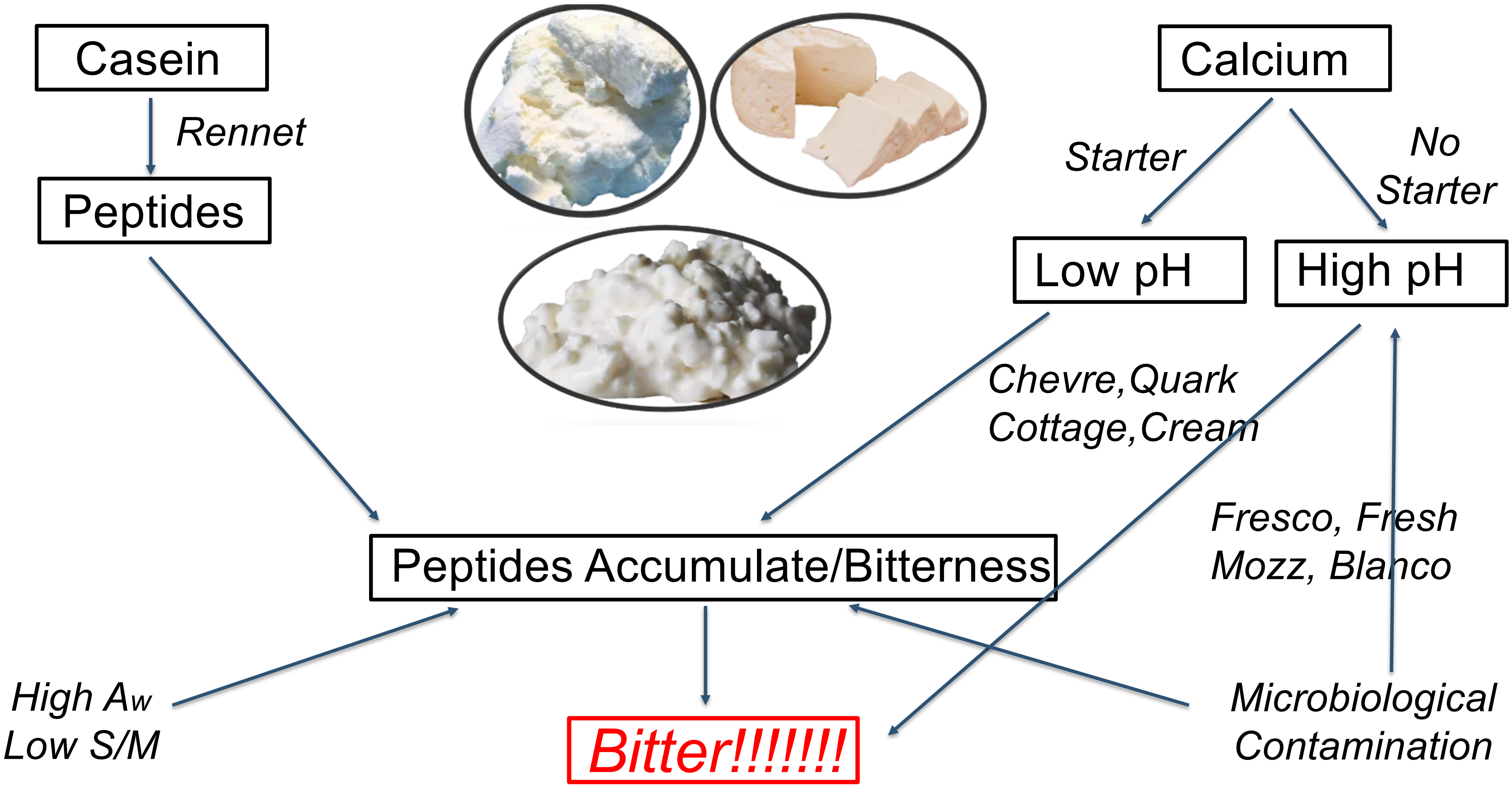
- Common defect in Cheddar, Monterey Jack, and Colby.
- Common defect in Swiss cheese.
- Common defect in surface ripened cheese.
- Common defect in mold ripened cheese.
- Common defect in Brick and Muenster.
- Common defect in fresh acid or high pH cheeses such as Quark, Cottage Cheese, Fresh Latin American Cheeses, Fresh Mozzarella, etc.

How Does Cheese Become Bitter?

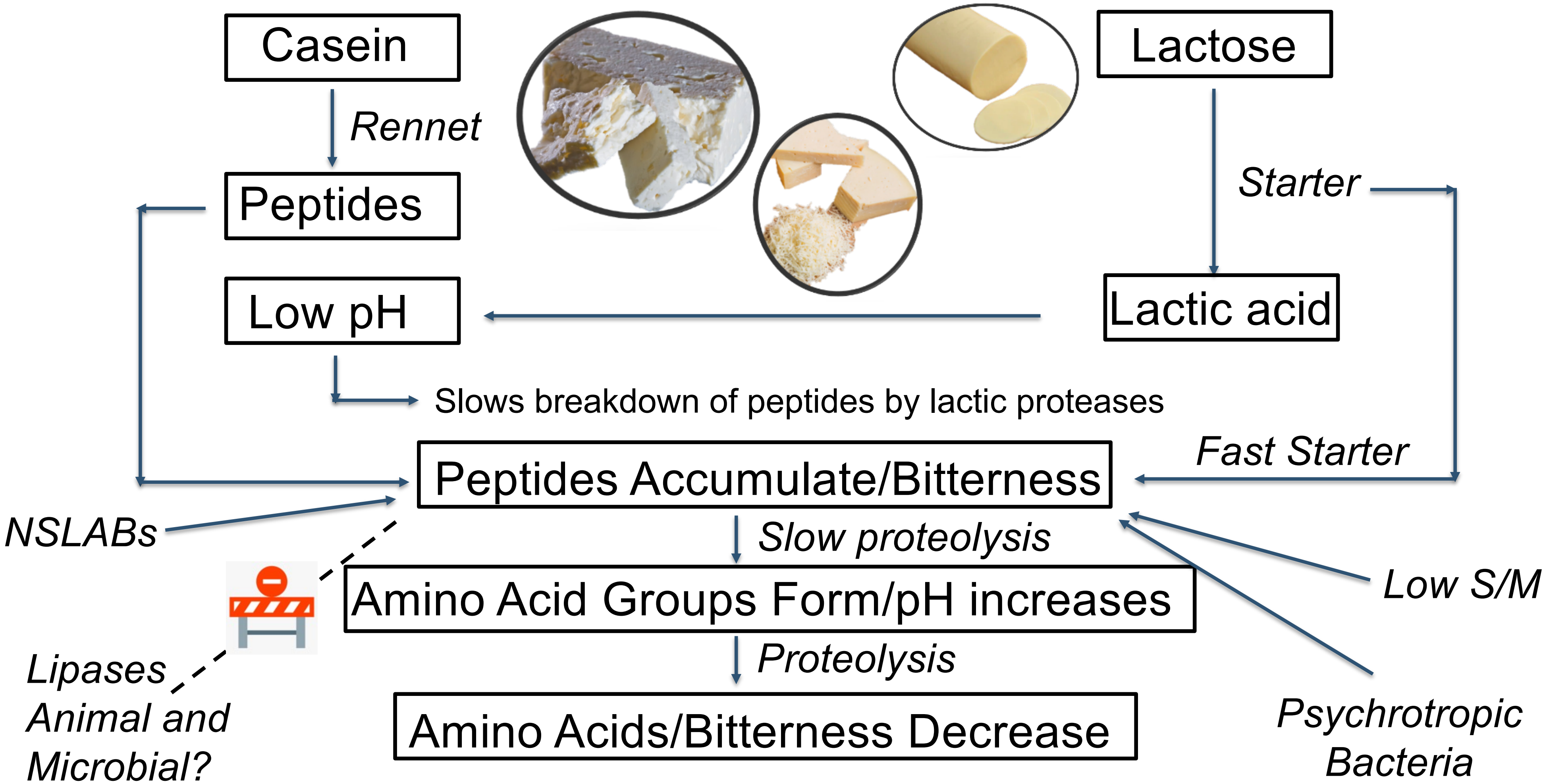
Bitterness in Cheddar is ***associated with the accumulation of hydrophobic peptides, which are formed by the action of the coagulant and starter proteinases***. Bitter peptides are derived from both α_{s1}- and β-caseins.



Bitter Flavour in Dairy Products. II. A review … L. Lemieux, R.E. Simard. *Lait* (1992) 72, 335-382



Bitterness Explored in Fresh Cheese – Dairy Industries International. Herbert Schmidt. University of Hohenheim, Germany


Casein
Rennet
Peptides
Low pH
Lactose
Starter
Lactic acid
Slows breakdown of peptides by lactic proteases
Fast Starter
Peptides Accumulate/Bitterness
NSLABs
Slow proteolysis
Amino Acid Groups Form/pH increases
Low S/M
Proteolysis
Lipases
Animal and
Microbial?
Amino Acids/Bitterness Decrease
Psychrotropic
Bacteria

Amino Acids and Bitterness

Non-bitter amino acids

Glutamine	Gin
Asparagine	Asn
Glycine	Gly
Serine	Ser
Threonine	Thr
Histidine	His
Aspartic acid	Asp
Glutamic acid	Glu
Arginine	Arg
Alanine	Ala
Cysteine	*Cys*

Bitter amino acids

Methionine	Met
Lysine	Lys
Valine	Val
Leucine	Leu
Proline	Pro
Phenylalanine	Phe
Tyrosine	Tyr
Isoleucine	Ile
Tryptophan	Trp

From Lehninger AL (1972) Biochemistry;

Summarizing Bitterness Causes

- **Microbiological contaminants** (Psychrotropic bacteria, NSLABs for example) are proteolytic which can cause bitterness.
- **Starter cultures** which break down long chain non-bitter peptides into smaller peptides can cause bitterness. Historically *Lactococcus lactis* ssp. *lactis* and *cremoris*. Also, some *Lactobacillus casei* strains.
- **Rennet**, particularly microbial or from flowers of plants (e.g. *Cynara cardunculus*) which break down long chain non-bitter peptides into smaller potential bitter peptides.

Reducing Bitterness - Milk Quality

- Review milk quality standards:
  - Heat stable microbes attacking casein can cause bitterness
  - Psychotropic bacteria (Pseudomonas)
  - Raw milk lactobacilli counts (<1,000 cfu/g target)
- Use of specific competing culture bacteria for gram negative bacteria.
- Check pasteurized milk for various NSLAB (<1) .
- Fresh cheeses are particularly vulnerable.

Reducing Bitterness - Starter Cultures

- Fast starter cultures tend to be more proteolytic increasing bitterness chances. (Lawrence, 1972).
- *Lactobacillus helveticus* in numerous studies showed enhanced peptidolytic activity and reduced bitterness in low-fat Swiss cheese (Ardô et al., 1989) with *Lactobacillus helveticus* CNRZ 32 reducing bitterness in Gouda (Bartels et al., 1987) .
- Lactic acid bacterium *Lactococcus lactis* subsp. *cremoris* is known to possess a debittering activity by Piët et al. (1990).
- Advancements are continuing with culture houses with *Lactobacillus helveticus* recognized as one of the common de-bittering cultures.

*Bartels, H. Accelerated ripening of Gouda cheese. I. Effect of heat-shocked thermophilic lactobacilli and streptococci on proteolysis and flavor development. Milchwissenschaft, 42 (1987), pp. 83-88

*Ardô Y, et al (1989) Studies of peptidolysis during early maturation and its influence on low-fat cheese quality. Milchwissenschaft 44, 485-490.

*Lawrence, R. C. et al 1972. Cheddar cheese flavor. 1. The role of starters and rennets. N.Z.J. Dairy Sci. Tech. 7:32.

Reducing Bitterness - Rennet

- Microbial coagulants work very well for long hold, hard cheeses due to increased levels of proteolysis. However, they are prone to increase bitterness in young cheeses, especially those which are higher in Aw/moisture and/or low in S/M.
- The coagulant retained in cheese curd is a major contributor to proteolysis during ripening. The retention of chymosin in cheese curd increased significantly when the pH of milk was reduced at rennet addition below pH 6.1, the pH at whey drainage below pH 5.7 (Lemieux and Simard, 1992).

Reducing Bitterness - Make Parameters

- Calcium content – Control calcium levels in your cheese. Fresh cheeses especially prone to issues.
- Cook temperatures – Controls starter activity or can deactivate coagulant activity (cooker water stretch temperature).
- Molds/Smear selection – Be aware of impact of your specific ripening agents.
- Acid control – Increase in acidity (low pH) can increase bitterness.
- Ripening temps – Accelerating proteolysis can cause peptides to accumulate.
- Salt in moisture – Low S/M levels allow for more starter activity as well as post manufacture contamination issues.
- Potassium – Used as a sodium replacer or sea salts with various minerals.
- Good Graders - Grading program documenting bitterness amongst other defects or attributes at various time points.

Bitterness Bottom Line!

The most effective methods for bitterness control in cheese involve reduction of total proteolytic activity by ***culture selection***, use of mixed cultures, ***proper selection and use of coagulant***, and ***adjusting environmental factors (i.e. microbiological, temperature, pH, etc.)***. Thus, it is now possible to manufacture non-bitter cheese with accelerated ripening and produce dietetic enzymic casein hydrolysate with reduced bitterness. (Lemieux and Simard, 1992).

Acidity in Cheese

- Acidity is expected in some cheese varieties:
  - Feta
  - Chevre/Quark/Cottage/Cream Cheese
  - Cheshire
  - Cheddar (to some degree)
- Acidity as a dominant flavor is a “defect” in some cheeses:
  - Hard Italian
  - Swiss
  - Gouda
  - Mozzarella
  - Muenster/Brick/Havarti
  - Monterey Jack/Colby

IMPROPER ACID DEVELOPMENT

"Controlling acidity and moisture content— those are two of the really big keys to successful cheesemaking. A lot of cheese defects are from improper moisture content and improper rate and extent of acid development."

Dean Sommer – Winter 2020 CDR Dairy Pipeline

How Does Cheese Develop Excessive Acid?

Acid development occurs because the starter bacteria ferment the lactose in the milk and produce lactic acid, which drives the necessary reactions for cheesemaking. Excessive acid can be developed in part, through **fermentation of excessive lactose** in fortified milks, **loss of buffering capacity** due to excessive wet acid development, **ripening conditions**, or **lack of salt**. These are amongst the primary conditions in making a high acid cheese.

Excessive Acid Issues in Cheese

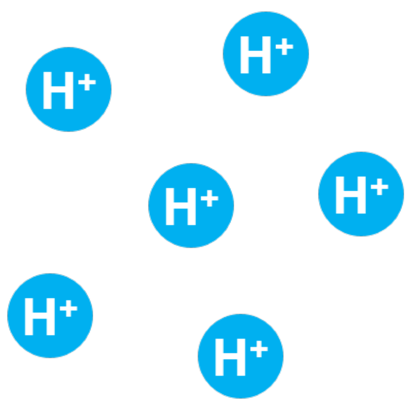
- Short/brittle cheese body that will not slice, shred, or cube.
- Results in pasty body in soft cheeses.
- Cheese will have grainy mouthfeel with an acid, sour, and bitter taste.
- Cheese will turn pale in color or more prone to pinking.
- Cheese loses serum during aging:
  - Cheese more prone to calcium lactate crystals on surface.
  - Cheese more prone to growth of microorganisms at the surface.

Causes of Too Much Acid Development

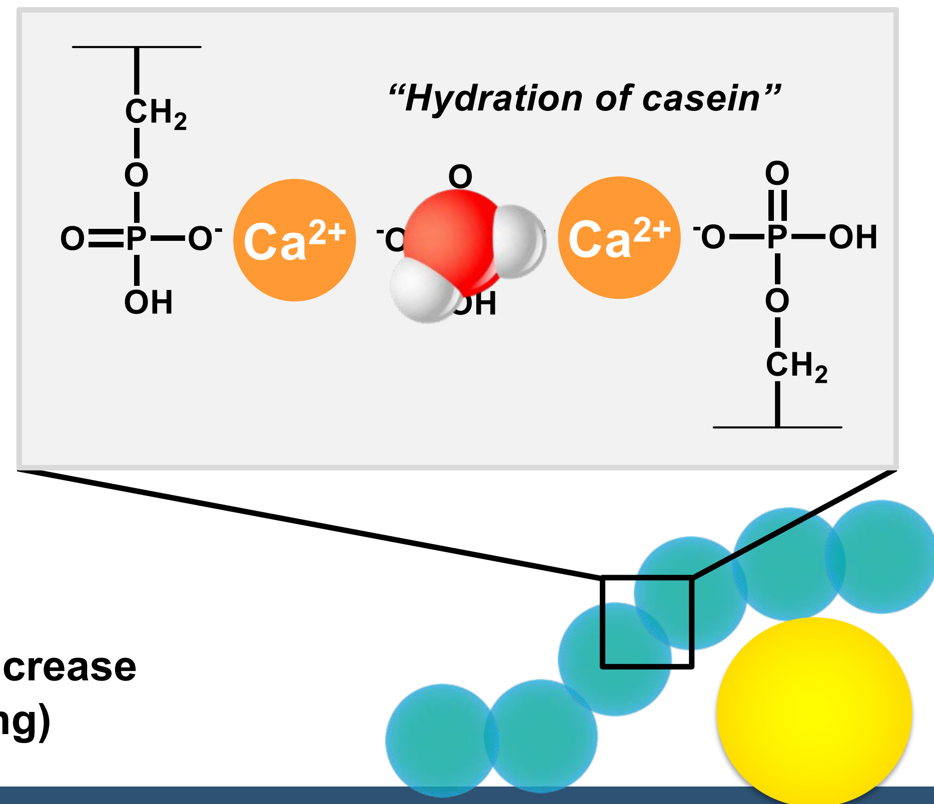
- Excessive lactose in milk:
  - Concentration of lactose through use of condensed milk, reverse osmosis (RO), NDM, or some secondary starters.
- Develop excessive “wet acid”, solubilizes calcium phosphate, resulting in loss of buffering capacity:
  - Use of aggressive cultures (fast acid producing cultures) / with high salt tolerance.
  - Use of acids to pre-acidity milk to low pH targets; citric amongst the worst if used at too high a level.

What is Buffering?

Acid being created…



Calcium displaced by H^+ (acid)



pH

5.3

← **pH will increase (buffering)**

Too Much Acid Development

- Too low drop in pH (~<5.00) within the first 24 – 48 hours.
- Low salt in moisture S/M phase (~<3.5%).
- Too much moisture in the cheese resulting in higher levels of lactose to be fermented by other heterofermentative lactobacillus.
- Too long a period or high temps when accelerating ripening.
- Too high lactic acid content; roughly ~>1200 mg/100 g cheese.

Reducing Acidity in Cheese

It's all about controlling fermentation!

Reduce Lactose

- Remove lactose from milk
  - Lactose standardization
  - Ultrafiltration/diafiltration
  - Microfiltration
  - Dilute milk with water
- Whey dilution
- Curd soak-wash
- Reduce moisture in cheese

Reduce Starter Activity

- Based on strain variability, inoculation rates, thermophilic vs mesophilic cultures, wet acid development, and salt sensitivity
- Avoid low pH at rennet addition/whey drainage
- Cool curd
- Adjust salt levels

Big Mistake Industry Makes to Correct for Acid Cheese!

A lot of cheesemakers rely on dry acid and will hoop their Cheddar when it has a pH between 5.8-6.0. "I'd run screaming out of the door if I saw that," Why? Because, if a cheesemaker develops acid in the milk or curd/whey (wet acid) then a lot of the lactic acid will go in the whey and will be removed when the whey is drained. Conversely, if acid is developed in the hoop (dry acid) where will that lactic acid go? It will stay in the cheese. This results in an acid Cheddar that is more likely to develop a bitter taste, whey taint flavors, and defects like calcium lactate crystals.

Dean Sommer – Winter 2020 CDR Dairy Pipeline

Blake, A. J., et al. 2005. Enhanced lactose cheese milk does not guarantee calcium lactate crystals in finished Cheddar cheese. J. Dairy Sci. 88:2302-2311.

Calcium Lactate Crystals on Cheese

- Is it a friend?
  - Many artisanal cheese connoisseurs believe it to be a sign of a good flavored and textured aged cheese
  - Small distributed aggregates may be preferred to a complete cover of crystals.
  - Common on aged cheeses such as aged Cheddar, aged Gouda, and Parmesan.

- Is it a foe?
  - While the crystals are relatively harmless, consumers often confuse the crystals with broken glass, yeast, or mold growth which implies a defect.
  - Is occasionally found on smoked cheeses surfaces.
  - Also occur in pasteurized processed cheese, associated with emulsifying salts, lactose powders, or preformed crystals in ingredient cheese.

Calcium Lactate Crystals

- Calcium lactate crystals, or calcium lactate pentahydrate (CLP) are white crystals found on the surface of rindless, ripened cheeses such as Cheddar, Gouda, and Colby.
- There are two forms of CLP:
  - **L(+)- lactic acid = Very soluble**
  - **D(-)-lactic acid = Very insoluble**

Development of Lactic Acid

- Starter bacteria ferment lactose to lactic acid and depending upon the strain of starter bacteria produce:
  - Mesophilic *Lactococcus* sp. (Cheddar and Colby) starters and Thermophilic *Streptococcus* sp. (Italian cheeses, Swiss) starter only produce L(+)-lactic acid (soluble).
  - *Lactobacillus delbrueckii sp. bulgaricus* and *Leuconostoc* sp. produce only D(-)-lactic acid (not soluble).
- Some NSLABs can convert L(+)-lactic acid to D(-)-lactic acid through a process known as racemization.

Cheesemaking and Calcium Lactate

- High NSLAB counts in raw milk (>1000 cfu/g) which survive pasteurization can mean problems:
  - >1 cfu / g produced from NSLABs in pasteurized milk can convert L(+)-lactic acid to D(-)-lactic acid (the insoluble lactic acid).
  - Biofilms made up of NSLABs are an issue.
- High lactose loads in some fortified milks can mean problems:
  - Historically NDM, Reverse Osmosis (RO), or condensed skim used to fortify milk resulting in elevated lactose levels in the serum phase carrying residual lactose to the finished cheese.
  - UF WILL remove SOME lactose but still CONCENTRATES some, but only to levels typical of normal milk. E.g. ~ 16% solids will equal ~ 4.7% lactose.
  - Concentrated milk maybe more prone to crystal formation due to higher calcium levels found in the milk.

Cheesemaking and Calcium Lactate

- Starters and Non-starter bacteria impacts:
  - Traditional mesophilic *Lactococcus lactis* starter cultures used in Cheddar cheesemaking produce only the more soluble L(+)-lactic acid through lactose fermentation.
  - Many researchers in different labs correlated crystals with racemization occurring because of the metabolism of certain nonstarter bacteria such as *Lactobacillus* sp and *Pediococcus*.
- Higher level of lactic acid development in the cheese
  - High lactose in milk.
  - Fast acid development.
  - Generally higher than ~ 1200 mg/100g sample. BUT this is arbitrary and not a guarantee either direction!

Cheesemaking and Calcium Lactate

- Wet acid development and salting pH (Dean's comment!)
  - It is critical to remove as much lactose from the cheese in the vat. This is achieved by using a starter that vigorously acidifies the curds before drainage and milling.
  - Blake et al. (2005) recommended drainage pH of 6.0 and milling pH of 5.3. This effectively allows the manufacturer to remove large quantities of lactate from the curds in the drained whey before pressing seals the cheese.
  - Lower drain and milling pH's promote the dissolution of colloidal calcium phosphate and the subsequent removal of the soluble calcium in the drained whey (Swearingen et al., 2004). This removes more lactose and calcium from the cheese matrix.

Swearingen, P. A., et al. 2004. Factors affecting calcium lactate and liquid expulsion defects in Cheddar cheese. J. Dairy Sci. 87:574-582.

Cheesemaking, Composition, and Calcium Lactate

- Salt content
  - Low salt in moisture (S/M) typically results in cheese with lower pH which decreases protein's ability to hold water during aging.
  - Usually <3.5% S/M or roughly <1.2% salt at ~37% moisture However even if range is met it is difficult to prevent CLP.
- pH
  - Lowest pH point will dictate cheese acid level and texture
  - Usually, <5.0 is a concern.
- Lactose
  - Residual lactose is a problem.
  - Salt sensitive cultures, phage, or cold curd can result in residual lactose.
  - NSLAB's can ferment residual lactose causing development of D(-)-lactic acid.

Development of a Crystal

- Calcium lactate formation is related to:
  - temperature, pH, amount of water ie. drying of surface.
  - “sweating” enhanced by low pH, proteolysis, high salt, too much calcium bound to casein, warm temperatures (fluctuating temperatures).
  - “seed crystal” or a small preexisting calcium lactate crystal gets larger which causes a larger formation of crystals.
  - seed crystals can be precursor to crystals on processed cheese (along with emulsifying salts).

Ripening, Conversion, and Packaging Impact on Calcium Lactate

- Temperature cycling (warm to cool) can increase crystal formation when it causes serum separation at the cheese surface or stimulates the growth of racemizing nonstarter bacteria that, in turn, convert L(+)- to D(−)-lactate (Agarwal et al., 2005; Rajbhandari et al., 2013).
- However……lower storage temperature generally results in a greater risk of CLP crystallization due to lower CLP solubility (Pearce et al., 1973; Johnson et al., 1990a,b; Chou et al., 2003).

*Rajbhandari, P. et al. 2005. Compositional factors associated with calcium lactate crystallization in smoked Cheddar cheese. J Dairy Sci. 88(11):3737-3744.

*Johnson, M. E., et al. 1990a. Effect of packaging and storage conditions on calcium lactate crystallization on the surface of Cheddar cheese. J. Dairy Sci. 73:3033-3041.

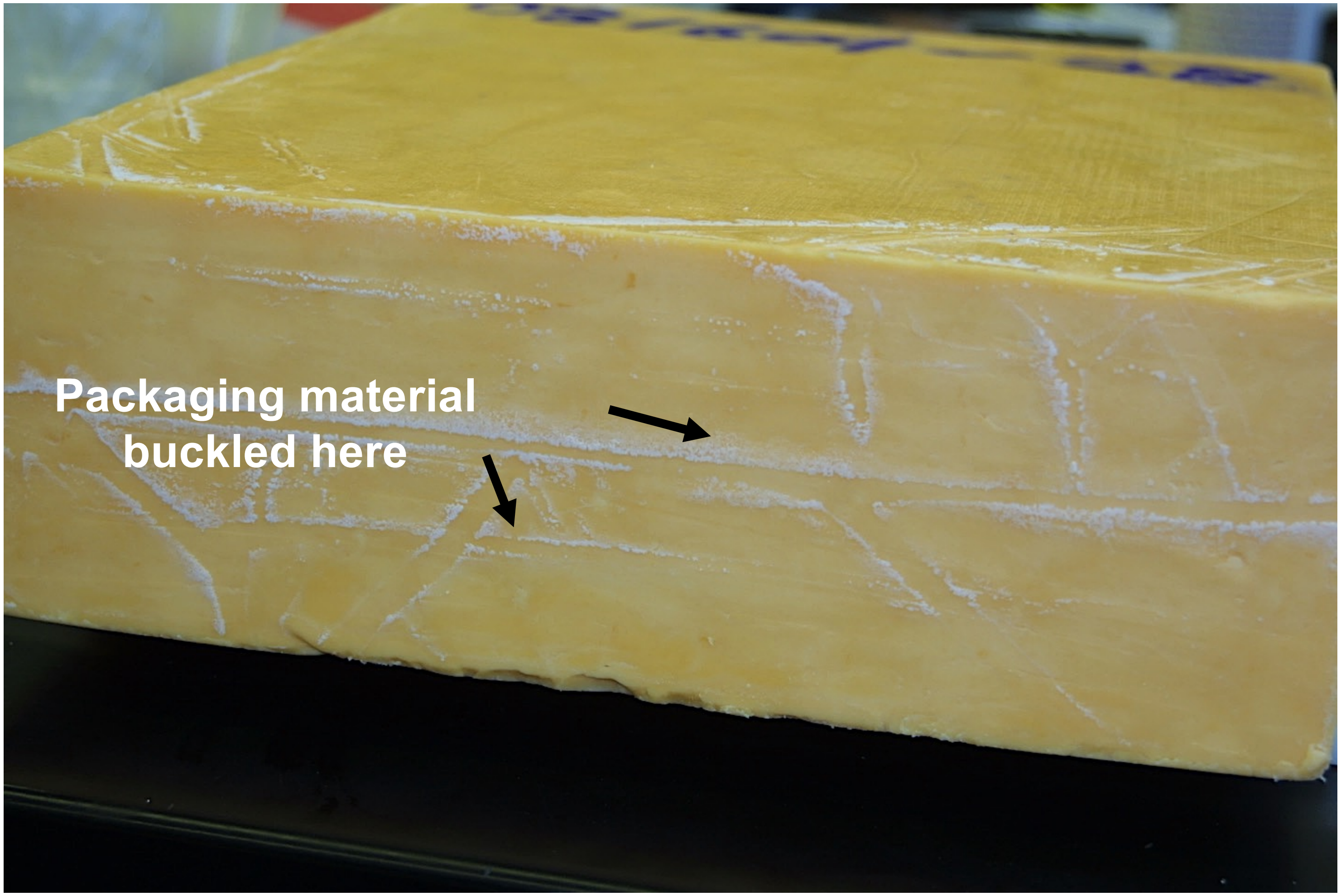
*Johnson, M. E., et al. 1990b. Influence of nonstarter bacteria on calcium lactate crystallization on the surface of Cheddar cheese. J. Dairy Sci 73:1145-1149.

Conversion and Packaging Impact on Calcium Lactate

Rajbhandari and Kindstedt (2014) demonstrated that cheese samples that were etched to create rough surfaces developed much greater CLP crystal coverage than samples with smooth surfaces when both were packaged loosely and stored at 39ºF.

Conversion and Packaging Impact on Calcium Lactate

- Johnson et al. (1990) first reported that much greater CLP occurred on consumer-sized cheese samples that were wrapped loosely (no vacuum treatment) than on samples that were vacuum packaged tightly.
- Johnson et al. (1990) compared vacuum packaging and gas flush. Those cheese packaged with CO_2 developed crystals earlier, and the crystals intensified more rapidly, than samples that were vacuum packaged tightly.


Packaging material
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Conversion and Packaging Impact on Calcium Lactate

- Longer cheese is in package= greater chance of developing crystals i.e. (not just age of cheese)
  - Cheese cut and packaged at 1 mo and aged 8 mo in package had a greater chance of developing crystals than the same cheese cut and packaged at 5 mo and aged 4 mo.
- Longer pull dates are an issue
- Cheese drying on the surface increases crystal formation

Conversion and Packaging Impact on Calcium Lactate

- Agarwal et al. (2005) compared tightly vacuum-packed Cheddar cheese samples with samples packed loosely by flushing with pure carbon dioxide, a 50:50 mixture of carbon dioxide:nitrogen, or pure nitrogen gas.
- Carbon dioxide in the headspace after sealing dissolved into the serum phase at the cheese surface, causing a decrease in pH due to the formation of carbonic acid. This allowed for crystal formation.
- Vacuum packaged tightly displayed little or no surface crystallization, even when cheeses contained a racemic mixture of D(−)- and L(+)-lactate. Loosely packaged gas-flushed samples developed intense CLP crystallization.

Agarwal, S., M. Costello, and S. Clark. 2005. Gas-flushed packaging contributes to calcium lactate crystals in Cheddar cheese. J. Dairy Sci. 88:3773-3783.

Calcium Lactate Crystals in Smoked Cheese

- Crystallization of L(+)-CLP may also occur at the surface of consumer cuts of naturally smoked Cheddar cheese with little or no D(−)-lactate.
- Natural smoking causes a dry acidic environment on the cheese surface, elevating levels of L(+)-lactate and calcium ions in the serum phase. (Rajbhandari and Kindstedt, 2005; Rajbhandari et al., 2009).

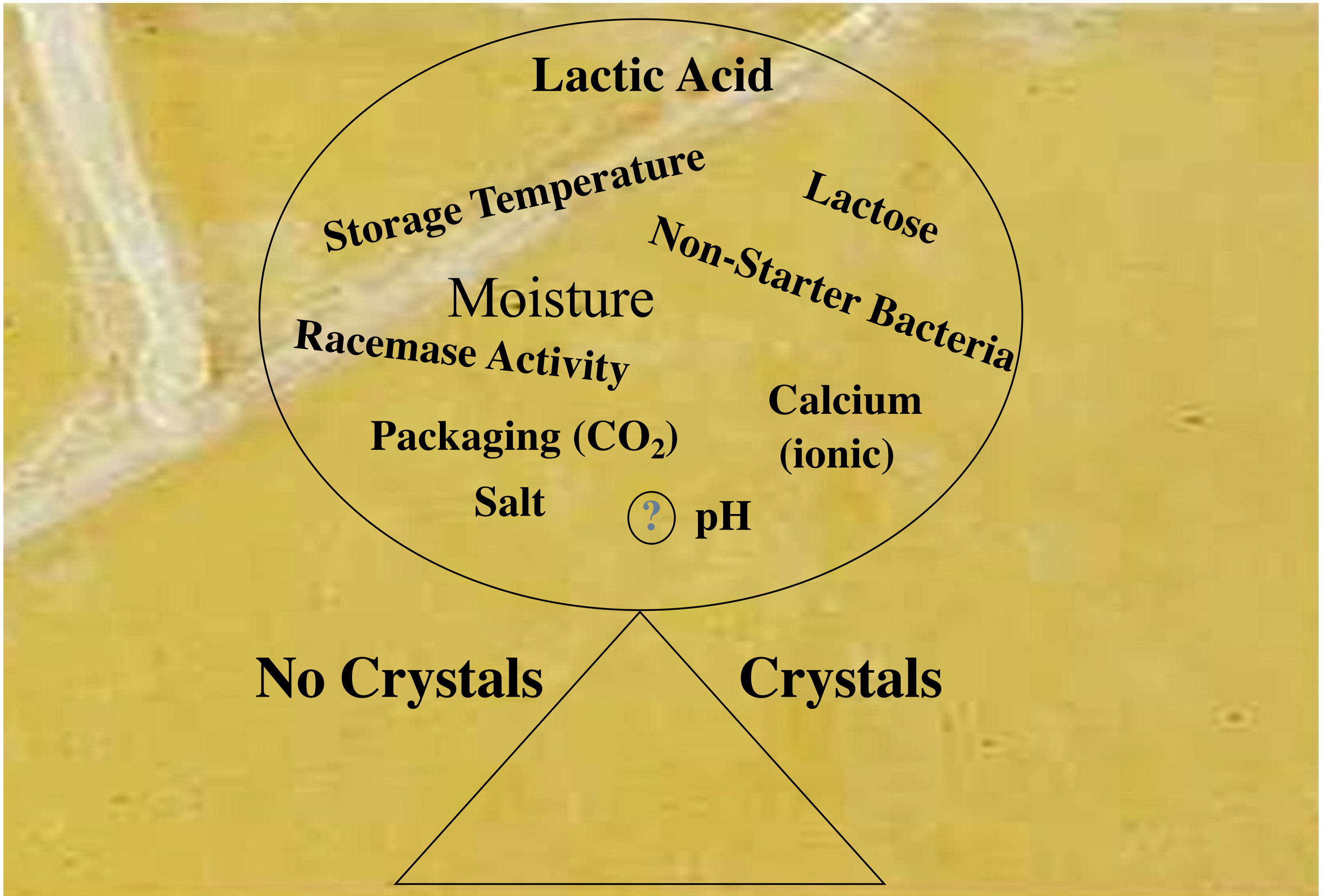
CLP Fixes Many Times are Rebuffed by Industry

- Milk concentration at high levels (>4% total protein) are currently used in most large facilities for plant efficiency.
- Some have issues with preacidification which solubilizes some calcium.
- Whey dilution or curd soaks, used in the 1980s are no longer economical given water volume needed and removal at the whey plant.
- Slow acid producing cultures are not practical given increasing milk volumes being run through the cheese plant.
- Today, thermo/meso culture blends used for fast makes leave unfermented lactose which become fermentation targets.
- Vacuum packaging is the normal method used.
- Lactose standardization is a viable alternative but not currently used in the industry.

Sodium Gluconate and Calcium Lactate

- Considered as a GRAS (Generally Recognized As Safe ingredient) that increases calcium lactate solubility through formation of calcium-lactate-gluconate complexes or calcium chelation (Phadungath and Metzger, 2011; Johnson, 2014).
- The presence of gluconate increases the solubility of calcium lactate.
- Added at a rate of ~2% per 1000 pounds of cheese.
- Preferred addition of sodium gluconate is after the final conventional salt application.
- Addition of sodium gluconate reduces lactic acid production, increases pH, increases moisture, and limits moisture migration in 640s.
- Can result in unfermented lactose which could cause gas or other issues.
- Cheese body softens due to calcium chelation. Can be positive or detriment.
- Flavor development can be impacted in long hold cheeses.
- Gluconic acid levels in cheese range from 0.26 to 2.8%.

Phadungath, C. Effect of sodium gluconate on the solubility of calcium lactate. J. Dairy Sci. 94(10): 4843-4849



Lactic Acid
Storage Temperature
Lactose
Non-Starter Bacteria
Moisture
Racemase Activity
Calcium
(ionic)
Packaging (CO_2)
Salt
? pH
No Crystals
Crystals

Bottom Line!

At the end of the day, it all comes down to basic cheesemaking practices. Good quality milk. Good ingredients. Good sanitation. Good GMP's. Watch CCPs such as initial milk pH, set pH, rennet pH, salting pH, pH at ~ 7 days. Keep good make records. Reliable compositional analysis. Proper packaging and package integrity. Evaluate your cheese. Have well trained motivated employees.

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