SOFT-RIPENED CHEESES

FROM

COW AND GOAT MILK

APRIL 16-17, 2005

THE TRAINING CENTER FOR
FARMSTEAD MILK PROCESSING

ASCI 201 FERMENTED DAIRY FOODS
LABORATORY EXERCISE 2
CHEDDAR CHEESE MANUFACTURE

INTRODUCTION

Cheddar cheese is a "sweet curd" cheese, which means that milk coagulation occurs at relatively high pH (i.e. about pH 6.50 - 6.60) due to the action of rennet enzymes. As with most cheeses, the rate of acid development during the manufacturing process is critical to Cheddar cheese quality. Of particular importance is the so-called "wet acid", i.e., acid produced before the whey is drained from the curd. If wet acid develops too quickly a number of problems will ensue: 1.) excessive calcium phosphate will be dissolved from the curd, thereby depleting the curd's buffering capacity and leading to abnormally low curd pH and defects such as bitterness, acid (sour), and crumbliness. 2.) Moisture removal becomes more difficult, thereby increasing the risk of excessive moisture in the final cheese and defects such as bitterness, pastiness, and weak body. Excessive "wet acid" is probably the most common cause of defects in Cheddar cheese.

On the other hand, serious defects also may result if acid development is too slow. Slow acid development means that the starter culture is not reproducing and metabolizing as quickly as it should. In this situation, unwanted contaminating organisms such as *E. coli* or worse, *Staph. aureus*, may be able to compete favorably and attain high numbers in the developing curd. The former may lead to gassiness and unclean flavor in the resulting curd while the latter may lead to a food poisoning outbreak. To make matters worse, slow acid development often results in curd with abnormally high pH, which tends to favor growth of unwanted contaminants. Thus, from a public health standpoint slow acid development is potentially much more dangerous than fast acid development.

A schedule for acidity development (pH and TA) for Cheddar cheese is shown in Figure 1. Following a schedule such as this will help insure that acid is produced at the proper rate at any given stage of the cheesemaking process. Inexperienced cheesemakers should refer to this schedule frequently during cheesemaking to gage whether acidity is developing "on time."

A number of factors govern the rate of acid development during cheesemaking. Among the more important are:

1. Starter inoculum size. The more starter culture added at the beginning of cheesemaking the faster the acid development. Since bacteria reproduce exponentially, a surprisingly small increase in starter inoculum size can lead to a surprisingly large increase in the rate of acid development. So beware!

2. Ripening time. After starter culture is added to the milk but before rennet is added, there is usually a period of 30 - 60 min, called the ripening time, during which the starter becomes acclimated to the milk, begins to reproduce, and produces a small amount of acid. If this ripening time is extended too long, starter numbers become too high too early in the cheesemaking process. Because bacteria reproduce exponentially, higher than normal starter population early in the cheesemaking process accellerates into much higher than normal starter population and much higher than normal acid development as cheesemaking progresses. Conversely, if ripening time is decreased, e.g. to 15 min., acid development throughout the cheesemaking process will be slower.

3. Cooking temperature. Starter bacteria, like all bacteria, have minimum, optimum, and maximum temperatures at which they will grow. Often, a few degrees difference can make a huge difference in starter growth rate and acid production. For example, SL/SC cultures used in Cheddar cheesemaking typically grow vigorously at 100 - 101°F but are completely inactivated at 104 - 105°F. Cheddar cheese generally is cooked at 100 - 102°F. Cooking at a lower temperature will tend to speed up acid development, while higher temperatures will slow it down or halt it altogether.

Unfortunately, control of acidity is not the only challenge facing the Cheddar cheesemaker. Another critical area is moisture control. Throughout the cheesemaking process, steps must be taken to insure that the finished curd falls within the narrow moisture range requisite for proper ripening. Among the more important steps used to control moisture are 1.) size of curd cut; 2.) cooking temperature; 3.) cooking time; 4.) cheddaring time; 5.) curd piling; 6.) salting rate. To complicate matters, some of the practices used to control moisture also influence the rate of acid development. Thus, it becomes a balancing act to control both moisture and acidity. It can be done, but it requires experience. "Book knowledge" alone is not enough.

OBJECTIVES

1. To manufacture Cheddar cheese.

2. To gain experience with manufacturing techniques that are used to control and optimize Cheddar cheesemaking.

MATERIALS

1. Milk - Pasteurized, unhomogenized whole milk (3.5% fat)

2. Starter Culture - Mesophillic lactic culture (blend of *L. lactis* and *cremoris*) 1.0 g / 220 lbs milk

3. Coagulant - Calf rennet (single strength)

PROCEDURE

Cleaning and sanitizing

1. The cheese vat must be cleaned and sanitized before use. First, rinse the vat with warm (ca. 100°F) water. Drain.

2. Fill vat about one-fourth full with hot (ca. 140°F) water. While filling, add enough detergent to give good foaming.

3. Thoroughly scrub all surfaces within the vat using a plastic-bristled brush. A green scrub cloth can also be used. **NEVER USE STEEL WOOL ON A CHEESE VAT OR UTENSILS.**

4. Drain detergent solution and rinse thoroughly with hot (140°F) water.

5. Measure 10 gal of cold water into the vat, add enough sanitizer to give 100 PPM available chlorine, and rinse down the sides of the vat for 5 min. Drain completely.

Cheesemaking

1. Obtain pasteurized skim and pasteurized cream from the dairy plant cooler.

2. Adjust the cheese vat jacket temperature to ca. 110°F. Determine the amount of cream and skim needed to give 220 lb of 3.5% fat milk. Weigh the correct amounts of skim and cream into the vat.

3. Stir milk continuously until the vat temperature reaches ca. 85°F. Immediately cool the vat jacket to 90°F.

4. Measure the pH and TA of the milk in the vat. Weigh out the correct amount of SL/SC starter culture as specified by the instructor. .265

5. Mix the starter with ca. 1 gal of cheese milk and mix thoroughly. Then add to the vat and stir for 5 min.

6. Measure TA every 15 min. Proceed to the next step when the TA increases by 0.005 - 0.01% from the initial reading or after 60 min, which ever comes first.

7. Dilute rennet (90 ml/1000 lb milk) 1:20 in cold distillled water. Immediately distribute diluted rennet throughout the milk and stir vat for 3 min.

8. Allow milk to remain completely still for 30 min. Check the coagulum for curd strength periodically using a spatula.

9. Cut curd when coagulum splits cleanly with a spatula. Horizontal cut lengthwise first. Then verticle cut lengthwise followed by verticle cut crosswise.

10. Allow the curd to "heal" for 5 - 10 min. In the meantime, measure PH and TA of the whey.

11. Begin cooking by slowly raising the vat temperature to 101 - 102°F in 30 min. During the first 10 min the temperature of the whey should increase only 2° per 5 min. Stir constantly.

12. Continue cooking at 101 - 102°F with periodic stirring until the whey TA increases 0.02% above its original value. Then drain off the whey. It should take about 1 hr and 45 min to 2 hr from the time the curd is cut until the whey is drained.

13. Trench the curd as the whey drains off and allow it to mat for 15 min. At that time, cut the curd at 6 - 8 inch intervals, turn the curd slabs over, and measure pH and TA of the whey collected at the vat exit.

14. Maintain the vat jacket temperature at 101 - 102°F and turn the curd blocks over every 15 min.

15. When the pH of whey exiting the vat reaches 5.40 - 5.30, adjust vat jacket temperature to 90 - 92°F and mill the curd blocks into "fingers" using the large knife and cutting board.

16. Allow the curd fingers to dry with periodic stirring for 15 min. Then salt the curd using 3.0 lb of coarse salt per 100 lb of curd. Salt should be added in 3 equal portions 10 min apart, with thorough stirring after each addition.

17. Line a 20-lb Wilson hoop with cheese press cloth and fill with curd fingers.

18. Place the filled hoop into the hydraulic press and slowly apply pressure up to 40 psi. Hold at 40 psi for 45 min.

CHEESEMAKING CHART

(Explanations on reverse side)

DESCRIPTION

Amount of starter may range from less than ½ % to 1 % or more — see back of chart for further explanation.

Ripening time may range from a few minutes to 1 hour or more.

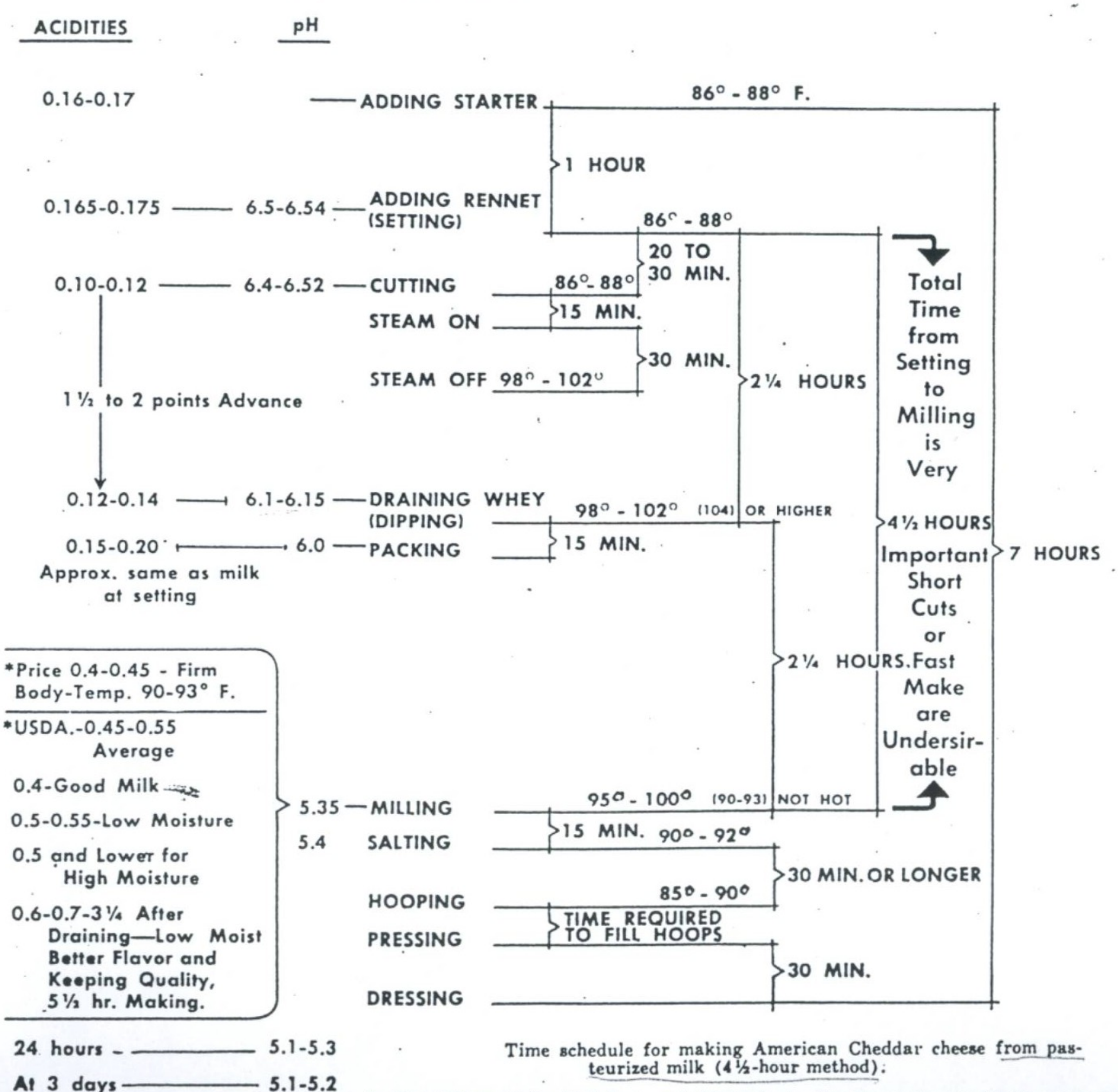
Cooking should be slow but steady and regulated to prevent excessive hardening of the outside surfaces of the curd, causing whey pockets and incomplete firming.

Final cooking temperatures may range up to 104° F. and above for desired firming.

Packing acidity may be as low as 0.15 % with cultures that produce acid fast in dry acid stage. However curd should be properly firmed at the time of draining.

Tolerances in acid production are tied very closely to solids content of milk, time of manufacture, moisture content of curd and purposes for which cheese is made—whether for early consumption, medium or long cure. Temperature and method of curing are also important. Cheese buyers should be consulted frequently for information on properties desired.

Too much wet acid or dry acid may produce sour or bitter flavors. pH should not be below 5.0 at any time.



Time schedule for making American Cheddar cheese from pasteurized milk (4 ½-hour method).

* Ref: Wilson H. L., Hall S. A., and Rogers L. A., The Manufacture of Cheddar Cheese From Pasteurized Milk, Jr. Dy. Sci., 28: 187-200 —Lochry H. R., Sanders G. P., Malkames Jr. J. P. and Walters H. E., Making American Cheddar Cheese of Uniformly

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GOUDA

Approx. Time	Make Procedure
0	Raw Milk at 86-88 °F, add 0.25-0.5% Rosell Aroma B bulk starter or direct-vat-set EZAL MM100, MM101 or BT002: 1 unit per 50-100 lb. milk Ripen milk for 30 minutes.
30 min.	Add 9 ml single-strength rennet (goat and cow milk) or 5 ml single-strength rennet (sheep milk)
70 min.	Check curdling time and cut the curds into 3/8" cubes after 3 x the curdling time. Check for clean break before beginning to cut. Heal curds for 5 min. before beginning to stir.
75 min.	Gently stir curds in whey for 15 minutes while keeping 86-88 °F.
1 1/2 h	Let curds settle to the bottom and push away from the front to clear the valve. Drain off whey equal to one third of original milk volume by dipping or using a curd gate and draining out of the valve. Add 130 °F water while stirring curds in an equal volume to replace the whey. Add water in two stages: first raise the temp to 95 °F and stir for 5 min. second add the remaining water to raise the temp further so that the final temp. should be 98-102 °F depending on the cheese moisture content desired.
1 h 45 m	Stir and cook for 30 minutes at 98-102 °F.
2 h	Let curds settle to the bottom of vat for 5 min. and then push and draw the curds towards the back of the vat to form the desired depth of the curd pack. Drain off whey/water until the curd pack is covered by 2 " and place a perforated press plate on top. Add 1 lb. weight per 1 lb. curd, equally distributed to press the curd pack.
2h 15 m	Press curds under the whey for 15 minutes.
2 1/2 h	Drain off the water/whey and remove weights and press plate. Cut blocks from the pack to fit directly into cheese hoops. Place on followers and begin pressing with 1 1/2 lb. weight per 1 lb. cheese. Use up to 3 lb. weight per 1 lb. cheese.

4 h Remove cheeses from press, turn over, and put back in hoops. Return to press.

6 h When acidity is 35-40 degrees or pH 5.4-5.5,
Remove cheeses from press and place in a cool (50 F) room overnight and then in a saturated brine the next morning or place immediately in a saturated brine for 3-4 hours per lb. of cheese depending on desired salt content.
Alternatively, rub cheese wheels with coarse flake dry salt once per day for each 3 lb. of cheese.

<u>Aging</u>

Drying: After brining or salting, wheels are air dried until the surfaces are dry but not cracked; rinds that are cracked will allow molds to penetrate the cheese. A room with 80-85% RH and 50-60 °F is required. The cheeses can be waxed as soon as the surfaces are dry enough.

Curing: Wheels are stored at 50-55 °F and 85-90% RH for at least 60 days. Cheeses in wax will last 6 months.
If a natural rind is desired, the cheeses must be cleaned periodically to remove unwanted molds. This can be done with a cloth or disposable sponge dipped in 2-3% warm brine solution. After approx. 30 days it is possible to use a brush for cleaning.
If the cheese has a natural rind, it can be aged indefinitely as additional moisture will be lost, which slows down microbial activity during curing. Aged Dutch Gouda is available which is 4 years old.

Notes: The higher the temp. during drying and aging, the greater chance the eye development. A slice of Gouda typically has a few pea-sized eyes.

Composition: 41-42% Moisture
48-50% Fat-on-dry-basis

Tomme Style Cheese

Heat milk to 90 F.

Add starter culture. For raw milk use (for pasteurized milk use twice these amounts):
EZAL MA 400.0 or EZAL MA 400.1
use 1U for 500 lb. milk

or MM series (for more gas production) + TA050 (S. thermophilus)
use 2U (1/tsp.) for 500 lb. milk + 1/4U for 500 lb. milk

or Rosell Aroma II
Use 1/2% for pasteurized milk and 1/4% for raw milk

After 30 minutes add 9-ml single-strength rennet per 100 lb. milk.

Check for curdling time and multiply this by 3.5 to get the time from adding rennet to cutting.

Rest curd 5 minutes.

Begin heating: 1 °F every 3 minutes to 95 F, then 1 °F every 2 minute to 100 F.
Total heating time is 25 minutes.
Heat higher (up to 102 F) when milk solids are low and (down to 98 F) when milk solids are high.

Cook at 100 F for 5-30 minutes to firm curds until they are springy in the grip of your hand.

Let curds settle for 5 min., then drain off whey to the level of curds. Scoop curds into cheese hoops (round forms) lined with cloths. Knead curds into hoops, place follower on top and press with two lb. weight per one lb. curd.

After 30 min. remove weights, take cheese wheels from cloths, turn, replace cloths and press for one hour more. Repeat this procedure two more times.

After 3-4 hours of pressing turn cheese out of cloths and hoops. Cheese should have pH 5.7- 5.8. Move cheese wheels to cellar @ 55-58 F.

After 3-5 hours put cheese in saturated (23% salt) brine. Brine cheese for 4 hours per lb. of cheese. Finished wheels are 8-9 inch in diameter and 3 inches thick and weigh 5 lb.

Aging: After the cheese wheels are removed from the brine, place on shelves and turn every other day. Molds should be brushed or patted down. In about one month, the characteristic grey moldy coat will grow in. After this, brush the rind every few days to keep the rind from being too thick. Allow molds to grow at random but the brushing will create a more uniform appearance.
Three month minimum aging
4-5 months for more flavor
Older cheeses beyond 6-8 months of age are susceptible to mite infestation and will deteriorate in quality.

Recipe for Tomme de Savoie from The French Cheese Book by Patrick Rance

15 liters milk for 1.5 kilos cheese. A 1.2-2- kilo cheese is about 18 cm in diameter, 5-8 cm high. the crust should be grey with a spread of red and yellow (mimosa-like) moulds. Paste should be semi-hard, white to yellow, and may have tiny holes called "*trous de moulage*". 40 percent FDM minimum. Flavor should be full and slightly salty.

Raw milk is renneted at 86-91.5 °F

After 25-30 minutes, harping and stirring (temperature may be raised to 92-97 °F) curd is reduced to grain of maize size by further harping or by hand-breaking of curd.

Artificial introduction of bacteria or moulds and washing of curd is forbidden.

After the curd is placed in forms lined with very fine muslin, it is pressed for several hours to release remaining whey. It is then salted in a brine bath or by hand-rubbing.

After four or five days drying it goes into a dry *cave*. *Affinage* in *caves* within the duchy must last at least six weeks. The moulds develop on the coat and are rubbed in by hand every time the cheese is turned. For the first week they may also be rubbed with salt, rubbing then being daily. Rubbing gradually drops in frequency thereafter. "*La fleur*" develops naturally.

Historical:
"Tomme" is an ancient mountain cheese made in the winter when conditions confine the family to the house and cows to the barn. It is made in farmers households when milk production is limited. The milk cannot be taken to a creamery to contribute towards making big cheeses; nor can cheeses made from it be collected and taken regularly to market. So a cheese is needed that will keep until marketing is possible, to tide the household over the cheeseless period during calving. The cheese is often made from partially skimmed milk as the family would take of some cream for it's own needs.

These excerpts are from The French Cheese Book by Patrick Rance.

The Italian version of tomme is "toma," which also an alpine cheese and is made throughout the Italian Alps.

VARIETY CHEESE MANUFACTURING RECORD

PLANT: ____________________ CHEESE TYPE: ____________________ DATE: ____________________

MILK LBS.: ____________________ MILK TYPE: ____________________

STARTER AMT: ____________________ TYPE OF STARTER: ____________________

OPERATION	TIME	TEMPERATURE	% ACID	pH	COMMENTS

CHEESE	DATE	POUNDS	% FAT	% H_2O	pH	YIELD	GRADE
BEFORE AGING							
AFTER AGING							

FUNDAMENTALS OF CHEESEMAKING
(Features Common to all Cheeses)

General Composition of Milk

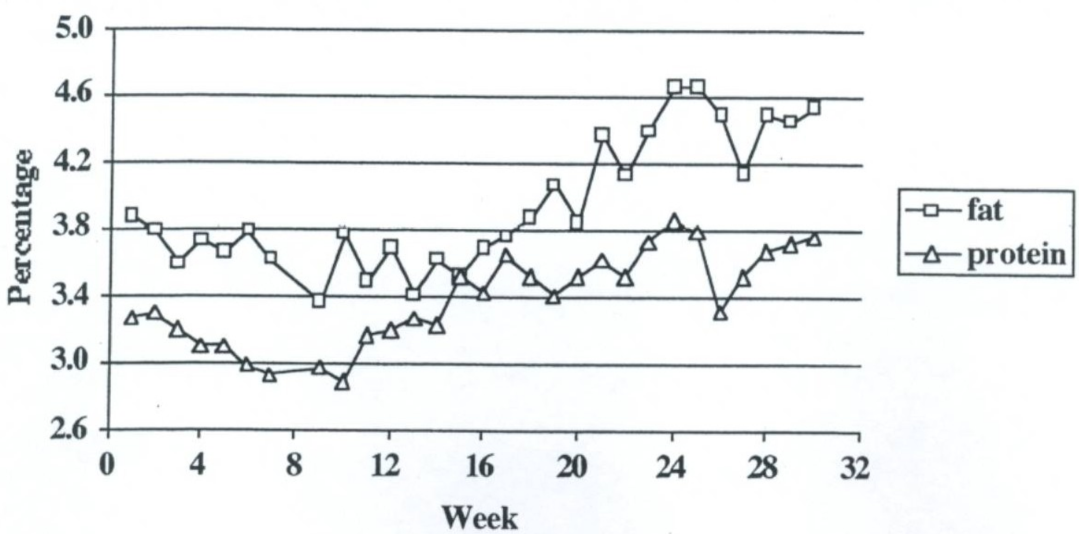
Milk is an extremely complex and highly perishable biological material. Successful handling and processing of milk for fluid (and frozen) use requires a thorough understanding of the properties of milk. Therefore, we will start our discussion by examining individual milk components and their properties.

1. Gross Composition

Component	% By Weight
water	87.0
lactose	5.1
fat	4.0
protein	3.2
salts(minerals)	0.7

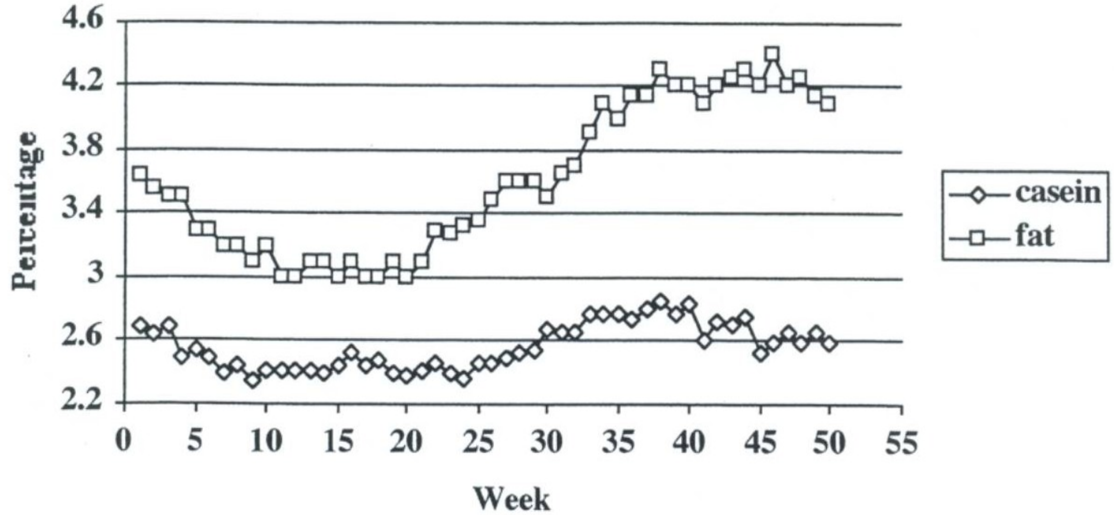
Note:** **These are "average values". Actual milk composition varies greatly among individual cows, breed of cow, season of year, stage of lactation, nutrition plane of cow, and many other factors including species (e.g., cow, goat, sheep).

Total protein and fat contents of farmstead cow's milk across season/lactation



Adapted from: P. Dixon. 1999. The effect of seasonal milk production on Cheddar cheese composition, quality and yield. M.S. thesis, University of Vermont

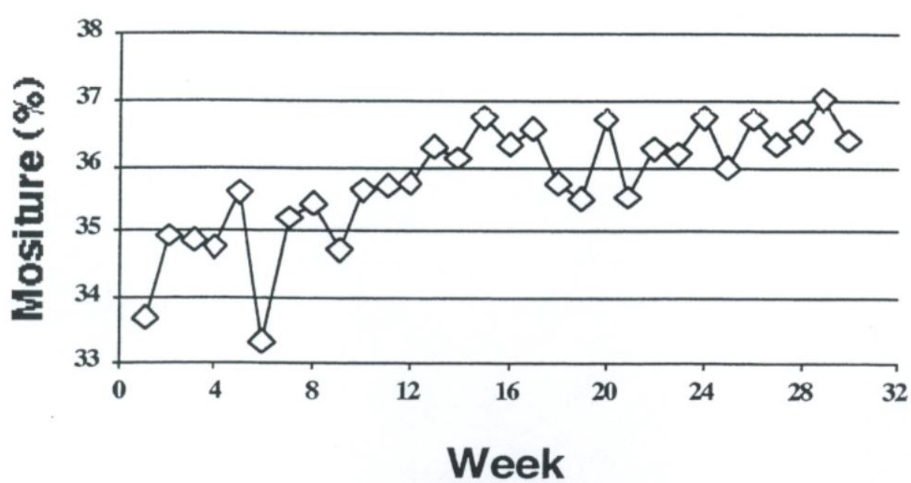
Casein and fat contents of commingled goat's milk across season/lactation



Adapted from: Guo, M.R., P.H. Dixon, Y.W Park, J.A. Gilmore and P.S. Kindstedt. 2001. Seasonal changes in the chemical composition of commingled goat milk. J. Dairy Sci. 84(E. Suppl.): 79-83

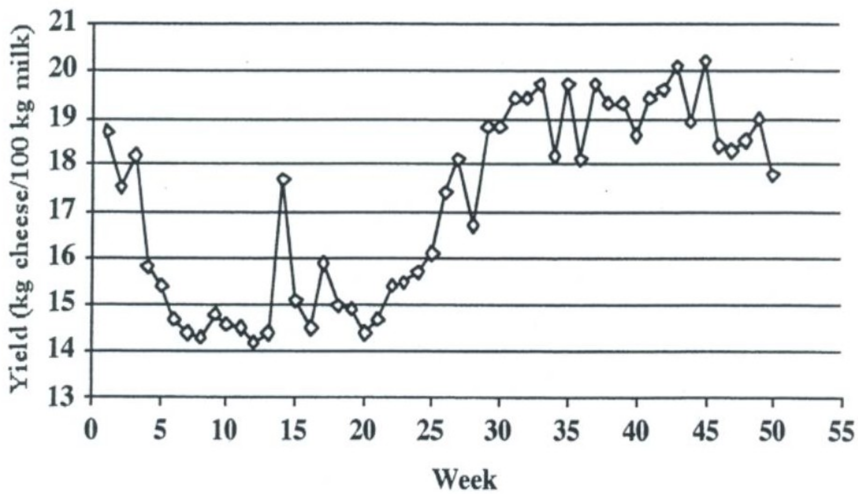
NOTE: When the composition of milk changes, the composition and yield of cheese will also change!

Seasonal variation in the moisture content of farmstead Cheddar cheese



Adapted from: P. Dixon. 1999. The effect of seasonal milk production on Cheddar cheese composition, quality and yield. M.S. thesis, University of Vermont

Seasonal variation in the yield of Chevre produced from commingled goat milk



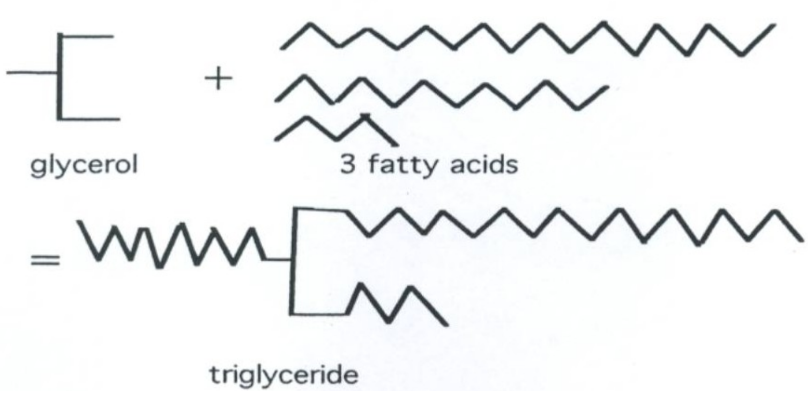
From: Kindstedt, P.S., M.R. Guo and P.H. Dixon. 2000. Is there a future for goat and sheep milk cheesemaking in the U.S.? J. Dairy Sci. 83(Suppl. 1):9

2. Selected Milk Components

A. Fat

- Mostly triglycerides (> 95%)

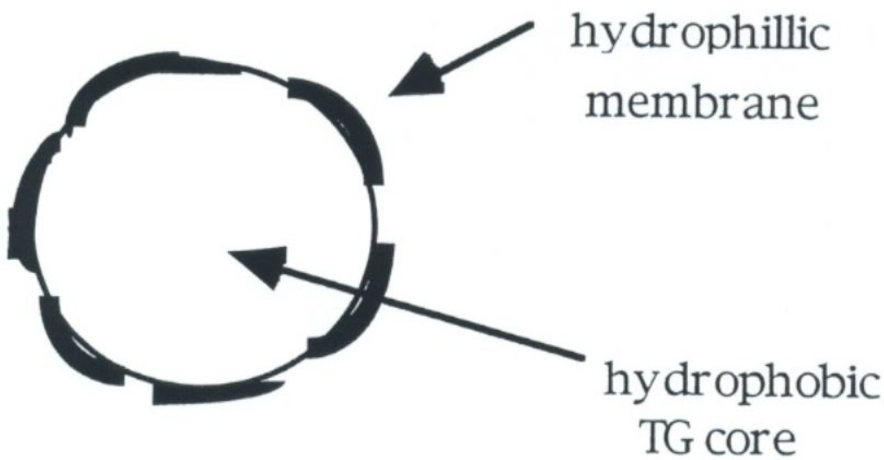
Shorthand schematic



- Fatty acid chains vary in length (2 - 28 carbons; most range from 4 - 18 carbons)

- Milkfat contains a high proportion of short chain fatty acids (C_4 - C_{10}). When short chain fatty acids are released from the triglyceride molecule, they assume powerful flavors and aromas that become very important in some cheeses.

- Milkfat exists as large globules (0.1 - 10 microns in diameter, ca. similar to bacteria). The globules contain an irregular surface membrane.



B. Protein

- **Caseins**

- Constitute ca. 80% of total protein in milk

- Coagulates at pH 4.6

- Coagulates at high pH (e.g., 6.5 - 7.0) under the action of the enzyme rennet.

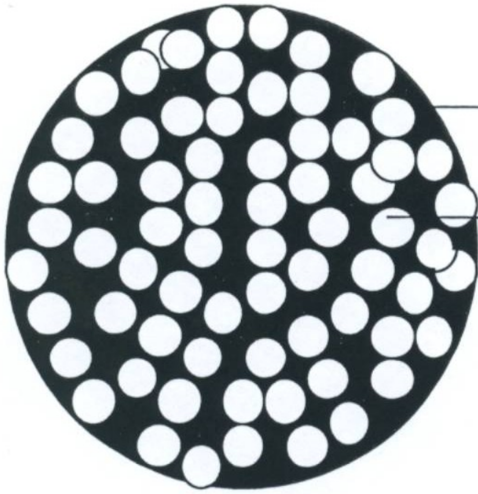
- Casein exists in a complex form called a micelle:

Casein Micelle Structure

- Individual casein molecules associated to form a spherical submicelle

- Submicelles aggregate to form a much larger spherical micelle

- The submicelles are held together as a micelle through calcium phosphate bonding



- about two-thirds of the total calcium in milk is contained within the casein micelles.

- Casein micelles act as a "sponge" that absorbs acid produced in the milk

- **Whey Proteins**

- Constitute ca. 20% of total milk protein

- Do not coagulate at pH 4.6 or due to the action of rennet. Therefore, they are released with the whey

C. Lactose

- Carbohydrate (milk sugar)

- Principal energy source for starter (and nonstarter) bacteria. The starter ferments lactose into lactic acid

- Lactose intolerance: lactose is soluble and therefore is lost with the whey. Only a small fraction of the lactose in milk is carried over into the cheese and most of the residual lactose in cheese is fermented during aging. Therefore, most cheeses do not pose a serious problem for individuals with lactose intolerance.

D. Salts (Minerals, Ash)

- Calcium:

- Constitutes about 30% of total milk salts

- About 1/3 of total calcium exists as ions in solution (Ca^{++})

- About 2/3 of total calcium is associated with casein micelles (as colloidal calcium phosphate)

- Phosphorus:

- Constitutes about 15% of total milk salts

- About 1/2 of total phosphorus is associated with casein micelles (esterified to casein an as colloidal calcium phosphate)

E. Enzymes

- Plasmin: (alkaline milk protease)
  - proteolytic enzyme, strongly attacks ß-casein at pH 6.7
  - activity increased with mastitis, late lactation
  - involved in regulation of milk synthesis; increases in late lactation
- Lipase
  - strongly attacks exposed triglycerides, producing free fatty acids
  - inactivated by pasteurization

Selective Concentration of Milk Components During Cheesemaking

During cheesemaking, some milk components are concentrated in the cheese curd while some remain partially or completely soluble and thus are removed from the curd as water is removed. The following table shows the selective concentration of milk components during Cheddar cheesemaking.

WHEY			CHEESE	
%	Lb	Milk (100 Lb)	Lb	%
95.5	83.1	water - 87 lb	3.9	4.5
96.0	4.9	lactose - 5.1	0.2	4.0
7.5	0.3	fat - 4.0	3.7	92.5
4.0	0.1	casein - 2.5	2.4	96.0
92.9	0.65	whey prot. - 0.7	0.05	7.1
50.0	0.35	salts - 0.7	0.35	50.0
40.0	0.048	Ca - 0.12	0.072	60.0
45.0	0.045	P - 0.010	0.055	55.0
96.0		Na - 0.06		4.0
	89.4	Total = 100 lb	10.6	

All cheeses are produced through selective concentration of milk components but the degree of concentration differs among cheese varieties.

The 8 BASIC STEPS IN CHEESEMAKING:

Step 1. Setting the Milk

Purpose

- To coagulate the milk

-Setting involves 2 biological agents:

1. Starter culture

Definition: Specific microorganisms (usually bacteria) which possess desirable characteristics when used in cheesemaking.

2. Rennet

Definition: Proteolytic enzyme(s)which causes rapid coagulation of milk under cheesemaking conditions. In many cheese types, rennet continues to be active during ripening and participates in cheese flavor and texture development.

-Setting can be accomplished in 2 different ways:

1. Acid coagulation (acid curd)

-Large starter inoculum added

-Little or no rennet added

-Starter produces acid, milk pH decreases

-Milk coagulates at isoelectric point of casein (pH 4.6)

- In the process of coagulation, the casein micelles are substantially depleted of calcium, resulting in a fragile curd that is unable to contract and expel moisture. This results in a cheese that is very soft and high in moisture.

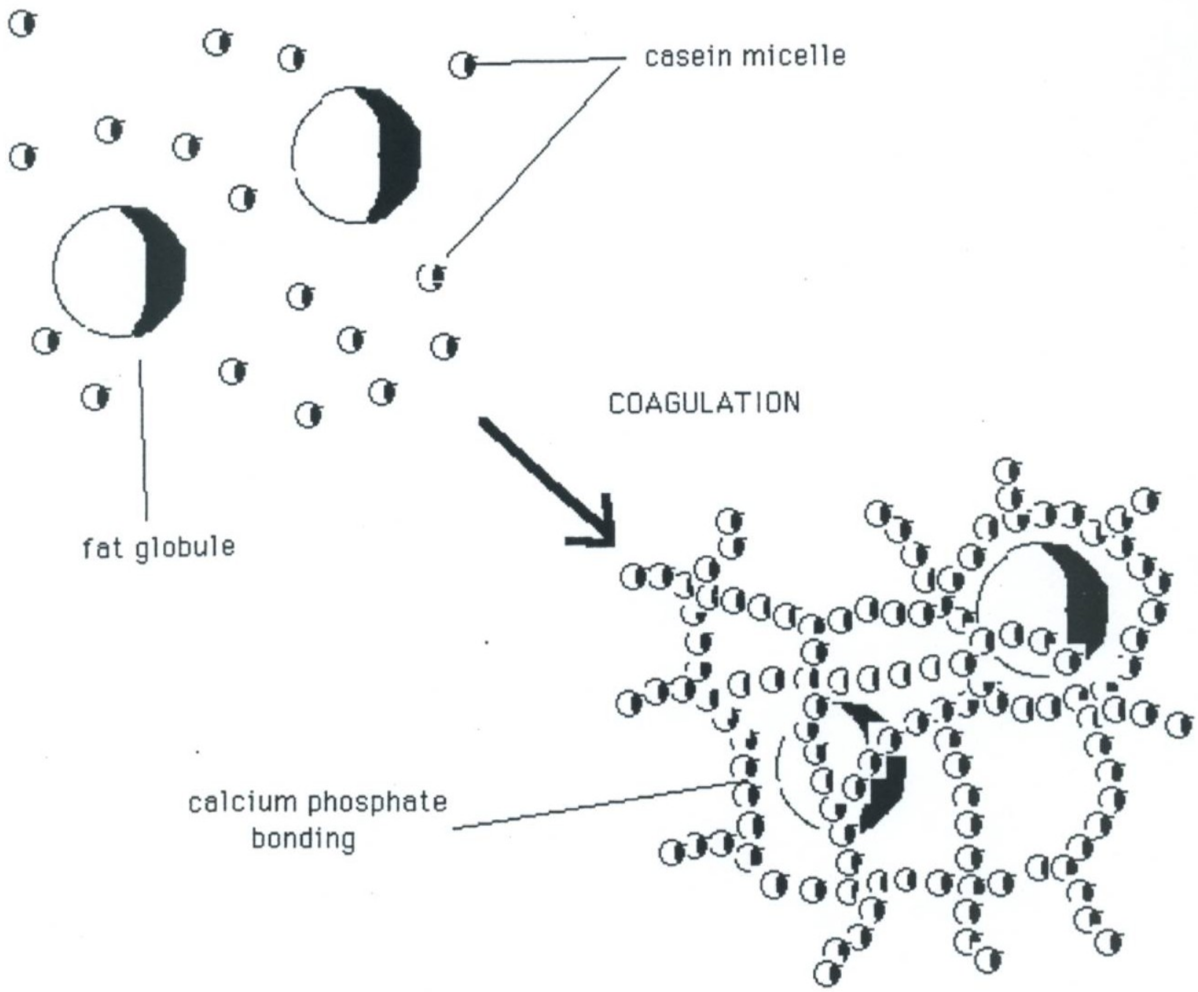
-Examples: Cottage, Farmers cheese, Cream cheese, Quarg

2. Rennet coagulation (sweet curd)

-Small starter inoculum added

-Addition of rennet causes milk to coagulate at a high pH (e.g. pH 6.5)

ILLUSTRATION OF MILK COAGULATION



Step 2. Cutting or Breaking the Curd

Purpose

- Increases curd surface area
- Facilitates uniform whey expulsion from curd
- Facilitates uniform heating (cooking) of curd
- Facilitates control of curd moisture

-Various utensils are used for curd cutting:

- Horizontal and vertical wire knives

  - wires strung across a rectangular steel frame at regular spacing (1/4 - 2 inch)

- Sword or saber
  -Used in the manufacture of traditional "Old World" cheeses such as Brie de Meaux. Used to make vertical cut only.

- Ladle or dipper

  -Used in the manufacture of traditional "Old World" cheeses such as Brie de Meaux. Used to make horizontal cut only.

- Break up curd

NOTE: Cutting initiates the selective concentration process that permits a solid cheese to be made from a liquid milk.

Step 3. Cooking the Curds

Definition: Heating the curd/whey mixture at a specific rate to a specific temperature for a specific time.

<u>Purpose</u>

- Facilitates curd shrinkage
- Facilitates whey removal
- Facilitates control of curd moisture
- Facilitates control of starter activity

Step 4. Draining Whey/Dipping Curds

Definition: Separation of curds from free whey. This can be accomplished in 2 different ways:

- Draining (running, draw): Whey is removed by draining through an exit valve at the bottom of the cheese vat. A metal strainer retains the curd in the vat. Examples: Cheddar, Mozzarella

- Dipping: Curds are removed from the cheese vat using a suitable perforated utensil (e.g. ladle) or cheesecloth. The curds are placed in suitable perforated forms and continue to drain while in the forms. Examples: Swiss, Camembert

<u>Purpose</u>

- Achieves permanent separation of curd from whey
- Permits curd to coalesce into a homogeneous mass
- Facilitates control of curd mineral content and pH

NOTE: PROPER CHOISE OF TIME AND ACIDITY (pH) AT DRAIN OR DIPPING IS <u>CRITICAL</u> TO GOOD CHEESEMAKING.

Step 5. Curd Knitting

Definition: Coalescence of curd particles into a homogeneous mass. Knitting is usually carried out at warm temperatures.

<u>Purpose</u>

- Serves as an incubation period for continued starter growth and activity.
- Facilitates control of curd moisture content
- Facilitates control of curd mineral content
- Facilitates development of desirable curd texture

Step 6. Salting

Definition: Addition of sodium chloride (NaCl) to curd. Salting can be accomplished in 2 different ways:

- Dry salting: Salt may either be rubbed onto the surface of the finished cheese or it may be mixed in with small (milled) curd pieces.
- Brine salting: The finished cheese is immersed in a salt brine (e.g. 23% NaCl) for a specified period of time.

<u>Purpose</u>

- Facilitates control of curd moisture content
- Initiates curd shrinkage - improves body and texture
- Arrests starter growth, activity, and acid production

    -Very important in certain cheeses (e.g. Cheddar)

- Inhibits growth of contaminating microorganisms

    -Example: *Clostridium butyricum*

- Exerts strong influence on enzymatic activity during ripening (especially proteolytic activity)
- Enhances 1. flavor (seasoning) and 2.) flavor development

NOTE: The function of salt and level of salt vary widely from one cheese variety to the next.

- Important Parameters for salting milled curd (e.g., Cheddar)
    - Curd temperature
    - Salting rate (e.g, 2.5 lb salt/100 lb curd)
    - Size and uniformity of curd chips
    - stirring and mellowing time

- Important parameters for brine salting
    - brine temperature
    - brine concentration
    - proximity of cheeses to one another
    - brine circulation

Step 7. Pressing

Definition: Compacting of curd into a solid form (e.g. block, wheel) with or without the use of external pressure.

Purpose

- Facilitates control of curd moisture
- Imparts a desirable shape, body and texture to the cheese

Step 8. Special Applications

Definition: This is a catch-all term which includes manufacturing practices unique to a given cheese type.

-Examples:

- Spraying mold spores onto Camembert cheese
- Needling curd for Blue cheese
- Warm room treatment for Swiss-type cheeses
- Stretching Mozzarella curd in hot water

DIVERSITY IN CHEESEMAKING
(Features that differentiate cheeses into 800+ different varieties)

There are over 800 cheeses produced throughout the world. They are all made by the same eight basic steps, and they all start out immediately after manufacture as bland, uninspiring curd. However, as they mature they develop into a dizzying array of cheeses that differ radically in flavor, aroma, and texture. Next we will examine the reasons why different cheeses mature so differently. All cheeses can be considered members of the same family but the degree of relatedness differs. Some may be considered brothers and sisters, while others are only distant cousins. There are two fundamental factors that determine whether a newly made cheese matures into a Swiss, Brie, Cheddar, Limburger or any of the other 800 or so other cheese types. The first factor is the basic structure and chemical environment of the cheese curd ***that is created on the first day of cheesemaking.*** The second factor is the artisanal and technological conditions that the cheese experiences ***during maturation*** (affinage).

1. Basic Structure and Chemical Environment of Cheese

Several parameters define the basic structure and chemical environment of the cheese curd ***that is created on the first day of cheesemaking***. They include cheese pH, calcium content, moisture content, fat content and salt content. Two of the parameters, pH and calcium content, play a dominant role in shaping the direction of maturation:

A. *Cheese pH immediately after manufacture*

- **Predisposes the cheese to specific microbial and enzymatic activity.**

Microorganisms and enzymes vary greatly in their sensitivity to pH. For example, some microorganisms and enzymes are strongly inhibited by low pH, whereas are stimulated by low pH. Therefore, pH has a very selective effect on the activities of organisms and enzymes during aging. The key is to maintain the pH at a level that optimizes the activity of desirable organisms and enzymes that contribute to flavor and texture while suppressing the activity of unwanted organisms and unwanted enzymatic changes.

<u>Examples</u>

*low pH Swiss - *Propionibacterium shermanni* growth inhibited: no eyes, flavor

*high pH Cheddar - *Propionibacterium shermanni* growth stimulated, eyes, Swiss-like flavor

*low pH Cheddar – excessive proteolysis, bitterness

- **Strongly influences cheese structure and texture.**

The casein (the bricks) and the calcium phosphate (the mortar) that form the structural matrix of cheese curd are highly sensitive to pH. Therefore, differences in the pH of the curd profoundly influence cheese structure and texture.

Examples

*low pH Mozzarella – unable to melt and flow

*high pH Mozzarella – excessively tough and fibrous

*low pH Cheddar – brittle, crumbly

B. *Cheese calcium to total protein ratio*

- **strongly influences cheese structure and texture**

  The casein in cheese can be thought of as "the bricks" of cheese structure and the calcium phosphate as "the mortar" that binds the bricks together. The amount of mortar (calcium) relative to the amount of bricks (casein) affects the strength of the structure. In general, cheese with high calcium to protein ratio will have a firm, elastic texture whereas cheese with low calcium to protein ratio will be less elastic and more brittle.

  Examples

  *Swiss cheese – firm, elastic structure needed

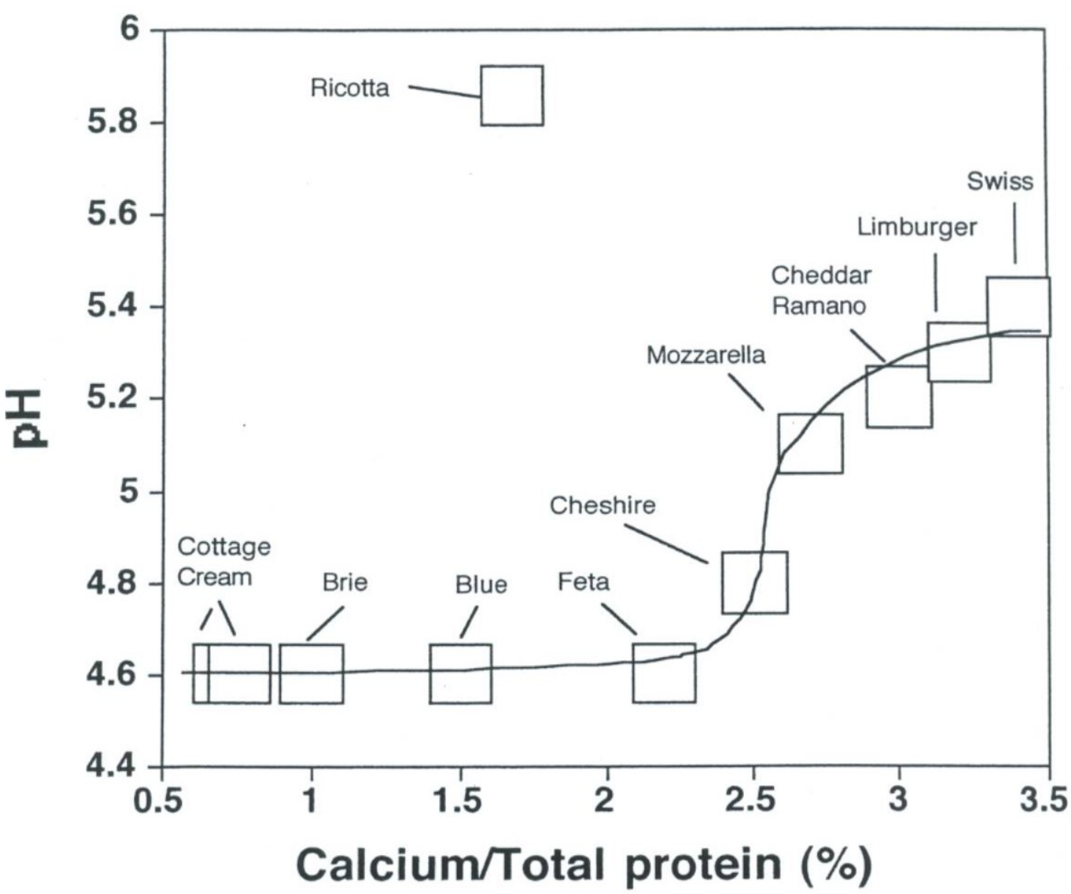
  *Mozzarella – stretching, melting characteristics

- **strongly influences the cheese pH immediately after manufacture**

  calcium phosphate acts as buffer (i.e., a "sponge" that absorbs acid). Therefore, cheese that is high in calcium will tend to be high pH.

Based on these 2 parameters, the various cheeses fall along a continuum ranging from high initial pH and high calcium/total protein to low initial pH and low calcium/total protein (see graph below). The pH and calcium content of the cheese, in turn, are directly governed by the schedule of acidity produced by the starter culture during manufacture. Therefore, ***control over the starter culture is the key to controlling the final characteristics and thus identity of the cheese.***

Cheese Classification Based on Chemical Relatedness



Adapted from: Lawrence, R.C., J. Gilles and L.K. Creamer. 1983. The relationship between cheese texture and flavor. N.Z.J. Dairy Sci. Technol. 18:175-190.

C. Moisture, Fat and Salt Contents

Beyond controlling the starter culture and attaining the correct initial pH and calcium content, the cheesemaker must also achieve targets for moisture, fat and salt content. These 3 compositional parameters (along with pH and mineral content) help to define the chemical environment within the curd. The chemical environment within the curd is the most important factor influencing cheese ripening because it governs microbial, enzymatic, and physico-chemical activity during the ripening process.

A. Moisture Content

- Significance: Moisture content strongly influences 1) microbiological and 2) enzymatic activity during ripening.

1. Microbiological activity

Microorganisms must have a minimum level of "free" or available water for growth. Not all of the water in cheese is available for microbial growth. Some of the moisture is in fact "bound" by casein. As a result, seemingly small changes in the moisture content of a particular cheese may result in large changes in the water available for microbial growth. As a general rule, as moisture content decreases, the curd environment becomes more harsh for microbial growth and fewer types of microorganisms are able to survive. Conversely, diverse microbial growth is favored at high moisture content, including unwanted contaminants.

Examples:

* high moisture cheddar – abnormal (e.g. unclean) fermentations

* high moisture Brie – blue, black, gray mold growth favored

* low moisture Brie - poor growth of white mold

2. Enzymatic activity

Many of the cheese flavors that develop during aging are the result of enzymatic breakdown of fat and protein. Also, the development of cheese texture during aging is strongly influenced by the enzymatic breakdown of protein. Enzymatic reactions (e.g., protein-degrading proteases, fat-degrading lipases) which contribute to cheese ripening take place in the water phase of the cheese. In cheese with relatively little free water (low moisture content), accessibility of enzymes to the protein or fat is impeded and enzymatic reactions and ripening in general, proceeds slowly. Conversely, enzyme reactions in curd with abundant free water proceed rapidly and ripening is accelerated. Off flavors and textures will develop during aging the normal enzymatic reactions proceed too rapidly.

Examples:

* high moisture Cheddar – bitterness, pastiness

* high moisture blue – untypical flavor (ammonia, sulfur)

B. Salt Content

- Significance: Salt in cheese is completely contained within the water phase of the curd. Therefore, the water phase of the curd is actually a dilute salt brine. The concentration of salt strongly influences 1) microbial and 2) enzymatic activity during ripening.

1. Microbiological activity

Microorganisms vary greatly in their sensitivity to salt. Some microorganisms are strongly inhibited by even low levels of salt, whereas others grow quite well at very high concentrations of salt. Therefore, salt content has a very selective effect on which organisms will and will not grow during aging. The key is to maintain the salt content at a level that optimizes the activity of desirable organisms that contribute to flavor and texture while suppressing the growth of unwanted organisms.

As a general rule, as salt content increases, the curd environment becomes more severe for microbial growth and fewer types of microorganisms are able to survive. Conversely, diverse microbial growth is favored at low salt content, including unwanted contaminants.

Examples:

*high salt Swiss – *Propionibacterium shermanni* growth inhibited: no eyes, little flavor

*low salt Cheddar – femented off-flavors, gas blowing

*low salt blue – *Brevibacterium linens* surface growth

2. Enzymatic Activity

Many of the cheese flavors that develop during aging are the result of enzymatic breakdown of fat and protein. Also, the development of cheese texture during aging is strongly influenced by the enzymatic breakdown of protein. Enzymatic reactions take place in solution, and the salt concentration in the water phase of the cheese strongly influences the rate at which enzymes catalyze reactions and the exact nature of the reaction. In general, high salt content tends to slow down enzymatic reactions whereas low salt content favors rapid reactions.

Examples:

*low salt Cheddar – excessive proteolysis, bitterness, pastiness

*high salt Cheddar – reduced proteolysis, lacks flavor, curdiness

C. Fat Content

- Significance: Fat content influences cheese texture. In general, higher fat content results in softer, more cohesive (sticky, pasty) texture.
- Significance: The optimum moisture content for a cheese will vary with fat content. As fat content increases, the optimum moisture content decreases

Example:

Cheddar cheese: At 32% fat, the optimum moisture content is ca. 36%

Cheddar cheese: At 36% fat, 36% moisture is excessively high. At 36% fat, the moisture content for Cheddar should be reduced to ca. 34%

2. Artisanal and Technological Conditions During Maturation

A. Surface Events During Maturation

i.) Rind Formation

A rind is a dehydrated layer at the surface of the cheese, which serves as a semipermeable barrier to moisture loss. Without a suitable rind, cheeses exposed to the relatively dry atmosphere at ambient conditions would quickly dry out due to excess moisture loss. For some cheeses (i.e., eye-forming cheeses), the rind also serves as a barrier to carbon dioxide release in order to build up high gas pressure within the cheese body needed to form eyes.

Rinded cheeses with no eyes or a few small eyes require a lower density rind whereas cheeses with numerous large eyes require a high density rind:

- Low density rind: (e.g., Gouda, Edam)

  - Brine salt to incorporate salt into the cheese and to develop a dehydrated layer at the cheese surface
  - Cure at cool temperature (e.g. 60 F) and moderate relative humidity (90% RH) for about 2 weeks.
  - Rub surface with a moist cloth and turn daily daily to keep surface smooth and free of growth

- High density Rind: (e.g. Swiss types)

  - Brine salt to incorporate salt and to develop a dehydrated layer at the cheese surface.
  - Cure at cool temperature (e.g., 50 - 60 F) and moderate relative humidity (90% RH) for about 2 weeks. Every day or two, rub surface with cloth dipped concentrated salt brine and sprinkle dry salt on the surface, then turn.
  - Transfer to warm room (68 - 75 F) at dry relative humidity (85% RH) for 2 to 3 weeks. Rub surface with brine wetted cloth, sprinkle dry salt on the surface and turn 2 or 3 times weekly.

ii.) Smear Formation (e.g., Limburger, Muenster)

Smears consist of a moist region at the surface of the cheese that will support the growth of the reddish bacteria known as *Brevibacterium linens*. This organism needs a relatively high pH, moist environment in order to thrive. To create this environment at the cheese surface, the cheese is rubbed with **dilute** (e.g., 5%) salt brine. Dilute salt brine applied to the surface helps to make the protein more soluble, leading to a soft moist surface layer.

- Brine salt or dry salt at the surface to incorporate salt.
- Transfer to cool (e.g., 60 F) room with high relative humidity (95% RH)
- Daily, rub cheese surface with 5% salt brine for 10 to 12 days

iii.) Simultaneous Rind and Smear Formation (e.g., Gruyere)

Some cheeses develop both at semipermeable rind and also a smear growth of *Brevibacterium linens* at the surface of the rind. Basically, such cheese combines the 2 functions described above. First, a rind is formed using a procedure generally similar to first steps described above for a high density rind. However, instead of promoting further rind formation in the warm room, the cheese surface is rubbed with dilute salt brine to create a microenvironment at the rind surface that will support the growth of *Brevibacterium linens*.

iv.) Surface Mold Formation (e.g., Camembert, Brie)

Some cheeses do not develop a rind *per see* but do develop a surface layer of mold (usually white mold) that is essential to the ripening process. The key is to provide the microenvironment at the cheese surface to favor the growth of the desired white mold.

- The initial cheese is made to fall within an optimum range of moisture content.
- The cheese surface is then pre-dried at warm (62 - 68 F) and dry (85% RH) conditions to select for growth of the white mold (*Pennicillium camemberti, caseicolum* or *candidum*)
- Transfer to cool (57 F) moist (95% RH) room for 12 days to promote mold growth. Turn cheeses periodically.

v.) Waxing/Packaging

- Protects the cheese surface from contamination and physical disruption
- Provides barrier to oxygen, prevents surface mold growth
- Should be semi-permeable to carbon dioxide

B. Temperature Conditions

Microorganisms vary greatly in their sensitivity to temperature. Some microorganisms are strongly inhibited by low temperature (e.g., 40 – 45 F), whereas others grow quite well. Therefore, temperature has a very selective effect on which organisms will and will not grow during aging. The key is to maintain the temperature at a level that optimizes the activity of desirable organisms that contribute to flavor and texture while suppressing the growth of unwanted organisms. As a general rule, as temperature increases, the curd environment becomes more hospitable for microbial growth and a wider spectrum of microorganisms are able to survive and grow, including unwanted contaminants.

Enzyme activity is also very temperature dependent. As a general rule, as temperature increases, enzymatic activity increases, which tends to accelerate the aging process and can lead to excessive enzymatic breakdown of protein and fat that give rise to off flavors and texture defects.

Starter Cultures and Acidity Measurement

A. Functions of the Starter Culture

Almost all cheeses utilize one or more starter cultures in their manufacture. Starter culture may be defined as a species or combination of species of microorganisms (usually bacteria) that are deliberately added to milk during cheesemaking to carry out certain desirable functions.

1. Production of lactic acid from lactose

The preeminent function of the starter culture is to provide a uniform, reproducible, predictable rate of acid production during cheese manufacture. Why is acid production so important to cheesemaking? Because the schedule of acidification (i.e., how quickly the acid is produced and how much acid is produced before vrs. after the whey is drained from the vat) profoundly influences 3 major parameters of cheese composition that determine the ripening pathways and quality characteristics of the final cheese.

- *Initial cheese pH*
- *Cheese mineral (calcium phosphate) content*
- *Initial cheese moisture content*

2. Outgrow and Suppress Undesirable (Spoilage) Microorganisms, Pathogens

Milk is an incredibly rich growth medium. Almost any microorganism will grow in milk, thus milk is extremely vulnerable to contamination. To make matters worse, the environment from which milk is harvested (the dairy farm) is rich in spoilage organisms and pathogens. Proper sanitation, milk handling practices, and pasteurization provide safeguards against unwanted microorganisms, but even the best managed cheese operations are not immune to possible contamination. The starter culture is the first line of defense against any spoilage bacteria or pathogens that, by hook or by crook, end up in the cheese milk. In general, the job of the starter is to grow vigorously and reproduce rapidly. An active starter will help to suppress unwanted contaminants by several different means.

- Production of lactic acid
- Production of antimicrobial compounds

  - Lactoperoxidase
  - Nisin
  - Bacteriocins

- Outcompete for food and nutrients

3. Contribute Suitable Enzymes for Ripening

4. Produce (or Fail to Produce) Gas and flavor

<u>Examples</u>:

- Gouda cheese: *Leuconostoc mesenteroides* ssp. *cremoris*
Lactococcus lactis ssp. *lactis biovar. diacetylactis*

***Both produce carbon dioxide and diacetyl

- Swiss cheese: *Propioibacterium freudenreichii* ssp. shermanii

***Produces carbon dioxide and propionic and acetic acids

B. Important Cheese Starter Cultures

1. Mesophilic Starters

- *Lactococcus lactis* ssp. *lactis* (formerly *Streptococcus lactis)*
- *Lactococcus lactis* ssp. *cremoris* (formerly *Streptococcus cremoris)*

  - Optimum growth temperature range: 25 - 30°C (77 - 90°F)
  - Maximum temperature: ca. 39 - 40°C (102 - 104°F)
  - Typical setting temperatures: 21 - 32°C (70 - 90°F)

- Principle function: Ferment lactose to lactic acid
- Cheese varieties: Cheddar, Cheshire, Colby, Jack types; Camembert, Blue, Brie and related types; Feta; Harvarti, Gouda; Cottage, Cream and other acid coagulated cheeses.

2. Thermophilic Starters

- *Streptococcus thermophilus*
  - Optimum growth temperature range: 35 - 41°C (95 - 105°F)
  - Maximum temperature: ca. 60°C (140°F)
  - Almost always used in combo with *Lactobacillus delbrueckii* ssp. *bulgaricus*

- *Lactobacillus delbrueckii* ssp. *bulgaricus*
  - Optimum growth temperature range: 43 - 45°C (109 - 113°F)
  - Maximum temperature: ca. 60°C (140°F)
  - Almost always used in combo with *Streptococcus thermophilus*
  - Produces acetaldehyde which gives a "yogurt-like" flavor

- *Lactobacillus helveticus*
  - Similar to *bulgaricus*

- Principle function: Ferment lactose to lactic acid
- Cheese varieties: Italian, Swiss-type cheeses

3. Gas and Flavor-Producing Starters

- *Lactococcus lactis* ssp. *lactis biovar. diacetylactis*

  - Ferments lactose to lactic acid
  - Ferments citrate to carbon dioxide and diacetyl
  - Strong gas and flavor producer
  - Cheese varities: Harvati, Gouda-types
  - Mesophilic: Similar temp. requirements as *L. lactis* ssp. *lactis*

- *Leuconostoc mesenteroides* ssp. *cremoris*

  - Weakly ferments lactose to lactic acid
  - Ferments citrate to carbon dioxide and diacetyl
  - Moderate gas and flavor producer
  - Cheese varities: Harvati, Gouda-types
  - Mesophilic: optimum growth 20 - 22°C (70 - 72°F).

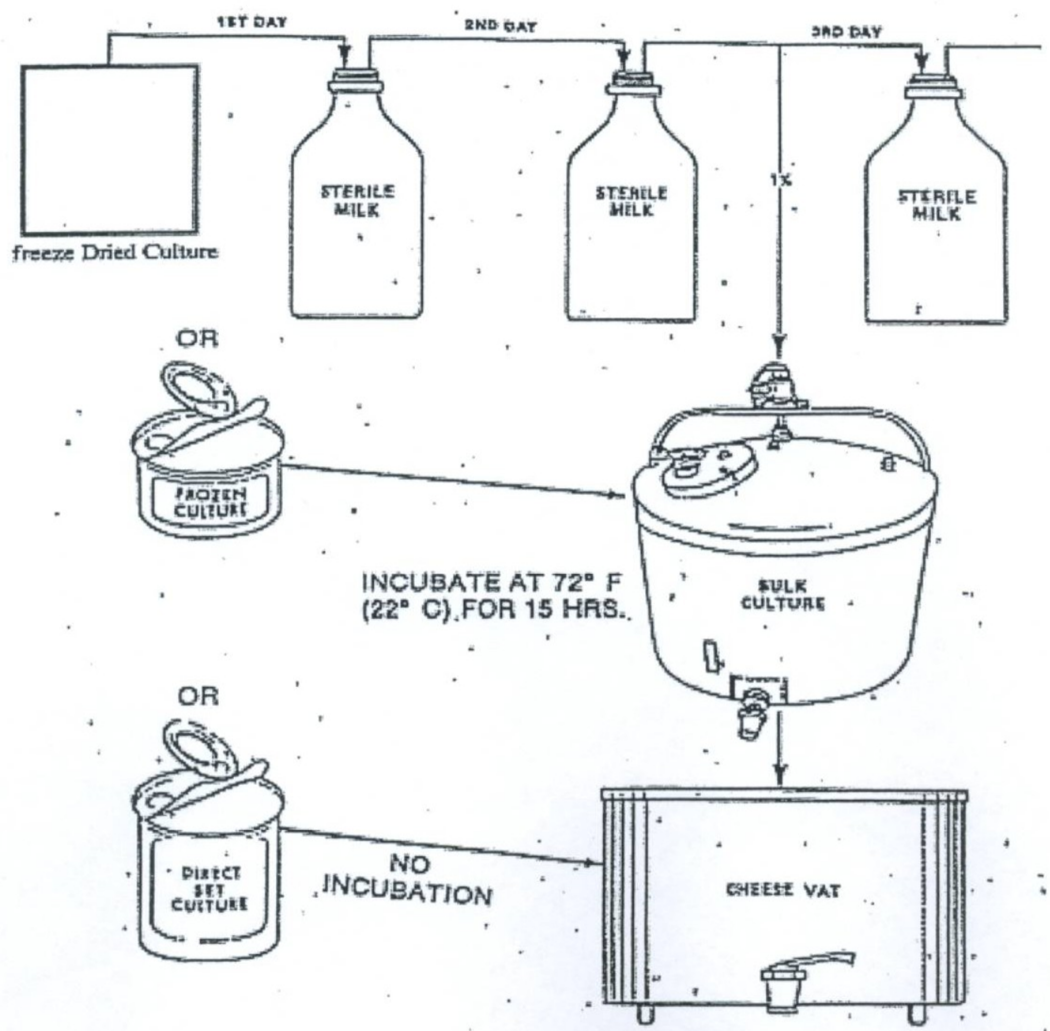
- *Propionibacterium freudenreichii* ssp. *shermanii*

  - Optimum growth range: 30 - 37°F (86 - 99°F)
  - Does not ferment lactose
  - Ferments latic acid to propionic acid, acetic acid, and carbon dioxide
  - May be present as natural flora or added to cheesemilk as an adjunct
  - Cheese varieties: Swiss-type

Commercial Forms of Starter Culture

Starter cultures used in cheesemaking can basically take 3 different forms: Freeeze dried, frozen concentrated, and direct vat set

Forms of Starter Culture



- Mother culture

  - Culture is transferred to new sterile milk and propagated daily
  - Starter milk is heat "sterilized" (e.g. 185F for 30 min)
  - Mother culture used to inoculate bulk milk (e.g. 10 gal milk can) to propagate bulk starter
  - Bulk starter used to inoculate cheese vat
  - Very labor intensive
  - Mother culture may become contaminated or change genetically over time

- Frozen concentrated

  - Example: Chr. Hansen REDI-SET
  - For use in bulk starter, not added to the cheese vat directly
  - Must be stored in ultra cold freezer (-40°C/-40°F)

- Direct Vat Set

  - Add directly to the cheese vat
  - Extremely convenient and user-friendly, but more expensive
  - Available in frozen concentrated and freeze-dried (2nd generation) form
  - Frozen DVS must be be stored in ultra cold freezer (-40°C/-40°F)
  - Some freeze dried DVS do not require ultra cold frozen storage

C. Inconsistent Starter Culture Activity and Starter Failure

The key to successful cheese making is a starter culture that consistently produces lactic acid at the optimum rate for the particular cheese variety. Variation in the rate of acid production from one vat to the next always means variation in cheese quality. There are a number of factors that can lead to variation in starter culture activity and, in extreme cases, failure.

1. <u>Factors Involving the Starter Culture</u>

- *Culture Storage and Handling Conditions*

  - Commercial starter cultures are standardized precisely for activity by the manufacturer. The activity of commercial cultures will be very consistent from one batch to the next provided that the culture is stored and handled properly.

  - **Follow manufacturer's instructions concerning storage and handling!** (for example, some culture companies stipulate that frozen concentrated cultures should be stored at -40°F for no more than 6 weeks.)

  - Never thaw and then refreeze a liquid frozen culture. This is particularly problematic when only part of the culture package is used and the rest is stored for use later. It is advisable to always use new DVS starter and discard any portion that is left over, rather than storing the left over starter for later use.

  - Minimize temperature fluctuation during storage. Don't store cultures in a freezer containing other products that may be opened and closed frequently.

  - **Follow manufacturer's instructions for thawing and inoculation!** Some frozen DVS cultures should be added directly to the vat without any thawing. Others should be thawed slightly. Others exist as a freeze-dried powder that can be mixed directly into a small portion of the cheesemilk and then added directly to the vat.

- *Differences in Activity Among Different Starter Strains*

  - Commercial culture suppliers offer many different strains of the same starter organism. Some strains may be characterized as faster acid producers whereas other strains may be slower acid producers. Therefore, changing to different strain of a starter may lead to a significant change in the rate of acid production during cheesemaking.

- *Bulk Starter Preparation*

  - Solids content of milk (media) used to grow up the bulk starter
  - Heat treatment/cooling of the starter milk (media)
  - Final pH of bulk starter: mesophilic ca. 4.8 - 5.0; thermophilic ca. 4.2 - 4.3

2. <u>Factors Involving the Chemistry of Milk</u>

- *Mastitic and Late Lactation Milk*

  - pH of the milk tends to be abnormally high

  - Milk contains inhibitory substances

  - More starter culture is needed to maintain consistent rate of acidification

- *Rancid Milk (high free fatty acid content)*

  - Free fatty acids inhibit starter activity

  - Potential causes of rancidity:
    - mastitis or late lactation
    - foaming, churning (disruption of milkfat globule membrane)
    - freezing/thawing (disruption of milkfat globule membrane)
    - psychrotrophic bacteria

- *Solids (Protein) Content of the Milk*

  - Casein micelles are rich in calcium phosphate and therefore act like an acid sponge, mopping up the lactic acid produced by the starter culture. Therefore, in general the greater the protein (casein) content in the milk, the greater the amount of starter that will be needed to maintain a consistent rate of acidification during cheesemaking. This is particularly challenging when cheese is made from seasonally-produced milk, because seasonal milk undergoes extremely large changes in protein content across season. Consequently, the cheesemaker must adjust starter usage periodically to maintain a consistent rate of acidification.

- *Agglutination*

  - Primarily a problem with acid coagulated cheeses. The symptoms are an apparent slow down in acid production and poor coagulation or failure of the milk to coagulate. A gelatinous precipitate forms on the bottom of the vat.

  - Caused by a reaction of milk immunoglobulins with susceptible starter strains, resulting in a starter cell-IGG complex that settles to the bottom of the vat. In effect, the starter culture is pulled down to the bottom of the vat.

- Agglutination can be prevented by using starter strains that are not agglutinin-sensitive.

3. Factors Involving Agents Introduced Into the Milk

- *Coliform bacteria*

  - Coliform bacteria aggressively ferment lactose to lactic acid. If large numbers of coliforms are present in the milk during cheesemaking, the acid development may appear excessively fast because both the coliforms and the starter are producing acid. In extreme cases, not only will the acid production be very fast but also the curds will float and the whey effervesce, because coliforms produce copious amounts of carbon dioxide.

- *Excessive Aeration*

  - In general, cheese starters are microaerophilic, meaning that they are most active when the level of dissolved oxygen in the milk is low. Milk handling practices that increase the level of dissolved oxygen such as splashing, foaming, leaky seals may have an inhibitory effect on the starter.

- *Antibiotics*

  - Cheese starters are very sensitive to the antibiotics that are used to treat mastitis. Animals that are under treatment for mastitis with antibiotics should be milked separately from healthy animals and the milk must not be used for cheese making or Human consumption. Segregation of milk from treated animals must be observed during the antibiotic treatment period and following the last treatment until the residue has cleared from the animal's system, as specified by the manufacturer. Furthermore, every load of milk should be tested for the presence of antibiotics before it is approved for cheesemaking.

- *Bacteriophage*

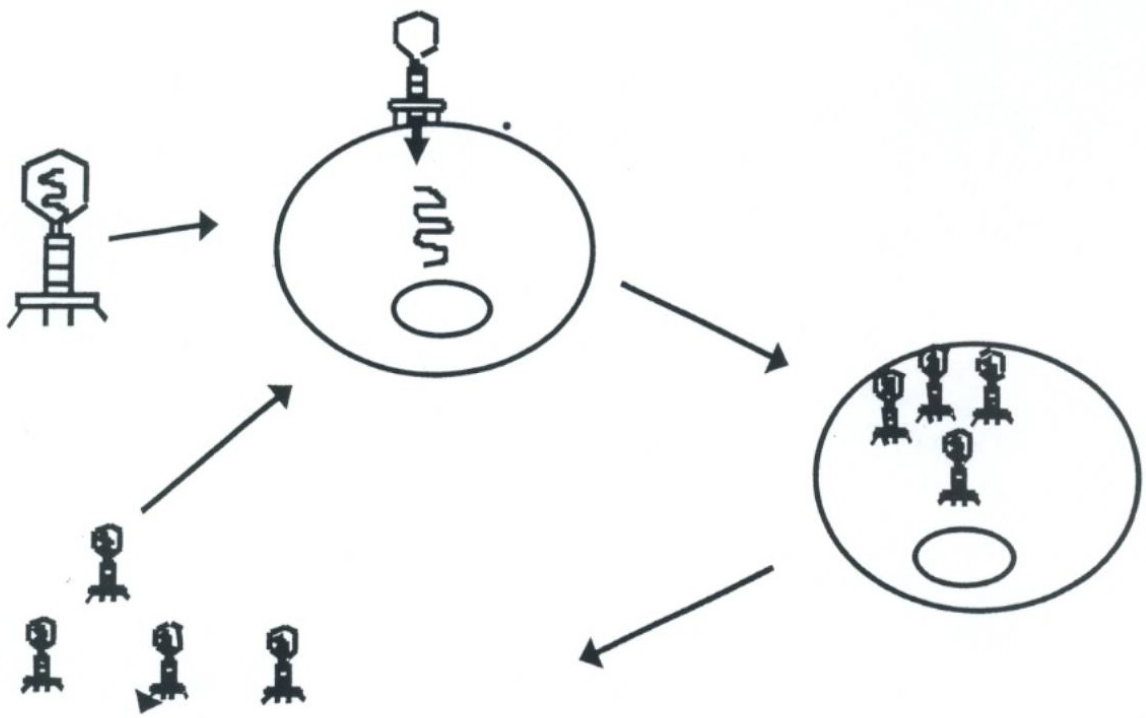
  - Bacterial virus that enters the starter cell, reproduces within the cell, and then causes the cell to self-destruct, releasing 50 - 150 new virus into the surrounding environment. The new phage then enter new starter cells and the cycle continues.

  - Phage are extremely strain specific. That is, they may attack only one strain of starter but leave others untouched.

  - Requirements for phage replication:

    - Suitable host strain
    - Time
    - Free calcium

Life Cycle of Bacteriophage



- Sources of phage:

- Raw milk and milk environment
- Dust, airborne contamination
- Whey and whey aerosols
- Pools of standing water

- Phage control and prevention:
  - Rotation of phage-unrelated stains
  - Thorough, effective cleaning regimen
  - Segregate whey from cheesemaking room
  - Chlorine fog if necessary
  - Control cross-contamination from barn to cheesemaking room

- *Sanitizer Residues*

  - It is important to completely drain all pipelines and equipment after sanitizing.

4. Factors Involving Cheesemaking Practices

- *Inoculation /Ripening Regimen*

  - After the starter is added to the cheese milk a period of time is allowed to elapse before the coagulant is added. This period is called ripening, and its purpose is to give the culture adequate time to become active. The ripening time is critical because it affects the rate of acidification throughout the remainder of cheese making. If the ripening time is too short and cheesemaking proceeds before the culture has become active, acidification will be behind schedule throughout cheesemaking. On the other hand, if the ripening time is too long, the culture may become overly active and acidification will be ahead of schedule throughout cheesemaking. In either case, cheese quality will suffer.

- *Temperature conditions*

  - Starter culture activity is very temperature sensitive. Therefore, it is absolutely essential that temperature be precisely controlled at every stage of cheesemaking. Be particularly aware of the surrounding ambient temperature and its affect on surface cooling. Also, make sure that your working thermometer is calibrated regularly against a primary thermometer.

D. Monitoring Starter Culture Activity: Acidity Measurement

We have seen that vigorous starter culture growth and uniform acid production are essential to good cheesemaking. Therefore, the cheese maker should routinely monitor acid development at critical stages during cheesemaking to determine whether the vat is progressing normally. Two different tests are commonly used to measure acidity: titratable acidity and pH. Although both tests measure acidity, what they actually measure differs because there are two different forms of acidity. To understand the two different forms of acidity we need to review what makes an acid an acid:

- All acids are capable of giving up a hydrogen ion (H^+) to the surrounding environment in the presence of water:

$$\text{ACID-H}^+ \xrightarrow[\text{in water}]{} \text{ACID} + \text{H}^+$$

- Acids are classified as either strong or weak. An acid is a strong acid if every molecule of the acid gives up its H^+ in the presence of water. An acid is weak if only some of the acid molecules give up their H^+ while some of the acid molecules retain their H^+ :

Strong Acid: $10\ \text{ACID-H}^+ \xrightarrow[\text{in water}]{} 10\ \text{ACID} + 10\ \text{H}^+$

Weak Acid: $10\ \text{ACID-H}^+ \xrightarrow[\text{in water}]{} 5\ \text{ACID} + 5\ \text{H}^+ + 5\ \text{ACID-H}^+$

- In essence, the difference between titratable acidity and pH is that titratable acidity measures all acid molecules in the sample, both strong and weak acids, whereas pH only measures those acid molecules that have released their H^+. Therefore, pH does not measure those weak acid molecules that have not released their H^+:

Measurement of Titratable Acidity

- Titratable acidity involves adding a known quantity of OH^- ions (in the form of NaOH) to a sample that contains acids. OH^- ions have an overwhelming ability to combine with H^+ ions from strong and weak acids. Therefore, each new OH^- ion added to the sample will combine with one H^+ ion from a strong or weak acid until all of the acid molecules have been stripped of their H^+ ions.

Strong Acid: 10 ACID-H^+ $\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow$ 10 ACID + 10 H^+

in water

10 H^+ + 10 OH^- $\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow$ 10 H_2O

(add 10 NaOH)

***If additional NaOH is added the sample becomes alkaline (i.e., no longer acidic) and an indicator solution (phenolphthalein) turns pink, informing the analyst that the titration is complete**

Weak Acid: 10 ACID-H^+ $\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow$ 5 ACID + 5 H^+ + 5 ACID-H^+

in water

5 H^+ + 5 OH^- $\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow$ 5 H_2O

5 ACID-H^+ + 5 OH^- $\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow$ 5 H_2O

(add 10 NaOH)

***If additional NaOH is added the sample becomes alkaline (i.e., no longer acidic) and an indicator solution (phenolphthalein) turns pink, informing the analyst that the titration is complete**

- In essence, titratable acidity counts the total number of acid molecules in the sample. The results are expressed as though all of the acid molecules consisted of lactic acid even though milk contains other weak acids besides lactic, which are also measured.

- Fresh milk of high quality contains no lactic acid. The %TA of fresh milk is due to other weak acids present in the milk, primarily phosphoric and citric acid. Phosphoric acid (i.e. phosphate) is a major component of casein micelles, therefore high protein milk will have a higher %TA than low protein milk.

Example:

9% reconstituted NFDM: %TA = .15
12% reconstituted NFDM: %TA = .20

Therefore, the production of lactic acid by the starter is determined by measuring the change in titratable acidity from the initial value of the milk.

Procedure for Measuring Titratable Acidity:

1. Measure exactly 9 ml of milk or whey into a clean white cup, or clear beaker or flask. (Ideally, exactly 9 grams of sample should be used, but 9 ml is close enough to 9 grams for most purposes).

2. Add 4 drops of phenolphthalein indicator solution (1% in 95% ethanol).

3. Slowly add 0.1 Normal sodium hydroxide from a burette and swirl the sample almost continuously.

4. Slowly and deliberately continue to add sodium hydroxide until the first discernable stable shade of pink is attained.

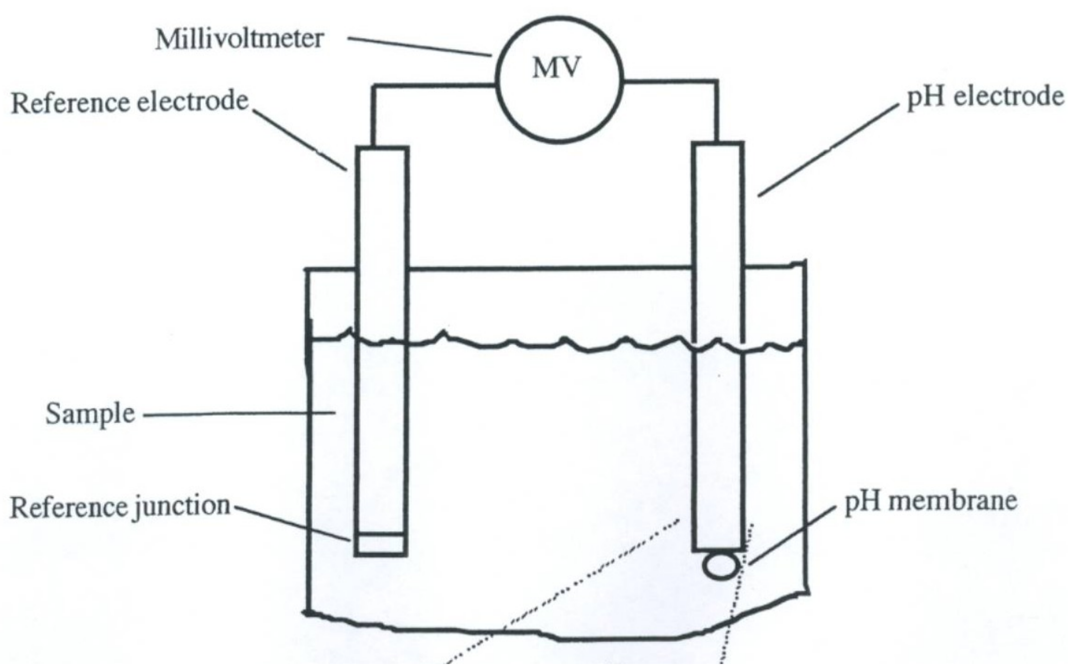
5. Multiply the burette reading (i.e., the total ml of sodium hydroxide added to the sample) by a factor of 0.1 to express the acidity value as lactic acid. For example, if it takes 1.6 ml of sodium hydroxide to reach the first stable discernable pink endpoint, the titratable acidity value will be.16%, expressed as lactic acid.

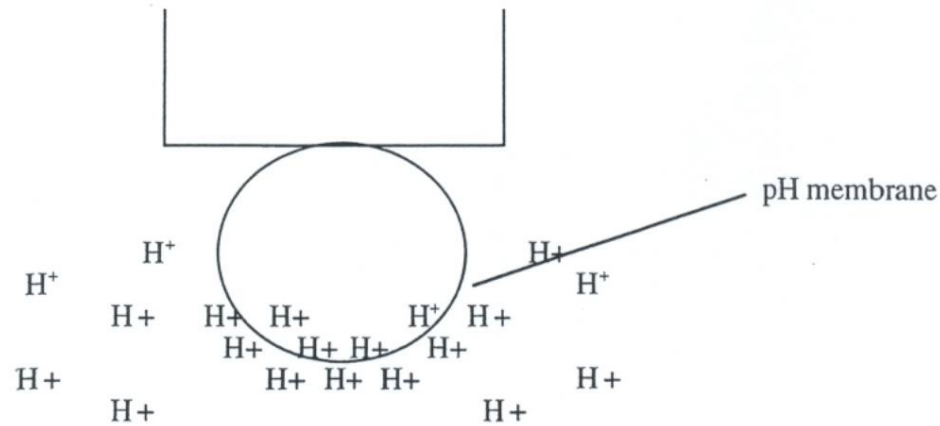
Sources of Error

- Inaccurate measurement of 9 ml of sample
- Variable amount of indicator used
- Titration completed too quickly (particularly important for high solids milk)
- Inconsistent color endpoint used/overtitration

Measurement of pH

- A pH measurement system consists of 4 parts: a pH sensing electrode, a reference electrode, a millivoltmeter, and a test sample.





- When a pH electrode is immersed in a sample which contains hydrogen ions (H^+), the hydrogen ions accumulate at the electrode surface and create an electrical potential, the size of which is related to the concentration of hydrogen ions in the sample.

- The reference electrode is designed to possess a constant electrical potential. The reference electrode and pH electrode are manufactured in such a way that the electrical potential at the surface of the pH electrode will be equal to that of the reference electrode potential when the 2 electrodes are placed in a test sample that has a pH value of 7.

- The millivolt meter measures the difference in electrical potential between the pH and reference electrode. If the electrodes are placed in a sample with a pH value of 7.0, the millivolt meter will measure a difference of zero millivolts between the pH and reference electrode.

- However, if the pH of the test sample is changed by 1 pH unit (for example, a change from pH 7 to pH 6, which representes a tenfold increase in hydrogen ion concentration) there will be a resulting change in the potential at the surface of the pH electrode equal to +58 millivolts at 20 C. Therefore, the millivolt meter will measure a difference in potential of + 58 millivolts between the reference electrode and the pH electrode.

- If the electrodes are placed in a sample with a pH value of 5, the pH electode will develop an electrical potential that is 116 millvolts higher than that of the reference electrode.

- The job of the millivolt meter is to measure the potential difference between the pH and reference electode and then translate that difference into a sample pH value (i.e. +58 mv = pH 6.0; +116 mv = pH 5.0; +174 mv = pH 4.0; etc.)

- Thus, it is evident that the pH meter measures the concentration of H+ ions in the sample, or in other words, those acid molecules that have released their hydrogen ions. Unlike titratable acidity, pH does not measure weak acids that hold onto their hydrogen ions.

Procedure for Measuring pH:

Every pH meter and pH and reference electrodes include operating instructions from the manufacturer. There are many different pH meter and electrode designs, therefore proper use and maintenance of pH equipment will vary from one model to the next. Make sure that you follow the recommended procedures for your equipment.

1. The pH meter first needs to be calibrated each time that it is used. Perform a two point calibration **according to the manufacturer's instructions** using pH 7.0 and pH 4.0 buffers.

- pH 7.0 buffer is used to adjust the system so that the potential difference between the pH electrode and reference electrode will equal 0 mv.

- pH 4.0 buffer is then used to adjust the system so that each difference in 1 pH unit will result in a potential difference of 58 mv. Thus, the if the pH meter detects less than a 174 mv potential difference for the pH 4 buffer, the calibration process brings the difference back up to 174 mv.

2. Once the instrument is calibrated, perform sample measurements according to the manufacturer's instruction. Sample temperature must be within 1 C of the temperature of the buffers used for calibration unless an automatic temperature compensator is used.

Sources of Error

- Clogged reference junction or pH electrode membrane (long stabilization time, drift)
- Improper filling solution
- Improper storage solution
- Uncontrolled variation in temperature

Defining a Target Acidity Schedule

Regardless of whether the cheesemaker measures pH or TA during cheese making, it is essential to develop target values for acidity at key stages in the manufacturing process to use as benchmarks for evaluating starter performance. In other words, it isn't very useful to measure acidity during cheesemaking unless one knows what the acidity value should be at given stage of the process. Some cheeses such as Cheddar and Mozzarella that made on a large industrial scale have well defined schedules of acidity that one can access readily in textbooks. An example of a Cheddar cheese acidity schedule is provided on the next page. For other specialty and artisanal cheeses, the cheesemaker may have to define their own targets for acidity. It is particularly important to define the following:

- initial acidity of the cheesemilk
- optimum acidity at the start of whey draining or dipping
- optimum acidity at the completion of whey draining
- optimum acidity of fresh cheese immediately manufacture (e.g., after pressing)

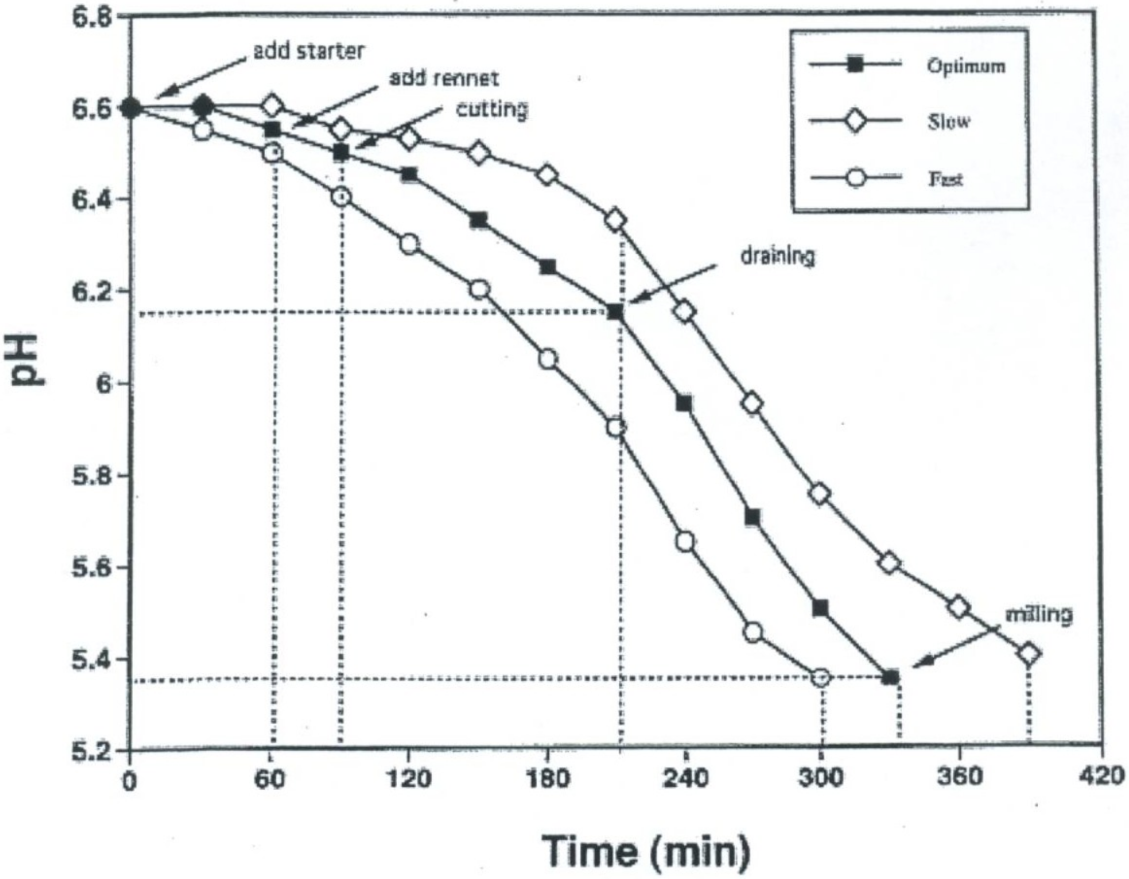
If pH or TA values are measured at various strategic points throughout cheesemaking, an acidity versus time curve can be generated and graphed using a personal computer and spreadsheet program such as Excel or Lotus. Such graphs can be used to monitor starter performance from vat-to-vat, day-to-day, week-to-week, etc. This provides a powerful tool for routine surveillance of the starter.

Example of a spreadsheet for monitoring pH and TA measurements at different times during the manufacture of cheddar cheese:

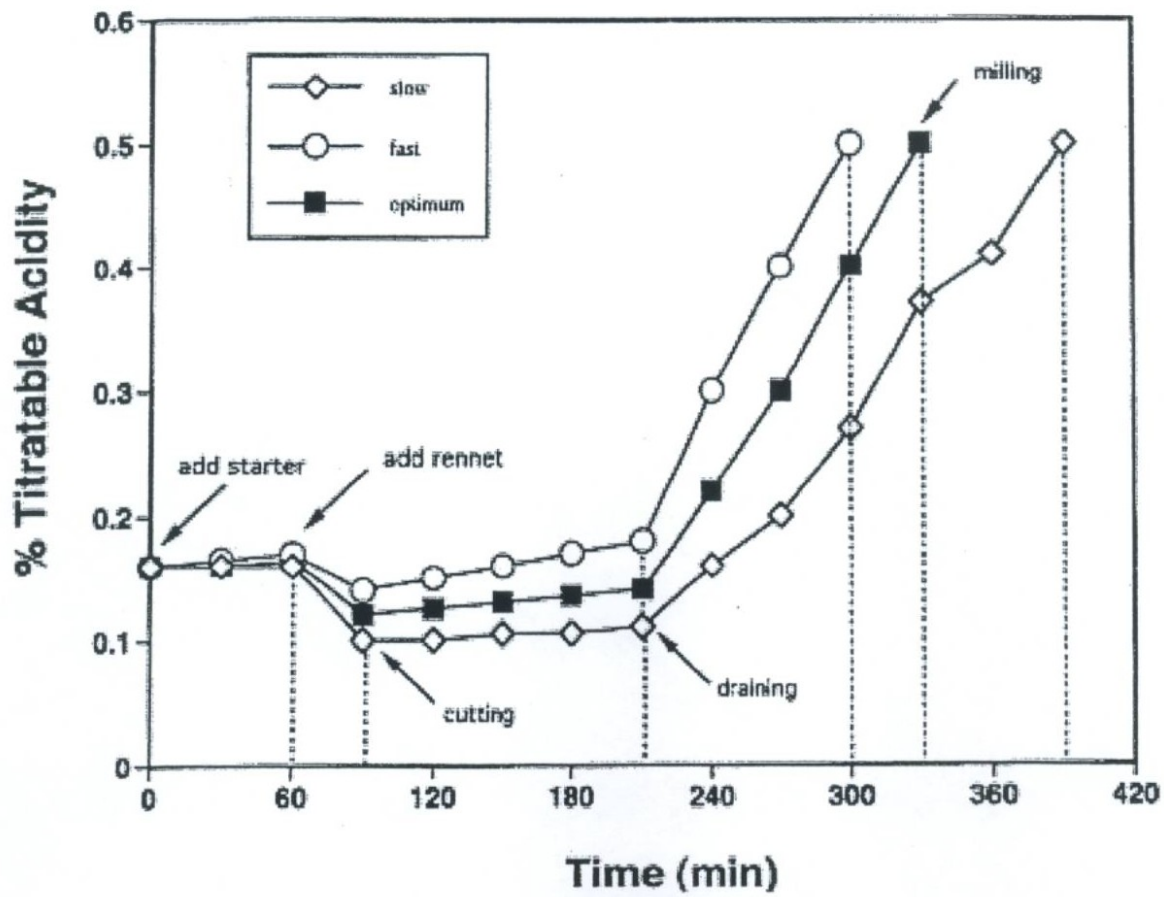
Farmstead 1 Tue, Aug 28, 1956 1:12 AM Page

	1	2	3	4	5	6	7	8
	Mfg Stage	Time (min)	pH Optimum	pH Slow	Fast	TA slow	TA fast	TA optimum
1	add starter	0	6.6	6.6	6.6	0.16	0.16	0.16
2		30	6.6	6.6	6.55	0.16	0.165	0.16
3	add rennet	60	6.55	6.6	6.5	0.16	0.17	0.165
4	cutting	90	6.5	6.55	6.4	0.1	0.14	0.12
5		120	6.45	6.53	6.3	0.1	0.15	0.125
6		150	6.35	6.5	6.2	0.105	0.16	0.13
7		180	6.25	6.45	6.05	0.105	0.17	0.135
8	draining	210	6.15	6.35	5.9	0.11	0.18	0.14
9		240	5.95	6.15	5.65	0.16	0.3	0.22
10		270	5.7	5.95	5.45	0.2	0.4	0.3
11	mill-fast	300	5.5	5.75	5.35	0.27	0.5	0.4
12	mill-optimum	330	5.35	5.6		0.37		0.5
13		360		5.5		0.41		
14	mill-slow	390		5.4		0.5		

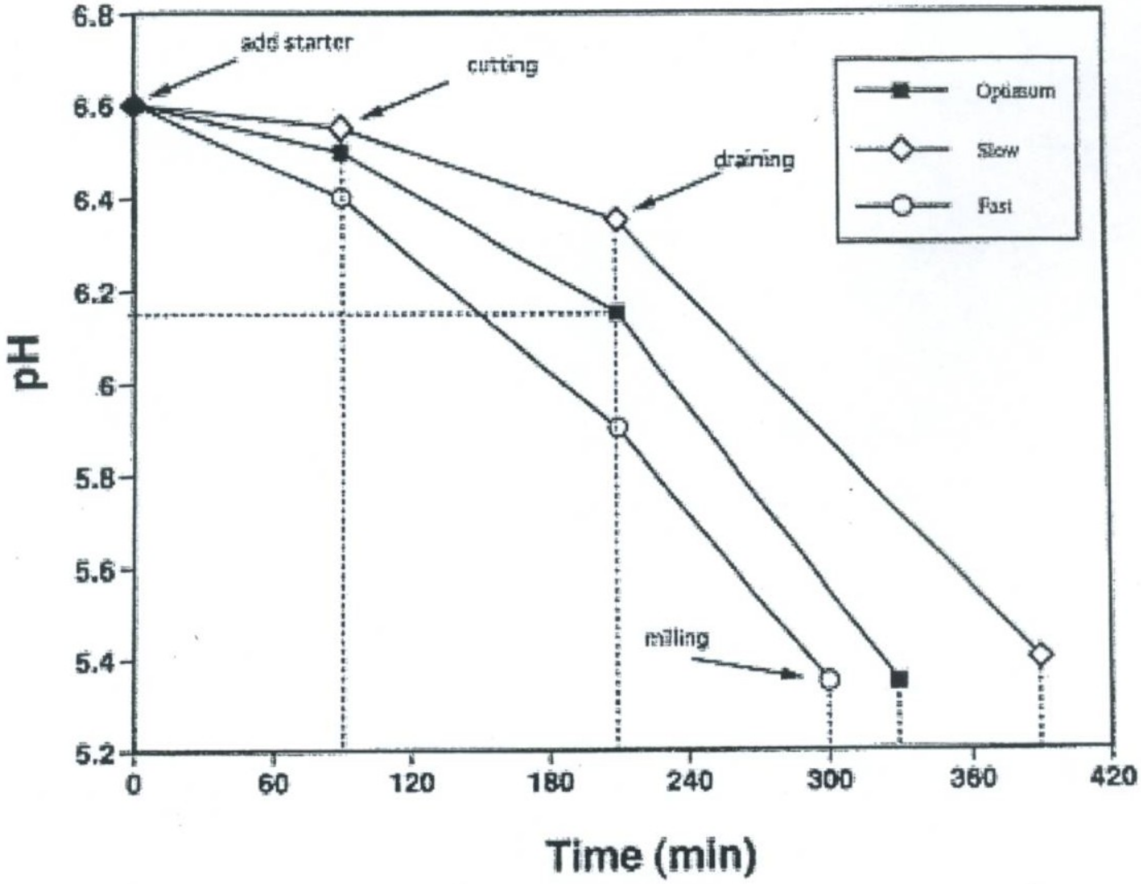
Examples of a graphic representation of spreadsheet data for pH and TA measurements at different times during the manufacture of cheddar cheese:



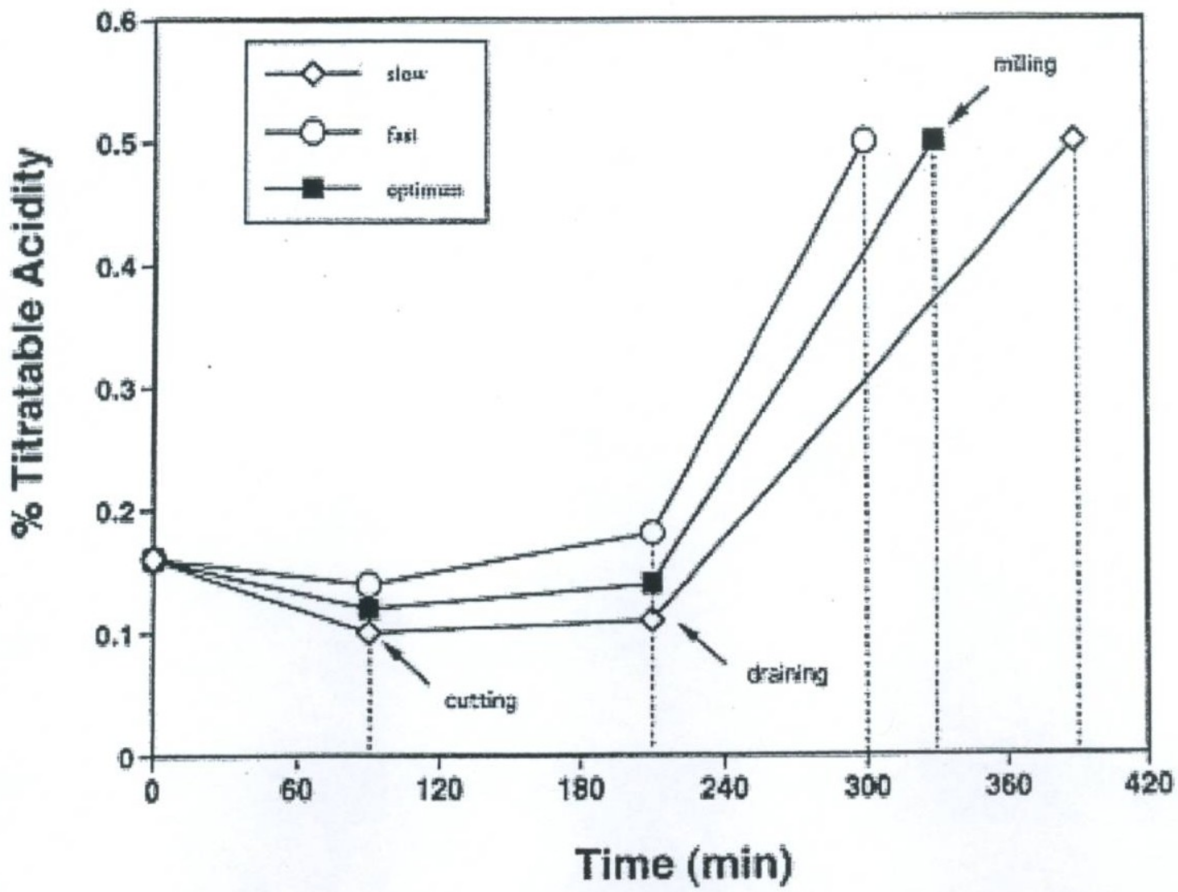
6.8
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
pH
0
60
120
180
240
300
360
420
Time (min)
add starter
add rennet
cutting
draining
milling
Optimum
Slow
Fast



0.6
0.5
0.4
0.3
0.2
0.1
0
% Titratable Acidity
0
60
120
180
240
300
360
420
Time (min)
slow
fast
optimum
milling
add starter
add rennet
cutting
draining



add starter
cutting
draining
milling
Optimum
Slow
Fast
pH
Time (min)



slow
fast
optimum
milling
cutting
draining
% Titratable Acidity
Time (min)

COMPARISON OF THERMOMETER READINGS

TEMPERATURE CONVERSION TABLES*

By Albert Sauveur

C.		F.	C.		F.	C.		F.
−17.8	0	32	1.11	34	93.2	20.0	68	154.4
−17.2	1	33.8	1.67	35	95.0	20.6	69	156.2
−16.7	2	35.6	2.22	36	96.8	21.1	70	158.0
−16.1	3	37.4	2.78	37	98.6	21.7	71	159.8
−15.6	4	39.2	3.33	38	100.4	22.2	72	161.6
−15.0	5	41.0	3.89	39	102.2	22.8	73	163.4
−14.4	6	42.8	4.44	40	104.0	23.3	74	165.2
−13.9	7	44.6	5.00	41	105.8	23.9	75	167.0
−13.3	8	46.4	5.56	42	107.6	24.4	76	168.8
−12.8	9	48.2	6.11	43	109.4	25.0	77	170.6
−12.2	10	50.0	6.67	44	111.2	25.6	78	172.4
−11.7	11	51.8	7.22	45	113.0	26.1	79	174.2
−11.1	12	53.6	7.78	46	114.8	26.7	80	176.0
−10.6	13	55.4	8.33	47	116.6	27.2	81	177.8
−10.0	14	57.2	8.89	48	118.4	27.8	82	179.6
−9.44	15	59.0	9.44	49	120.2	28.3	83	181.4
−8.89	16	60.8	10.0	50	122.0	28.9	84	183.2
−8.33	17	62.6	10.6	51	123.8	29.4	85	185.0
−7.78	18	64.4	11.1	52	125.6	30.0	86	186.8
−7.22	19	66.2	11.7	53	127.4	30.6	87	188.6
−6.67	20	68.0	12.2	54	129.2	31.1	88	190.4
−6.11	21	69.8	12.8	55	131.0	31.7	89	192.2
−5.56	22	71.6	13.3	56	132.8	32.2	90	194.0
−5.00	23	73.4	13.9	57	134.6	32.8	91	195.8
−4.44	24	75.2	14.4	58	136.4	33.3	92	197.6
−3.89	25	77.0	15.0	59	138.2	33.9	93	199.4
−3.33	26	78.8	15.6	60	140.0	34.4	94	201.2
−2.78	27	80.6	16.1	61	141.8	35.0	95	203.0
−2.22	28	82.4	16.7	62	143.6	35.6	96	204.8
−1.67	29	84.2	17.2	63	145.4	36.1	97	206.6
−1.11	30	86.0	17.8	64	147.2	36.7	98	208.4
−0.56	31	87.8	18.3	65	149.0	37.2	99	210.2
0	32	89.6	18.9	66	150.8	37.8	100	212.0
0.56	33	91.4	19.4	67	152.6			

NOTE:

The numbers in the center column refer to the temperature either in degrees Centigrade or Fahrenheit which it is desired to convert into the other scale. If converting from Fahrenheit degrees to Centigrade degrees the equivalent temperature will be found in the left column, while if converting from degrees Centigrade to degrees Fahrenheit, the answer will be found in the column on the right. These tables are a revision of those by Sauveur & Boylston, metallurgical engineers, Cambridge, Mass.

*From "Sealtest Laboratory Manual," Courtesy Sealtest Foods Div., National Dairy Products Corp.

STARTER CULTURE EQUIVALENTS

Rosell bulk		Ezal DVS
meso III	L. lactis L. cremoris	MAO — series 2 bacteria species
meso III + thermo A	L. lactis. L, cremoris S. thermophilus	RA — series 3 bacteria species

1) EZAL DVS needs 30 min. longer ripening in milk before adding rennet than bulk starter.

2) 1U (unit of acidification) will inoculate 50 lb. milk at the same rate as 1/2 lb. bulk starter (1%).

e.g.

1U Ezal MA014
0,5 lb. Rosell meso III → 50 lb. milk

equals 1% addition rate

EZAL 20, 50, 100, 200 U } package sizes

MA400.1 / 400.2 > 2U, 10U, 20U

EZAL DVS Culture

20U = "strength" "activity"

1/4 tsp ~ → 1U → 50 lb = 1% bulk culture

	wt
20U	15,0g
package	5,0g
20U culture	10,g

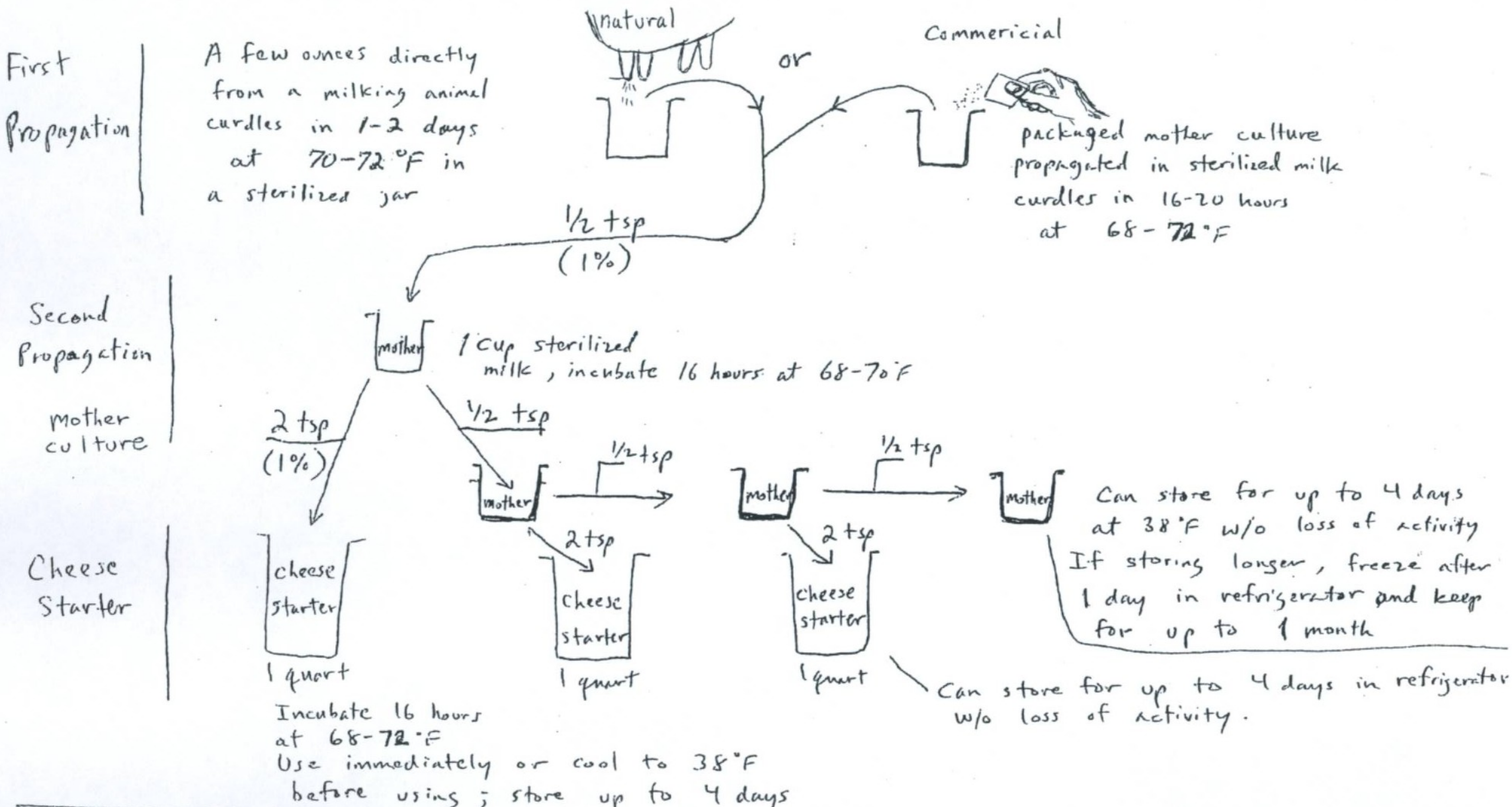
$\frac{10g}{20U} = \frac{.5g}{1U}$

? MM100 at 1% rate

80 lb milk ÷ 50 = 1,6 U

1,6U × .5g/U = 98g

Method of Preparing Bulk Starter Cultures, Mesophilic type



- Can freeze mother culture as ice cubes and store up to 1 month

- Aroma Cultures:

Larger inoculum (2%) Lower temp 64 °F Less aroma bacteria esp. Lc. diacetylacis	CO_2 less early gas less aroma	CO_2 more gas more aroma	Smaller inoculum (1/2 %) Higher temp 72 °F More Lc. diacetylactis more eyes from early gas

Preparation of a Mesophillic Starter Culture

1) Sterilize a clean 1 litre Mason jar and its cover in boiling water for five minutes.

2) After sterilizing the jar remove from water, let jar cool to room temperature then fill with your own fresh skimmed milk or 1 % homo milk from the grocery store.

3) Place the jar of milk in a water bath until the level of the water is equivilent to the top of jar.

4) Bring the water bath to a rolling boil and hold here for thirty minutes.

5) Carefully remove the jar from the water bath and allow to cool to 72 F or 20 -22 C. To check if the milk in the jar is adequately cooled hold the jar next to your cheek and it should feel tepid or just slightly warm, this takes approximately 6 - 8 hours after removing from water bath.

6) Innoculate the sterile milk by adding 3/8 tsp of the freeze dried starter culture sprinkling the culture evenly on the surface of the milk. Allow the culture to dissolve somewhat (takes about two minutes) replace the lid of the jar and gently rock the jar back and forth to mix the culture into the sterile milk. To ensure the culture is adequately mixed look at the bottom of the Mason jar to see if there are any yellow granules , if so continue to rock the jar until they have disappeared, as this represents culture powder that has not dissolved into the milk.

7) Place the jar in a warm place where the temperature is stable at 72 F or 22 C. up as high as 77 F or 25 C. where the jar will remain for 12 - 24 hours until the milk has thickened The most ideal location to prepare the meso type culture is in the cupboard over the refrigerator wrapped in a hand towel.

8) After 12 hours from the time of innoculation check to see if the milk has coagulated or thickend this usually takes about 16 hours under favourable conditions but it can be sooner if the room temperature is higher than 72 F. When the culture has the consistency of a good firm yoghurt you have reached the coagualtion point.

9) Chill the culture immediately by placing the jar in the fridge, it will keep as a fresh active culture for 3 - 4 weeks. The fresher your culture the better your cheesemaking results. The culture can be used for cheesemaking right after the coagulation point is achieved. 10 Grams of mesophillic culture can be made into 10 litres of "mother" culture by following the above procedure. DO NOT FREEZE YOUR PREPARED CULTURE.

10) Keep the un-used portion of your culture package in the freezer where it will remain active for three years.

11) It is not necessary to prepare a culture in order to make cheese, the freeze dried cultures can also be used as a direct set culture by adding the culture at the recommended rate according to your recipe. You can prepare cheese by adding the powder into your cheese pot or vat for direct innoculation.

*The above procedure can be used to prepare mesophillic and aroma cultures only.

Table 2. Cheese varieties grouped according to their approximate contents of fat in the dry matter (F/DM). Maximum moisture and minimum fat contents are listed as defined in the Dairy Products Regulations[1]. An estimated protein-fat ratio (P/F) of the milk is given for each group of cheese.

F/DM and P/F	Varieties	Moisture	Fat
F/DM = 50-51 P/F* = 0.99-0.89 P/F** = 0.96	Asiago	40	30
	Blue	47	27
	Butter	46	27
	Brick	42	29
	Brie	54	23
	Camembert	56	22
	Canadian style Brick	42	29
	Canadian style Munster	46	27
	Cheddar	39	30
	Colby	42	29
	Fontina	46	27
	Jack	50	25
	Limburger	50	25
	Monterey	44	28
	Muenster (Munster)	50	25
F/DM = 47-49 P/F* = 1.12-1.03 P/F** = 1.07	Baby Gouda	45	26
	Farmers	44	27
	Feta	55	22
	Gouda	43	28
	Montasio	40	28
	St. Jorge	36	31
F/DM = 44-47 P/F* = 1.17-1.21 P/F** = 1.19	Caciocavallo	45	24
	Danbo	46	25
	Elbo	46	25
	Emmentaler (Swiss)	40	27
	Esrom	50	23
	Fynbo	46	25
	Gruyère	38	28
	Havarti	50	23
	Kasseri	44	25
	Maribo	43	26
	Provolone	45	24
	Samsoe	44	26
	Tilsiter (Tilsit)	45	25
	Tybo	46	25
F/DM = 38-42 P/F = 1.47	Baby Edam	47	21
	Bra	36	26
	Edam	46	22
	Mozzarella (Scamorza)	52	20
	Pizza	48	20
	Romano (Sardo)	34	25
F/DM = 29-32 P/F = 2.50	Parmesan	32	22
	Part skim Mozzarella	52	15
	Part skim Pizza	48	15

[1] In Canada Agricultural Products Standards Act.

P/F* Range of values depends on moisture content of the cheese. The lower the cheese moisture, the higher the required P/F.

P/F** Is an average value which can be used for all cheese in the group.

SURFACE RIPENED CHEESE LABORATORY

PRESENTED BY
CENTER FOR DAIRY RESEARCH
MADISON, WISCONSIN

AUGUST 19, 1992

SURFACE RIPENED CHEESES
BY
JOHN JAEGGI

AUGUST 19, 1992

I. Introduction

a. Semi-soft varieties (Limburger,Brick,Fontal)
   1. Between 39-50% moisture
   2. Not less than 50% FDM
   3. Cheeses ripen from the surface towards the center of the cheese
   4. Cheeses have little or no rind

b. Hard varieties (Gruyère, Appenzeller, Comté)
   1. Up to 40% moisture
   2. 45% FDM minimum
   3. These varieties ripen from the surface towards the center of the cheese
   4. These cheeses have a rind of various degrees, varying with the cheese moisture

II. The Process of Surface Ripening

a. Factors that affect ripening process
   1. Moisture of the cheese
      a. no whey pockets that may hold residual lactose
      b. too much moisture results in irregular consistancy and often an unclean odor
   2. Size of the cheese
      a. small cheese will allow for quicker ripening time due to a larger surface area being exposed and shorter distance for the enzymes to penetrate into the cheese
      b. larger cheese (>6 lbs.) will increase the time it takes for the smear enzymes to penetrate to the cheese interior
   3. Curing of the cheeses during ripening
      a. must have a seperate, enclosed curing room, especially if other cheese varieties are made in the plant. The room temperature should range from 55°- 60° F and have a relative humidity of 95 - 98% for semi-soft varieties. For hard varieties that require a rind, relative humidity should range from 85 - 92%.

b. the cheese placed in the curing will vary in age from 2 days with Limburger and brick to 3 days with gruyère. The cheeses should be rubbed within two days of entering the curing room with a 2 to 3% salt water solution for limburger or in the case with Gruyère, rubbed with plain salt. It is best to apply this solution with a semi-firm brush that "holds" the salt water solution when the brush is dipped into the pail or can that contains the salt water.

c. cheeses in the curing room will eventually develope a reddish-orange color over the cheese. If the curing room is established this should take no more than 4 or 5 days. At this point, a soft brush that "holds" water should be used, reason being a harder brush will wipe the smear developing on the surface.

4. Microbiological composition of the smear

a. 1-2 days after salting the yeasts, including Torula and Mycoderma which are found in limburger, begin to grow in large numbers. Yeasts thrive at the 55° to 60° F temperatures and also grow readily in the high humidity. The yeasts can tolerate a low pH (Limburger typically runs 4.85 - 5.00 pH) and a high salt concentration on the cheese surface. Because cheeses are brined or dry-salted, the cheese surface is higher in salt content, helping to inhibit other organisms from growing.

b. 3-4 days after salting the yeasts change the cheese surface due to their metabolizing the lactic acid, thereby raising the pH of the surface, allowing the growth of micrococci and B. linens. The surface pH at this point is 5.5 to 5.85. At this pH the yeasts may contribute to proteolysis on the cheese surface. Proteolysis also occours to eliminate curdiness and produces a smooth, butter-like consistancy.

c. molds can appear on the cheese surface during curing but is not desirable. The most common variety is Geotrichum candidum. By keeping the cheese surface "moist" with the smear, this will inhibit the growth of the mold on the cheese surface due to competition for "food".

d. 5-10 days after salting, the cheese can be removed from the curing room, exact time depending on the flavor intensity desired. Upon wrapping, the smear can be washed off the surface or left on, again depending on the intensity desired.

III. Defects and their Prevention

a. Lack of surface growth
   1. low temperatures
   2. high salt concentration
   3. low humidity. "toad skin" develops when the surface dries to the point where the smear won't penetrate.
   4. too hard of brush used on surface will wipe smear off.

b. Mold growth
   1. when cheese surface is too dry and smear development is inibte

2. Brushes, shelves, and the room should be kept as clean as possible to prevent mold contamination. The curing room should be periodically washed with 200 p.p.m. chlorine, then followed with 400 p.p.m. of quaternary ammonium. The quat will penitrate cracks and pores in the floor, wall, and ceiling, thus helping inhibit mold.

c. Discoloration
   1. when orange "blotches" appear (b.linens) a soft brush should be used to smear these evenly around the cheese to give the surface color an even appearance

d. Body defects
   1. corky curdy body comes from excessive washing of the curd, inadequate acid development, or low moisture cheese.
   2. a weak and pasty body is caused by high moisture, high acidity, or undersalting.
   3. mealiness is a grainy chacteristic caused by excessive acid development during manufacture or curing. Can happen in high moisture, no-wash cheese.
   4. openness in small numbers is desired but in large numbers is considered a defect. It can happen due to curd firmness, whey-curd ratio at drain, pH and temperature of the curd. High pH and firm curd will cause more mechanical openness.
   5. gassiness can be caused by coliforms, yeasts, heterofermentative lactobacillus, to name a few.
   6. splits come from anaerobic spore-forming bacteria that create gas rapidly in poorly fused curd. It is more likely to happen in a higher acid cheese

e. Growth of pathogens
   1. staph aureus can contaminate through milk, equipment, and human carriers. Milk should always be pasteurized especially for smear-ripened cheese.

   2. salmonella can contaminate the same routes as s. aureus and like s. aureus, surface-ripened cheeses provide the perfect hosts (high pH, high humidity, medium range temperature).

IV. Making the Smear Solution

a. 3 to 100 salt to water ratio is best

b. best to get bacterial strains of yeasts, b.linens, and micrococci from a culture house if it is possible. These can be grown up in a tryptic soy broth. This will prevent bringing in contaminants from another plant. If this isn't possible just cut the surface off the cheese you are trying to duplicate and place in the 2% salt water solution and the bacterial flora will grow (as will mold or other contaminants).

SURFACE-RIPENED
CHEESE

Procedures

TIME TABLE FOR AMERICAN CHEESE LAB
August 8, 1992
300 lbs milk per vat

	Vat number 1 Sweet Brick	Vat number 2 Richelieu	Vat number 3 Fontina
12:45	Starter (21.6 mls DVS 850)		Starter (21.6 mls DVS B11 & 1 gram PS1)
1:30		Starter (10.8 mls DVS 850 & DVS ST75 30 gram)	
1:45	Rennet (27.5 ml)		Rennet (27 ml)
2:00		Cheese Color (3 ml)	
2:15	Cut (1/4 knives)	Rennet (39 ml)	
2:20			Cut (3/8 Knives)
2:30	Heat on	Cut (3/8 knives)	
2:35			Drain 33% Whey
2:45			Add Water (130F)
2:50			Ajust Temp to 102
3:00	Heat off (101F)	Dip	
3:05	Drain (to 1 inch over curd)		
3:10	Add Water (150£ at 101F)	First Turn	
3:15			
3:20		Second Turn	
3:30	Final Drain	Third Turn	
3:35	Dip		
3:40		Fourth Turn	
3:45	First turn		Press under Whey
3:50		Fifth Turn	
3:55	Second turn		
4:00		Into Brine	Drain Whey
4:10	Third Turn		
4:15			Cut and Hoop
4:20	Into Brine		

MAKE RECORD FOR WASHED-CURD BRICK CHEESE

MILK	STARTER	CHEESE	
Pounds 350 Milk fat 3.5-3.8 Pasteurization 145°F for 30 min.	Age 15 hr. Acidity 0.70 pH 5.00 Type Lactic streptococci	H_2O % 43-44 Fat % 29-30 FDB % 52 Salt % 1.75 SMP % 4.0 pH 5.20-5.30	Yield % 11.7-12.0 $\frac{\text{lbs. cheese}}{\text{lbs. milk fat}}$ 3.2

Operation	Time Hr:Min	Temp °F	pH	Acid %	Comment
Add Starter[a,b]	0:00	88	6.65	0.16	400 mls (.25%)
Add Rennet	0:00				32 mls
Coagulation	0:12				
Cut Curd[a,b]	0:30		6.62	0.10	1/4" knives
Steam On	0:45				By Schedule*
Steam Off	1:15	101			
Drain[a,b,c]	1:20		6.60	0.11	Leave 1" ov whey over curd
Add H_2O	1:25				175# at 101°
Drain[a,b,c]	1:45		6.60	0.50	Leave 1" ov whey over curd
Dip	1:50				
1st Turn[c]	2:00				Add metal followers
2nd Turn[c]	2:30				Keep hoops close together on metal
3nd Turn[c]	3:30				drain racks in a 70°F. room. Add
4th Turn[c]	4:30				5 lb. wts. on cheese at 2:30 and
5th Turn[c]	5:30				remove it at 5:30
Brine[c]	7:30				24 hrs. in 22% brine
Smear Development	Approximately 2 wks. at 60-65°F; relative humidity 90%				
Finishing	Wash smear growth from bricks; dry surface of bricks and parraffin. Hold at 40°F.				

*Heating Schedule

Minutes from steam on	0	5	10	15	20	25	30
Temperature °F	88	89	91	93	96	99	102

[a]Titratable acidity measurement
[b]pH of milk or whey measurement
[c]pH of curd measurement

RICHELIEU

the method of manufacture was as follows:

1. 100 gallons pasteurized milk containing 4.2 percent fat used.
2. Add 0.5 percent starter and 0.5 percent *S. thermophilus* culture.
3. Ripen the milk for 45 minutes at 106° F.
4. Add 1 ml. cheese color per 100 pounds milk.
5. Add 13 ml. rennet per 100 pounds milk.
6. After 15 minutes from adding rennet, cut with 3/8 inch knives.
7. Stir curd and whey carefully with a large perforated stainless steel ladle.
8. Place curd in perforated stainless steel hoops, with enough curd in each hoop for four pounds cheese.
9. Keep hoops in an incubator maintained at 115° F. The water under the hoops should be maintained at 125° F.
10. After five to six hours the acidity of the whey that drains from the curd should be 0.50 percent.
11. During incubation turn the curd every 10 minutes during the first hour and every 20 minutes during the last hour.
12. Remove the hoops with cheese and place them in a refrigerator for 30 minutes.
13. Remove hoops and place the cheese in a bath of saturated brine for 18 hours.
14. Cure the cheese at 40° F. and 95 to 98 percent relative humidity.
15. Wash the cheese twice weekly with warm 4 percent brine after mold has started to grow on the surface.
16. Yield of cheese: 12 pounds from 100 pounds 4.2 percent milk.
17. When the cheese is ready to sell, it is dried in a cool room, then wrapped in waxed paper, or cut into ½ pound prints, and placed in Cryovac film bags.

"Richelieu." has been made regularly, at the Dairy School, St-Hyacinthe, Quebec, Canada.

Cal Poly Fontina Procedure

The milk was inoculated with 1.5-2% mesophilic mixed multiple strain lactic starter culture. In order to have moderate eye development, 1 gram Propionibacterium shermanii per 440 pounds (200 kg) of milk was added. Culture was added to pasteurized milk warmed to 88°F (31°C). The milk was ripened for one hour or until a pH of 6.54 was attained. The pH of the milk at renneting appears to be a critical control point since it influenced the quality of the cheese.

Single strength calf rennet was added at a rate of 3 ounces per 1000 pounds (90 ml per 453 kg) of milk. A firm coagulum occurred in 20-30 minutes. The coagulum was cut with 3/8 inch (9.5 mm) wire curd knives. The curd was gently stirred for 15 minutes, during which time the curd firmed. No additional heat was applied at this time.

At the end of the 15 minutes, whey was removed until 30% reduction of the original milk volume was attained. This took approximately 5 minutes. Water at 130°F (54°C) was added until the original volume of the vat was reached. At this time, the temperature of the vat should have been 102°F (39°C). If the hot water addition did not raise the temperature of the curds and whey to the desired temperature, the steam jacket was used. The addition of water should not exceed the amount of whey which had been drained. The amount of whey removed in combination with the amount of water that was added had a marked effect on the final pH, flavor and body of the cheese. The watered curd and whey were stirred for 1 hour, during which time the curd firmed.

The gathering and pressing of the curd under the whey, which is referred to as prepressing, is an important step. The vat must be measured and the curd must be pushed back and pressed so that portions of prepressed cheese can be cut from the mass that are the proper size and weight. If a solid piece of prepressed cheese is not used, eye development is poor and the cheese does not have the proper appearance. Pressing under the whey was performed by using a solid plastic sheet and applying 5 pounds per square foot (224.4 kg per m2) of force.

After 30 minutes prepressing, the whey was drained and the curd was pressed for an additional 30 minutes. The prepressed cheese was cut into 10 pound (4.5 kg) blocks, which approximated the size of the hoops, and placed into metal hoops lined with plastic cheesecloths. The cheese was pressed overnight at 5-8 psi in a conventional cheddar cheese press.

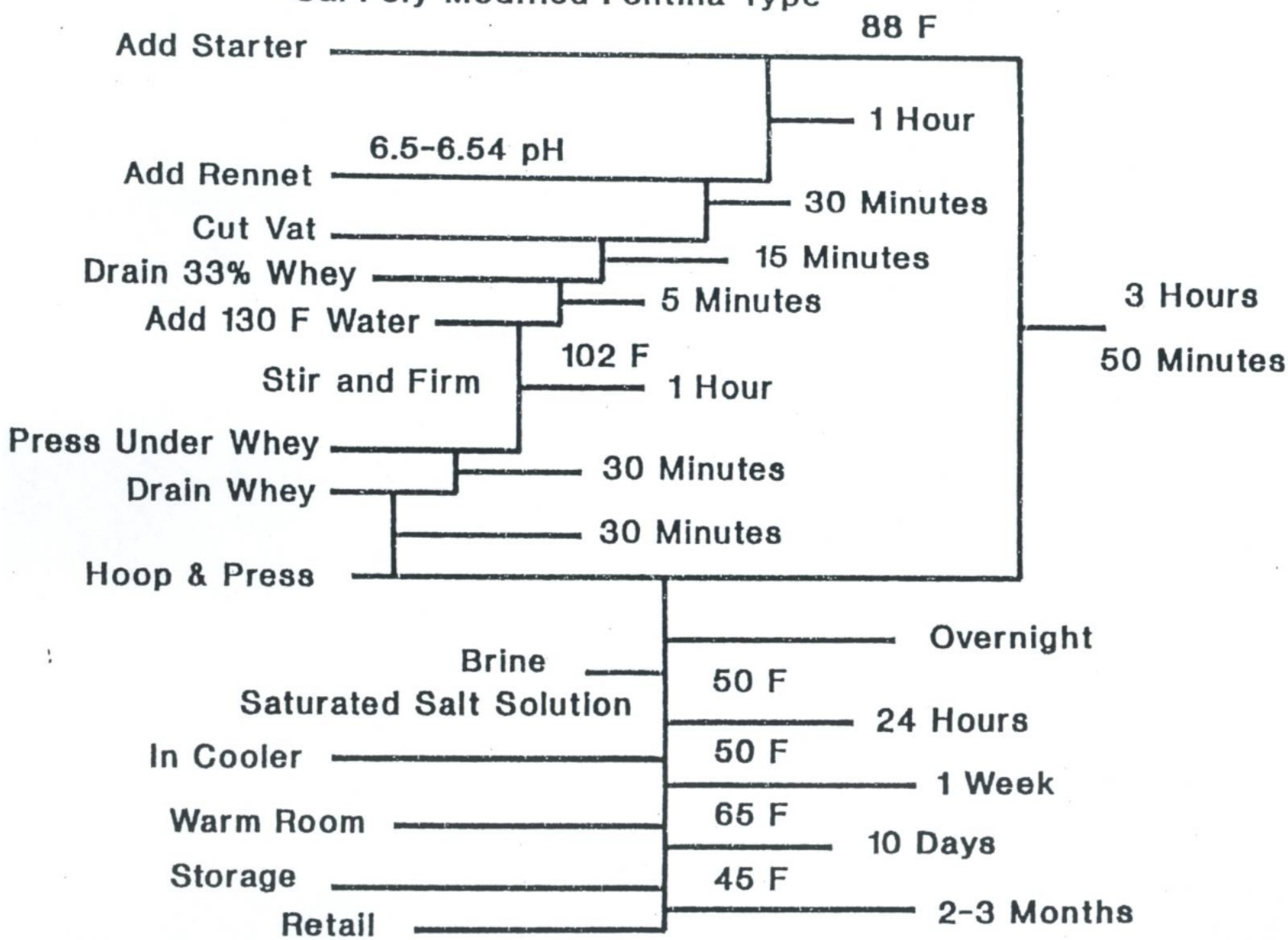
After pressing, the cheese was removed from the hoop and placed in a saturated salt brine at 50°F (10°C). Brine time was dependent on the size, shape and finish of the pressed cheese. In this case, the cheese was brined for 24 hours. The cheese was airdried and vacuum-packaged in heat shrinkable plastic bags.

The cheese was stored at 50°F (10°C) for 7 days. This was done to allow salt and moisture equilibration. The cheese was placed in a warm room at 65°F (18°C) and cured for 1 to 3 weeks. The shorter cure times resulted in cheese with little eye development. The 2-3 week treatments produced cheese with more eyes. These cheeses had an appearance similar to Danbo or Baby Swiss. After the warm room, the cheeses were placed in a cooler at 45°F (7°C) and stored for 1-2 months, during which time the smeared rind is developed.

Moisture in the finished cheeses was 40-42% with a 50% FDB. Using this procedure, a 10.5% yield was attained. The cheese was ready for market 1 to 2 months after manufacture. By using the breathable plastic bag, repackaging of the cheese was not necessary.

CHEESEMAKING CHART

Cal Poly Modified Fontina Type



Salting & Brining

Carol Chen, Researcher
Center for Dairy Research

I. Why we add salt to Cheese

A. Flavor Enhancement

B. Control Starter and Non-Starter Organisms

C. Regulates Enzyme Activity

D. Promotes Curd Syneresis

E. Firm Texture

II. Methods of Salting

A. Direct addition and mixing of salt crystals to broken or milled curd pieces
ex. Cheddar or Cottage

B. Rubbing of dry salt or salt slurry
ex. Blue Cheese

C. Brining
ex. Edam, Gouda, Mozzarella, Provolone

D. Combination of B and C.
ex. Traditional Swiss

E. Mozzarella
Dry salting vs brining

III. Brining

A. How to make a brine solution

Salt (NaCl)		19.95 kg
Calcium Chloride	($CaCl_2 \bullet 2H_2O$)	1.58 kg
Acetic Acid		31 mls pH 5.00
Sodium Acetate	($NaCH_3OO \bullet 3H_2O$)	.38 kg

To 100 kg of water

1. NaCl Concentration

   a. Salt Absorption
   The higher the salt concentration, the higher the salt absorption rates

   b. Methods of Measuring Salt Concentration

      i. Baume's hydrometer
      ii. Chloride Analyzer

2. Acidity

   a. pH of brine = pH of cheese

   b. Low brine pH
   Results in very hard rind

   c. High brine pH
   Results in slippery, greasy cheese

3. Calcium Concentration

   a. Calcium of brine = Calcium of cheese

   b. Low calcium
   Results in soft weak rinds = Rind Rot

   c. High calcium
   Results in firm, dry hornlike rind

4. Temperature

   a. Ideal brine temperature = 45°F

   b. Lower Temperatures
      - slower salt absorption
      - less whey loss into brine

   c. Higher Temperatures
      - faster salt absorption
      - high whey loss into brine
      - potential problem, protein swelling and growth of undesirable organisms in cheese

   d. Cheese temperature should be equal to the temperature of the brine

5. Agitation

   Prevents localized dilution around the cheese

B. Brine Maintenance

1. Visual Inspection

2. Microbial Counts

   Yeast & Mold Counts (Potato Dextrose Agar)
   Coliform (Violet Red Bile Agar)
   Addition of anti-mold agent, such as Delvocid

3. Corrective Measures

   a. Daily or weekly skimming

   b. Filtration

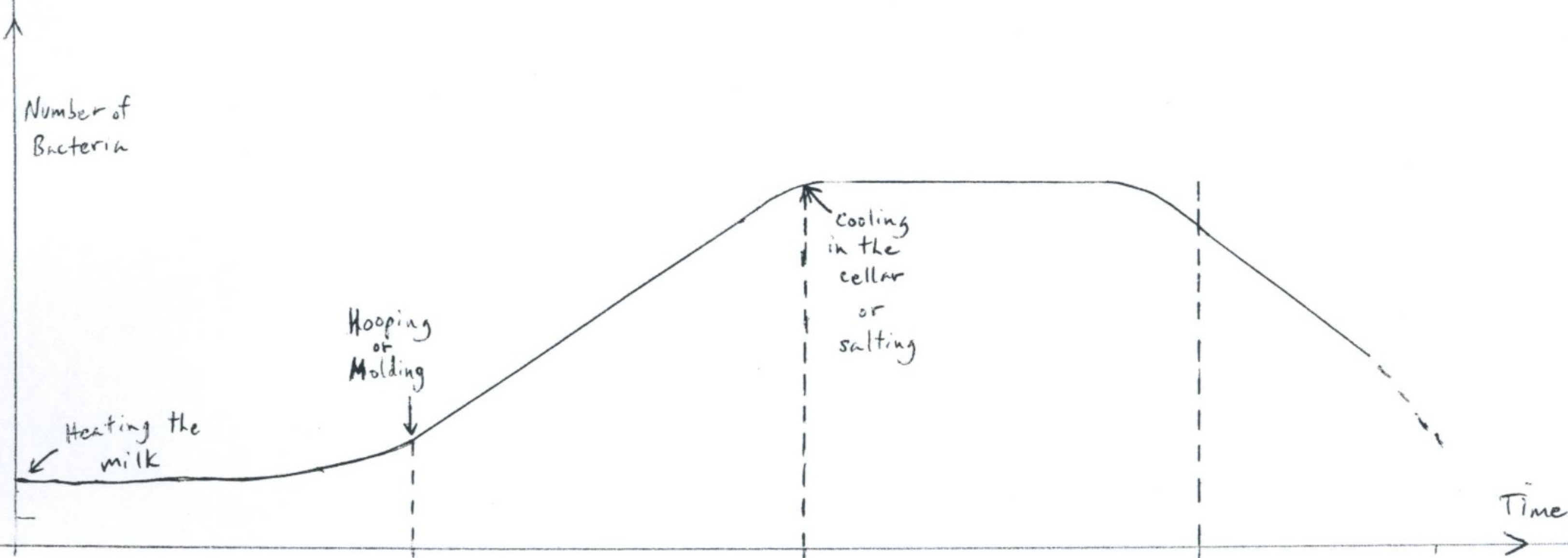
   c. Heat Treatments 1/2 hr. 45'

   d. Microfiltration

   e. UV Systems

4. Standardization

The Development of Lactic Bacteria During Cheesemaking



Latent

Phase when bacteria adapt to their environment.
e.g. EZAL MA400 = 3 hours
(Direct-vat-set culture)

Growth

Phase when bacteria multiply intensively: they consume most of the lactose and produce most of the lactic acid.

Plateau

Stationary phase
No more Bacterial growth or lactic acid production.

Decline

Bacteria die.
The environment is hostile.

Acidity/pH Testing

It is important to test the acidity of milk and whey during cheese making for two reasons;
(1) Fresh milk quality
(2) Acid development during cheese making

<u>Fresh milk quality</u>

Normal ranges are:

Holstein cow, Alpine or Saanen goat = 15 - 18
Jersey or Brown Swiss cow, Nubian goat = 17 - 21

In late lactation when milk protein is very high the acidity of fresh milk can be higher than normal.

An acidity of 25 or more indicates that the milk is souring. In this case, cheese making must be changed accordingly:

- Reduce the amount of starter by 1/2 or more
- Speed the cheese making process up to avoid making acid cheese, which involves eliminating the ripening period before adding rennet, cooking the curds at a higher temperature for less time, draining whey for a shorter time, and salting the cheese sooner.

<u>Acid Development</u>

Each cheese recipe has bench marks for acidity at the different steps in the process. These benchmarks should be established and followed as closely as possible every time you make cheese. This will indicate if the acidity is developing at the normal rate during cheese making. In case of abnormal acid development, proceed as follows:

- If acidity is developing too quickly, the cheese making process should be speeded up as in the case of soured milk.
- If acidity is developing slowly patience is required as the process will take longer before you can salt the cheese.
- If the acidity is developing very slowly in pasteurized milk the cheese may not turn out well and may pose a health risk because the starter bacteria are not doing their job and there are no natural bacteria in the milk that can take over the fermentation.
- If the acidity is developing very slowly in raw milk there is also a health risk, however the cheese may turn out well because the natural bacteria may develop sufficient acidity in time.

Acidity is typically measured at the following points in the cheese making process:

1. In fresh milk at the start of cheese making
2. In whey after curds are cut
3. In whey from the top of curds before ladling curds for goat cheeses or before cutting cottage cheese curds
4. In whey while curds are draining in forms (this is usually done 2 - 3 times at hourly intervals and before salting)
5. In whey at the end of cooking curds and before draining

Salting Cheese

(1) Dry Salting after milling for a large quantity of curds: It is best to apply the salt in 3 portions (equal) 10 minutes apart. In this way there is enough salt in the cheese and less is lost to the whey. For making small batches, salt can be added at once. Keep curd temp 90-93°F for Cheddar types.

(2) Brining Wheels
Either use whey + salt to make the brine, or follow the recipe for making brine from water, calcium chloride, vinegar, and salt (Winter 2000, Farmstead Cheesemaking).

- It is important to control the temperature of the brine, 50-55°F, especially if using a whey brine to prevent growth of yeast + mold.
- 4 hours per one # cheese is an average time for brining, which should be shortened if the cheeses are less than 4" thick, e.g., 3 hours per one # cheese for 3" thick cheeses.
- The brine should always be saturated with salt (23% solution).

What Is Cheese Ripening? Some Thoughts From *The Cheese Bible**

"The environment in which the majority of cheeses are ripened is usually a ripening cellar or a special storage room. As far as possible, its atmosphere imitates the natural atmosphere of the cave, which for centuries has been used to ripen cheeses (the caves of Roquefort are a well-known example). The ripening cellar may be humid and warm, or relatively cool.

"The climate of the cellar is determined by the ambient temperature and relative humidity, as well as by the natural movement of air in the space. Although the temperature can range from 32 to 77° F, the majority of cheeses are ripened at between 46 and 60° F. The relative humidity can range from 75 to 98 percent, but as a rule lies between 85 and 95 percent. During maturation there is a constant exchange between ripening gases, such as carbon dioxide and ammonia, from the cheese and oxygen in the air, which is crucial for the growth of both aerobic surface flora and interior flora.

"For most cheeses, a relatively slow process of achieving a balanced distribution of important constituents (such as water, sodium chloride, lactose or lactic acid) throughout the cheese is set in motion or continued in the initial stage of ripening. This is an important prerequisite for the rest of the process, which must be as even as possible. Ripening, which is also called aging or curing, refers to the process by which the constituents of the milk retained in the cheese (such as protein, residual sugar, and fat) are further broken down to produce the required flavors and qualities of the specific cheese.

"Enzyme activity is the driving force of this process. It may be initiated by the milk itself, or by various aids (for example, rennet or rennet pastes), and it may also be set in motion naturally by microorganisms that have landed in or on the raw cheese through contact with the equipment, the brine bath, or the surrounding air. The main sources of enzymes are the acidifying and ripening cultures that have been used. Very occasionally, it is just the acidifying cultures (such as the lactic acid bacteria in the case of fresh cheeses), but usually the ripening flora are composed of many groups of microorganisms. These may be lactic acid bacteria, propionic acid bacteria (in the case of certain hard cheeses) or cultures such as yeasts and "noble" molds (white and blue molds)."

*Excerpted from ***The Cheese Bible***, by Christian Teubner, Friedrich Wilhelm Ehlert and Heinrich Mair-Walburg. East Rutherford, N.J.: Viking-Penguin, 1998.

Tips on Aging Cheese

Author's note: Do not use this information as a rote formula. It is provided as a reference point only. Nothing can replace looking at and handling your cheese directly.

Aging cheese -- or in French, "Affinage" -- is the art and science of providing the right environment to nurture cheese over time. The single most important key to success is the quality of the cheese to be aged and the milk it is made from. Not every wheel made is best for aging, even by a master cheesemaker.

How do you learn to recognize which wheels will thrive when aged and what to do to nurture them? By observation and experience.

Aging:

"Affinage" literally means "finishing." To quote from the AOC, the agency that controls the Appellation d'Origine Controlée:

> "Aging: this phase is fundamental to give to cheese all its characteristics of flavor, color and texture. Every variety of cheese has optimal conditions for aging: temperature, relative humidity, duration. During aging, the cheeses are regularly turned over, their rinds may be brushed, washed and perhaps garnished with ash, hay, or herbs..." (D. Strongin)

Or, as Christian Teubner says in *The Cheese Bible*:

> "Ripening, which is also called aging or curing, refers to the process by which the constituents of the milk retained in the cheese...are further broken down to produce the required flavors and qualities of the specific cheese."

The Building Blocks of Aging:

- Good cheese, in particular, cheese that has the right structure for aging. (For the cheesemaker, it begins with good milk to make the cheese. Then, according to R.C. Lawrence, H. A. Heap, and J. Gilles, "The single most important factor in the control of cheese quality is the acid production in the vat."
- The right temperature and humidity for the individual cheese.
- Turning the cheese to counteract the effects of gravity.
- Controlling mold growth and rind formation.
- Enough time to ripen to perfection.

"Choose the right cheese to mature, and then watch it." - Randolph Hodgson

"Change the environment and you change the cheese." - Mariano Gonazalez

Useful Temperatures and Humidities

(Source: Randolph Hodgson)

Since each batch of cheese is unique, there are no hard and fast rules about what to do. The following is a reference, but in the end what will work for you is what works best for <u>your</u> cheese.

14°C (57° F) 95% RH mainly for wash rinds
12°C (53.6° F) 85% RH most traditional rinded harder cheese
10°C (50° F) 90% RH bloomy rinds
5°C (41° F) some blues and fresh cheeses

These are guidelines only, for instance, Neal's Yard ripens Stilton at 12'C and 85% RH although it is a blue. Other blues under those same conditions fall apart.

CHEESE	TEMPERATURE	RELATIVE HUMIDITY	TIME of RIPENING	OBSERVATIONS
APPENZELLER	10–14 ° C 50–57 F	75 – 80 %	4 to 6 months	Coating w. sulz *
ROQUEFORT	08–10 ° C 46–50 F	96 %	5 to 10 months	Ripened in caves
ASIAGO	10–12 ° C 50–53° F	85 – 90 %	4 to 6 months	For gratin cheese 12 to 18 months
STILTON After blueing	18 – 21 °C 64 – 69 F 7 ° C 44.6 °F	80 – 90 %	5 to 9 weeks 6 to 15 months	
BRIE After dev. white felt.	10–14 °C 50–57 F 10 °C 50°F	80 – 85%	4 weeks 4 to 5 months	
CAMEMBERT	12–13 °C 53.6–55.4 F	90 – 95 %	21 to 35 days	
CANTAL	8–10 °C 46.4–50° F	70 – 75%	3 months	Keep rind clean
CHEDDAR	7–12 °C 44.6–53 F	80 – 85 %	Young 5 to 6 months Mature 9 to 14months X-Mat. Up to 2 years	
COULOMMIERS	10 °C 50° F	90 %	8 weeks	
DANABLU	5–10 °C 41–50° F	90 – 95 %	6 to 8 weeks	
EDAM	12–14°C 53.6-57° F	75 – 80 %	Up to 8 weeks	
EMMENTAL Eyehole formation	3–7° C 37.4–44.6 20–24 °C 68–75° F	85 – 90 % 80 – 85 %	6 to 12 months 3 to 6 weeks	
GORGONZOLA	4–5 °C 39–41° F	80 – 90 %	5 months	
GOUDA	10–15 °C 50–59°F	80 %	6 to 12 months	
GRUYERE	First 10°C 50°F then15–20 °C 59–68° F	80 – 85 % 90 – 95 %	3 weeks 2 to 3 months	To dry Turn and wash
LIMBURGER	15°C 59° F	90 –95 %	3 to 4 weeks	
LIVAROT	12°C 53.6° F -	95 %	2 to 3 months	
MANCHEGO	First 12–15°C 53.6–59F then 5°C 41° F	75 – 90 % 70 %	8 weeks Fresco – 5 days Curado – 90 days Viejo – over 90 days	Rub w/ olive oil Or wax coated
PARMESAN	10°C 50° F	75 %	2 to 4 years	Rub w/ olive oil
PECORINO	15–18°C 59–64° F	75 – 80%	8 months	Rub with salt often
PONT L'EVEQUE	14–20°C	85 – 90%	5 to 6 weeks	

*Sulz is a liquid mixture of wine, yeasts, salt and spices (seasoning) *Chart courtesy of Mariano Gonzalez*

A COLOR CODED IDENTIFICATION GUIDE TO WHAT COULD BE GROWING ON YOUR CHEESE

BLACK

Mucor: Also known as cat's fur and poil de chat. It is a dark gray to black, tall fuzzy growing fungus that feels greasy. Undesirable on most cheeses except a tomme de savoie type cheese. Dislikes salt, acidity and dry conditions. On harder rinded cheese it is fairly easy to remove when it first appears with a stiff brush and salt water.

Penicillium: Black spots that permeate the rind. Cannot be washed or brushed off. Appears to be cosmetic.

BLUE

Penicillium: Many different strains. It is fine on the surface of non-blue cheese, but will penetrate if given the chance. Keep it in check with washing and brushing. Likes high acidity and oxygen.

WHITE

Scopulariopsus: Many cheeses have this without knowing it. It can appear in different forms:
1. Flaky, like dandruff, on the rind. Needs to be removed before any other rind starts or the rind will just build up and eventually flake off too.
2. Under the rind and into the cheese. It makes the rind very thick and also makes a small break in the rind in which rogue molds may enter. They also provide a nice home for mites.

Penicilium: They two most common strains are Candidum and Camberti. Fluffy, soft and not greasy. Likes acidity and oxygen. Control on hard cheese with washing and brushing. If left on harder cheese it will eventually break down the rind. On softer cheese patting helps keep it in check. More and less aggressive strains are available.

Geotrichum: Also know as peau de crapaud or oidium. Greasy. Produces ammonia. Dislikes acidity, salt, and low temperatures. Can produce a slippery, slimy rind.

BROWN

Mites: Powdery with a distinct odor. Reproduces every 10 days. They will eat the rind. Brush into a bucket of water or onto a wet floor. Be aggressive. Be careful not to get them on other cheese or make them airborne. Put the infested cheese below the ones that are not. Can fumigate with methyl bromide, but not recommended. Diatomaceous earth, mint, oak ashes, oil and vacuum cleaners have been reported to work.

Name unknown: Brownish-gray, powdery to chalky and dry. Often seen on caerphilly. It will ripen the cheese under the rind. Brush to remove; do not wash or it will produce a purple stain and a soft rind.

ORANGE

Brevibacterium Linen: Yeast must be present first to change the composition of the rind to make it suitable for the b-linen to grow. Desirable on washed rind cheese. Likes salt and high humidity. Produces a strong smell and flavor. Can purchase innoculants.

PURPLE

Aspergillus: Many different strains. Purplish-brown tuft that spores yellow. Rare to find on cheese. Like humidity. Dislikes salt, vinegar and abrasion. Will ruin rinds very quickly.

Bulk Tank Milk Quality Analysis-Bacterial Information

Type of Bacteria	Potential Sources: Sheep	Potential Sources: Environment	Means of Spread	Procedures to Reduce Risk: Sheep	Procedures to Reduce Risk: Environment
Staph. aureus(SA)-Coagulase positive staphs	Infected mammary gland, teat lesions, udder and teat skin. Cuts and lesions on milkers hands.	Can colonize milk contact surfaces in butterfat deposits	Sheep-to-sheep by milker hands. Lambs suckling transfer between infected and non-infected halves.	Milk mastitis ewes last. Cull chroniclly infected ewes. Use dry period therapy on ewes with mastitis history. Sanitize milkers hands frequently during milking.	Soon after milking-**thoroughly clear** metal contact surfaces to **remove** **milkfat and proteins. Sanitize surfaces** and rinse before milking
Staph. species(SS)-Coagulase negative staphs	Normanl teat and udder skin colonizer. Most common cause of **subclinical** mastitis.	Can colonize milk contact surfaces in butterfat deposits.	Sheep-to-sheep by milker hands. Lambs suckling transfer between infected and non-infected halves.	Minimal opportunities under current milking procedures. Use dry period therapy if can identify ewes with subclinical mastitis.	Soon after milking-**thoroughly clear** metal contact surfaces to **remove** **milkfat and proteins. Sanitize surfaces** and rinse before milking
Staph. chromogenes(SG)-Chromogenic colony, coagulase negative staph.	Normanl teat and udder skin colonizer. A common cause of **subclinical** mastitis.	Can colonize milk contact surfaces in butterfat deposits.	Sheep-to-sheep by milker hands. Lambs suckling transfer between infected and non-infected halves.	Minimal opportunities under current milking procedures. Use dry period therapy if can identify ewes with subclinical mastitis.	Soon after milking-**thoroughly clear** metal contact surfaces to **remove** **milkfat and proteins. Sanitize surfaces** and rinse before milking
Other Streps(OS)-*Strep. uberis, Strep dysgalactiae* & other species.	Infected udders. Found on many parts of the cow:hair, lips, vagina,feces. Unknown for sheep.	Manure, dirt, mud, water and bedding-especially straw.	Environment to sheep udders-especially around lambing. Sheep-to-sheep by milker hands. Potentially from lambs suckling between infected and non-infected halves.	Minimal opportunities under current milking procedures. Use dry period therapy if can identify subclinical ewes. **Dock tails. shear inside of hind legs.**	Keep sheep environment as **clean a** **dry** as possible to reduce udder contamination with manure and dir
Coliforms(CO)-*E. coli, Klebsiella* spp.and other gram negative bacilli	Infrequently from infected udders.	**Manure**, dirt, mud, water and bedding-especially straw.	Environment to sheep udders-especially around lambing. Sheep-to-sheep by milkers hand. Possibly from lambs suckling between infected and non-infected halves.	Minimal opportunities under current milking procedures. Use dry period therapy if can identify subclinical ewes. **Dock tails. Shear inside of hind legs.**	Keep sheep environment as **clean a** **dry** as possible to reduce udder contamination with manure and dir
Miscellaneous(MI)-All other microbes: bacilli, gram negative rods, fungi etc.	Minimal source.	Manure, dirt, straw and water from milking and from storage and shipment in unclean, unsanitized containers.	Primarily from the environment contamination-unclean, unsanitized milk contact surfaces. Air borne spores and fungi at milking.	Keep sheep udders as clean as possible. **Dock tails. Shear inside of hind** legs.	Keep sheep environment as clean a dry as possible. **Use proper washi and sanitation procedures for all r contact surfaces**. Monitor water qu from tap and hoses.

Note: BTM analysis is a subjective monitor of milk quality may facilitate problem solving on-farms. Current explanations are from limited experiences with sheep dairy practices. Revisions recommended as new formation obtained.

Milk Processing Critical Control Point Analysis- Bacterial Information

Type of Bacteria	Potential Sources	Effects on Products	Procedures for Problem Solving
Psychrotrophic Pseudomonas Alcaligenes Achromobacter Flavobacteria	**Post-pasteurization contamination** Water for rinsing and washing equipment. Dirty equipment surfaces. Marginal cooling after packaging.	**Enzymatic deterioration** Off-flavor development such as Rancidity and bitterness	Check the equipment related to the CCP for signs of contamination. Cool products rapidly after packaging and store at 5 C. Test water for contamination.
Thermoduric Bacilli Clostridia Lactobacillus Micrococcus Microbacterium	**Raw milk contamination** Dirty milking equipment. Unsanitary milking conditions. Poorly cleaned raw milk hauling and storage equipment	**Textural defects in cheese** Gas slits after 1 month and late gas blowing with off-flavor development	Reduce the bacteria level in raw milk Check for poorly fermented (aerobic) silage if finding Clostridia
Coliform E. coli Klebsiella Other Gram negative bacteria	**Post-pasteurization contamination** Water for rinsing and washing equipment. Dirty equipment surfaces. Workers hands.	**Flavor and Textural Defects** Gas formation and unclean flavors in all products	Check the equipment related to the CCP for signs of contamination. Workers must keep hands clean. Cleaning water must be hot enough to destroy bacteria
Lactic Acid Streptococci Lactobacilli	**Raw milk contamination** Build up of bacteria on dirty milking equipment.	**Flavor and Textural Defects** Difficult to control fermentation when making products	Reduce the bacteria level in raw milk Look for build up of old milk on milking equipment. Detect sour milk smell

HACCP PROGRAM: CLEANING EQUIPMENT

1. Immediately after using equipment, wash all milk, whey and curd residues from equipment with lukewarm water.

2. Wash in soap and hot (not <120 °F) water with correct concentration as written on soap container label. Need hot water to dissolve fat.

3. Rinse with cold or lukewarm water to remove soap film.

4. Place equipment so that it can drain and air dry.

5. Sanitize equipment immediately before use with:

- 100 PPM Chlorine for 1 minute
- 25 PPM Iodine for 1 minute
- Acid sanitizer for 1 minute
- 170 °F water for 5 minutes by spray or immersion

At these concentrations there is no need to rinse off the sanitizer. Rinsing is a bad idea if your water is contaminated, e.g., with coliform. Since the water quality is tested infrequently, the quality is not always known and rinsing poses a risk of contamination.

RESIDUES ON STAINLESS STEEL

1. PROTEIN - blue to purple sheen is caused by :

- inadequate cleaning
- rinsing with hot water
- waiting too long between rinsing and cleaning

Remove by "pasting" ; sprinkle powdered soap on the metal surface and scouring with a pad soaked in hot water. It will take considerable elbow grease to get it off.

2. MILKSTONE - white to gray scale is caused by mineral deposits from:

- the same things as protein buildup
- hard water

Remove by cleaning with a manual acid cleaner and following the directions on the container.

3. FAT is greasy and rinse water or sanitizer will bead up on metal (and plastic) surfaces. It is caused by:

- soapy water not hot enough
- not enough scrubbing

Remove by recleaning with at least 120 °F soap solution.

FINAL NOTE:

When the sanitizer is applied to a dry metal surface, it should run across it as a smooth uninterrupted sheet. Any beading or gaps is due to some residual "soil" (curd particles, fat grease, and protein or mineral deposits).

If you notice beading or gaps, take the extra time to clean the equipment and reduce the risk of contaminating the milk and cheese.

HANDLING AND WASHING MILK CANS

1. Sanitize directly before use for milking and storage

2. Transport cans to cheese house in a clean truck bed

3. Immediately after emptying, rinse cans with lukewarm water

4. Wash cans individually by adding 1 quart hot (not < 120 °F) soapy water to each can. When finished scrubbing one can dump soap solution; do not reuse for the next can.

5. Rinse with cold water

6. Turn upside down and place on rack for drying

7. It is better to wash cans in the milk storage room if possible; the risk of spreading farmyard microorganisms is reduced. If the milk storage room is next to the cheese room it is easy to do this. If cans are transported, the vehicle must be very clean to keep dirt out of the cheese house.

8. Regularly inspect cans for cracks and soil build up (especially around the outer rim)

THE BUSINESS OF FARMSTEAD CHEESE, YOGURT, AND BOTTLED MILK PRODUCTS

Considerations for Starting a Milk Processing Business

by Peter Dixon

CHOICES TO MAKE

PRIVATE	or	OPEN TO PUBLIC
FARMSTEAD	or	PURCHASED MILK
FAMILY OPERATED	or	EMPLOYEES
SEASONAL	or	YEAR-ROUND
NEW HERD	or	EXISTING HERD/MILK SALES
SILAGE	or	DRY HAY
RAW MILK	or	PASTEURIZED MILK
WHOLE MILK	or	STANDARDIZED MILK
AGED CHEESE	or	FRESH DAIRY PRODUCTS
NATURAL-RIND CHEESE	or	RINDLESS CHEESE
BULK (homemade) STARTER CULTURES	or	DIRECT VAT SET (freeze-dried) CULTURES
PROCESSING WHEY	or	WHEY DISPOSAL
DIRECT SALES catalog/mail order farm stand farmers market	or	WHOLESALES distributors middle men mark ups
PROCESSING FACILITY FREE-STANDING	or	PROCESSING FACILITY CONNECTED TO BARN
CHEESE AGING CELLAR/CAVE	or	CHEESE AGING ROOM ABOVE GROUND

CHOICES HAVE IMPACTS

1. Type and Size of Equipment

2. Type of Packaging

3. Labor: how much is needed, how much can be shared between farm and processing

4. Plant Design: space requirements, air ventilation and filtration

5. Product Cooler and Cheese Aging Room Design

6. Production Scheduling (number of days per week processing milk)

7. Product Pricing

8. Size of Inventory and Rate of Return on Start up Costs

9. Level of Safety Risk and Precautionary Measures Needed to Assure Product Safety:
   - product perishability relates to storage and distribution conditions
   - raw milk versus pasteurized milk products

10. Septic design:
    - bathroom waste
    - whey into system or outside of system

11. Type of Distribution:
    - refrigerated
    - frozen
    - short or long range

12. Leasing Facilities
    - on off days
    - in off season

REGULATIONS

The "Grade 'A' Pasteurized Milk Ordinance" (PMO) is the FDA's regulation book for the dairy industry, which sets down rules for the production of milk on farms, quality/safety standards for raw milk and milk products, and rules for the processing of milk and for construction of facilities.

The Vermont Department of Agriculture, Food and Markets has published a Vermont dairy regulation handbook, which is a simplified version of the PMO. If you are considering starting a milk processing business, it is a very good idea to contact the Dairy Division inspector in your region (there are only two for the entire state of Vermont), invite him out and go over your plans together. This way, you will have a very clear idea of the regulations from the beginning.

The Federal Code of Regulations (CFR) contains legal definitions of all dairy products. If a certain product is not listed, there is no legal criteria for how it is made or federal standards for its composition. For example, there are federal composition standards for chocolate milk, lowfat yogurt, and Cheddar and Cottage cheeses but there are none for Chevre, Brie, and Leicester cheeses. The CFR also sets down "Good Manufacturing Practices" (GMP's) for food production, which are used as guidelines for personal hygiene and safe food production. These are worth reading to find out where the inspectors are coming from and what they are looking for in terms of a sanitary operation.

The Vermont Cheese Council has published a "Code of Best Practice," which sets down GMP's used in making, aging, and selling cheese. There is also a section on creating a Hazard Analysis and Critical Control Point (HACCP) program for a cheese business. The same concepts are adaptable to businesses making other processed milk products. It is wise to become familiar with HACCP because this is the direction that the milk industry is moving in to produce safer dairy products.

The Dairy Practices Council publishes seventy three "guidelines" concerning issues such as animal housing, parlor construction, vacuum pump installation, waste management, cleaning and sanitation, milk quality, and HACCP systems for the dairy industry.

Vermont has a relatively low key regulatory climate compared to other states. The days of legal retail sales of bottled raw milk are gone but the inspectors will work with small-scale milk processors to find solutions to burdensome regulations, e.g., innovative vat pasteurizer designs and using wooden shelving for aging cheese. Listed below are some of the important aspects of the regulations that must be considered.

For the Farmstead Processor:

1. Construction of milking parlor and milk storage room
   - smooth, impermeable materials
   - easily cleaned
   - covered floor drains
   - well ventilated
   - separate hand washing sink and towels
   - screens to keep out flies and rodents
   - mandatory monthly milk testing for antibiotics, total bacteria, fat, and somatic cells; results must be posted in the milk room

2. Construction of processing, storage and aging facilities
   - smooth, impermeable materials
   - easily cleaned
   - covered floor drains
   - well ventilated
   - separate hand washing sink in processing room and towel dispenser
   - separate bathroom if there are employees other than immediate family members
   - physically separated raw storage and receiving area if making pasteurized dairy products
   - kiln for heating wooden boards to at least 150 °F for 30 minutes if using wooden shelving for aging cheese
   - Product contact surfaces must be stainless steel or food-grade plastic
   - Welds on all milk/product contact surfaces must be "3A", which means highly polished (expensive to make)
   - coolers do not need drains but the floors must be sloped to the doorways so that they can be cleaned and dried
   - storage tanks that are cleaned in place must have chart temperature recorders to show time/temp of milk storage and cleaning cycle
   - each batch of milk must be tested for antibiotics using a rapid analysis (Penzyme, Snap, Charm) before it is processed; results are posted in plant for official review
   - potable water supply; inspected every six months
   - State inspection of facilities every three months
   - finished products tested each month for antibiotics, coliform bacteria, total bacteria (for uncultured products, e.g., fluid milk, directly acidified cheeses), and sensory evaluation
   - plan for whey disposal

For the Processor who is purchasing milk from other farms:

3. Additional requirements to those listed above
   - must be bonded or have guaranteed letter of credit
   - must give farmer 90 days notice prior to terminating milk purchases

- is responsible for carrying out mandatory milk testing
- in the case of transporting milk in a mobile tank, there must be a separate enclosed washing facility with a floor drain
- for transporting milk in cans, a separate washing bay is not required
- milk handler's license is required for all people in the business who are involved in transporting milk and receiving milk (if farmers deliver their own)

PLANNING

There are many choices to make in starting a milk processing business. As more small-scale milk processors get into the market, it is becoming increasingly harder to find the niche that is needed to sustain a business. This is why entrepreneurs need to do their homework before deciding how to launch their businesses. It is critical to have a clear vision of the type of business you want, how much income you want from it, and how much time you can put into it. The next step is to research the market to find products which are in demand. This will help you generate ideas for choosing potential products, how and where to place them, the strategy for promoting the business and the products, and which prices are realistic.

The following list of aspects to be considered in starting a milk processing business may be helpful:

1. Business plan:
   - goals
   - vision/mission
   - strategy
   - 2 and 5 year plans

2. Timeline for production and sales:
   - construction of facilities
   - equipment purchases and installation
   - start up
   - product research and development phase
   - release of product to market

3. Raw ingredient requirements:
   - balancing milk and cream volumes
   - products using cream
   - products using lower fat milk

4. Farmstead situation:
   - how much will the milk processing business add to overall farm income

- how much of the owners' (family's) time is available for processing and marketing
- what else is done to add extra value to the milk, e.g., feeding whey to livestock, making ricotta from whey

5. Level of production required:
   - to pay back investment
   - returns to labor
   - make profit

6. Cost analysis:
   - pay the farm for the milk
   - figure in the R&D phase
   - figure in 30 day billing cycle
   - calculate when first cash will be received
   - estimate percentages of direct sales and whole sales
   - include shrinkage/waste of product:
     - 15% during first year
     - 5% is the normal operating amount
   - set your prices based on what you need to carry the operation
   - make high-priced products in limited quantities
   - different products have different profit margins

7. Sales:
   - direct sales to consumers increase profitability and take extra time/labor
   - whole sales to a retailer carry at least a 45% mark-up
   - whole sales via a distributor carry an additional 20% mark-up

8. Products:
   - diversify the product line over time
   - flavors
   - higher and lower fat contents
   - ethnic
   - high and low priced
   - limited/seasonal and "bread and butter"

9. Markets:
   - level of service
   - nature of demand, e.g., year-round, seasonal
   - packaging

   Distribution:
   - do it yourself; how to make it cost-effective
   - using a distributor; what is their level of involvement/promotion

MARKETING

1. Research

It is important to research the market to find out a few things before deciding what to make. At the least, a survey of stores and restaurants in your region will give you a starting point for a business, which focuses on local sales. Depending on your business concept you may need to look at the metro markets as well. Ethnic products have very good potential but you must find out where the specific ethnic populations live. During your research, take notes and buy some products that might work for you to get a sense of the quality of the competition. The research should give you information on the following:

- potential products for food service (includes deli counters) and retail end-users
- prices
- organic, conventional, and farmstead products
- competition
- packaging
- supply and demand of specific products

2. Product compatibility with type of business:
    - seasonal products
    - food service (includes deli counters) and/or retail end-user
    - at least one "bread and butter" product
    - degree of product diversity and extent of product line

3. Budget:
    - includes cost of packaging and labeling, promotion, distribution, and customer service
    - higher in the early years; as much as 15% of gross sales
    - normal operating budget is 8% of gross sales
    - define a long term strategy to figure the cost of marketing

4. Image and Promotion
    - tell your story
    - pictures speak louder than words
    - farmstead
    - small-scale
    - family operated
    - organic
    - handmade
    - fresh

FACILITIES

These are the basic requirements for different types of dairy products. The different functions in the business must be done in separate rooms to prevent cross contamination of pasteurized milk with raw milk and finished products with packaging materials.

1. *Raw Milk Cheeses - aged more than 60 days:*
   - production room
   - mechanical room
   - aging and brining room
   - packaging/shipping room

2. *Soft-ripened Cheeses from pasteurized milk, e.g., Camembert. Brie, Muenster, Brick, and Limburger:*
   - raw milk receiving/storage room
   - pasteurization/production room
   - mechanical room
   - salting/drying room: 80% RH, 60-65 °F
   - aging room: min. 95% RH, 45-55 °F
   - finished product cooler: ambient RH, 34-40 °F
   - packaging/shipping room

3. *Fresh Cheeses from pasteurized milk, e.g., Chevre, Cottage, and Ricotta:*
   - raw milk receiving/storage room
   - pasteurization/production room
   - cooled draining room
   - mechanical room
   - finished product cooler: ambient RH, 34-40 °F
   - packaging/shipping room

4. *Fluid and Cultured Milk Products:*
   - raw milk receiving/storage room
   - pasteurization/production room
   - mechanical room
   - finished product cooler: ambient RH, 34-40 °F
   - packaging/shipping room

5. *Ice Cream and Butter:*
   - raw milk receiving/storage room
   - pasteurization/production room
   - mechanical room
   - finished product cooler: ambient RH, 34-40 °F
   - packaging/shipping room
   - freezer/hardening room

Other Considerations:

An entry room to the processing room is an excellent idea. There should be a large window between the entry room and the processing room for visitors to view the operations. The entry room can have many functions, such as a worker changing area, a visitor viewing area, and a store. It should be sized according to the specific needs of the business. A foot bath can be placed in the doorway on the processing side. Visitors should not be allowed to come into the processing room unless they put on clean boots or shoe covers.

The mechanical room should be large enough to contain the furnace or boiler, circulator pumps, hot water heater, the electrical panel, an air compressor (if needed), and space for tools and spare parts. If an ice water builder is being used, there should also be a space for it outside of the processing room, although the boiler room may not be the best choice.

Construction: Key Points (often overlooked):

- concrete knee walls in all rooms for storing milk, processing milk, and aging rinded cheese
- no wood below two feet from the floor
- floors sloped correctly to drains to prevent puddles
- sloped window sills with epoxy paint or marine varnish
- as little wood as possible in the processing room
- metal doors
- sealed concrete, epoxy-coated or tiled floors
- fiberglass paneled interior walls
- covered light fixtures
- separate washing room and kiln for washing and drying wooden shelving adjacent to cheese aging room
- cheese cellars and caves are more energy efficient and have higher natural humidity than above-ground cheese aging rooms
- ventilation fans are needed in the milk processing and storage rooms
- ventilation in cheese aging rooms should be sufficient to prevent build up of ammonia; for soft-ripened cheeses 98 feet per minute air speed is required

EQUIPMENT

The following list has some options depending on which products are made. For example, a cream separator is not needed unless some products are made from low or high fat milk and a curd mill is used for Cheddar and other English-style cheeses. If the milk processing room is attached to the barn, the milk can be pumped directly to the vat or pasteurizer. A clean-in-place (CIP) (stainless steel pipe) loop is needed to clean out the delivery line unless the piping can be taken apart and washed by hand. If the processing facility is by itself, the milk can be hauled in cans or in a stainless steel or food grade plastic tank.

1. *Raw Milk Cheeses - aged more than 60 days:*
   - furnace or steam boiler
   - milk pump and hauling tank or milk cans
   - stainless steel piping and/or milk hose
   - vat
   - cream separator
   - drain table and/or press table
   - hoops and followers
   - cheesecloth
   - drain matting
   - milk stirrer and other tools, e.g., curd fork, shovel, squeegee
   - curd harps
   - curd scoop and/or pail
   - curd mill
   - vacuum sealing machine and/or waxing system if rindless cheese is made
   - weights for direct pressing, e.g. water jugs, gym weights
   - cheese press: compressed air or hydraulic or lever-action
   - wooden boards and drying kiln or metal shelving with plastic matting
   - whey removal system: pump, hose, and stock tank or bulk tank
   - hot water kettle for "pasta filata" cheeses

2. *Soft-ripened Cheeses made from pasteurized milk:*
   - furnace or steam boiler
   - milk pump and hauling tank or milk cans
   - stainless steel piping and/or milk hose
   - vat or tubs or basins
   - vat or HTST pasteurizer
   - Air compressor if using HTST
   - cooling water system
   - cream separator
   - drain table
   - hoops
   - cheesecloth

- drain matting
- milk stirrer
- curd harps and/or ladles
- curd scoops
- whey removal system: pump, hose, and stock tank or bulk tank
- hot water kettle for "pasta filata" cheeses

3. *Fresh Cheeses made from pasteurized milk:*
   - furnace or steam boiler
   - milk pump and hauling tank or milk cans
   - stainless steel piping and/or milk hose
   - vat or tubs or basins
   - vat or HTST pasteurizer
   - Air compressor if using HTST
   - cooling water system
   - cream separator
   - drain table
   - hoops
   - drain bags or cheesecloth
   - drain matting
   - milk stirrer
   - curd harps and/or ladles
   - curd scoops
   - whey removal system: pump, hose, and stock tank or bulk tank
   - filling/sealing machine or filling machine and hand sealer or vacuum sealer and hot water dip
   - hot water kettle for "pasta filata" cheeses and ricotta

4. *Fluid and Cultured Milk Products:*
   - furnace or steam boiler
   - milk pump and hauling tank or milk cans
   - stainless steel piping and/or milk hose
   - vat or HTST pasteurizer
   - Air compressor if using HTST
   - cooling water system
   - cream separator
   - homogenizer
   - plate cooler
   - surge tank
   - batch tanks for flavors and standardizing
   - Milk bottling machine and capper
   - filling/sealing machine or filling machine and hand sealer for cultured products
   - bottle washer for glass bottles
   - incubation chamber for cup-style yogurt
   - filling/sealing machine or filling machine and hand sealer

5. *Ice Cream and Butter:*
   - furnace or steam boiler
   - milk pump and hauling tank or milk cans
   - stainless steel piping and/or milk hose
   - vat or HTST pasteurizer
   - Air compressor if using HTST
   - cooling water system
   - cream separator
   - homogenizer
   - plate cooler
   - batch tanks for aging, flavoring and standardizing
   - butter churn
   - ice cream freezer
   - fruit feeder
   - filling machines
   - freezer for finished products

Other possibilities:

These pieces of equipment may or may not be necessary:

- insulated storage tank
- refrigerated storage tank (farm bulk tank)
- ice builder
- centrifugal pump for pumping raw milk and/or whey
- positive pressure pump for pumping curd and/or soft cheeses and cultured products
- refrigerated delivery truck
- freezer delivery truck
- jet-recirculation parts washer

PASTEURIZATION

1. *Vat or Batch Pasteurizer*

- legal requirements for products:
  - minimum 145 °F for 30 minutes for milk products less than 10 % fat
  - minimum 150 °F for 30 minutes for milk products more than or equal to 10 % fat or containing sweeteners
  - minimum 155°F for 30 minutes for eggnog

- components
  - s/s covers of hinged or dome top design
  - s/s leak detector valve
  - indicating thermometer
  - recording thermometer and chart recorder (wind-up or electronic)
  - air space thermometer and culinary steam
  - heat source: low pressure steam or 190 °F water
  - cooling source: refrigerated water or well water

2. *HTST Pasteurizer*

- legal requirements for products:
  - minimum 161 °F for 15 seconds for milk products less than 10 % fat
  - minimum 166 °F for 15 seconds for milk products more than or equal to 10 % fat or containing sweeteners
  - minimum 175 °F for 15 seconds for eggnog

- components:
  - feed pump
  - balance tank
  - timing pump (positive pressure with variable speed drive)
  - press frame and plates: regeneration and heating sections
  - flow diversion valve and pneumatic controls
  - holding tube
  - heating control system
  - cooling section in press for doing fluid products (exit 38 °F)

3. *Boiler Horsepower example for 500 gallons:*

- Vat pasteurizer: 40-145 °F in 45 minutes requires 18.2 HP
- HTST: 40-163-88 °F requires 6.2 HP

Cheese Made

Projected Cheese Production and Sales

VARIETY	# Weeks	Lb. made	Lb. made	% of	# Weeks	Lb. sold/yr	Sale price	Production	Profit
Year one:	made	per week	/year	Total	sold		per Lb.	cost per Lb.	per Lb.
Mozzarella	16	180	2880	41	16	2880	5.75		
Parma/Roman	26	36	936	13	0	0	0		
Sour cream	26	50	1300	18	26	1300	2.91		
Provo	26	54	1404	20	14	756	6.7		
Feta	26	22	572	8	26	572	6.25		
Asiago			0	0	0	0	6.92		
TOTAL		342	7092	100		5508	5.26	5.24	0.02
Year two:									
Mozzarella	22	180	3960	19	22	3960	5.75		
Herds/Asiago	43	86	3698	18	23	1978	10.6		
Sour cream	43	120	5160	25	43	5160	2.48		
Provo	43	110	4730	23	43	4730	5.92		
Feta	43	75	3225	16	43	3225	5.5		
		571	20773	100		19053	5.36	5.22	0.14
Year three:									
Mozzarella	22	200	4400	17	22	4400	5.75		
Parma/Roman	43	86	3698	15	43	3698	10.6		
Sour cream	43	120	5160	20	43	5160	2.57		
Provo	43	140	6020	24	43	6020	5.92		
Feta	43	100	4300	17	43	4300	5.5		
Asiago	43	44	1892	7	43	1892	6.92		
		690	25470	100		25470	5.89	5.50	0.39
Year four:									
Mozzarella	22	200	4400	13	22	4400	5.75		
Parma/Roman	43	142	6106	18	43	6106	10.6		
Sour cream	43	190	8170	24	43	8170	2.36		
Provo	43	180	7740	23	43	7740	5.92		
Feta	43	120	5160	15	43	5160	5.38		
Asiago	43	60	2580	8	43	2580	6.79		
		892	34156	100		34156	5.86	5.21	0.65
Year five:									
Mozzarella	22	230	5060	12	22	5060	5.75		
Parma/Roman	43	195	8385	19	43	8385	10.4		
Sour cream	43	260	11180	26	43	11180	2.31		
Provo	43	216	9288	21	43	9288	5.79		
Feta	43	144	6192	14	43	6192	5.38		
Asiago	43	76	3268	8	43	3268	6.79		
		1121	43373	100		43373	5.79	5.15	0.64

Organic Milk @ $20/cwt

Projected Return to Labor
and Profit

Five Ye

	Year one	Year two	Year three	Year four	Year five	
Lb. Milk used	61,600	180,600	240,800	301,000	361,200	
Lb. Cheese made	7,092	19,880	24,577	31,902	41,850	
Yield (Lb. milk/lb. cheese)	9	9	10	9	9	
SALES:						
Cheese/Sour cream	$28,983	$102,273	$150,141	$200,405	$251,405	
EXPENSES:						
Waste disposal	1,200	1,200	1,200	1,200	1,200	(to empty septic tank)
Licenses, Permits and Fees	3,000	1,500	1,500	1,500	1,500	
Cheese Ingredients	234	686	915	1,144	1,373	($.38/cwt for rennet , salt & cultures)
Milk ($20/cwt)	12,320	36,120	48,160	60,200	72,240	
Taxes	600	1,200	1,200	1,200	1,200	
Energy	2,500	6,000	7,980	10,613	14,116	(oil,electric, & wood)
Insurance (liability)	1,200	1,200	1,200	1,200	1,200	
Loan ($60,000)	5,300	10,600	10,600	10,600	10,600	(6% x 7 years)
Outside Labor ($12/hr.)	0	12,480	16,598	22,076	29,361	($9/hr. + $3/hr to Feds)
Marketing (10% Of Sales)	2,898	10,227	15,014	20,041	25,141	(phone,packaging, distribution, & service)
Cheese Room Supplies	500	600	800	1,000	1,200	(incl. cleaning supplies)
Office Supplies	300	600	900	1,200	1,500	
TOTAL EXPENSES	$30,052	$82,413	$106,068	$131,974	$160,630	
Cheese Production Cost/lb.	4.24	4.15	4.32	4.14	3.84	(not including owner's labor)
RETURN TO LABOR	($1,069)	$19,860	$44,074	$68,431	$90,775	
Partner's Labor Cost	$28,600	$55,000	$55,000	$55,000	$55,000	
Assumption:	(110 h/week	(110 h/week	(110 h/week	(110 h/week	(110 h/week	
$10/hour	x 26 weeks)	x 50 weeks)	x 50 weeks)	x 50 weeks)	x 50 weeks)	
PROFIT	($29,669)	($35,140)	($10,927)	$13,431	$35,775	
Cheese Production Cost/lb.						
incl. owner's labor	8.27	6.91	6.55	5.86	5.15	

onventional Milk @ $15/cwt

Projected Return to Labor
and Profit

Five Year Pla

	Year one	Year two	Year three	Year four	Year five			
.b. Milk used	61,600	180,600	240,800	301,000	361,200			
.b. Cheese/S. cream made	7,092	19,880	24,577	31,902	41,850			
'ield (Lb. milk/lb. cheese)	9	9	10	9	9			
SALES:								
Cheese/Sour cream	$28,983	$102,273	$150,141	$200,405	$251,405			
EXPENSES:								
Vaste disposal	1,200	1,200	1,200	1,200	1,200	(to empty septic tank)		
Licenses, Permits and Fees	3,000	1,500	1,500	1,500	1,500			
Cheese Ingredients	234	686	915	1,144	1,373	($.38/cwt for rennet , salt & cultures)		
Milk ($15/cwt)	9,240	27,090	36,120	45,150	54,180			
Taxes	600	1,200	1,200	1,200	1,200			
Energy	2,500	6,000	7,980	10,613	14,116	(oil,electric, & wood)		
Insurance (liability)	1,200	1,200	1,200	1,200	1,200			
Loan ($60,000 @ 6%)	5,300	10,600	10,600	10,600	10,600	(6% x 7 years)		
Outside Labor ($12/hr.)	0	12,480	16,598	22,076	29,361	($9/hr. + $3/hr to Feds)		
Marketing (10% Of Sales)	2,898	10,227	15,014	20,041	25,141	(phone,packaging, distribution, & service)		
Cheese Room Supplies	500	600	800	1,000	1,200	(incl. cleaning supplies)		
Office Supplies	300	600	900	1,200	1,500			
TOTAL EXPENSES	$26,972	$73,383	$94,028	$116,924	$142,570			
Cheese Production Cost/lb.	3.80	3.69	3.83	3.67	3.41	(not including owner's labor)		
RETURN TO LABOR	$2,011	$28,890	$56,114	$83,481	$108,835			
Partner's Labor Cost	$28,600	$55,000	$55,000	$55,000	$55,000			
Assumption:	(110 h/week	(110 h/week	(110 h/week	(110 h/week	(110 h/week			
$10/hour	x 26 weeks)	x 50 weeks)	x 50 weeks)	x 50 weeks)	x 50 weeks)			
PROFIT	($26,589)	($26,110)	$1,114	$28,481	$53,835			
Cheese Production Cost/lb.								
incl. owner's labor	7.84	6.46	6.06	5.39	4.72			

Production Costs and Returns

Cheese Type	Aging period (days)	Lb. milk/ Lb. cheese	Milk cost ($.20/lb.)	Overhead cost/Lb.	Labor cost/Lb.	Total Cost/Lb.	Wholesale Price/Lb.	Profit/Lb.
Mozzarella	0	7.0	1.40	2.75	1.50	5.65	6.50	0.85
Provolone	60	9.0	1.80	2.85	1.50	6.15	6.50	0.35
Ricotta	0	2.4	0.48	0.50	1.50	2.48	4.00	1.52
Asiago	90	11.5	2.30	2.85	1.50	6.65	7.00	0.35
Herdsman	150	10.0	2.00	2.95	1.50	6.45	7.00	0.55
Toma	90	8.5	1.70	2.85	1.50	6.05	7.00	0.95
Brie & Camembert	25	8.0	1.60	3.05	1.70	6.35	8.50	2.15
Feta	10	8.0	1.60	2.75	1.50	5.85	6.50	0.65
Parmesan	365	12.5	2.50	3.35	1.50	7.35	8.00	0.65
Butter (made with	0	0	0.00	0.30	1.00	1.30	8.00	6.70
cream from Asiago milk)								
Asiago cheese comparison	1,200 lb. milk	Price/lb.	Value	Total Value	Cost/lb.	Cost	Total Cost	Profit
Herdsman (whole milk)	120	$7	$840	$840	6.45	774	$774	$66
Pinnacle (2.5% fat milk)	96	$7	$670		6.65	607		
& Butter	35	$7	$228	$898	1.30	46	$653	$245
& Butter	35	$8	$280	$950	1.30	46	$653	$297
Whole milk cheese and								
Ricotta Comparison	1,200 lb. milk	Selling Price	Value	Total Value	Cost/lb.	Cost	Total Cost	Profit
Toma only	141	$7	$988	$988	6.05	854	$854	$134
Toma (1,030 lb. milk) and	121	$7	$848		6.05	733		
Ricotta (whey & 170 lb. milk)	70	$4	$280	$1,128	2.48	174	$907	$221

Breakdown of Actual Cheese Sales

	2001	2002	2003	2004	2005
	(6 months)				
Farmer's Markets		8,342			
Festivals		4,609			
Total Retail $		12,951	36,000		
Wholesale $					
Local (15 mile radius)		12,257			
CSA's		6,318			
Other wholesale		58,906			
Total Wholesale $		77,481	84,000		
Total Cheese Sales	25,181	90,432	120,000		
TOTAL EXPENSES	27,436	88,218	92,752		
Return to Owner's Labor	-2,255	16,782	18,248		
PROFIT	-2,255	0	9,000		

Organic Milk @ $.20/cwt

Actual Return to Labor and Profit

	Year one	Year two	Year three	Year four	Year five	
Lb. Milk used	64,655	170,461	167,995			
Lb. Cheese made	6,177	18,992	19,135			
Yield (Lb. milk/lb. cheese)	10.5	9.0	8.8			
SALES:						
Cheese/Butter	$25,181	$102,273	$120,000			
EXPENSES:						
Equipment	0	11,474	4,000			
Waste disposal	600	1,440	1,526			(to empty septic tank)
Licenses & Prof. Services	2,375	3,022	3,073			(permits, accountant, equipment service and maintenance)
Cheese Ingredients	246	648	638			($.38/cwt for rennet , salt & cultures)
Milk ($20/cwt)	11,638	34,092	33,600			
Taxes & Repairs	600	1,454	2,235			
Energy	1,401	4,869	4,757			(oil,electric, & wood)
Insurance (liability)	848	1,950	2,523			
Loan and Credit Card	3,390	10,736	13,422			(6% x 7 years loan & credit card)
Outside Labor ($12/hr.)	0	0	7,271			($9/hr. + $3/hr to Feds)
Distribution	1,573	7,467	8,413			(phone, promotion & service)
Service/Promotion	553	3,017	6,327			(vehicles, mileage, and shipping)
Packaging	3,326	6,069	7,325			(packaging, labels, & boxes)
Cheese Room Supplies	614	1,327	930			(incl. cleaning supplies)
Office Supplies	204	653	369			
TOTAL EXPENSES	$27,368	$88,218	$92,410			
Cheese Production Cost/lb.	4.43	4.65	4.83			(not including owner's labor)
Owner's salary	$6,177	$13,682	$16,621			
Production cost/lb.	5.43	5.37	5.70			
PROFIT	($8,364)	$373	$10,969			

Cheese Made

Actual Production and Sales
of Cheese

VARIETY	Batches	Lb. made	Lb. made	% of	# Weeks	Lb. sold				Sale price	Production	Profit
Year one: 2001	made	per week	/year	Total	sold	per year	Inventory	Shrink	% Shrink	per Lb.	Cost per Lb.	per Lb.
Mozzarella	30	71	2122	34.4	29	2000	0	122	3.8			
Parma/Roman	5	68	342	5.5	0	0	342	0	0			
Provo	17	86	1463	23.7	20	1000	463	0	0			
Toma	1	72	72	1.2	0	0	72	0	0			
Herdsman	20	87	1746	28.3	20	790	956	0	0			
Ricotta	10	43	432	7.0	29	400	0	32	7.4			
TOTAL	29	213	6177	100.0		4190	1833	154	2.5	6.01	5.43	0.58
Year two: 2002												
Mozzarella	55	123	6405	33.7	52	6225	0	180	2.8			
Herdsman	16	126	2021	10.6	52	1186	835	0				
Pinnacle/ Asiago	30	92	2770	14.6	52	1664	1106	0				
Butter	30	19	568	3.0	30	568	0	0				
Provo	21	119	2492	13.1	43	2292	200	0				
Feta	8	99	794	4.2	52	621	173	0				
Toma	20	88	1767	9.3	52	1461	306	0				
Ricotta	36	52	1858	9.8	52	1700	0	158	8.5			
Brie & Camembert	6	53	317	1.7	10	317	0	0				
	52	365	18992	100.0		16034	2620	338	1.8	6.31	5.37	0.94
Year three: 2003												
Mozzarella	53	95	5009	26.2	45	4959	0	50	1.0			
Herdsman	7	76	529	2.8	45	529	0	0				
Pinnacle Asiago	18	126	2275	11.9	52	1345	930	0				
Butter	18	29	514	2.7	45	514	0	0				
Provo	19	119	2269	11.9	40	2003	266	0				
Feta	7	147	1030	5.4	52	1000	30	0				
Toma	23	138	3171	16.6	52	1733	1438	0				
Ricotta	24	56	1338	7.0	45	1300	0	38	2.8			
Brie & Camembert	22	136	3000	15.7	45	2600	400	0				
	45	425	19135	100.0		15983	3064	88	0.5	6.45	5.70	0.75
Year four: 2004												
Mozzarella												
Parma/Roman												
Sour cream												
Provo												
Feta												
Asiago												
Year five: 2005												
Mozzarella												
Parma/Roman												
Sour cream												
Provo												
Feta												
Asiago												

Farmstead cheese				notes
	Year # 1	Year # 2	Year # 3	may be stretched to 5 year
50 cow herd	1 mornings milk	2 full days/week	30 cow all days	
lbs milk	61,600 lbs	240,800 lbs	361,200 lbs	17,000 lb herd average
SALES	32,283	157,897	252,528	$6.50 / lb cheese (butter)
COSTS				
Ingredients	8,624	33,712	50,568	$14 / cwt milk
Taxes	1,200	1,200	1,200	
Energy	2,500	7,980	14,116	
Insurance	1,200	1,200	1,200	
Loan	*$18,400*	18,400	18,400	*1st year-module* then $70k note
Outside Labor	0	20,750	36,700	
Marketing	3,228	15,790	25,253	10% marketing cost
Supplies	500	800	1,200	
TOTAL	35,652	99,832	135,484	
Return to labor	-3,369	58,065	117,044	

Westminster Dairy LLC

UPC Product #	Product	Pack size # pcs	size	Case Cost	Unit Cost	Freight	Profit Margin	ADI Case	ADI Unit	MSRP Unit	1.5 m/up SRP Unit
Organic Fresh Pasteurized Cheeses											
	Mozzarella	6	1 lb	29.50	4.92	0.10	24.7%	39.97	6.66	N/A	9.99
	"	6	8 oz	15.30	2.55	0.10	24.3%	21.00	3.50	N/A	5.25
	"	12	8 oz	30.60	2.55	0.10	24.3%	42.01	3.50	N/A	5.25
	Smoked Mozzarella	6	1 lb	31.50	5.25	0.10	23.5%	41.96	6.99	N/A	10.49
	"	6	8 oz	16.50	2.75	0.10	25.5%	22.95	3.83	N/A	5.74
	"	12	8 oz	33.00	2.75	0.10	25.5%	45.91	3.83	N/A	5.74
	Ovilini	6	1 lb	29.50	4.92	0.10	24.7%	39.97	6.66	N/A	9.99
	Ricotta 6x8 - 9.90	6	1 lb	16.50	2.75	0.10	25.5%	22.95	3.83	N/A	5.74
	Camembert	6	8 oz	21.00	3.50	0.10	22.7%	27.94	4.66	N/A	6.99
	Brie	1	2 lb	6.50	6.50	0.10	23.7%	8.65	8.65	N/A	12.98
Organic Raw Milk Cheeses											
	Jersey Feta	1	lb	4.15	4.15	0.10	22.7%	5.50	5.50	N/A	8.25
	Smoked Jersey Feta	1	lb	4.50	4.50	0.10	23.3%	6.00	6.00	N/A	9.00
	Livewater Toma	1	lb	4.90	4.90	0.10	23.1%	6.50	6.50	N/A	9.75
Organic Raw Milk Cheeses, Packaged											
	Jersey Feta	12	8 oz	27.90	2.33	0.10	23.5%	38.04	3.17	N/A	4.75
	Smoked Jersey Feta	12	8 oz	30.00	2.50	0.10	22.0%	40.00	3.33	N/A	5.00
	Livewater Toma	12	8 oz	32.40	2.70	0.10	23.5%	43.92	3.66	N/A	5.49

I. Approximate Steam Consumption: Lbs/Hour

Batch Pasteurizer: Assume 40-145° heating milk, in 45 minutes.

Capacity (Gallons)	Lbs/Hour	Approximate Boiler HP
300	375	10.9
400	500	14.5
500	625	18.2
600	750	21.7
800	1,000	29.0
1,000	1,250	36.3

High Temperature Short Time Pasteurizers (HTST): Assume 40-163-88° with 61% regeneration and blend temperature by-pass.

Capacity (Gallons)	Lbs/Hour	Approximate Boiler HP
500 GAL/HR	214	6.2
1,000 GAL/HR	428	12.4
1,500 GAL/HR	642	18.2

Cheese Vats: The time used for the heating will vary, depending upon the cheese. For general assumptions, we consider heating 90° – 105° for a 30 minute time.

Capacity (Gallons)	Lbs/Hour	Approximate Boiler HP
300	80	2.4
400	107	3.1
500	134	3.9
600	160	4.8
800	214	6.2
1,000	268	7.8

*** FINAL BOILER SIZE WILL DEPEND UPON PROCESS NEEDS. IF THERE WILL NOT BE A CASE WHERE THE PASTEURIZER & VAT OPERATE SIMULTANEOUSLY, THEN THE BOILER CAN BE SIZED FOR THE PASTEURIZER, PLUS AN ADDITIONAL 10-20% FOR HEAT LOSS, OR FUTURE EXPANSION.**