The production complexity of a complex fluid

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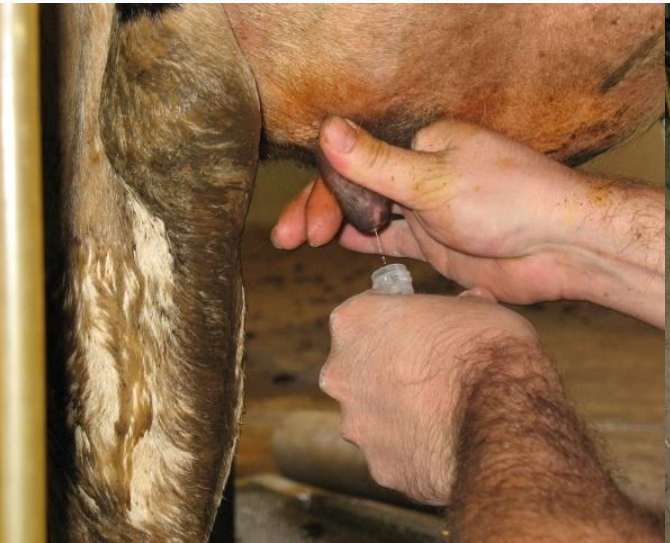

Outline

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- Introduction
- **Complexity of milk and its quality for the industry**
- Curd firmness and milk clotting time for cheese production
- Milk quality for monitoring health
- On-line milk separation

The Challenge of monitoring a modern Dairy farm

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The basic **production unit** in the dairy is the individual cow

A modern farm comprises a large amount of heterogeneous basic **production units**

Physiological and interface changes (lactation curve, health problems, feed etc.) dictate that these basic production units by themselves are not homogeneous between sessions and between days

Precision dairy farming: Managing Individual Cows in Large Herds

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- Herds of all sizes comprised of individual animals.
- Each one of these animals contribute to the performance of the entire herd.

The key to success in whichever herd size is taking good care of each individual animal.

Management system

Automated Data Collection and Analysis

New 24 years old Concept :

Management by exceptions.

zoom-in on exceptions and treat individually

to improve total performance

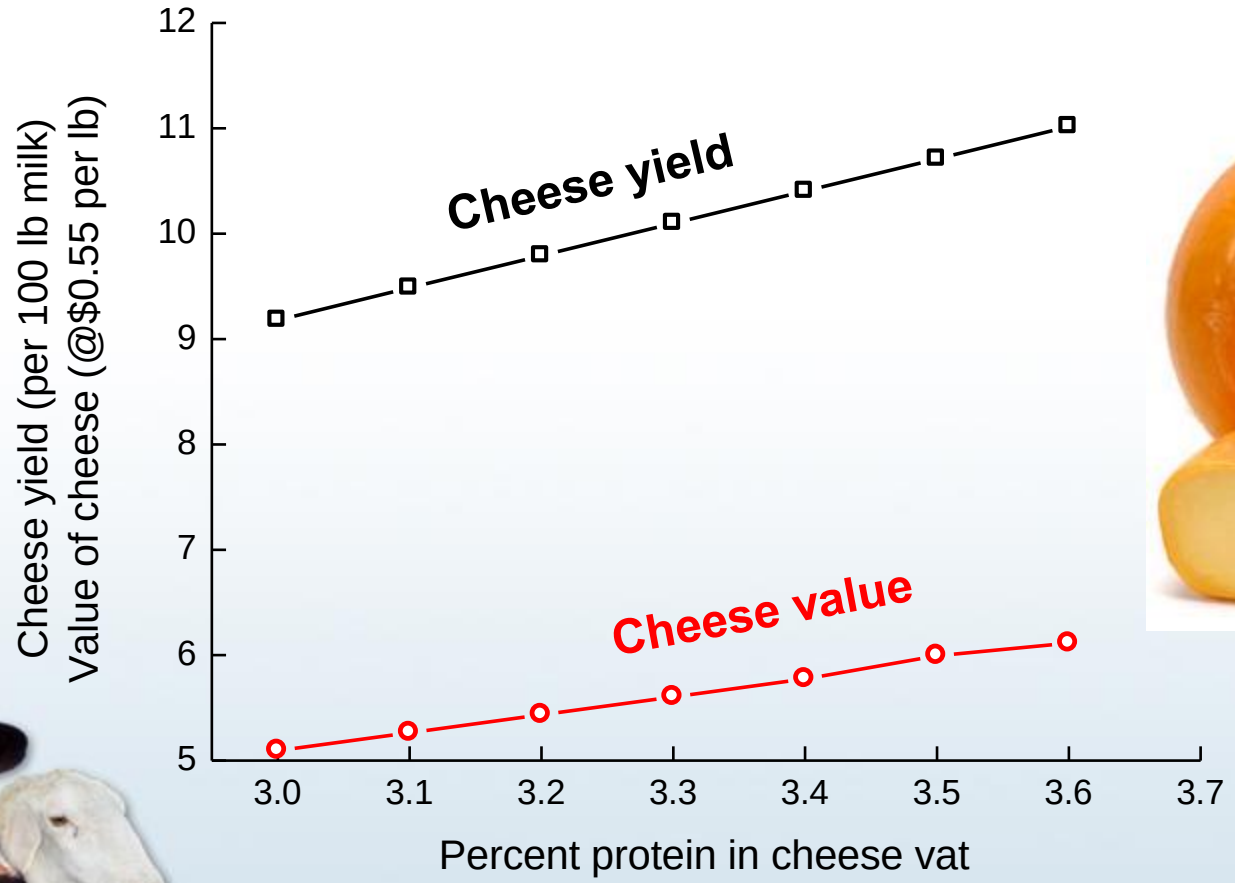
Dairy farmers focus on optimizing the product flowing into the bulk milk tank

Meanwhile, on the other side of the milk tank extensive research is going on

- …"milk constituent levels have taken on new importance in herd management.
- In addition to being indicators for cow health and nutrition, constituent levels now **directly impact farm income."** (Heinrichs et al., Penn. State Univ.)

The Market Needs

- **Milk value** - The value of the milk depends on quality and composition
  - Milk value for Cheese Manufacturing - USA

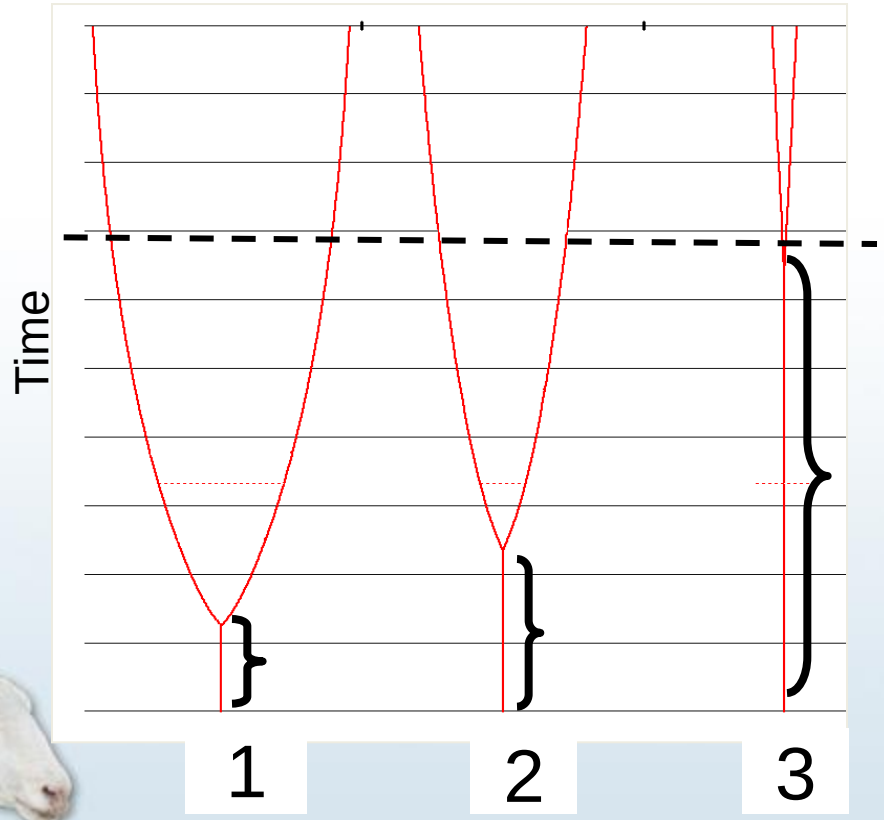


Borg, 1971. Journal of Dairy Science, *54:1134-1136*

Optigraph: the gold standard for evaluating milk quality for the cheese industry – efficiency of process

Clotting time (seconds) - RCT

Curd firmness (volts) 90 min after coagulating enzyme addition (Cy, Cf)



Curd firmness (volts)

Clotting time (sec)

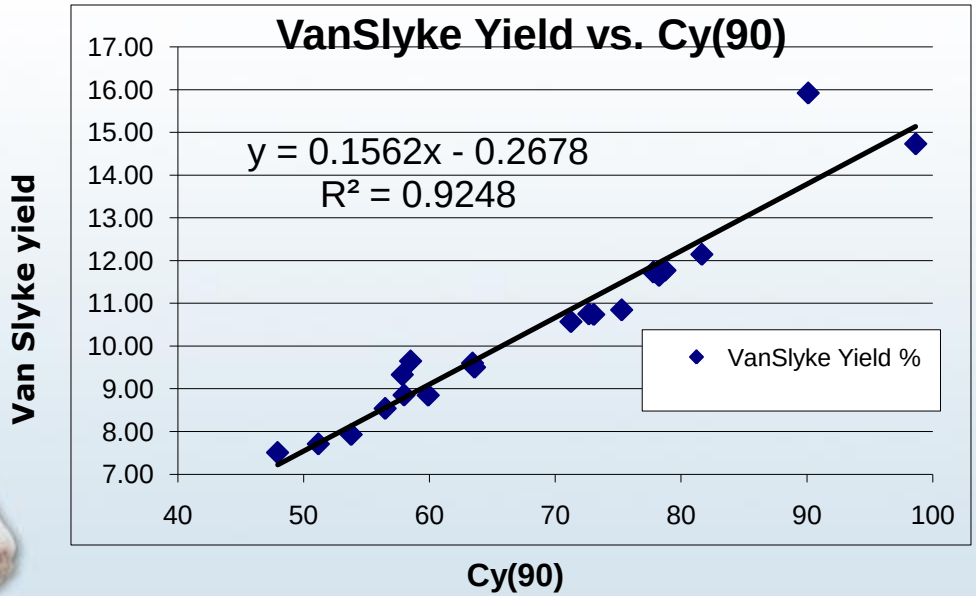
The Market Needs

- **Milk value** - The payment for the milk is formulated by composition

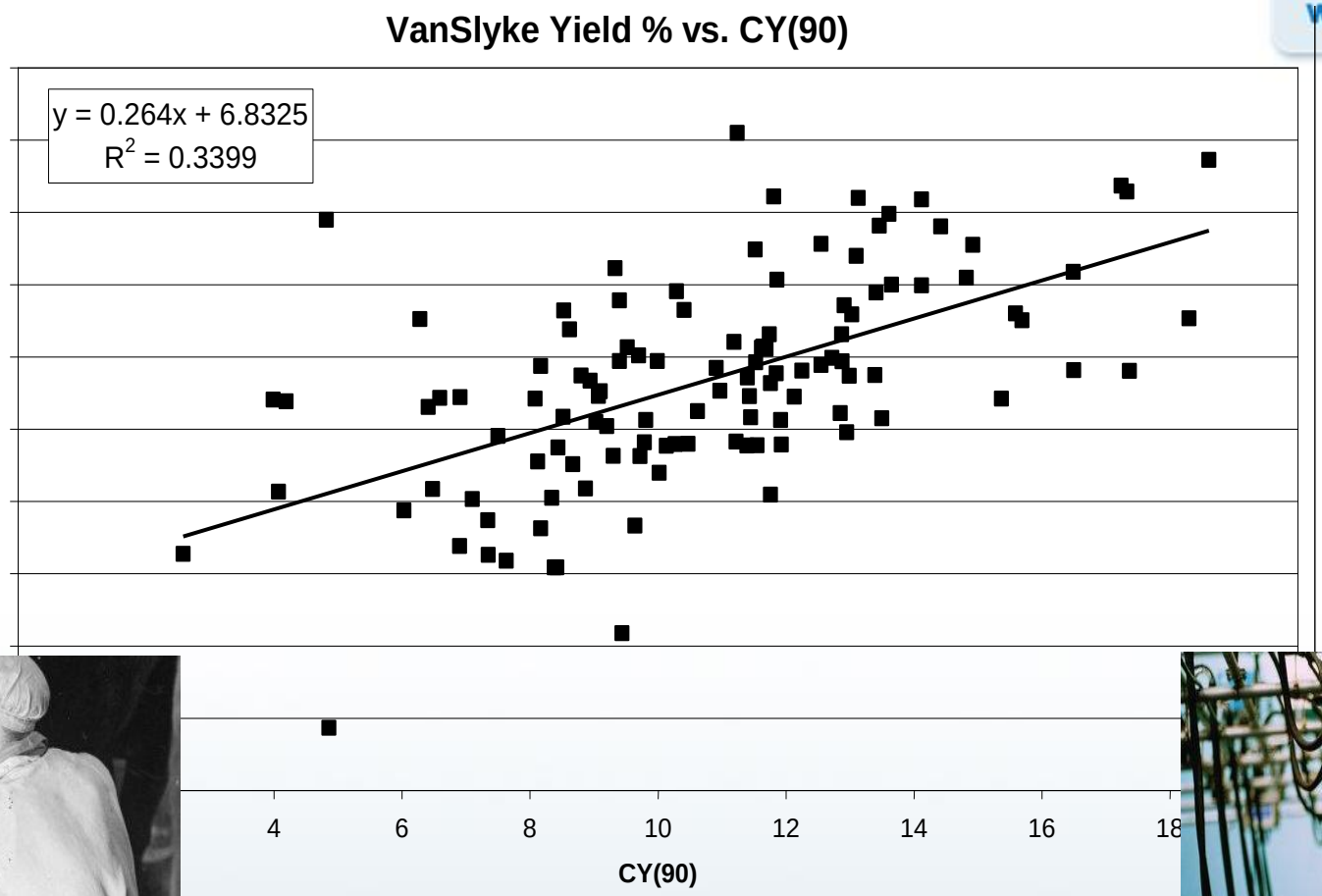
Percent Yield = {[0.93*F + (C-0.1)]*1.09}/(1-W)}

- **F** = % fat in milk
- **C** = % casein (protein) in milk
- **W** = % moisture in the cheese/100

Van Slyke Price formula for Cheddar cheese



Van Slyke Price formula for Cheddar cheese applied for individual cow's milk



un-unified basic production units

Un-unified Product?

The composition of milk (mg/L)

Water: 76-80	
Fat: 30-40	**emulsified in water**
Caseins: 30-40	**colloids**
Whey proteins: 6-7	**globular proteins**
Enzymes	**~70 different Enzymes**
Minerals: 7-8	**soluble and bound to protein**

Milk Proteins

α_{s1}-Casein

α_{s2}-Casein

β-Casein

κ-Casein

Whey Proteins

α-lactalbumin

β-lactoglobulin

Blood Serum Albumin

Immunoglobulins

Proteose peptone

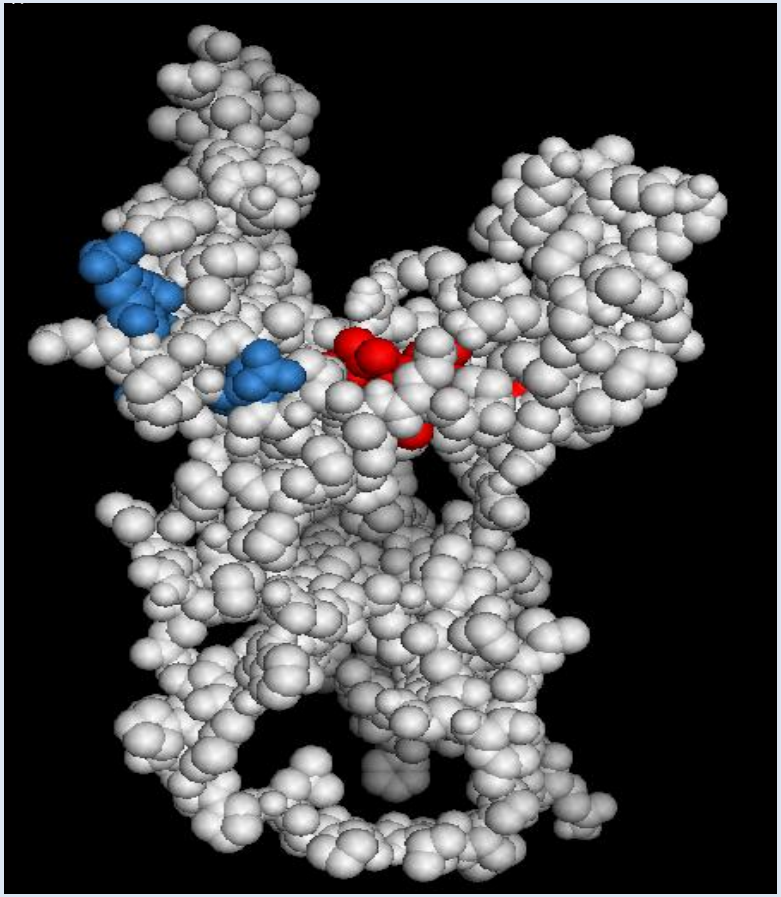
Caseins ratio:

α_{s1}-CN:α_{s2}-CN:β-CN:κ-CN – 3:0.8:3:1

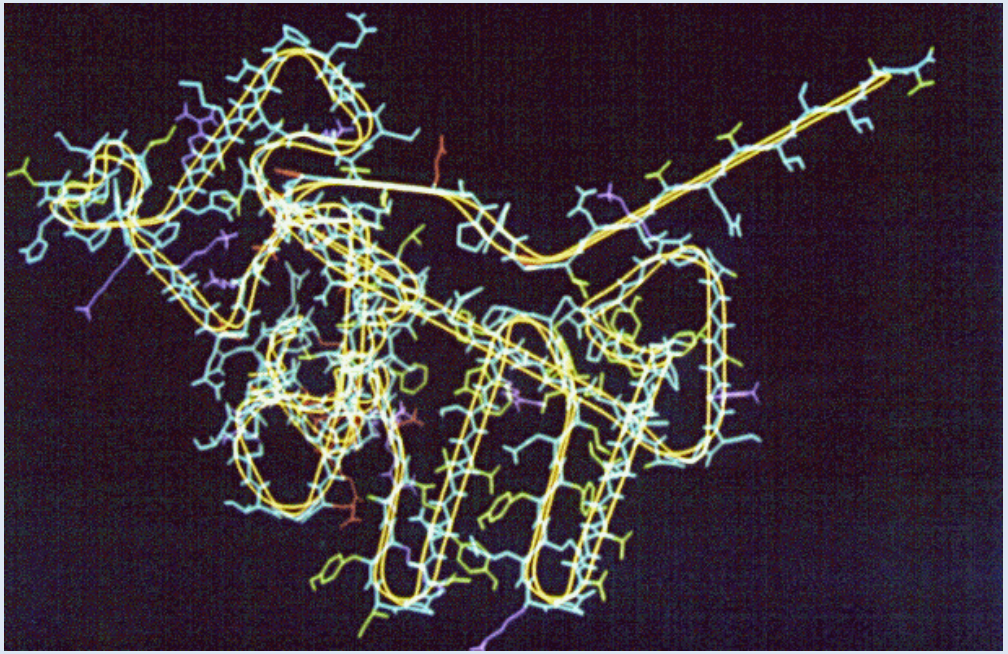
Properties and “packing” of Milk Proteins

- Resistant to thermal treatment, including boiling and sterilization
- Unstable at 4.6 pH (isoelectric point)
- Extremely flexible structures
- No data available on crystal form of caseins - do not form crystals
- Do not have well defined three-dimensional structure
- Best evidence for secondary and tertiary structure is obtained from x-ray diffraction

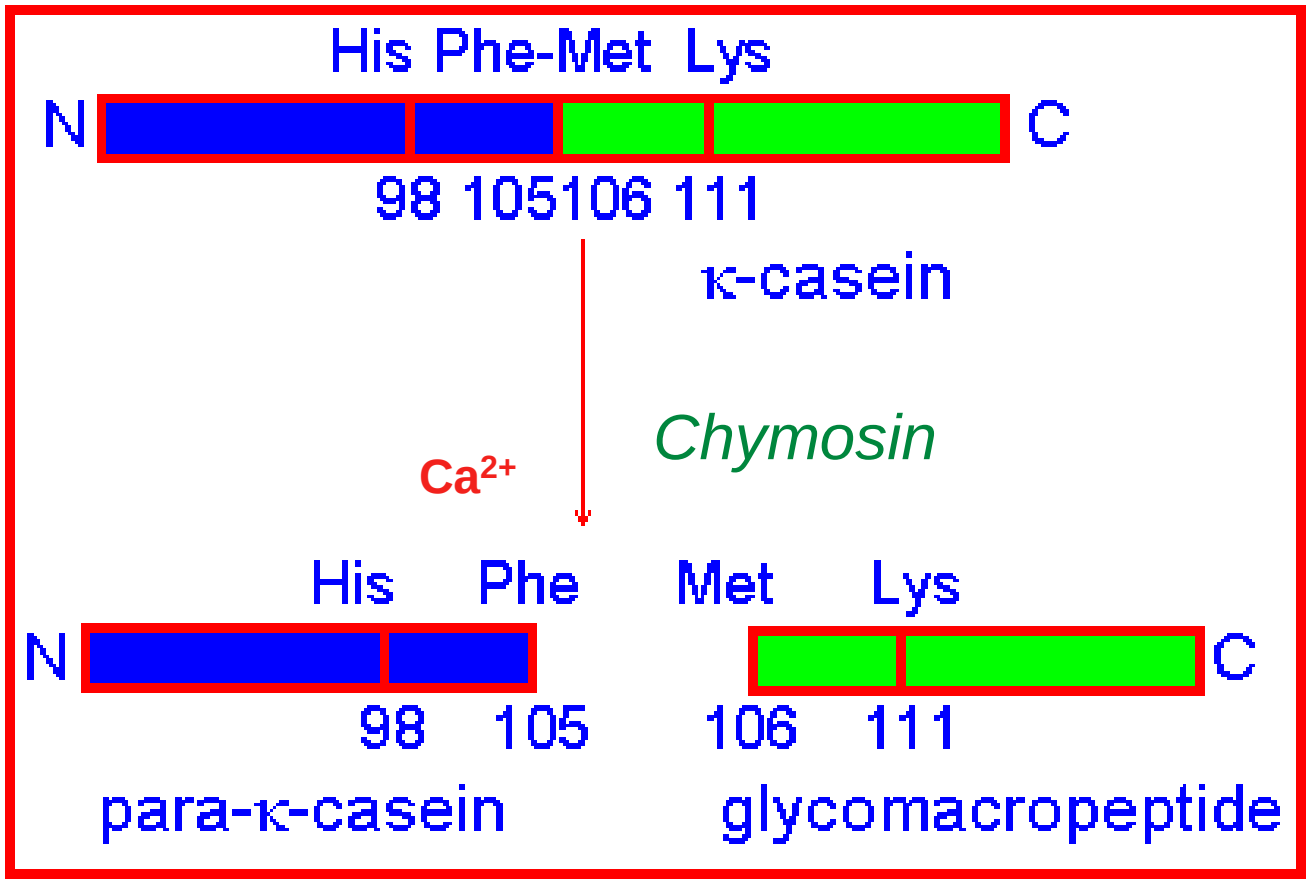
β-Casein structure



Three-dimensional model for κ-casein



Enzymatic Coagulation process

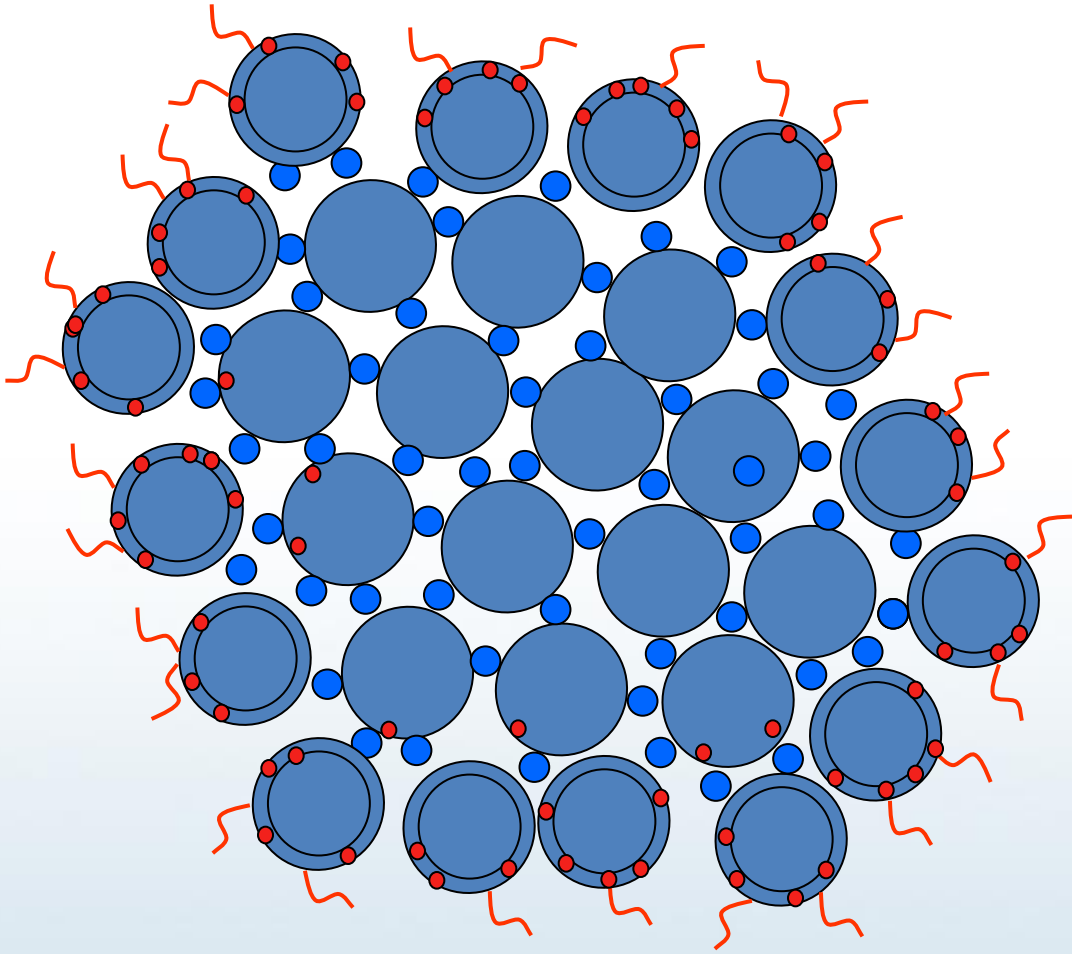


Enzymatic coagulation of milk proteins - casein micelle sub-unit

Hydrophobic α-casein and β-casein center

$Ca_9(PO_4)_6$ complex

k-casein rich surface



Casein micelle

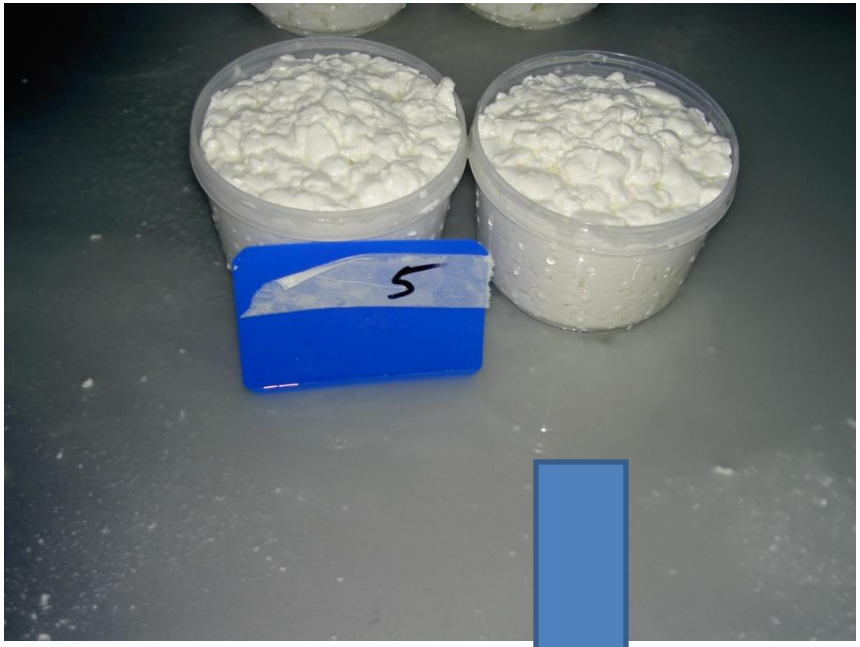
Deterioration of milk quality

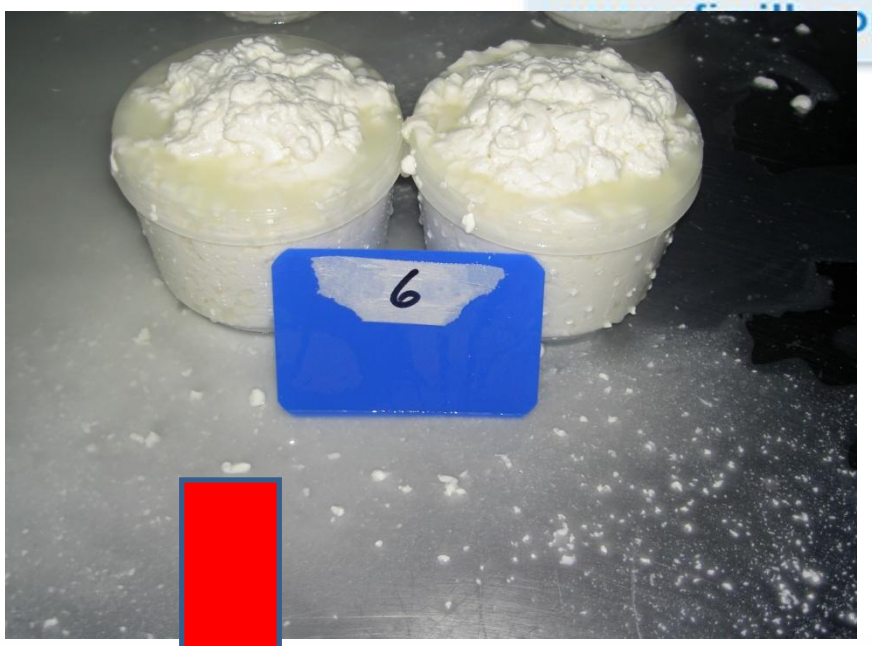
In the udder during production and between milking

During post milking storage

Healthy

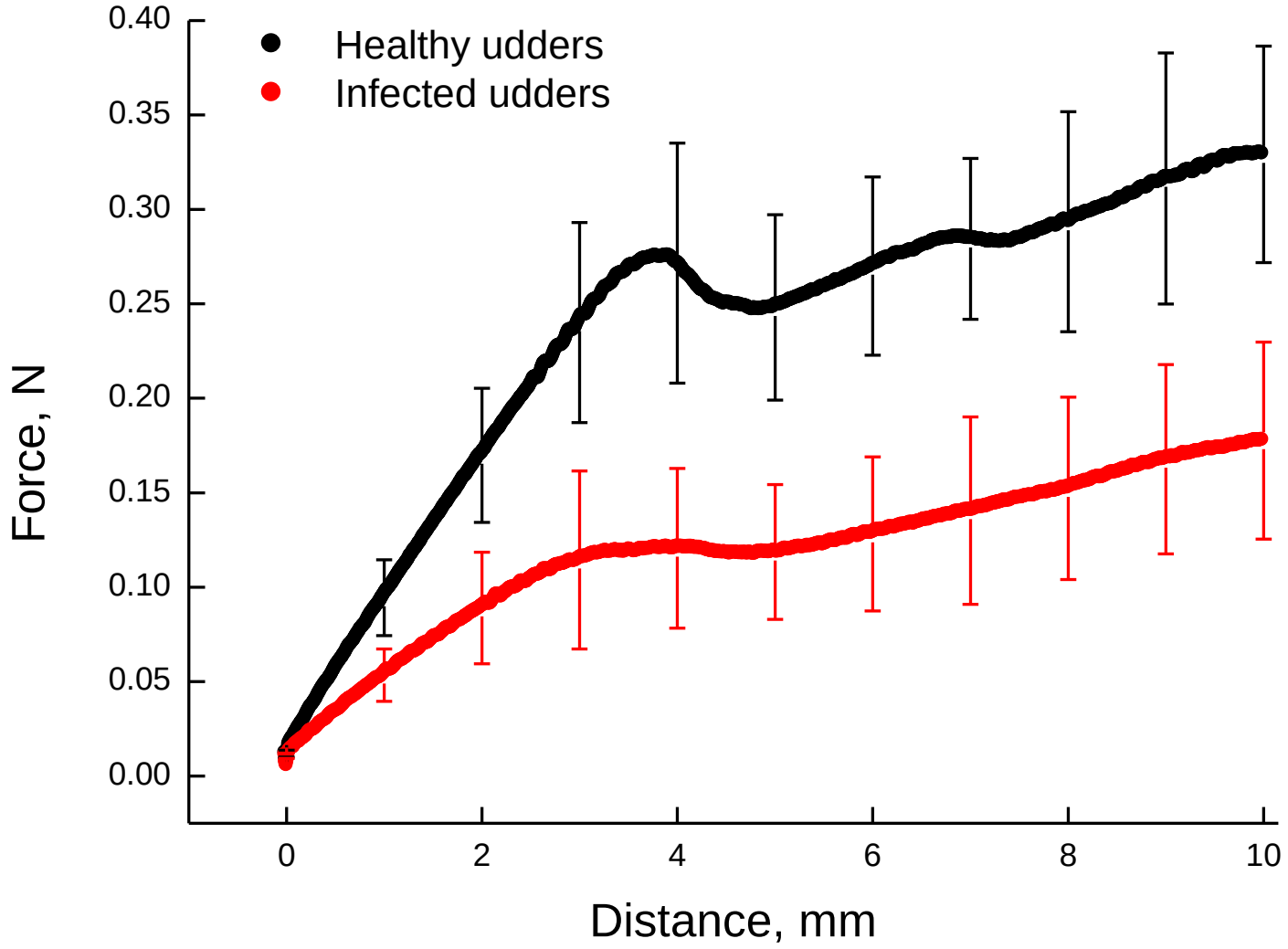
Strep. dysgalactiae



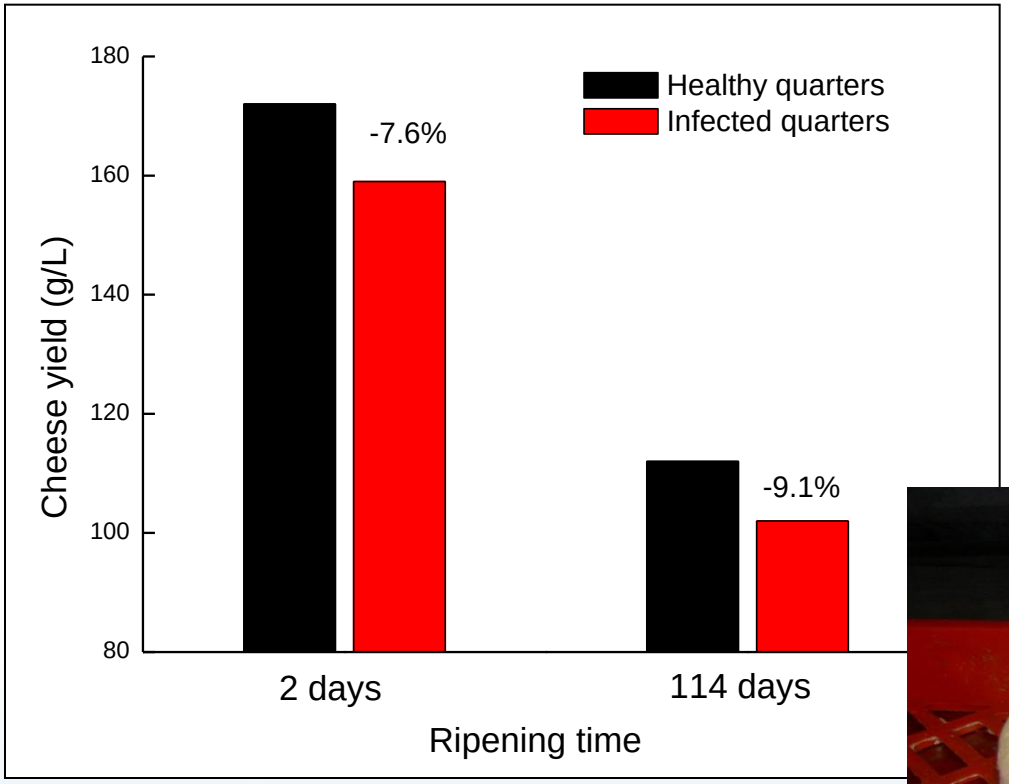


Day 2

Cheese hardness (48 h) (*Strep. dysgalactiae*)



Cheese yield (g/L)



Merin et al., 2008. Dairy Science & Technology, 88:407-419

Can milk coagulation properties be used for diagnostics?

Staph. chromogenes

Strep. dysgalactiae

Results: single udder level

45 uninfected udders

51 bacteria infected udders – no clinical score

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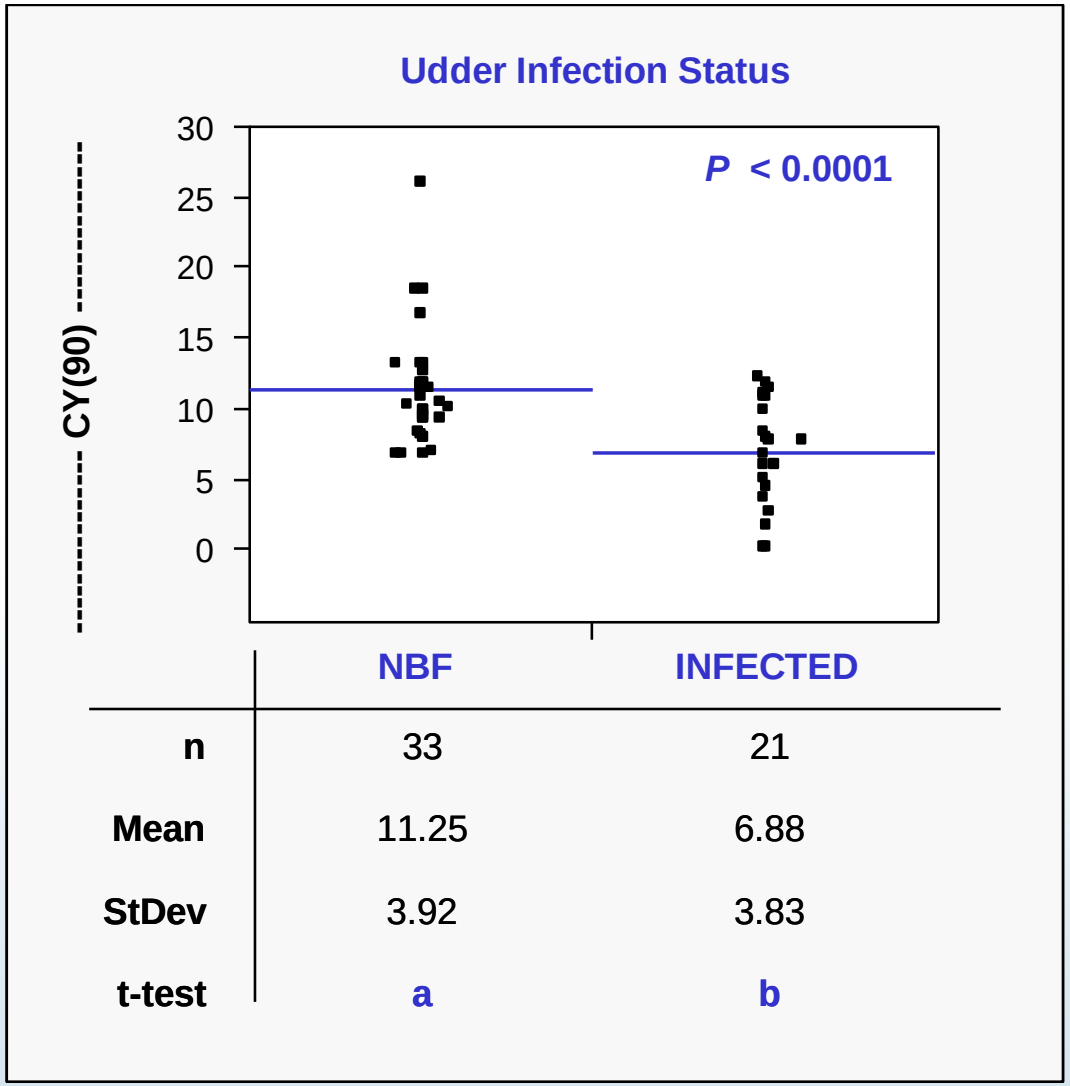
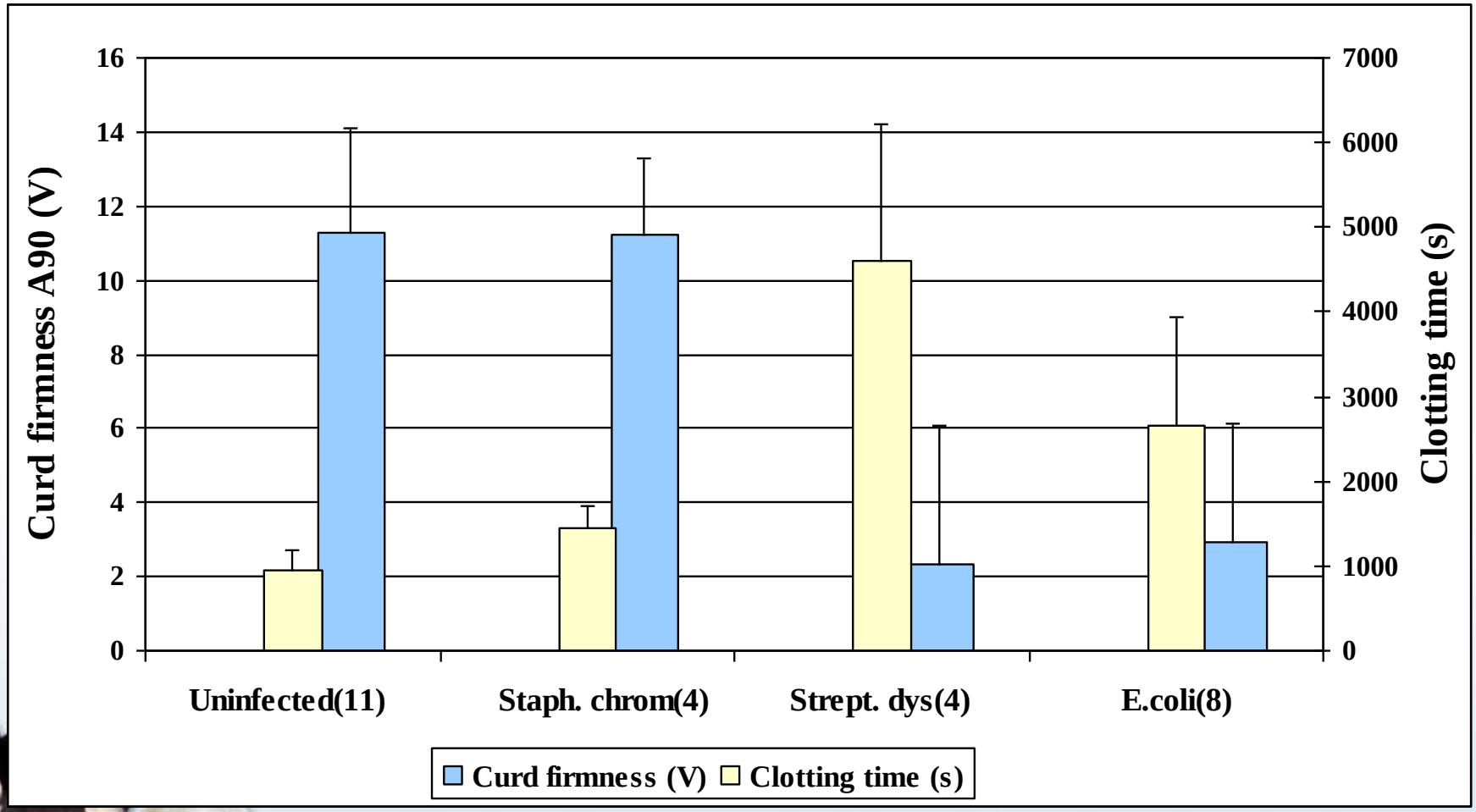
Parameters	Infected	NBF	*P*[F]
SCC (x 1000)	1241±103	99±19	0.001
Fat (g/L)	38.3±0.8	37.0±1.8	NS
Protein (g/L)	34.7±0.7	33.9±0.7	NS
Casein (g/L)	25.6±0.6	26.9±0.6	NS
% Casein of protein	75.85±0.7	78.72±0.7	0.001
Lactose (g/L)	42.1±1.4	49.8±1.2	0.001
Clotting time (sec)	2394±238	930±220	0.001
Curd firmness (Volt)	4.71±1.18	11.57±1.03	0.001

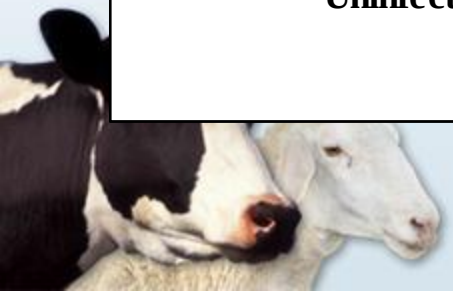
The Cy-90 distribution, mean, Standard deviation (StdDev) and t-test significance level (*P* value) between NBF and Infected udders



	NBF	INFECTED
n	33	21
Mean	11.25	6.88
StDev	3.92	3.83
t-test	a	b

Cheese making parameters in uninfected and infected udder

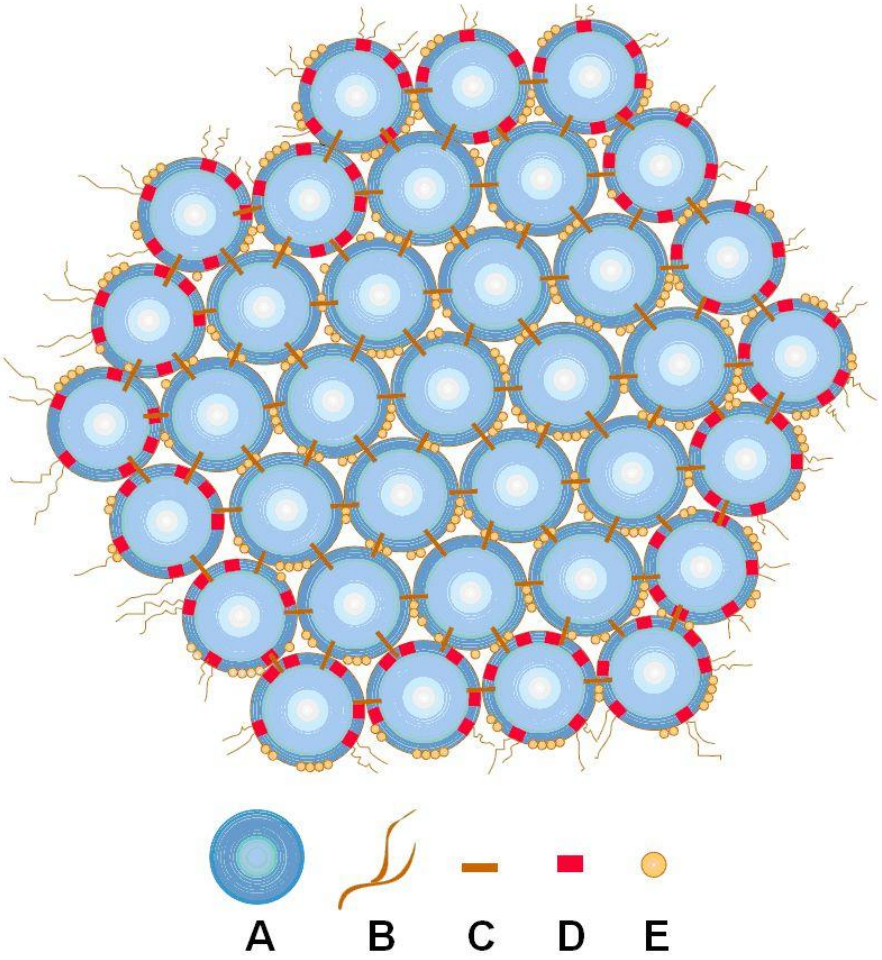




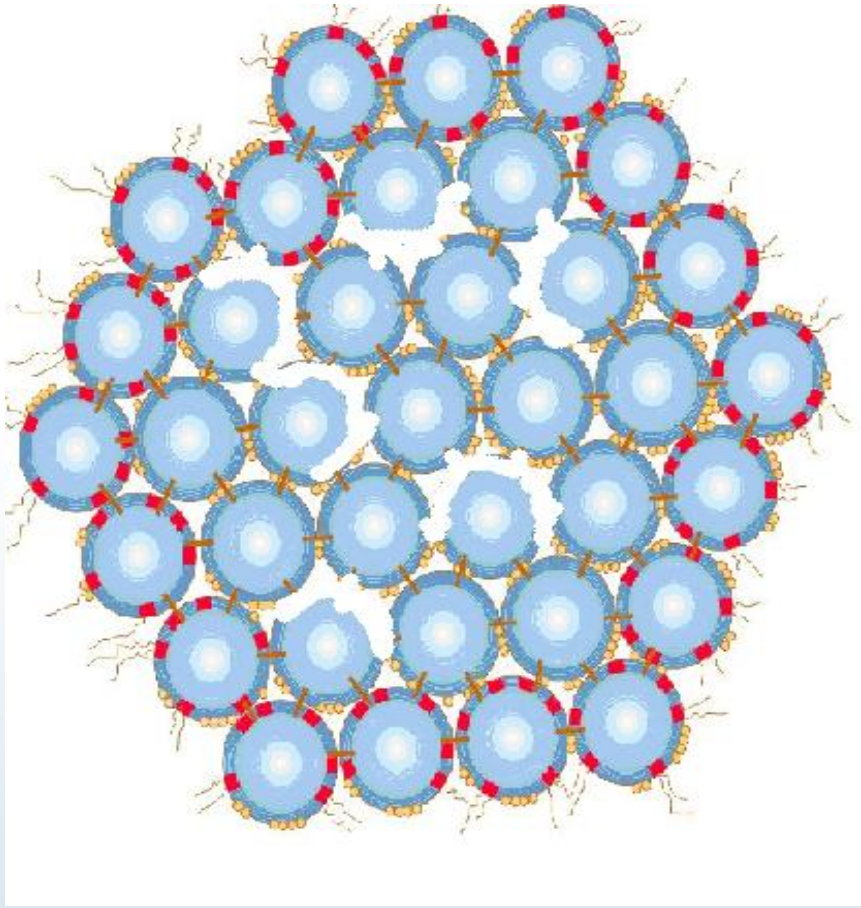
The idea of low curd firmness

Casein micelle

Compact structure



Loose structure



A: a submicelle; B: protruding chain; C: Calcium phosphate; D: κ-casein; E: phosphate groups

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Automated on-line analysis of milk constituents at every stall

- Fat
- Protein
- Lactose
- Blood
- **Cy & RCT**

This new feature operating on-line allows controlling the properties of milk entering the bulk milk tank

management by exceptions of the milk tank to optimize its value

Bulk milk tank

Average milk of all cows

SCC, Fat, Protein and Casein

Average product

Bulk milk tank

Average milk of all cows

SCC, Fat, Protein and Casein

Average product

"Industrial milk"

Optimal product

Milk unfit for human consumption

Bulk milk tank

Average milk of all cows

Scc, Fat, Protein and Casein

Average product

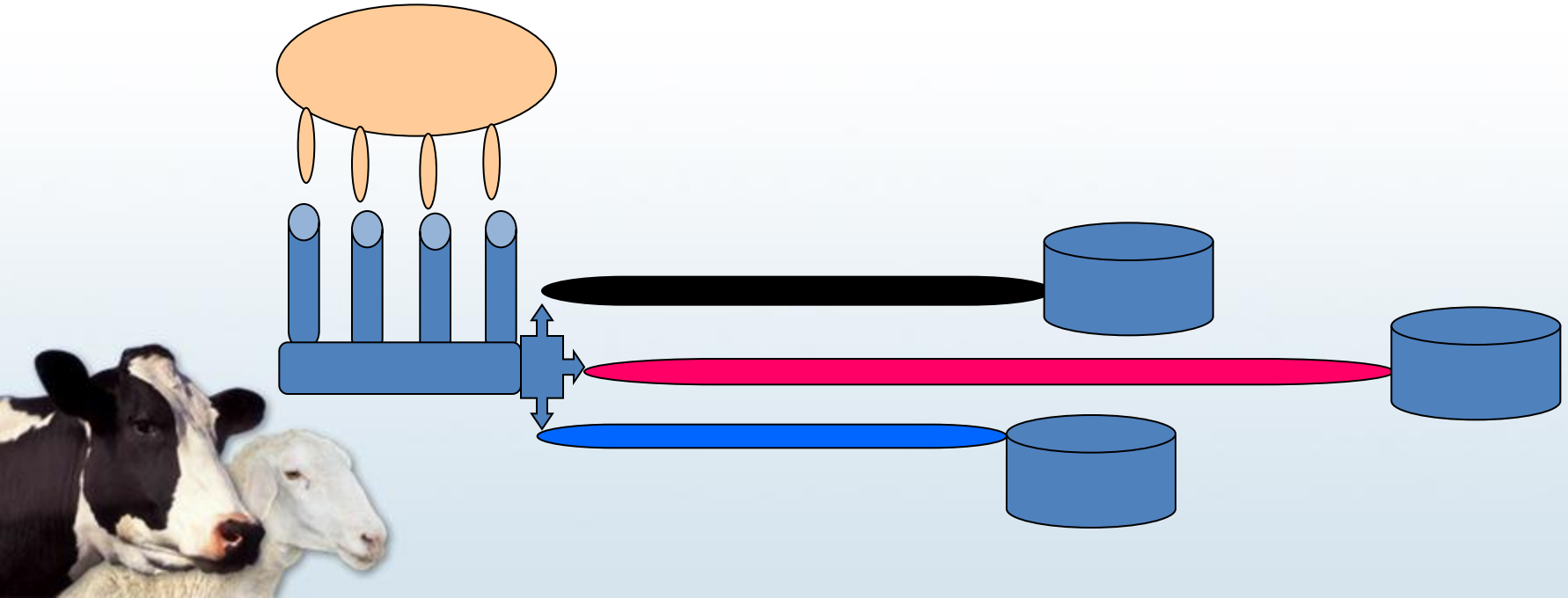
Cheese

Maximal product

Drinking milk

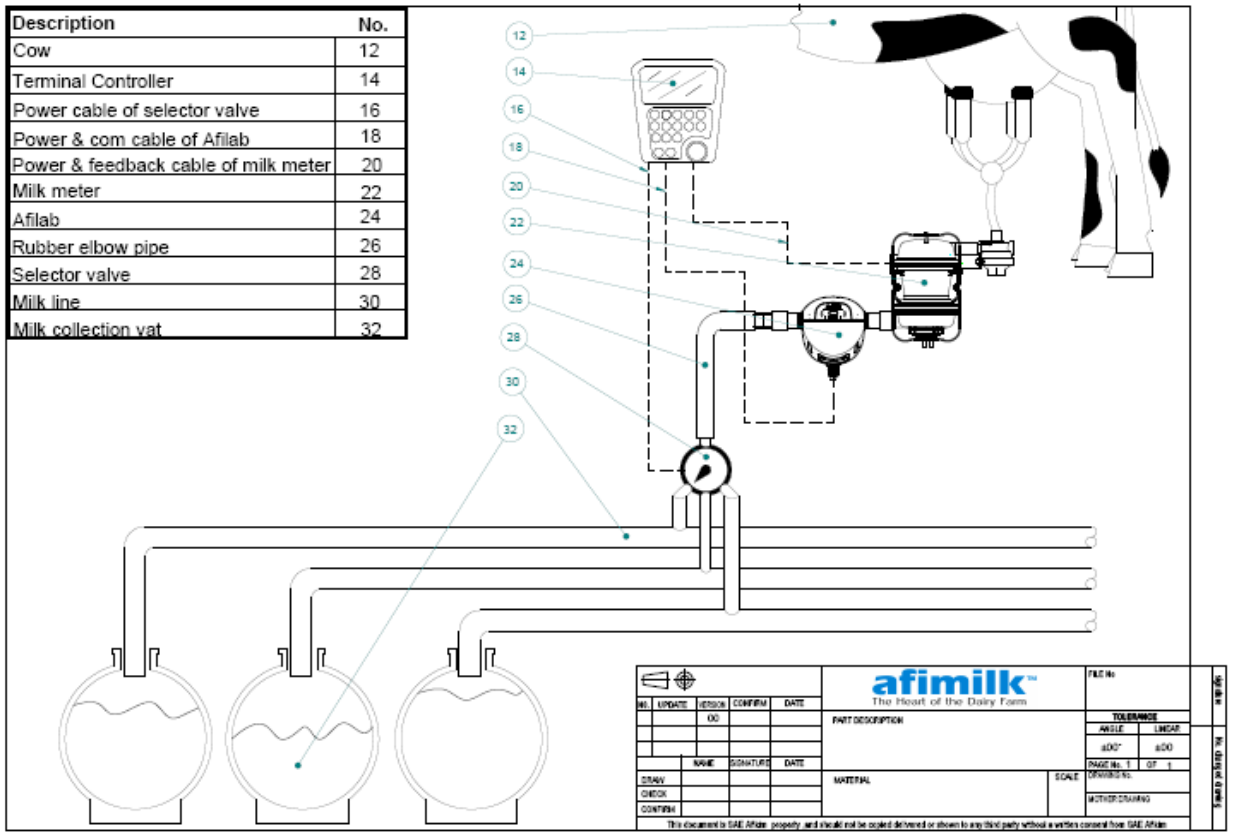
Maximal product

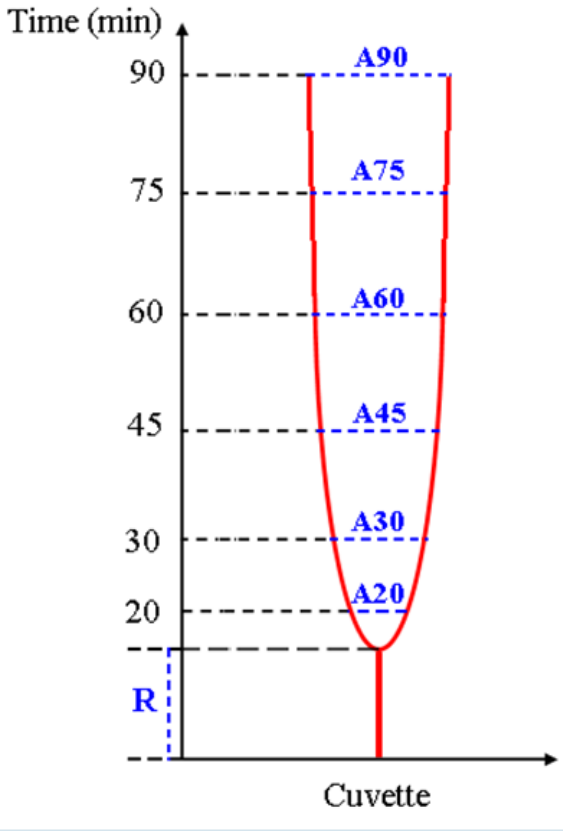
On-line milk separation at the individual cow level will enable prevention of “unfit” milk from entering the milk tank as well as a product adjusted for industrial channeling



On–line apparatus for milk separation

Description	No.
Cow	12
Terminal Controller	14
Power cable of selector valve	16
Power & com cable of Afilab	18
Power & feedback cable of milk meter	20
Milk meter	22
Afilab	24
Rubber elbow pipe	26
Selector valve	28
Milk line	30
Milk collection vat	32





Field test results: real time analysis of Cy and RCT by the Afilab

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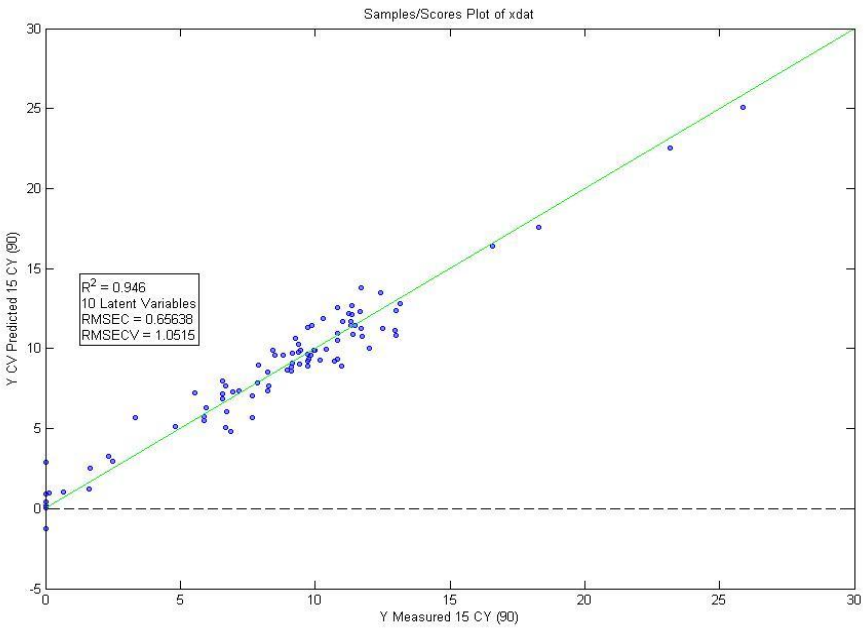
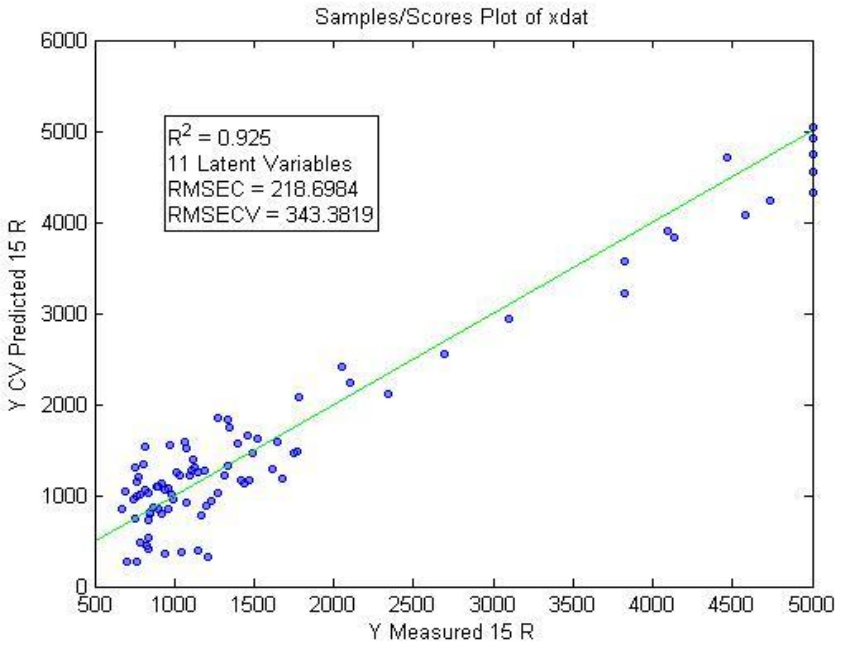
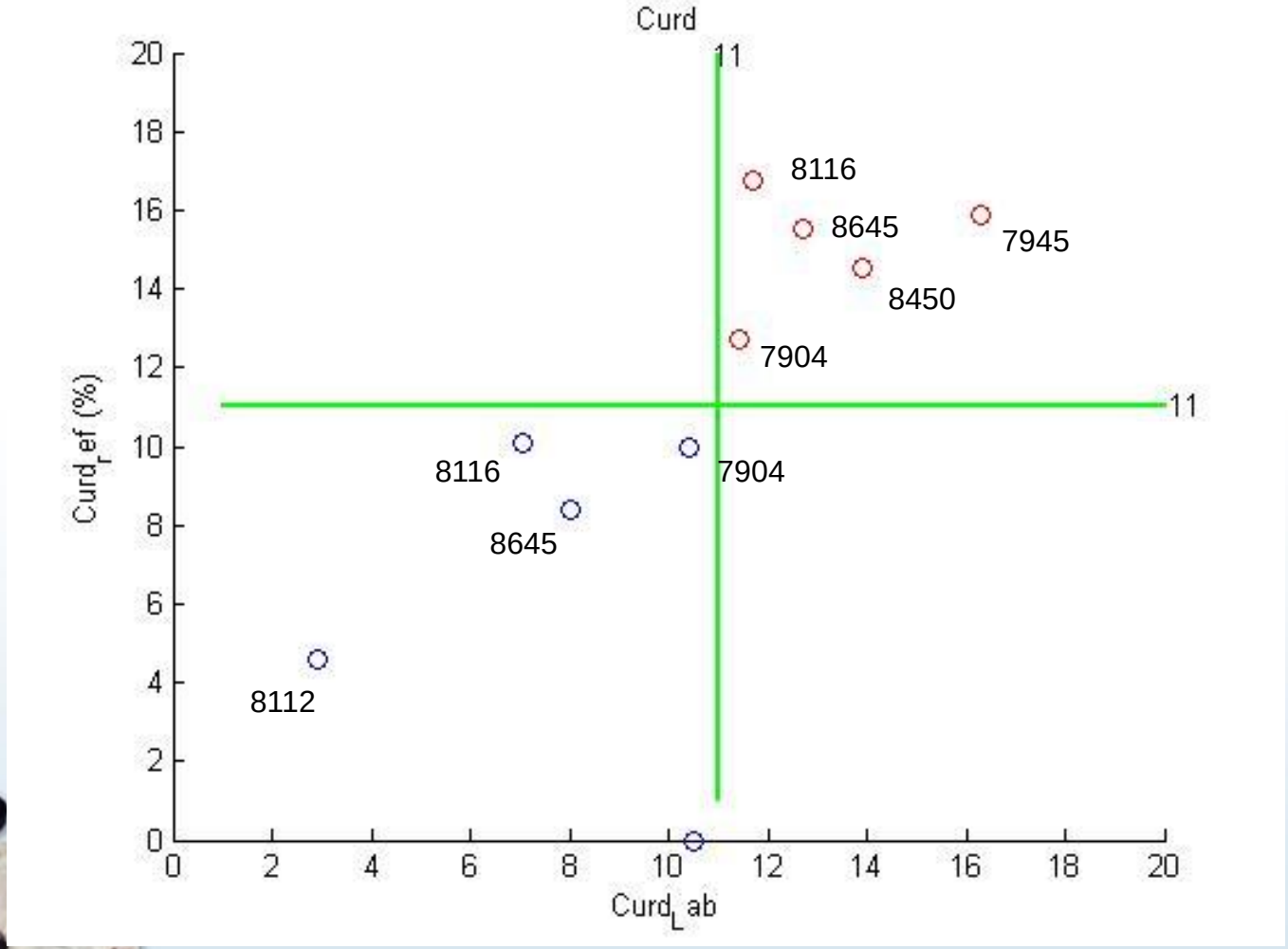
CY(90) – Curd firmness



RCT – Rennet clotting time



On-line milk separation based on CY – field test results



Maximal product separation: cow level (9 cows)

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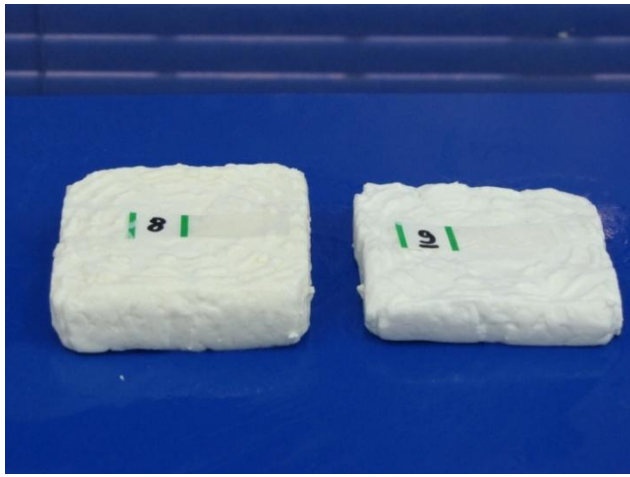
Cheese production from 100 mL

The objective:

optimal 30/70 yield

Channeling for

drinking/cheese making



Production Channel	Milk yield (kg)	Cy (60)	R - Clotting time (min)	Dry matter (g)	Fat %	Protein %	Lactose %
"Cheese"	11.27	9.1	15.3	21.77	4.65	2.90	5.02
"Liquid"	3.73	6.8	19.2	15.15	2.14	2.99	5.10
Difference	75/25	-25%	+25%	-30%	-54%	+3%	+2%

Optimal product separation:

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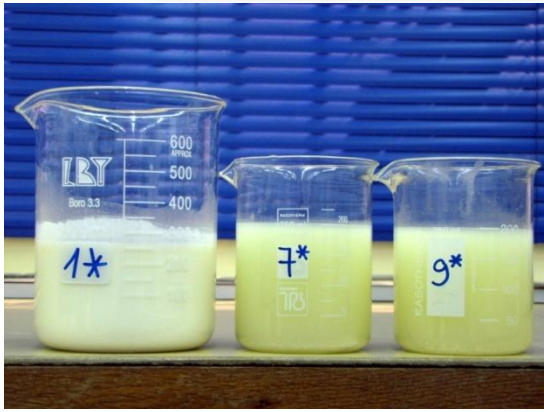
Cheese production from 300 mL

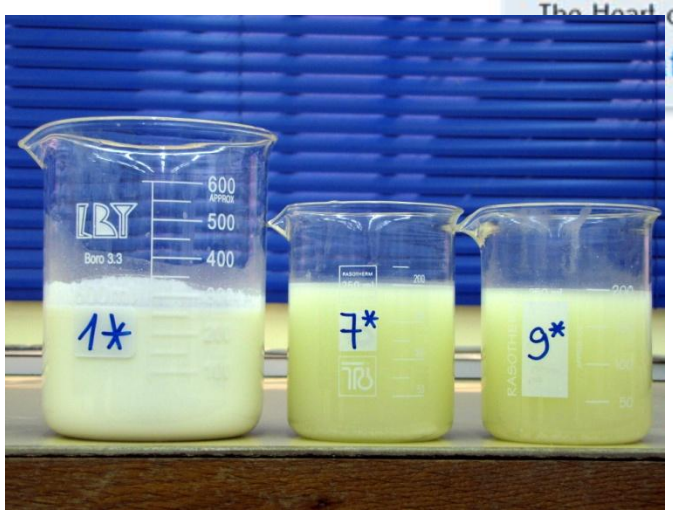


Product	Cy(60)	Whey protein %	Fat in Whey %	Dry matter g	Fat %	Protein %	Lactose %	SCC x 1000
a. Optimal	12.4	0.91	0.2	25.83	4.53	3.44	5.05	28
b. “unfit milk”	0.6	na	na	0.0	4.18	3.04	4.16	7767
c. 10/90 mix	10.6	0.98	0.4	24.2	4.50	3.40	4.96	800

summary

Our management system concept of improving production through management by exceptions is extended and can now manage the milk in the tank and improve the value of the product as well as it's volume

For better performance shift the critical point for research of milk properties **from the exit of the tank to its entrance on the individual cow level**



Thank You