MILK QUALITY CONTROL

Dairy Vietnam
Ngành sữa Việt Nam

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VIETNAM BELGIUM DAIRY PROJECT

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PREFACE

Milk provides us with essential elements that are vital for our development and growth. We all start our life with drinking milk and we all know that dairy cows can produce milk for humans consumption. But who knows what is really in it? Milk is a rich source of proteins, minerals and vitamins and researchers have identifi ed more that 100 different components in milk.

Dairy processing companies collect the milk from thousands of cows and mix it all together to produce their delicious products. But is all the milk from all these cows the same? No, it is not. In fact, there are large variations in composition and quality of different milk.

Dairy processing companies want to ensure a high quality product with lots of nutritive elements for their consumers. So they need to know what kind of milk the collect. Therefore, they test the 'quality' of the milk. But what is milk quality? Is it the milk fat %, milk protein %, bacteria count, somatic cell count or antibiotic residue in the milk?

This booklet aims to introduce the basic facts about milk and it aims to clarify some basic terminology of milk quality. When people discuss about the quality of milk, they should understand the difference between milk composition, bacteria count, somatic cell count, residue etc. The price of fresh milk is affected by the world milk price Vietnamese dairy farmers must compete with farmers anywhere in the world. But farmers that produce a high quality product will always receive a good price for their product! We hope that this booklet can help to improve the quality of the fresh milk in Vietnam!

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Chapter 1:

SECRETION OF MILK

- Milk production in the udder
- Lactation

I. MILK PRODUCTION IN THE UDDER

1. Structure of the udder

The cow's udder is an organ divided into four separate quarters containing a complex network of various sized ducts, blood vessels, secretory cells and muscle tissue. Each quarter has one teat with its own separate mammary gland, which makes transfer of milk from one to another impossible.

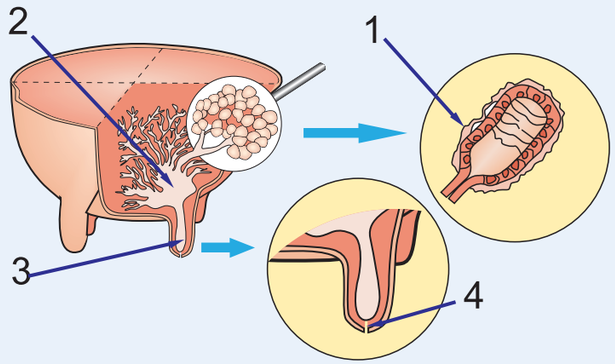


Figure 1.1: Sectional view of the udder

Legends:
1. Alveolus
2. Cistern of a quarter
3. Teat cistern
4. Teat channel

The secretory cells secret milk into the alveoli. The alveoli surrounded by muscle cells. When the muscle cells contract milk is pushed out of the alveoli into the ducts and milk cistern.

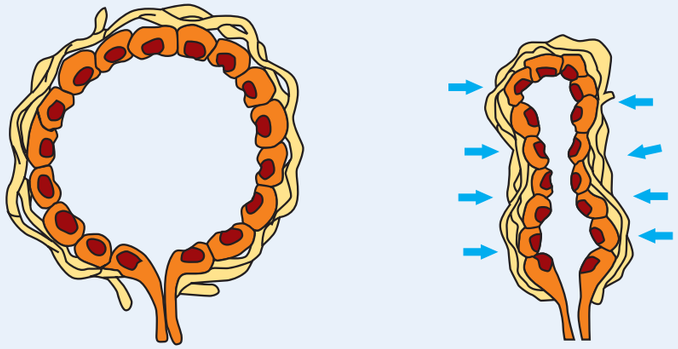
The cistern of each quarter has an extension reaching down into the teat; this is called the teat cistern. At the end of the teat there is a channel of 1 - 1.5 cm long. Between milkings the channel is closed by a sphincter muscle which prevents milk from leaking out and bacteria from entering the udder.

Picture 1.2. Muscle structure surrounded protect the udder against mechanical injuries

2. How is the milk secreted in the udder?

Milk is produced at all time and most of milk in the udder (60%) is stored in the alveoli and only 20% in the ducts and 20% in the cistern.

When cow is milked, the muscle cells surrounding the alveoli receive a signal to contract. This signal is delivered in the form of oxytocin. Oxytocin is produced and stored in the gland. When the cow is prepared for milking by correct stimuli, oxytocin is released into the bloodstream.



Alveolus before being stimulated by oxytocin

Alveolus after being stimulated by oxytocin

Figure 1.3.Expression of milk from alveolus

Note: A hormone is a substance produced by an organ in the body and released in the blood stream who gives signals to certain organs to increase or decrease a certain activity.

Cows are stimulated by the calf's sucking on the teat. The oxytocin is released when the cow feels the calf sucking. A modern dairy cow lets down her milk if stimulated properly by the sounds, smells and sensations associated with milking. These factors create a conditioned reflex to release oxytocin from its store into the blood stream.

Figure 1.4. Factors affecting the secretion of oxytocin

It takes between 60 - 90 seconds for the oxytocin begins to take effect on the udder after being released and causes the muscle-like cells to compress the alveoli. The pressure forces the milk down into the teat cistern, from which it is sucked into the teat cup of a milking machine or pressed out by the fi ngers during hand milking.

The effect of oxytocin is gradually faced away and it disappears after 5 - 8 minutes. Milking should therefore be completed within this time. The action of oxytocin is blocked when the cow feels fear or is agitated. If the milking procedure is prolonged, the cow becomes irritated and may become diffi cult to milk.

Remember: The better milking preparation the more milk letdown!

II. LACTATION

1. What is a lactation?

Before calving the cow's udder begins to secret milk already for her calf's feeding after birth. After calving, the cow starts her period of milking. The duration between starting milking and drying off is called "lactation".

A lactation is ideally 305 days, but practically it is usually more, followed by a two-month dry period prior to the next calving.

Figure 1.5: Lactation curve

2. How does the milk yield change during a lactation?

After calving four to ten weeks the cow reaches highest yield level (peak yield) during the entire lactation. A high peak yield normally means a high total yield. The peak yield varies with many factors, i.e. breed, nutrition.

Milk yield is decreased approximately 7 - 10% per month after the peak. The normal decline of milk yield gradually happens and reaches the lowest at dry off date. The figure 1.5 shows a normal curve of a lactation.

Picture 1.6. Measuring and recording milk yield are an important task

Remember: Keep your milk yield record properly in order to evaluate your cows' potential

SUMMARY OF CHAPTER 1

- Milk is produced in the alveoli in the cow's udder
- About 60% of the milk stored in the alveoli, while only 40% is stored in the milk cisterns and milk ducts
- During milking, milk alveoli contract and milk is released. The alveolionly contract after oxytocin has been released in the bloodstream
- Oxytocin release is affected by the stimuli that the cow receives just before and during milking
- When cows are milked in a calm, peaceful environment, more oxytocin will be released. The oxytocin release can easily reduce when a cow is in pain or in fear (barking dogs, being hit, ...)
- After giving birth to a calf, a cow should give milk for about 305 days. Then she should be dry for about 60 days and give birth to another calf
- Top milk production is reached around 10 weeks after calving. A higher top production usually means a higher total production in that lactation

Chapter 2:

MILK COMPOSITION OF A HEALTHY DAIRY COW

- **Introduction**
- **Description of components**
- **Testing the milk composition**
- **Factor infl uencing the milk composition**

I. INTRODUCTION

Milk is composed of water, fat, protein, minerals, vitamins and lactose. Each component has a given rate. This rate is dependent on breed, stage of lactation, nutrition, health, season and management of herd.

The whole mature milk contains:

- Water: 85.5 - 89.5 %
- Fat: 2.5 - 6 %
- Solid-non-fat (SNF): 7.1 - 11.4 %
  - Protein: 2.9 - 5 %
  - Lactose: 3.6 - 5.5 %
  - Mineral: 0.6 - 0.9 %
  - Vitamin

The total dry matter is the sum of all components excluding water, around 12% of whole milk.

Milk from healthy cows also contains somatic cells and bacteria.

MILK COMPOSITION OF A HEALTHY DAIRY COW

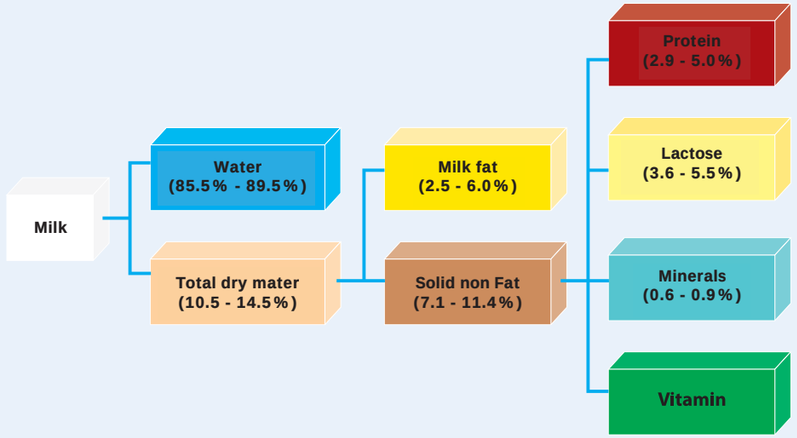


Figure 2.1. Milk composition

The first milk after calving is called colostrum. Colostrum contains higher amount of protein, minerals, and milk fat but it contains less lactose than mature milk. It contains antibodies and growth factors for the newborn calf to boost its immunity. Milk produced in the first 5 days after calving can not be delivered to the processing company. The composition of colostrum gradually changes to that of mature milk.

II. DESCRIPTION OF COMPONENTS

1. Water

About 88% of milk is water. Milk production is very rapidly affected by a shortage of water and drops the same day that drinking water is limited or unavailable. This is one reason why the cow should have free access to a plentiful supply of drinking water at all times.

Picture 2.2. Fresh water needs to be supplied all the time

Note:

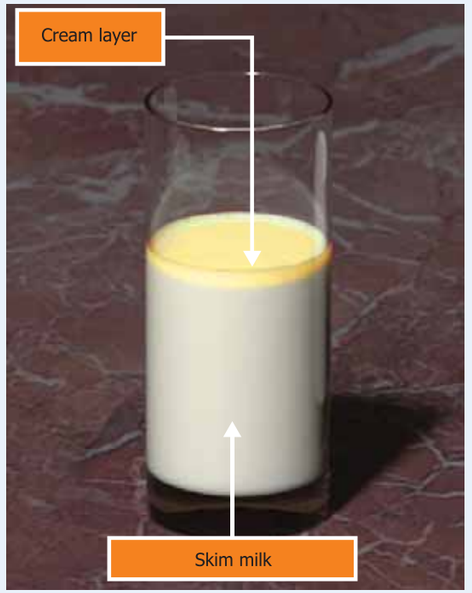
- If water is added to the milk after milking, the added water is easily detectable by several methods!
- Withholding water to a cow before drying off is animal tortune and completely unnecessary!

2. Milk fat

Normally, fat makes up from 2.5 to 6.0% of milk, varying between breeds of cattle and with feeding practices. Fat is present in milk in small globules suspended in water.

As the fat globules are not only the largest particles in the milk, but also the lightest, they tend to rise to the surface when milk is left to stand for a while. (picture 2.3). This process can be accelerated by centrifugation of the milk. The top layer, after centrifugation is called cream and contains most of the fat and also proteins.

This part is used to make butter. The bottom layer is called skim milk and contains protein and other substances.



Picture 2.3. Milk fat float on top

The milk fat is an important criterion while evaluating fresh milk. Therefore fresh raw milk should be stirred periodically to prevent the aggregation of fat globules.

Fat in milk is a rich energy source in a dietary energy for human and most milk producers pay a premium for milk with high fat content.

3. Milk protein

Protein molecules are the second largest dry components in the milk. The primary group of milk proteins are the caseins. Caseins take up to 80% of total protein of cow's milk. Protein is a very important content to determine the quality of milk. Milk with more protein has a higher nutritive value.

4. Lactose

Lactose (milk sugar) is a sugar found only in the milk, it is also a large energy source along with the milk fat. Lactose is not as sweet as other sugars (about 30 times less sweet than cane sugar).

Lactose plays a major role in milk production in the cow. The process of making lactose is responsible for drawing water into the milk. Because of the close relationship between lactose and the amount of water drawn into milk, lactose content is the least variable component of milk.

5. Minerals

Milk contains a number of minerals. The major minerals found in milk are calcium and phosphorous. They are both mostly associated with the casein micelle structure. Both of them are essential for the development of bone and soft issues of animals.

Milk also contains most other minerals found in the body. Minerals occur in milk as mineral salts. The amount of salts are variable. Towards the end of lactation, and even more in the case of udder disease, the salt content increases and gives the milk a salty taste.

6. Vitamin

Milk contains all the major vitamins. Among the best known are vitamin A, B_1, B_2, D, E, K.

III. TESTING THE MILK COMPOSITION

The milk composition is an important criterion while evaluating fresh milk, because they determine the nutritive value of the milk. Most processing companies pay a premium for milk with higher levels of milk fat and protein. Some companies test the exact amount of milk fat and milk protein while other companies prefer to test the total dry matter and/or Solid Non Fat.

Picture 2.4. Automated milk analizer

Density test

The density test is performed to find out if any substance was added to the milk (water, milk powder,…).

Besides, the density of the milk depends on its temperature and its composition (Fat, SNF). Depending on the composition the density of the milk varies within the range of 1,027 to 1,033 kg per liter at 20° C. The density of water is 0.9982071 kg per liter at 20°C. So, if water is added to the milk the density of the milk will decrease. Generally spoken, if any substance is added to the milk its density will change.

Freezing point

Milk is tested for its freezing point (international recognized reference test) in order to determine the presence and the amount of water that is added to the milk.

The freezing point of water is 0°C. Milk contains different solutes that are lowering the freezing point of milk to about half a degree Celsius below that of water.

The freezing point for 100% milk is -0.510°C. Each increase in freezing point of 0.005°C from -0.510°C towards zero equates to the addition of about 1% water to the milk.

If the value is very low, it usually means that water was added to the milk.

Milk analyse

The components of the milk can be tested using classical laboratory techniques, but nowadays modern milk analyzers can give a result in a few seconds. The usual milk composition indicators are:

- Dry matter (%) = Fat (%) + Protein (%) + Lactose (%) + Minerals (%)
- Milk fat (%)
- Milk protein (%)
- Solid non fat (%) = Protein (%) + Lactose (%) + Minerals (%)

IV. FACTORS INFLUENCING THE MILK COMPOSITION

1. Nutritious factors

To produce large quantities of high quality milk, a cow needs to eat a lot of high quality feed and the ratio concentrate/forage need to be correct. Any limitation in terms of feeding quantity, quality on ratio will result in reduced yields and reduced milk fat and protein content.

Figure 2.5. Utilization high quality grasses for dairy

The specific effect of nutrition on the components of the milk are rather complex. Important to remember is that a cow needs to be fed high quality grass, fresh water, concentrate and mineral need to be supplemented correctly.

2. Stage of lactation

Milk quality (Solid and protein) is very high at calving and then declines as yield increases, reaching a minimum at about 50 - 70 days after calving.

Both fat and protein in milk tend to increase after 70 days after calving, but protein only rises signifi cantly if the cow becomes pregnant. In later lactation in the pregnant cows, both fat and protein rise more rapidly than the others.

Sugar in colostrum is low but rises rapidly after calving to reach a peak by two weeks into lactation. This level is maintained for four weeks and then fallen gradually towards the end of lactation.

Picture 2.6. Using concentrate in ration needs to be correct

3. Diseases

Disease can make an effect on the yield as well as on fat and protein content. Some examples are:

- Mastitis leads to a reduction in yield, lactose and milk fat. Milk protein levels will increase slightly with mastitis but the protein is of lower quality.
- Liver fluke can depress both milk fat and protein.
- Heavy infusions of lice and gastrointestinal worms may also reduce milk quality.

Some diseases can transfer germs into milk then infect human like tuberculosis. Other diseases and injuries also affect milk quality because of reducing feed intake and/or metabolic disorder.

Picture 2.7. Have solutions to prevent germs from entering the cow

4. Cow breed

Milk compositions are different among breeds (see Table 1). Fat and protein levels in the milk are heritable characteristics.

Gains in milk composition made from breeding are permanent and accumulate from year to year. Benefi ts of sire and cow selection, and of mating decisions made today, will continue to be realized in all future descendants of the herd. In this respect, selection is a very productive means of improving milk composition.

Table 1. Milk components from different breed

(%)	Holstein friesian	Jersey	Zebu	Ayrshire	Brown Swiss
Water	87,8	85,0	85,3	86,9	86,7
Fat	3,5	5,5	4,9	4,1	4,0
Protein	3,1	3,9	3,9	3,6	3,6
Minerals	0,7	0,7	0,8	0,7	0,7
Lactose	4,9	4,9	5,1	4,7	5,0

Picture 2.8: Ayrshire

Picture 2.9: Brown Swiss

Picture 2.10: Holstein Friesian

Picture 2.11: Jersey

5. Climate conditions

High temperature and humidity affect feed intake that can be associated with pronounced variations in milk yield and composition. Temperatures consistently above 30^{o}C will reduce milk yield as well as the percentage of milk protein, because of a reduction in energy intake.

During hot conditions cooling of cows can be achieved by nature and manual ventilation, sprinkler and fan systems, heat reducing roof.

Cows in early to mid-lactation and receiving little or no supplementation will be affected the most by heat stress.

Picture 2.12. Making comfortable environment for dairy cows

6. Heat treatment

Milk is heat treated at the processing companies to kill any pathogenic micro-organisms that may be present. Heat treatment also causes changes in the constituents of the milk. The higher the temperature and the longer the exposure to heat, the greater the changes. Brief heating to a high temperature can have the same effect as longer exposure to a lower temperature.

Milk heated at 75^{o}C for 20 - 60 seconds will start to smell and taste "cooked". This milk is not accepted by processors.

Picture 2.13. Milk processing line

Remember: Milk should never be heat treated before delivering to the milk collection point.

7. Changes in milk quality during storage

The fat and protein in milk may undergo chemical changes during storage condition. The resulting reaction products can cause off-fl avours, principally in milk and butter.

Chemical reactions that make milk fat and protein breakdown are caused by enzymes. Enzyme sources are ready in milk or produced by bacteria. The temperature during storage just keeps reactions happened slowly. Therefore if milk is stored for a long time, it will break down, even if it is kept of a low temperature.

Picture 2.14. Milk is stored in cooling tank in milk collection point

Remember: Milk should be kept in the storage temperature as soon as possible after being milked.

SUMMARY OF CHAPTER 2

- Milk contains about 88% water and 12 % dry matter.
- The main components of dry matter are milk fat, milk protein, milk sugar and minerals.
- Milk with a high dry matter content has a higher nutritive value.
- Most processors pay a higher price for milk with more milk fat and milk protein.
- The percentage of each component (= milk composition) is affected by nutrition, stage of lactation, cow's health, cow's breed and the season.

Chapter 3:

SOMATIC CELL COUNT (SCC) BACTERIA COUNT (BCC) RESIDUES

Definitions

- Somatic cell count (SCC): The number of somatic cells per ml milk
- Bacteria count (BC) : The number of bacteria per ml milk
- Residue: The presence chemical products in milk that result from treatment the cow, feed addition.

I. SOMATIC CELL COUNT

1. What is somatic cell?

Somatic cells are body cells from the cow. Milk from healthy udders always contains a low amount of body cells, but the number increases in case of an infection in the udder. Even in cases of sub-clinical infections, which means that there are no signs of infection (swollen, red, painful...), the number of somatic cells is increased.

The number of somatic cells is proportional to the severity of the infection and to the loss in milk production caused by the infection.

The somatic cell content of milk from healthy cows is a lower than 150.000 cells/ml.

Remember: High somatic cell counts are an indicator for udder infections (mastitis)!

2. Counting somatic cells

Somatic cells can be counted in milk from an individual cow or from the bulk tank. Individual counts can fi nd the exact cows with sub-clinical udder infections, while count in the bulk tank gives an indication of the udder health of the herd.

A commonly used 'cow-side' test is the California Mastitis Test (CMT). This test can indicate the level of infection in each quarter, but it does not give an exact cell count. A small amount of milk is mixed with an equal amount of reagent. The solution is swirled to mix it and the amount of gel reaction is estimated (from none to almost solidifi ed).

Picture 3.1. CMT helps estimating the level of infection quarters.

Exact somatic cell somatic cells counts can be done by microscope, but nowadays modern analysers are used.

Picture 3.2. The somatic cell counter

Interpretation of cell counts:

- ≤ 150.000 cells/ml — Excellent
- 150.000 – 250.000 cells/ml — Good
- 250.000 – 400.000 cells/ml — Moderate mastitis
- > 400.000 cells/ml — Mastitis problem

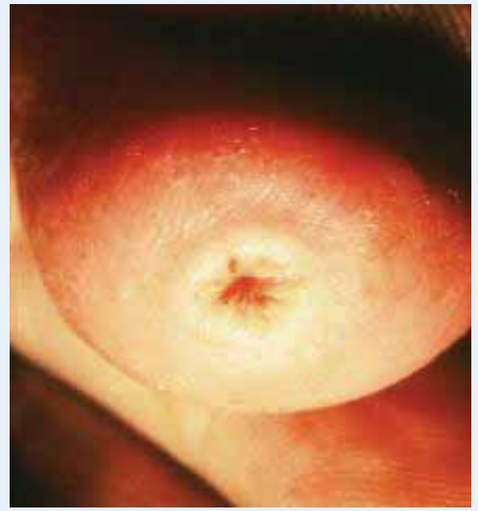
A higher somatic cell count is related to higher level of udder infection and to higher level of production loss!

II. BACTERIA COUNT

1. How do bacteria enter the udder?

In healthy animals, milk inside the udder does not contain bacteria. In between milking times the sphincter muscle of teat channel avoid that bacteria can enter the udder. After milking, the sphincter muscle needs 30 minutes to one hour to close completely.

Picture 3.3. Teat channel is closed



Picture 3.4. Teat channel is opened

However, during milking, bacteria from the teat, skin, feces, milker or environment can enter the udder and get into the milk.

Milk is a very rich nutritious environment for bacteria to develop. Bacteria can develop very quickly. The amount of bacteria can double in 30 minutes. From ten bacteria, after 12 hours it develops to 167 million bacteria!

Low temperature cannot kill bacteria, but it can inhibit their development. Milk should be stored at a temperature below 4 oC. When the milk is collected by the processing company, a total amount of 100.000 cell/ml is acceptable.

Picture 3.5. Bacteria from environment can enter the udder and milk

High bacteria counts are mostly caused by poor hygiene milking and/or not good storage. The degree of infection depends on the cleanliness of the cow's environment and those surfaces with which the milk comes into contact as well as the temperature of storage. The surfaces of equipment are usually much greater sources of infection than the udder!

2. Does mastitis cause high bacteria count?

Subclinical mastitis: research has shown that milk from subclinically infected udder has less than 10.000 bacteria/ml.

Clinical mastitis: milk from clinically infected udder can contain very high amount bacteria, up to millions/ml. Milk from clinically infected animals should never be brought to milk collection point.

Remember: the high bacteria count is an indicator of poor milking hygiene, dirty equipment and/or too high milk storage temperature! High bacteria counts isn't an indicator of mastitis!

3. Effect of bacteria on the milk

When bacteria develop, they can alter milk quality through destruction of milk fat, milk protein and milk sugar. Most bacteria can convert the milk sugar into lactic acid. This acid makes the milk sour. When the acid levels increase, the protein structure becomes instable. High level of acid can indicate a high level of bacteria in the milk.

4. Counting bacteria

Many tests measure the amount of bacteria on milk. Some tests can be done in the milk collection center while other tests can only be done in a laboratory. Commonly used tests include:

Testing in the milk collection point:

Alcohol test

The test is quick and simple. It is based on instability of the proteins when the levels of acid are increased (because of bacteria) and acted upon by the alcohol. Also increased levels of albumen (colostrum milk) and salt concentrates (mastitis) results in a positive test.

Picture 3.6. Alcohol test in milk collection point

Lactic acid test

The lactic acid test is used as an indicator of milk's hygienic quality and of its state of preservation.

The presence of lactic acid or lactate in milk is due to the fermentation of lactose caused mainly by lactic bacteria. Just milked milk does not contain lactic acid, but this increases after awhile and its concentration is closely correlated to the total bacterial charge.

pH test

Fresh cows milk has a pH of between 6.7 and 6.5. Values higher than 6.7 denote mastitis milk and values below pH 6.5 denote the presence of colostrum or bacterial deterioration. Because milk is a buffer solution, considerable acid development may occur before the pH changes. A pH lower than 6.5 therefore indicates that considerable acid development has taken place. This is normally due to bacterial activity.

Testing in the laboratory:

Dye Reduction Tests

The two most common dye reduction tests are the Methylene Blue Test and the Resazurin Test. These dyes will, when added to milk which is incubated at 37^{o}C, be chemically reduced if there is microbial activity in the milk. Generally, the time required to change the colour of the dye is shorter if there is high bacterial activity in the milk (many bacteria) and longer if there is low bacterial activity (few bacteria).

Dye reduction tests do not indicate anything about he kind of bacteria in the milk, they only indicate the number of bacteria.

Total Plate Count Test

The plate count method is used for determining total number of bacterial colonies per ml sample. A measured amount of milk is placed on agar plates and the number of colonies are counted after incubation.

Picture 3.7. Counting bacterial colonies on agar plate

All above described test are determining the total number of bacteria. Many other tests can be done to determine the kind of bacteria. For example, counting the E.coli bacteria gives an indication of the fecal contamination of the milk.

III. RESIDUES

1. Introduction

Milk can contain residue of all kinds of chemical products, including veterinary drugs, pesticides, feed additives etc. Such kind of residues can be hazardous for the consumer. Therefore, all chemical products should be used according to the label and withholding time should be respected. The withholding time is the number of days that milk cannot be used for human consumption following treatment.

Many tests are available to detect all kinds of residues.

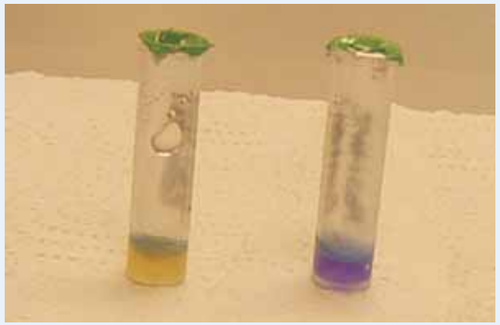
Remember: Antibiotics can transfer from one quarter to another through the extensive blood network throughout the udder. This is the reason why the milk of all quarters should be discarded.

2. Delvo Test

The Delvo test is a broad spectrum screening test which detects the complete range of antibiotic residues. This is a fast, simple and accurate test and is recognized worldwide as the international standard test.

Picture 3.8. Delvo tester

A small amount of milk is added to a solution containing a specific amount of microorganisms and needs 3 hours to interpret the results, sample that turns yellow is negative (no antibiotics), sample that turns purple is positive (antibiotic is present).



Picture 3.9. The results of Delvo test

Note: Copan test is similar to the Delvo Test

3. Yoghurt test

The yoghurt test is a rudimentary test where it is attempted to make yoghurt out of milk in order to test the presence of antibiotics.
Bacteria are indispensable for the making of yoghurt, since they ferment the milk sugar (lactose) into lactic acid. Antibiotics are well known for their destructive effect on bacteria. If antibiotic residues are present in the milk it will inhibit the bacterial growth and thus the production of lactic acid. As a result you can not make yoghurt out of milk that contains antibiotic residues.

Figure Somatic cell count & bacteria count:

	Somatic	Bacteria
Origin	From inside the udder (= cow cells)	Mainly from outside
Affect of storage	Do not increase during storage	Keep increasing in number during storage Increase more with higher temperature
Indicator of	Udder infection	Milking hygiene & storage
Acceptable number	≤ 150.000 cells/ml	≤ 100.000 cells/ml

SUMMARY OF CHAPTER 3

- Somatic cells in the milk are cow body cells, mainly white blood cells.
- An increased number of somatic cells in the milk indicate an infection of the udder.
- The somatic cell count from healthy animals is lower than 150.000 cells/ml.
- The number of somatic cells does not increase after the milk left the udder.
- A higher somatic cell count is linked with a higher milk production loss.
- Bacteria cells in the milk originate from the cow's skin, teat, farmer, environment and milking equipment, etc.
- An increased number of bacteria in the milk indicate dirty milking tools and poor milking hygiene.
- A total bacteria count up to 100.000 cells/ml is acceptable.
- The total number of bacteria keeps on increasing during storage. Theincrease will be higher when the storage temperature is higher.
- Residue of chemical products in the milk can be hazardous for the consumer.
- Withholding times for veterinary drugs should be respected at all times.
- Feed and minerals for dairy cows should never contain antibiotics.

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