Milk Testing and Payment Systems

Resource Book

a practical guide to assist milk producer groups

FAO
FIAT PANIS

Milk Testing and Payment Systems
Resource Book
a practical guide to assist milk producer groups

By
Jurjen Draaiyer
Brian Dugdill
Anthony Bennett
Jerome Mounsey

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) or of the World Health Organization (WHO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO or WHO in preference to others of a similar nature that are not mentioned.

Introducing the book

This "Milk Testing and Payment Systems Resource Book" is part of a series of practical field guides for people working in small-scale dairying in developing countries. These field guides are produced by the livestock group, of the Animal Production and Health Division of the Food and Agriculture Organization (FAO) of the United Nations.

The book provides information on simple and cost effective milk sampling, testing and payment systems to be used for small-scale milk collection in developing countries. It describes the development of sampling, testing and payment systems from simple to more sophisticated, according to needs, and includes all the steps to take in order to implement such systems.

The objective of the book is: (i) to assist in setting up a proper monitoring and payment system for quality raw milk in order to produce high quality products and (ii) to increase the income from milk for milk producers and small-scale entrepreneurs. At the same time, the book addresses the need to improve food safety during the vital first stages of the dairy food chain. A first introduction to this subject may be found in the "milk producer group resource book", published by FAO in 2002.

The book aims to play a role in rural livelihood enhancement in developing countries, in a gender sensitive and sustainable way, through helping milk producer groups gain competitive market access for supplying consumers with safe affordable milk and dairy products. The target audience is people working in small-scale milk collection in developing countries. This audience comprises milk producer groups, collection-centre staff, including laboratory technicians, extension workers and other people working in the sector such as development workers and project staff.

Please send your comments to Anthony.Bennett@fao.org at FAO.

Samuel Jutzi
Director, Animal Production and Health Division
FAO Rome

How to use this book?

This book is meant to be a resource book on milk testing and payment systems for milk producer groups and people working with these groups. It is a basket full of resources from which you can select the parts you feel are helpful to your group.

The methods and tools described in this book are basic guidelines. It is hoped that the book will support innovation in adapting the methods and tools described to your own situation. It is not necessary to read the book from the beginning to the end before you start. The intention is to provide a menu of suggestions - pick from the chapter summaries in Box 1 on the next page.

Although considerable efforts have been made to ensure that website links mentioned in this publication are current and up to date, it should be noted that websites are subject to change. Therefore, the FAO dairy webpage (http://www.fao.org/ag/againfo/themes/en/dairy/home.html) is recommended as a primary information source.

Please feel free to contribute anything that you think is useful when working with milk testing and payment systems!

BOX 1: A BRIEF EXPLANATION OF THE CHAPTERS

chapter one: read this first!
Here the background information for the book is given: the objectives, focus of the book and the target audience.

chapter two: milk sampling
Here general sampling procedures for raw milk are introduced; topics are equipment, procedures, preservation methods, storage and transport of samples and periodic, random and composite sampling.

chapter three: milk testing
Chapter three focuses on raw milk testing relevant to milk payment systems. The testing methods are divided into the following groups: quantity, organoleptic characteristics, compositional characteristics, physical and chemical characteristics, hygienic characteristics, adulteration and drug residues. The use of modern, rapid automatic milk analysers is also covered.

chapter four: milk payment systems
This chapter describes the different approaches to the development of milk payment systems. First, the necessary steps to introduce a payment system are described, followed by a description of the recording of payments and the development of payment systems.

chapter five: examples of payment systems
Chapter five describes examples of payment systems, starting with the simpler systems; a possible development into more sophisticated systems is also shown. Each example will have suggestions for practical ways to accept or not accept the milk received.

annex one: information sources and references
The information sources provides information on publications, websites and addresses for the specific subjects mentioned in this book.

annex two: weights and measures
The metric system is used in this book for measurements and in this annex you will find conversion factors for metric to imperial and vice versa.

annex three: milk composition
Guideline figures are provided for the composition of milk from different species.

annex four: glossary
Here you will find an explanation of the key words used in this book.

Thank you!

The first substantive draft of the resource book was produced by Jurjen Draaiyer, at FAO Headquarters in 2003 with contributions from FAO colleagues.

Anthony Bennett, Dairy and Meat Officer, FAO Animal Production and Health Division, Rome and Brian Dugdill, co-ordinated the field testing work in Bangladesh and Mongolia in 2006 and 2007, supported by:

- Esanul Bari (Bangladesh), National Project Co-ordinator, Grameen Bank/UNDP/FAO-BGD/98/009 Community Livestock and Dairy Development project and Managing Director, Grameen Fisheries and Livestock Foundation, Dhaka
- Frazer Moffat (UK), then Engineering Consultant, FAO-GCSP/MON/001/JPN Dairy Food Security project, Mongolia
- Nazim Ali Mondal (Bangladesh), Consultant, FAO-TCP/BGD/2903 Training Programme for the Small-scale Dairy Sector project and, former Deputy General Manger, Bangladesh Milk Producers'; Cooperatives Limited (Milk Vita), Dhaka
- Tsetsgee Se-Od (Mongolia), National Project Director, FAO-GCSP/MON/001/JPN Dairy Food Security project, Ulaanbaatar

Jerome Mounsey did the final editing and led the finalisation of the publication at FAO, Rome in 2009.

Recent developments

Since the resource book was originally commissioned there have been many developments in milk testing, most notably in low-cost, user-friendly, rapid automatic milk analysers (AMAs) and devices for speeding up the determination of the presence of antibiotics and inhibitors in milk. These analysers produce virtually instantaneous and simultaneous test results for: (i) temperature, (ii) density, (iii) fat, (iv) solids-not-fat and thus total solids, (v) protein, (vi) lactose, (vii) minerals (ash), (viii) freezing point, (ix) added water percentage and (x) pH.

The analysers are new and powerful tools for facilitating clean milk production and milk screening tests, especially when linked to low-cost, computerised digital milk weighing and payment systems. They are also powerful tools for improving and maintaining milk quality, e.g. with 12-volt adaptors they can travel with milk collectors and provide instant results, with instant printouts to show to producers.

These and other lessons learned during field validation through FAO dairy projects and other partners are incorporated into this book.

Contents

Chapter 1. Read this first

1.1. Why this book?

Milk is nature's most complete food - practically the only foodstuff that contains all the different substances known to be essential for human nutrition. However, it is quite a complex and perishable substance. Milk needs to be carefully checked and tested at each stage of the dairy food chain to ensure that consumers get milk that is safe and wholesome.

The objective of this milk testing and payment systems resource book is to provide information on simple and cost effective raw milk sampling, testing and payment systems. The information in the book can be used for small-scale milk collection and processing in developing countries, and specifically for small-scale milk producer groups or enterprises.

It is hoped that the information in the book will lead to the improvement of milk testing and payment systems, which contribute to: (i) an increase in the incomes of milk producers and small entrepreneurs; (ii) an increase in the volume and quality of locally produced milk and dairy products; and (iii) an improvement of the safety and hygiene of milk and dairy products in developing countries.

There can be several reasons for introducing a milk testing and payment system. The list below gives some of the reasons for introducing milk testing and payment systems:

- **Increasing the yield of dairy products:** The yield of milk products will depend on the amount of total solids present, e.g. the greater the amount of solids in milk the greater the yield of cheese and butter. For this reason, a payment system based on milk solids may be introduced.
- **Improving the safety and hygienic quality of the milk:** if this is one of the main objectives, a payment system based on hygienic quality may be introduced.
- **Avoiding adulteration:** if one of your aims is to discourage farmers from adding water or other substances to the milk, or from supplying milk with antibiotics, then your payment system should be designed accordingly.
- **Ensuring fair payments to each milk producer:** a fair and clear payment system that is understood by all members of the milk producer group will make sure fair payments are made.

The book is not intended to be a detailed laboratory manual. It therefore does not describe standard laboratory techniques like the use of pipettes, titration or making agar plates for microbiological testing. Similarly it does not cover HACCP (Hazard Analysis Critical Control Point) based systems. More

information on these may be found in annex 1: information sources and references. More information on where to source small-scale dairy equipment and supplies, including for milk testing and payments may be found in the FAO Directory of Small-scale Dairy Processing Equipment: http://www.fao.org/ag/againfo/themes/documents/LPS/DAIRY/SDE/Suppliers.htm

This book is a follow up to the "Milk Producer Group Resource Book" that was published by the FAO Animal Production Service in 2002.

1.2. Focus of the book

The focus for the milk sampling, testing and payment systems described in this resource book is on the following topics (see also definitions below):

- **Developing countries.**
- **Small-scale** milk collection and processing.
- **Raw milk** sampling and testing.
- **Simple and cost effective** sampling, testing and payment systems.
- **Interactions** between sampling, testing and payment.
- **Development of testing and payment systems** from simple to more sophisticated, according to needs, including the steps to take.

Target audience

The target audience for this resource book is people working in small-scale milk collection in developing countries. This audience comprises:

- Milk producers and milk producer groups.
- People working in milk collection and processing centres.
- Dairy laboratory technicians.
- Small-scale milk traders and processing entrepreneurs.
- Extension workers in the field of dairy development.
- Other people working in the sector, including development workers and project staff.

Definitions

For the purpose of this book, the following definitions will apply:

- **Small-Scale**: where milk collection and processing units are involved that collect or process less than 5,000 litres per day.
- **Developing Countries**: In this book, the list of the Development Assistance Committee (DAC) is used.

- **Raw milk**: milk is the normal mammary secretion of milking animals, including milk from cows, goats, sheep, yaks and yak-crosses, buffaloes, camels and mares that is not in any way processed, reconstituted, or recombined.
- For **other definitions**, see the glossary in annex 4.

Metric system

The metric system is used in this book for measurements. In the back of this book (annex 2), you can find conversion factors for metric to imperial and vice versa.

Chapter 2. Milk sampling

2.1. Introduction

If you want to know the details of all the milk collected, you would have to test all the milk from each producer every day, or even milk from each animal. This is impractical because of cost, time involved and inconvenience. In order to reduce cost and time, sampling procedures are designed.

In this chapter, general sampling procedures are introduced for raw milk. Through proper sampling, a representative sample is obtained that provides an accurate estimate for the total amount of milk. The chapter describes the equipment to be used, the procedures to be followed, preservation methods and storage and transport of samples. The chapter concludes with a description of periodic, random and composite sampling in order to reduce the costs of sampling and testing.

2.2. Sampling equipment

The basic kit needed is: (i) an agitator, (ii) a dipper, (iii) sample containers and (iv) a steriliser. It is important that the material of the equipment used does not affect the test results. Sampling equipment should preferably be made of stainless steel. Alternatively, other suitable material of adequate strength can be used, for example adequately galvanised iron. Solder should be capable of withstanding a sterilizing temperature of 180 °C. All surfaces should be smooth, free from cracks and all corners rounded.

Agitators
Agitators (also called plungers) for mixing milk need to be large enough to produce adequate mixing. In view of the different shapes and sizes of containers, no specific design of agitator can be recommended for all purposes, but the design should be such that damage of the inner surface of the container is avoided during mixing.

For mixing liquids in buckets or cans, an agitator of the design and dimensions shown in figure 1 is suitable. The length can be adjusted to the depth of the can. An agitator of the design and dimensions shown in figure 2 is suitable for use for larger vessels (e.g. road and farm tanks).

Figure 1: Agitator (plunger) for cans and buckets (in mm)

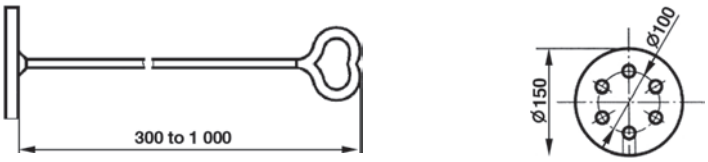
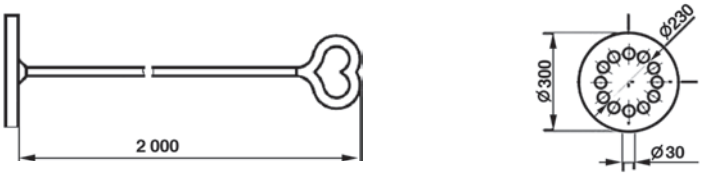


Figure 2: Agitator (plunger) for road, rail and farm tanks (in mm)



Dippers

A dipper of the shape and size shown in figure 3 is suitable for collecting samples. The capacity of the sample containers shall be such that they are almost completely filled by the sample taken by the dipper.

Sample containers

Sample containers should adequately protect the sample and not affect the test results. Appropriate materials include glass, some metals (e.g. stainless steel) and some plastics (e.g. polypropylene). The containers should preferably not be transparent, but if they are transparent they should be stored in a dark place. Containers and closures should be dry, clean and either sterile or suitable for sterilization by one of the methods described below.

The shape and capacity of the containers depend on the particular requirements of sampling, and could be e.g. 100, 150 or 250 ml. It is desirable to avoid air space by filling the bottles to the top, leaving however sufficient space to allow for expansion of the rubber stopper. Single-service plastic containers as well as aluminium foil of adequate strength (sterile and non-sterile) and suitable plastic bags, with appropriate methods of closure, may be used.

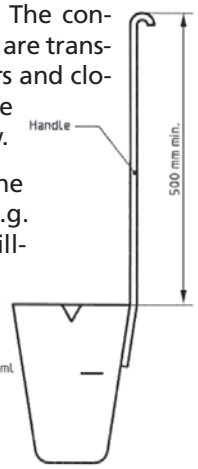


Figure 3: dipper for taking samples

Containers other than plastic bags should be securely closed either by a suitable stopper or by a screw cap of metal or plastic material. If stoppers are used, they should be made from non-absorbent, odourless material. Do not use cork stoppers or caps with cork seals on containers for microbiological examinations. Sample bottles, which are to be examined for flavour should be closed with greaseproof, non-absorbent stoppers to avoid change of odour or taste.

Sterilizing of sampling equipment
Sampling equipment has to be clean and sterilization is required for microbiological testing. Disposable plastic equipment also needs to be sterile. Sterilization can be performed by one of the two following methods:

A. Exposure to hot air at 170-75 °C for not less than 2 hours.

B. Exposure to steam at 121 ± 1 °C for not less than 20 minutes in an autoclave.

After sterilization by method A or method B, sampling equipment should be stored under sterile conditions. If, in a particular situation, sterilization by method A or method B is not possible, methods C, D or E below can be used. These methods are to be regarded as secondary methods only, and sampling equipment has to be used immediately after sterilization:

C. Exposure to a suitable flame working surfaces of the sampling equipment come into contact with the flame.

D. Immersion in at least 70% *(V/V)* ethanol solution.

E. Ignition with 96 % *(V/V)* ethanol. (**CAUTION:** 96 % ethanol is hygroscopic - its concentration may change over time).

After sterilization by method C, D or E, sampling equipment should be cooled under sterile conditions or, in the case of method D, be rinsed with the ethanol solution before sampling.

Rubber components of sampling equipment can be sterilized by immersion for at least 10 minutes in boiling water if they are used immediately. Rubber stoppers can be sterilized in an autoclave as in method B.

2.3. Sampling procedures

Sampling should be performed by an authorized, properly trained, person. That person shall be free from any infectious disease. Sampling for microbiological examination shall always be undertaken by an experienced person. Samples for microbiological examinations should be taken before other examinations, and using aseptic techniques and sterilized equipment and containers.

It is important to obtain representative samples of the product. The following procedure can be followed for sampling of raw milk:

1) Wash and dry hands, keep hands clean during sampling operation.

2) Mix milk thoroughly, by inverting, stirring or plunging the container for at least 5 minutes. If the volume is small, it can be poured to and from one product container to another of the same volume. Any

milk fat adhering to the neck and under the shoulder of the can shall be well mixed with the remainder of the milk. Milk churns (fat separates) easily at 26.5 to 29.5^{0}C and agitation near this temperature should be avoided.

3) Check milk temperature (see 3.5.4, page 24) and record it on the sample container label.
4) Take the sample as soon as possible after mixing. Make sure the size of the sample is sufficient for all necessary tests.
5) Seal each sample container airtight immediately after filling.
6) Label the samples with all the necessary information (see below).
7) Place sample in sample case and cool the sample when necessary.
8) Rinse equipment used for sampling after use.
9) Samples should be taken in duplicate.

Sample labels
Samples should have a label attached with the following information:

- identification of the product
- nature of the product
- identification number
- name / signature of the person responsible for taking the samples

Figure 4: Example of a label for a milk sample

Milk Producer .....
Reference No.....
Sample of (1).....
Taken by (2).....
.....
Time and temp. of sampling.....
Date of sampling.....

(1) Insert description of the sample of milk taken, e.g. whole milk, skimmed milk, etc., as the case may require.
(2) Insert name and description of the person by whom the sample was taken.

If necessary, additional information may be included, such as:

- purpose of sampling;
- mass or volume of the sample;

- unit from which the sample was taken;
- condition of the product;
- storage conditions at the moment of sampling;
- preservatives added.

2.4. Preservation of samples

Under some circumstances, it may not be possible to test the sample immediately and a preservative may be needed. Preservatives should normally not be added to samples intended for microbiological or sensory examination, only for chemical and physical analysis. Make sure you mix the milk and preservative well. Preservatives may be added to some dairy product samples, provided that:

- the preservative does not interfere with subsequent analyses;
- the nature and quantity of preservative are stated in the sampling report and, preferably, indicated on the label.

Preservatives should preferably be:

- easily dispersed in milk;
- adding colour to indicate presence;
- stable during storage;
- non-toxic;
- disposable without causing pollution, and
- low cost.

Some examples of preservatives are:

Sodium / Potassium Dichromate (e.g. 1 % strength)
Milk samples for fat testing may be preserved with Potassium dichromate. One tablet or 1 ml 10% solution in a 100 ml sample bottle is adequate. Dichromate has toxic properties and care should be taken while handling Potassium Dichromate.

Advantages: Low cost; colour to indicate presence of preservative; easily dispersed in milk.

Disadvantages: Toxic; fat tests deteriorate with time; pollutes.

Bronopol
Bronopol (2-bromo-2-nitro-1,3-propanediol) can be used at the rate of 0.02% to 0.06%. Bronopol has been a very satisfactory preservative in laboratories counting somatic cells by the microscope method.

Advantages: Low cost; easily dispersed in milk; low toxicity.

Disadvantages: Must be stored under dry conditions; does not prevent yeast growth in un-refrigerated samples.

Formaldehyde

Advantages: Low cost; easily dispersed in milk.

Disadvantages: Interferes with fat tests in electronic equipment; liquid state.

Hydrogen Peroxide

Advantages: Low cost; easily dispersed in milk; low toxicity.

Disadvantages: Low stability; no colour; short preservation time; liquid state.

2.5.Storage and transport of samples

The condition of the sample should not be affected during storage and transport. During storage and transport, precautions should be taken to prevent exposure to off-odours, direct sunlight and other adverse conditions. The storage temperature after sampling should be reached as quickly as possible and should be between 0 and 4 °C.

Samples should be transported to the testing laboratory immediately after sampling. Transport time should be as short as possible, preferably within 24 hours. It is desirable that samples of milk are delivered for testing on the same day they are taken for chemical examination.

Generally, the samples should be examined within 4 hours of collection. The result of analysis of any sample, if the temperature of sample has exceeded 7.0°C during a storage period of 4 hours, may be unreliable. At a storage temperature of 0 to 4 °C, no detectable increase in bacterial counts will normally occur within 24 hours.

2.6. Pre-treatment of samples

If samples of milk to be tested have been stored for some time, fat globules might rise to the surface, and after some time a thin layer of cream can be found on the top. The fat globules rise to the surface because of the lower density of the fat as compared to that of the rest of the milk.

In order to make a homogeneous sample, the sample should be heated in a water bath to 35 - 40 °C, while making sure no water can evaporate from the milk. Keep the lid or stopper on the sample container. Due to heating, the fat globules become liquid and it will then be easier now to make a homogeneous sample by agitation. After agitation, the milk should be

cooled to 20 °C, after which the tests are carried out. Testing should start as soon as possible after this pre-treatment.

2.7. Periodic, random and composite sampling

It is expensive and labour intensive to analyse all milk supplies on a daily basis for all parameters. In order to reduce costs and time, you can sample and test the milk periodically, at random or use composite samples. If you want, for example, to do a test for somatic cell count, you might want to test only periodically (e.g. every month) at irregular intervals and take samples randomly, e.g. only five milk producers at the time.

Periodic sampling

Sampling and testing for composition can be taken once a week or, more commonly, once every two weeks and tested immediately. Some sampling can be done periodically at irregular intervals.

Random sampling

Alternatively, milk can be sampled and tested on a random basis, for example without prior knowledge of the milk producers. When milk of uniform quality is supplied in bulk units (for example, cans filled from storage tanks), the number of random units to be sampled can be as follows:

Table 1: Number of random units to be sampled

Total Number of Units	Number of Units to be Selected
1	1
2-5	2
6-20	3
21-60	4
61-100	5
Over 100	5 plus one for each additional 100 units or fraction thereof

Composite samples

Composite samples are samples that are pooled together over a certain period. For example, you could sample some milk each day from one milk producer over one or two weeks, add a preservative and test the composite sample at the end of the period. All daily samples are pooled in one bottle (of at least 150 ml). A composite sample must consist of a minimum of 20 ml of milk, and each individual sample taken should be at least 10 ml. The composite samples should be stored under refrigeration (0 to 4 °C). Make sure you keep the sample bottle securely closed between samplings.

Depending on the preservative added, a composite sample should not be kept in storage for more than 15 days and must be tested within three days after the last addition.

Chapter 3. Milk testing

3.1. Introduction

The milk tests described in this chapter are for raw milk only, and the results of the tests described can be used for screening or can be included in payment systems. Other tests available for raw milk are not included, as they are not related to milk payment systems described in this book. Milk testing has to be carried out with as little delay as possible after milk collection. The testing methods are divided into the following groups:

- Quantity
- Organoleptic characteristics
- Compositional characteristics
- Physical and chemical characteristics
- Hygienic characteristics
- Adulteration
- Drug residues

Each test is described below; the purpose of each test is mentioned first, then the type of test as follows:

- **Tests for screening**: the test results are used to determine whether to accept the milk, e.g. at collection centre level, sometimes referred to as platform level.
- **Tests for payment system:** directly included in payment system.
- **Tests for grading:** included in a grading system.

ISO is the International Organization for Standardization. Together with the International Dairy Federation (IDF), ISO has been developing standards for the testing of milk. Full texts of the ISO standards can be purchased from ISO (see Annex 1. information sources and references).

Please note:
This book is not a laboratory manual. The procedures for the tests found in this book are thus only described in basic detail. The procedures for using laboratory equipment and reagents, as well as the ***safety precautions*** *to be taken are not described. Please refer to official laboratory and equipment manuals and reagent labels for these procedures.*

Please also note:
The composition and characteristics of milk vary between species, breeds, and regions. When designing a milk testing and payment system, always make sure you know the values of the milk within your region. Annex 3 gives some average data on milk composition and other characteristics.

3.2. Measuring quantity

Though not really a test, quantity is described in this chapter, as it is the first *check* of milk collected. Quantity can be measured in volume or weight.

Volume versus weight
As most payment systems are based on milk solid contents (see annex 3, page 71), it is more appropriate to measure the weight of milk (1 litre of milk on average weighs 1.031 kg). If you have no other way of determining the weight of the milk and you have determined the specific gravity (see 3.5.1 page 21), you can convert volume into kilos:

litres x specific gravity = kilos.

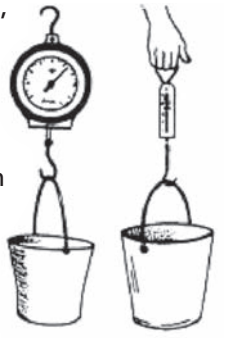
Container method (volume)
This method uses small containers made either to hold definite quantities of milk such as 1/2 litre, 1 litre or with internal graduations, from which the milk level in the container can be read.

Dipstick method (volume)
If you do not have other measuring instruments, you can use the dipstick method to measure the volume in e.g. a standard 40-litre milk can. The dipstick method uses a graduated stick that can only be used in containers of equal size (see below).

"To make a dipstick, put a stick or rod in the standard can and pour repeatedly exactly half a litre of water in the can, mark the dipstick at the water level with a knife or waterproof marker each time until the can is full. Write the numbers at each mark (e.g. 0.5, 1, 1.5 etc) and your dipstick is ready! Make sure you always use the same can each time you use your dipstick, because the same stick cannot be used for measuring the contents of other types of containers; also make sure it is kept clean!"

Spring balance or electronic scale method (weight)

A spring balance (see Figure 5:) measures the weight of the milk. Please note that this method can easily give wrong readings, and frequent adjustments even on the same day may be necessary. A standard weight has to be used to check and calibrate the reading regularly.



A better method to weigh the milk would be to use a good quality bench weighing scale, or a platform weighing scale (see Figure 6:). Either the balance or scales should be capable of an accuracy of 0.05 kg and may be the mechanical or the digital type.

Figure 5: Spring balance

Flow-meter method (for larger volumes)

In modern road tankers, the milk is measured by a flow meter, which is a volumetric measurement. A de-aerator is necessary to remove air from the milk; air that may have entered the milk during pumping will result in increased milk volumes.

Figure 6: Platform weighing scale

3.3. Organoleptic characteristics

3.3.1. Introduction

Testing milk for organoleptic characteristics is also called sensory testing and uses the normal senses of sight, smell and taste in order to determine the overall quality. The result of this test is obtained immediately and is of minimum cost. This type of testing can be very reliable if carried out by an experienced person. Testing for organoleptic characteristics is used as a screening test to determine whether to accept the milk or test the milk further.

3.3.2. Appearance

The colour of **cow** milk should be slightly yellowish white; a different colour may indicate milk, which is unsuitable for processing. In order to judge the appearance of the milk, remove the lid of the milk container and note the appearance of the surface of the milk **and** the lid, note any abnormal colour of the milk, visible dirt and particles, changes in viscosity etc. After emptying the container, inspect the inside of the lid and the container for visible dirt and impurities. Take note of the following appearances:

- **Visible dirt and impurities** can indicate that the milk is produced under unhygienic conditions.
- **Yellow** milk can indicate pus or colostrum.

- **Reddish** milk could indicate that there is blood in the milk.
- A **"blue thin"** colour and a thin and watery appearance can indicate that the milk contains added water or skimming (fat removal).
- **Large clots** can indicate sour milk or mastitis milk.
- **Small white clots** or grains can indicate either Mastitis milk or milk adulterated with flour and / or skim milk powder.

3.3.3. Taste and smell

A bad smell or taste of the milk may be caused by bacteria, chemical reactions or by other flavours absorbed by the milk. Judging the quality of milk by its taste and smell requires considerable skill, which can only be acquired by practice.

The taste of milk is more permanent and easy to define than smell. ***Taste raw milk only after making sure that it is from healthy animals***. Any abnormal smell is noticed by inhalation of air standing above the milk in the upper part of the milk can. Samples for tasting must be spread around in the mouth in order to identify the taste. In addition to these basic tastes, the mouth also allows us to distinguish characteristics such as coolness, warmth, sweetness, etc. The different abnormal flavours are described as follows:

1) **Acid flavours** are easily detected by smell and taste. The flavour is caused by the growth of acid-producing bacteria that reduce lactose to lactic acid.
2) **Rancid and bitter flavours:** a pure bitter flavour can be detected by taste only. The rancid flavour can be detected by both the senses of smell and taste and is caused by lipolysis (deterioration) of fat.
3) **Feed flavours** like garlic, onion, beets, poorly made silage, certain plants and pastures can cause off-flavours to milk.
4) **Flat flavours** are quite easy to detect. A very slight oxidized flavour suggests flat flavour as well as low solids and/or low-fat milk.
5) **Malty Flavours** are very suggestive of malt. The flavour is caused by the growth of the bacteria Streptococcus lactis var. maltigenes.
6) **Oxidized flavours** are sometimes described in such terms as "oily", "stale", "tallowy", "cardboard" or "sunshine". The oxidized flavour is characterized by a quick taste reaction.
7) **Salty flavours** are easy to detect; and often associated with milk from cows in an advanced stage of lactation or mastitis milk. It is caused by an increase in chlorine and decrease in lactose content.

8) **Unclean flavours** suggest mustiness, staleness and foul stable air.

9) **Other flavours** such as drugs, disinfectants and detergents can also be causes bad smell and flavour.

3.4. Compositional characteristics

3.4.1. Introduction

Compositional characteristics are the features of raw milk related to natural composition that have special importance for the value for further processing. They are therefore key characteristics of a milk payment system. Simple but time-consuming compositional tests have been developed over the years. These tests require substantial laboratories with relatively costly equipment, materials and staff. More recently user-friendly, low-cost and rapid automatic milk analysers have been developed and successfully introduced for small-scale as well as large-sale applications. These units require minimal space, no reagents or consumables and give virtually instant results. The traditional tests are covered first in the resource book. Rapid milk analysis is described in section 3.9, page 44.

3.4.2. Gerber test for fat

Use: test for grading or payment system.

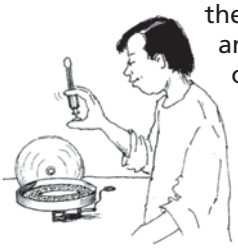
Advantages: relatively simple to use.

Disadvantages: equipment needed.

Alternatives: Babcock test, rapid automatic milk analyser (AMA) (3.9, page 44).

Introduction

The traditional standard reference method for fat analysis is based on either weight or volumetric determination. There are many analytical methods for the determination of the fat content of milk; the Gerber test is widely used all over the world.



Principle

The test is a volumetric method in which fat is separated from milk by centrifugal force. Sulphuric acid is used to dissolve the protein that forms the membrane around the fat (fat globules) and amyl alcohol is added to improve the separation of fat from other solids.

Equipment and materials

a) Sulphuric acid (density 1.807 - 1.812 g/ml at 27 °C, colourless).

b) Amyl alcohol.

c) Butyrometers (see Figure 7:): 6%, 8% and 10% scales depending on fat content.

d) Stoppers and shaker stands for butyrometers made from a suitable grade of rubber or plastics.

e) 10 ml pipette for sulphuric acid (with rubber suction device).

f) 10.75 ml pipette for milk.

g) 1 ml pipette for amyl alcohol.

h) Centrifuge, electric or hand driven.

i) Water bath at 65 $\pm$ 2 °C.

Procedure

1) Use the 10 ml pipette to transfer 10 ml of sulphuric acid into the butyrometer.

2) Fill the 10.75 ml pipette with milk and deliver the sample into butyrometer.

3) Add 1 ml of amyl alcohol using the 1 ml pipette and close. Shake the butyrometer in the shaker stand until no white particles are seen and invert it a few times.

4) Put the butyrometer in the water bath for 5 min.

5) Take it out and dry with a cloth, put it in the centrifuge, placing two butyrometers diametrically opposite, centrifuge at maximum speed for 4 minutes.

6) Transfer the butyrometers, stoppers downwards into water bath for 3-10 minutes.

7) Bring lower end of fat column on to a main graduation mark by slightly withdrawing stopper.

   - the colour of the fat should be straw yellow;
   - the ends of the fat column should be clear and sharply defined;
   - the fat column should be free from specks and sediment;
   - the water just below the fat column should be perfectly clear;
   - the fat should be within the graduation.

Interpretation

Note down the upper and lower scale readings corresponding to the lowest point of fat meniscus and surface of separation of fat and acid. The difference between the two readings gives the percentage by mass of fat in milk. The reading has to be done quickly before the milk cools. The butyrometers should be emptied into a special container for the very corrosive acid-milk liquid, and the butyrometers should be washed in warm water and dried before the next use. Fat testing is often carried out on composite or random samples in order to reduce time and costs involved in testing.

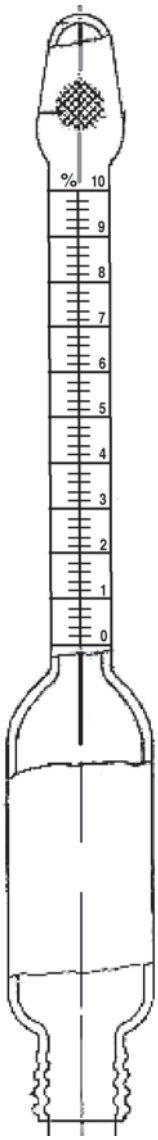


Figure 7: Butyrometer

3.4.3. Solids test

Use: test for payment.

Advantages: quick, cheap.

Alternatives: rapid AMA (3.9, page 44).

Introduction

The Totals Solids (TS) content in milk is the mass percentage of substances in the milk, comprising fat, protein, lactose, minerals and vitamins. The TS content of milk can either be measured by using an estimation from the lactometer reading, by drying the milk and weighing the solids or by using rapid AMAs. Solids-not-fat (SNF) in milk comprises protein, lactose, minerals and vitamins. Here only the calculation method is described.

Calculation of Solids based on density

Total Solids can be estimated from the corrected lactometer reading (see 3.5.1, page 21) and the fat content of the milk (see 3.4.2, page 17), using the following formula:

$$TS\ (\%) = 0.25\ (L) + 1.22\ \text{fat}\ \% + 0.72$$

(L = Lactometer reading in degrees)

Once you have the estimation for Total Solids, you can estimate SNF as follows:

$$SNF = TS - \text{fat}\ \%$$

Table 2 provides some examples of SNF calculations:

Table 2: Example of SNF calculations

Producer no.	fat %	density - degree	TS %	SNF %
1	4.2	1.036 = 36	14.84	10.64
2	3.5	1.032 = 32	12.99	9.49
3	2.8	1.028 = 28	11.14	8.34

3.4.4. Protein test

Use: test for payment, suitability for cheese making.

Advantages: relatively quick.

Disadvantages: not very accurate.

Alternatives: rapid AMAs (3.9, page 44).

Principle

When formaldehyde is added to milk, the free amino groups of the protein react with the carbonyl groups of formaldehyde causing the milk to become acidic. The acidity developed is related to the amount of protein present, which may be measured by titrating with sodium hydroxide (NaOH) using phenolphthalein as an indicator.

Equipment and Materials and equipment

a) White porcelain evaporating basin, 30 ml capacity.

b) Pipette, 10 ml capacity with 0.1 ml subdivisions.

c) A glass stirring rod.

d) Saturated aqueous potassium oxalate.

e) 0.5% phenolphthalein solution.

f) N/9 sodium hydroxide.

g) 40% formalin solution: made neutral by adding a few drops of phenolphthalein and then adding sodium hydroxide drop by drop until a faint pink colour is obtained.

Procedure

1) Place 10 ml of milk in a white porcelain basin.

2) Add 0.4 ml of saturated aqueous potassium oxalate and 0.5 ml of 0.5% phenolphthalein solution.

3) Allow to stand for 2 minutes and titrate with N/9 NaOH until a pink colour is obtained, note the reading.

4) Add 2 ml neutral 40% formalin, which will discharge the pink colour.

5) Continue the titration with N/9 NaOH until a pink colour of equal intensity is again obtained; note the new reading.

Interpretation

The number of ml of the N/9 NaOH used after the addition of the formalin multiplied by 1.74 gives the percentage protein in the milk, e.g. for cow milk: 1.9 ml x 1.74 = 3.31%. If the percentage casein in the milk is required, multiply the titration figure obtained in step 6 above by 1.38, e.g. 1.9 ml x 1.38 = 2.62%.

3.5. Physical and chemical characteristics

3.5.1. Lactometer test for water addition

Use: test for payment or screening; determine added water, level of solids or removal of fat.

Advantages: quick, cheap.

Disadvantages: can be inaccurate, influenced by temperature and fat.

Alternatives: freezing point test (3.5.2, page 22), rapid AMA (3.9, page 44).

Principle

With a lactometer (also called hydrometer, see Figure 8:), the specific density (also called gravity) of milk is measured. The specific gravity of the milk varies according to the proportions of fat, SNF and water. At 15 °C, the normal density of the milk ranges from 1.028 to 1.034 g/ml, whereas water has a density of 1.0 g/ml.

Equipment and materials

a) Thermometer (3.5.4, page 24).

b) Lactometer.

c) Cylinder of suitable rigid material with a minimum diameter of 35 mm and a minimum internal depth of 225 mm (e.g. 250 ml).

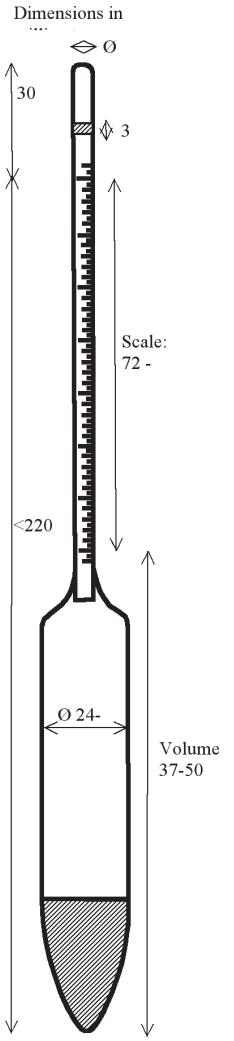


Figure 8: wide-range lactometer dimensions

Procedure

1) Sample the milk (see chapter 2) while taking care not to introduce air bubbles into the milk during sampling, as these would interfere with the readings.

2) Place the sample in the cylinder, measure the temperature and place the lactometer slowly into the milk until it is floating freely.

3) The lactometer should be read at the top of the liquid meniscus, i.e., where the meniscus appears to meet the stem. Record the reading together with the temperature.

Interpretation

Readings between 1.028 and 1.033 are considered normal and are sometimes recorded as degrees using the last two figures, i.e. 28 and 33. It is best to combine the lactometer reading with a fat test (see 3.4.2, page 17): if the results of the fat test are low and the density is high (e.g. 1.035), then the milk might have been skimmed. If the results of the fat test are low and the density is low (e.g. 1.027), then water might have been added to the milk. You can use the lactometer reading together with the fat content to estimate the SNF content of the milk (see 3.4.3, page 19). Make sure you adjust readings according to the temperature as indicated in table 3. Please take note that at high altitude milk boils at a lower temperature

Table 3: Temperature adjustments for lactometer readings

Temp (°C)	17	18	19	20	21	22	23	24
Correction:	-0.007	-0.005	-0.003	0.000	+0.003	+0.005	+0.008	+0.011

At other temperatures the correction is approximately + 0.0024 for each degree Celsius above 24 °C. The average density of milk from various species is given in Annex 3.

3.5.2. Freezing point test for water

Use: test for payment or screening; determine water content, confirmation of density test.

Advantages: more accurate than lactometer test.

Disadvantages: equipment needed.

Alternatives: lactometer test (see 3.5.1, page 21), rapid AMA (3.9, page 44).

Principle
Milk and water have different freezing points; therefore added water in milk can be detected by measuring the freezing point of the sample. Water has a freezing point of 0 °C, whereas 'normal' milk has a freezing point of around -0.540 °C, due to dissolved components (mainly lactose and salts). If milk has failed the lactometer test, a freezing point test can confirm the findings.

Materials and equipment
Cryoscope.

Procedure
The milk sample is measured using the Cryoscope together with a sample of pure water as per the suppliers operating instructions.

Interpretation
The difference between the two samples is called the Freezing Point Depression (FPD). At a measured freezing point of less than -0.530 °C, there is an indication that water has been added to the milk. There may be considerable variation in freezing points due to variations between animals. In practice, the freezing-point depression of quantities of 900 litres or more is unlikely to be less than -0.540 °C while milk from a single animal is unlikely to have a freezing- point depression of less than -0.530 °C.

The addition of sugar, salt or milk powder to mask addition of water will not be detected by the freezing point test. The development of acidity in a sample of milk causes an increase in the freezing-point depression, which might mask, partially or completely, the contrary effect of added water. A statement of the titratable acidity of the sample, should therefore accompany the freezing-point test at the time of testing (see 3.5.8, page 28).

3.5.3. Sediment test

Use: screening or grading test to judge cleanliness of milk.

Advantages: cheap.

Disadvantages: does not indicate bacteriological quality, uses a lot of milk.

Alternatives: organoleptic tests (see 3.3, page 15).

Principle
The amount of dirt in milk may be an indicator of the hygienic conditions during milk production and handling. By filtering milk through a white disc, these dirt particles become visible. The presence of sediment however, does not necessarily indicate the bacteriological quality of the milk.

Materials and equipment

a) Sediment tester with filtering surface 2.5 cm in diameter.

b) White Lintine Cotton Discs-32 mm in diameter, exposed filtration area 28 mm in diameter.

c) Two Sieves, one coarse corresponding to 850 micron IS Sieve and the other fine corresponding to 425-micron IS Sieve.

d) Sediment Disc Rating showing 0.0, 0.5, 1.0, 2.0, 3.0 mg sediment or higher concentration as required (under rural conditions e.g. 0.0, 0.2, 2.0, 5.0 and 7.0 mg), per 500 ml of milk.

Procedure

1) Filter a measured sample of milk (usually 250 ml) through a lintine cotton disc (rough side facing upwards) held in the sediment tester so that a filtration area of 28 mm (diameter) is exposed.

2) Compare the sediment disc with the sediment standard discs and record the sediment score.

3) Discs can be preserved by pouring on a few drops of 5% percent formaldehyde solution, then dried for showing to milk producers.

Interpretation

For the purpose of comparison, it is convenient to use about five prepared standard discs to classify the milk. Milk can be then classified according to the five discs grades: Excellent, Good, Fair, Poor and very Bad. Any hair, files, pieces of hay or straw, or any large particles of dirt shall be reported separately. Be aware that the lack of sediment is not always indicative of ideal conditions, because the milk might have been strained at the farm.

3.5.4. Temperature test

Use: test for screening or grading system.

Advantages: simple, cheap.

Alternative: rapid AMA (3.9, page 44).

Principle and procedure

Most bacteria prefer to grow in the temperature region of 20 °C to 45 °C. It is therefore important to cool the milk as quickly as possible after milking. Usually refrigerated milk is kept at a temperature of 4 °C. Bulk raw milk, when received from a chilling station in the factory should have a temperature below 7 - 8 °C. The temperature of milk can be determined with a dairy thermometer; it is important to mix the milk well.

Materials and equipment
A dairy thermometer with preferably the following characteristics:

a) Overall length 255 ± 10 mm.

b) Scale length 100 ± 5 mm.

c) Distance from lowest graduation line to bulb bottom - 110 ± 5 mm.

d) Scale range + 10 to + 45 °C.

e) Graduation interval 0.5 °C.

f) Maximum scale error ± 0.25 °C.

g) Filled with red alcohol.

Procedure

1) Mix milk well and hold the thermometer at least 30 seconds in milk

2) Record the temperature to the nearest 0.5 °C.

3.5.5. pH test

Use: test for screening.

Advantages: simple, cheap.

Disadvantages: regular calibration.

Alternative: rapid AMA tests (3.9, page 44).

Principle and procedure using indicator paper strips
A rough estimate of pH may be obtained using paper strips impregnated with an indicator. Paper strips treated with bromocresol purple and bromothymol blue can be used as screening tests for milk. Bromocresol purple indicator strips change from yellow to purple between pH 5.2 and 6.0, while bromothymol blue indicator papers change from straw yellow to blue-green between pH 6.0 and 6.9.

Principle and procedure using pH meter
A pH meter depends on the potential difference between two electrodes when they are in contact with a test sample. One electrode called a reference electrode (a glass electrode) independent of the pH of the milk is connected to an electrode whose potential is proportional to the pH of the milk (a calomel electrode). The pH of the milk depends on the hydrogen ion concentration in the milk. A pH meter measures the current produced by the difference in potential between the two electrodes.

First, the pH meter has to be prepared:

1) The pH meter should be kept in a dry atmosphere.

2) Before using a new glass electrode, or a glass electrode that has been stored for some time, soak the electrode in N/10 Hydrochloric acid for about 5 hours.

3) Care should be taken not to scratch glass electrodes against the sides of beakers or other hard surfaces during storage or testing.

4) The level of saturated potassium chloride in the calomel electrode should be checked before making pH measurements.

5) Crystals of potassium chloride should be present in the solution within the electrode.

6) The rubber stopper or cap on the filling arm of the calomel electrode should be removed before use.

Then the pH meter should be standardised:

1) Rinse the electrodes with distilled water and wipe them gently with tissue or filter paper.

2) Use the control knob of the meter to set the temperature of the buffer used to standardise the meter.

3) Standardise the pH meter against a buffer solution of known pH. Use a buffer solution with a pH as close as possible to that of the test solution.

4) Turn the range selector to the pH range covering the pH of the buffer control until the pointer of the meter reads the pH of the buffer.

5) Set the range switch to zero.

6) Before measuring the pH of the test sample, rinse the electrodes with distilled water and dry them.

7) Set the temperature control knob to the temperature of the sample.

8) Place the test sample in position and allow the electrodes to dip into the solution.

9) Switch the range selector knob to the proper range and read the pH.

10) Rinse the electrodes after use and keep the electrode tips in distilled water between tests.

Interpretation

Always follow the manufacturer's instruction for the particular instrument for interpreting the pH reading. Normal cow's milk has a pH of 6.5 to 6.8.

3.5.6. Clot on boiling test

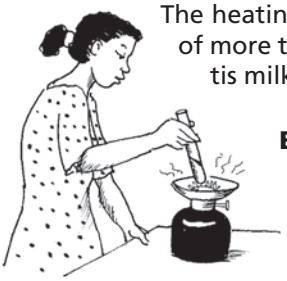
Use: test for screening, rapid testing of increased acidity.

Advantages: simple, quick, cheap, definitive result (milk either coagulates or not).

Disadvantages: slightly sour milk is not detected

Alternatives: alcohol test (see 3.5.7, page 27), acidity test (see 3.5.8, page 28), other hygiene tests (see 3.6, page 30)

Principle



The heating of milk in an advanced state of souring (acidity of more than 0.20%) or abnormal milk (colostrum or mastitis milk) will result in clotting.

Equipment and materials

a) Test tubes (15.0 x 1.0 cm, preferably with a mark at 5 ml).

b) Source of heating, e.g. a boiling water bath or a flame.

Procedure:

1) Put test tubes with about 5 ml of milk in heating source for up to 4 minutes.

2) Rotate the tubes in an almost horizontal position and examine the film of milk or side of the test-tube for any precipitated particles.

Interpretation

The acidity of milk that gives a positive test is generally above 0.22% (as lactic acid) or has an abnormally high percentage of protein like colostrum milk. Such milk cannot stand the heat treatment in processing and is therefore not suitable for distributing as liquid milk or for processing. Such milk must therefore be rejected. Please take note that at high altitude milk boils at a lower temperature. This test is not very sensitive to slightly sour milk.

3.5.7. Alcohol test

Use: test for screening, rapid assessment of acidity.

Advantages: quick, cheap.

Alternatives: Clot on boiling test (see 3.5.6, page 27), Acidity test (see 3.5.8, page 28).

Principle
Proteins in milk that has become sour (i.e. because of lactic acid formation) will coagulate when mixed with alcohol.

Equipment and materials
a) Test tube.

b) Pipette.

c) 68% ethanol solution (by weight: e.g. mix 68 ml 96% alcohol with 28 ml distilled water) or 75 % ethyl alcohol by volume (density 0.8675 g/ml at 27 °C).

Procedure
1) Mix equal amounts (e.g. 2 ml) of milk and ethanol solution in test tube with the pipette.

2) Agitate by gentle movement and look for coagulation.

Interpretation
Milk containing more than 0.21% acid and milk that is abnormal (e.g. colostrum or mastitis milk) will not pass the test. This milk is not fit for further processing.

3.5.8. Titratable acidity test

Use: test for screening, determine suitability for processing.

Advantages: more precise than alcohol and clot on boiling tests.

Disadvantages: variation exists between cattle breeds.

Alternatives: Clot on boiling test (see 3.5.6, page 27), Alcohol test (see 3.5.7, page 27).

Principle
A dye, which changes colour at a specific pH, is added to the milk, and titrated with a base (added little by little) until the colour changes. By recording the volume of base required and the volume of the milk sample, the amount of lactic acid can be calculated. In this book, we express lactic acid as a percentage but it can also be expressed in other ways according to the test, e.g. Soxhlet Henkel degrees, Thorner degrees or Dornic degrees.

Equipment and materials
a) Two white porcelain dishes (hemispherical, 60 ml capacity).

b) 10 ml pipette reading 1-10 ml and 1 ml pipette.

c) Measuring cylinder (25 ml).

d) Burette (0.1 ml graduations, with soda-lime guard-tubes).

e) Glass rod for stirring (flattened at one end).

f) Phenolphthalein indicator solution (0.5% in 50% alcohol): Dissolve one gram of phenolphthalein in 100 ml of 95 percent ethyl alcohol. Add 0.1 N sodium hydroxide solution until one drop gives a faint pink colouration. Dilute the distilled water to 200 ml.

g) 0.1 N sodium hydroxide solution: (i) prepare a concentrated stock solution of sodium hydroxide by dissolving equal parts of sodium hydroxide (sticks or pellets) in equal parts of water in a flask; (ii) close the flask with a rubber stopper and allow any insoluble sodium carbonate to settle out for 3 to 4 days; (iii) use the clear supernatant liquid for preparing the standard 0.1 N Solution. About 8 ml of stock solution is required per litre of distilled water.

Procedure

1) Measure accurately 10 to 20 ml of milk in two porcelain basins.
2) Add an equal volume of boiled, cooled water.
3) Add 1.0 ml of the phenolphthalein indicator solution. Rapidly titrate the contents of basin 1 against the standard sodium hydroxide solution stirring the contents with a glass rod until the first definite change to a pink colour, which remains for 10-15 seconds.

4) Complete the titration within 20 seconds.
5) Basin 2 will serve as a control for comparing change of colour of milk from opaque white to faint pink.

Interpretation

The more sodium hydroxide added, the more acid the milk. You can calculate the titratable acidity (as lactic acid per 100 ml of milk) as follows:

$$lactic\text{ - }acid(\%) = \frac{9.V_1.N}{V_2}$$

V_1 = volume in ml of the standard sodium hydroxide required for titration;
N = normality of the standard sodium hydroxide solution, and
V_2 = volume in ml of milk taken for the test

Normal milk acidity ranges from 0.10 to 0.20% lactic acid. Any value in excess of 0.20 % can safely be reckoned as developed lactic acid. Due to the opacity of milk, the end-point of titration is not sharp, so care has to be taken to adjust the conditions to reach the same end-point.

3.6. Hygienic characteristics

3.6.1. Introduction

The hygienic characteristics of raw milk are related to its hygienic condition, cleanliness and quality, specifically referring to bacteria and somatic cells. The results of the tests described below can be used in a payment system either as a screening test or in a bonus / penalty system or grading system.

3.6.2. Resazurin test

Use: test for screening or payment system, indicator for hygienic quality.

Advantages: simple, quick, cheap.

Disadvantages: some equipment needed.

Alternatives: Methylene Blue reduction test (see 3.6.3, page 31), Total bacterial count (see 3.6.4, page 33).

Principle

When bacteria grow in milk they use up the oxygen present. Certain chemical dyes such as Resazurin change colour according to the amount of oxygen present. These two facts are used in dye-reduction tests. Under standard conditions, the time taken to change or reduce the colour of the dye provides a good indication of the bacteriological quality of milk. The Resazurin test is thus an indicator of the hygienic quality of milk. Resazurin first colours the milk blue, then changes to pink and finally to white during the reduction process. The change in colour depends on the number of bacteria present in the milk and their colour reducing properties, as well as the number of leucocytes. The Resazurin test can be carried out as a 10-minute, 1-hour or 3-hour test. The 10-minute Resazurin test is a rapid screening test used at the milk platform. The 1-hour test and 3-hour test are more accurate, but in this book, only the 10-minute test is described.

Equipment and materials

a) Water bath at 37-38 °C.

b) Sterile test tubes (150 x 16 mm, internal diameter 13.5 mm, accurately marked at 10 ml).

c) Straight-sided, blow-out delivery 1 ml pipettes.

d) Sterile 10-ml pipettes - straight-sided, blow-out type.

e) Sterile rubber stoppers for closing tubes.

f) A Lovibond comparator with a Resazurin disc.

g) A standard solution of Resazurin (0.005%) - prepared by dissolving one standard Resazurin tablet in 50 ml. distilled water. The solution should be stored in a tightly stoppered dark-coloured bottle in a refrigerator and, preferably, prepared fresh after every 8 hours.

h) Clock or watch.

Procedure

1) Fill two test tubes with 10 ml milk.
2) Pipette 1 ml of Resazurin solution to the first tube and stopper.
3) Mix by inverting the tube twice in 4 seconds.
4) Place the tube in the water bath and record the time.
5) Take the tube out after 10 minutes and immediately transfer to the Lovibond comparator.
6) Place the second tube (without Resazurin) in the comparator disc, then revolve the disc until the colour which indicates the quality of the milk is matched by one of the standards.

Interpretation

Note the number of the colour, when the colour falls between two disc numbers, it shall be recorded as the half value, for example, a reading between 3 and 4 shall be recorded as 3.5. Tubes giving a reading between 0 and 1 - streaky pink or very pale pinks - are recorded as 0.5. Table 4 gives an indication of the colour numbers linked to a hygienic grade of milk, which can be used in a payment system.

Table 4: Reading and results (10 minute Resazurin test)

Disc No.	Colour	Grade of milk
6	Blue	Excellent
5	Light blue	very good
4	Purple	Good
3	Purple pink	Fair
2	Light pink	Poor
1	Pink	Bad
0	White	Very bad

3.6.3. Methylene Blue test

Use: test for screening and payment system, indicator for hygienic quality/ bacterial content.

Advantages: relatively simple and cheap.

Disadvantages: some equipment needed, longer than Resazurin test.

Alternatives: Resazurin test (see 3.6.2, page 30), total bacterial count (see 3.6.4, page 33).

Principle

As for the Resazurin test, the activity of reducing bacteria determines the time it takes to decolourize Methylene Blue from blue to white.

Equipment and materials

a) Thermometer 0-100 °C, at 0.5 °C intervals.

b) Water bath at 37-38 °C.

c) Supply of 1 ml pipettes (bacteriological grade).

d) Test tubes graduated at 10 ml; rubber stoppers for closing tubes.

e) Methylene Blue solution: dissolve a standard tablet in 200 ml distilled water in a sterile flask. Allow the mixture to stand several hours to ensure complete solution, at no time expose to light.

Procedure

1) Fill test tube with 10 ml of sampled raw milk.

2) Add 1 ml of the Methylene Blue solution from a pipette taking care that the pipette does not come into contact with any of the milk in the tube or with the wetted side of the interior of the tube.

3) Close the tube with a sterile rubber stopper. On no account, allow the fingers to be exposed to the mouth of the test-tube or with the part of the stopper, which is exposed to the test tube.

4) Slowly invert each tube twice for mixing so that the whole column of contained air rises above the level of the milk.

5) Within 5 minutes place tube in water bath and note the time.

6) Prepare the following control tubes:

   (A) 10 ml of mixed milk +1 ml of tap water, and

   (B) 10 ml of mixed milk +1 ml of Methylene Blue solution.

7) Use mixed milk from several producers for the milk controls to obtain an average fat content and colour. Fit both control tubes with stoppers and immerse for 3 minutes in boiling water to destroy the natural reducing system present in the milk; place in the bath.

8) Examine samples after 30 minutes and remove completely decolourized samples or decolourized samples up to 5 mm of the surface. Comparison of the experimental tubes with control tube (B) will show when decolourization begins and comparison with control tube (A) will show when it is complete.

9) Record the time at which decolourization is observed.

10) Repeat this at half-hourly intervals.

Interpretation
Interpret the results according to the table below.

Table 5: Interpretation of MBR test results

Time take to decolourize	milk grade
<30 minutes	very bad
30 minutes to 1 hour	bad
1 to 2 hours	fair
2 to 4 ½ hours	good
> 4 ½ hours	excellent

3.6.4. Total Bacterial Count test

Use: test for screening or grading; determine total number of bacterial colonies.

Advantages: guide to general good hygiene.

Disadvantages: delay in reading/interpretation of results (3 days), needs expensive equipment and skilled staff, test needs to be carried out immediately after sampling.

Alternatives: Methylene Blue test (see 3.6.3, page 31), Resazurin test (see 3.6.2, page 30).

Principle
The Total Bacterial Count (TBC) is also referred to as the Standard Plate Count, Total Viable Count or Colony Count. This method involves growing bacteria into colonies on an agar gel, which contains nutrients to support microbial growth. Milk is diluted and added to the agar in a sterile container, the Petri dish is then incubated at 37-38 °C for two days. The colonies are counted after the three days.

Equipment and materials

a) Thermometer 0-100 °C, at 0.5 °C intervals.

b) Refrigerator for storage.

c) Pipettes (1.1 ml for delivering 0.1 ml / 1.0 ml without recharging).

d) Dilution Bottles - of borosilicate, resistant glass with glass stopper, size about 170 ml, marked for 1: 100 dilution.

e) Flat bottom Petri Dishes - of about 10 cm diameter, depth 15 mm.

f) Incubator - electrically heated, thermostatically controlled, provided with shelves so spaced as to assure uniformity of temperature.

g) pH meter.

h) Colony counter - with guide plate, ruled in centimetre squares.

i) Diluent - phosphate buffer or quarter strength Ringer's solution for dilutions may be used:

- Prepare stock phosphate buffer solution by dissolving 34 g of potassium dihydrogen phosphate in 500 ml of distilled water. Adjust to pH 7.2 with 1 N sodium hydroxide solution and make up to 1 litre distilled water.
- Prepare stock Ringer's solution by dissolving in 1,000 ml distilled water 9.0 g sodium chloride, 0.42g potassium chloride 0.42 g, 0.24 g anhydrous calcium chloride and 0.2g sodium bicarbonate 0.2 g. For use as diluent, take 250 ml of the stock solution and make up to 1000 ml with distilled water.

j) Use a plating medium of the following composition: 5.0 g Tryptone, 2.5g Yeast extract, 1.0 g Glucose (dextrose), 6.5 g Sodium Chloride, 15.0 g Agar, 1000 ml distilled water, final pH: 7.0 ± 0.1.

Procedure

1) Prepare dilution blanks: fill dilution bottles with phosphate buffer or Ringer's solution so that after sterilization each will contain 99 ml, or other desired amounts. After sterilization and before use, observe the amount in each blank and discard those with variations of 2%.

2) Select dilutions: Normally for routine control, prepare not less than two plates per sample selecting dilutions so that total colonies on at least one plate will be between 30 and 300. To prevent possible errors in computations, avoid the use of odd dilutions, where standard bacteria counts per millilitre are normally fewer than 10,000; prepare plates from 1: 10 and 1: 100 dilutions.

3) Identify plates: before making dilutions, arrange the plates in order and identify each one with the sample number and with the dilution to be used therein. Also record date and plating time for each set of samples.

4) Measure and deposit test portions using a sterile pipette in each series of plates, pour the medium promptly, and mix using smooth circular movements.

5) Place plates in incubator: arrange plates so that each plate is separated horizontally from adjacent ones and from the top and walls of the chamber by at least 2.5 mm. Incubate plates at 37.0 ± 0.5 °C for 48 hours.

Interpretation
Count the colonies, with the aid of magnification under uniform and properly controlled, artificial illumination. Use the colony counter, equipped with a guide plate, ruled in centimetre squares. Record the total numbers of colonies, avoid mistaking particles of un-dissolved medium or precipitated matter in plates for pinpoint colonies. To distinguish colonies from dirt, specks and other foreign matter, examine doubtful objects carefully.

After counting the colonies, calculate the plate count per millilitre / gram: the numerical estimate of colonies per plate is multiplied by the proper dilution factor and the result recorded as 'Plate Count' per millilitre (PC/ml)' or 'Plate Count per gram (PC/g)'.

3.6.5. Direct Microscope Bacteria Count test

Use: determine amount of single bacteria, quick screening of milk, and grading milk on basis of clump counts.

Advantages: quick (10 - 15 minutes).

Disadvantages: laboratory equipment and highly skilled staff needed.

Alternatives: total Bacterial count test (see 3.6.4, page 33), Methylene blue reduction test (see 3.6.3, page 31).

Principle
A microscope is calibrated so that the exact area of the microscopic field is known; a milk sample is spread, allowed to dry and stained with a suitable dye. The average number of bacteria per microscopic field is determined after examining between 5 and 60 fields.

Equipment and materials

a) Clean and dry microscope slides of clear glass - (optional sizes 2.5 x 7.5 cm, 5.0 x 7.5 cm or 5.0 x 11.25 cm).

b) Special glass or cardboard guide plates, convenient size 5.0 x 11.25 cm. with 16 or 24 round or square areas, each one square cm.

c) Pipette or syringe for transfer of 0.01 ml of milk.

d) Needle, bent-point - suitable for spreading milk over 1 cm^2.

e) Drying device - level surface at 40 °C.

f) Forceps or slide holders - suitable for dipping and holding slides.

g) Trays or jars - equipped with tight-fitting covers.

h) Slide storage boxes, cases or files.

i) Compound microscope - binocular (preferably) or monocular with 1.8 mm oil-immersion objective, sub-stage and condenser, mechanical stage, and oculars for different magnifications.

j) Stage micrometer - slide ruled in 0.1 and 0.01 mm.

k) Xylene - or any other fat solvent may also be used.

l) Ethyl alcohol - 95 percent.

m) Immersion oil - of refractive index 1.51 to 1.52 at 20 °C.

n) Alcoholic methylene blue chloride solution - add 0.6 g methylene blue chloride to 100 ml of 95% ethyl alcohol. The mixture is shaken for some time, left at room temperature for 24 to 48 hours, shaking at intervals until the dye is completely dissolved, stored in clean, tightly closed container.

Procedure

1) Determination of Microscopic Factor (MF): focus on the scale of the stage micrometer with the 16-mm objective. Place a drop of immersion oil on the micrometer scale and focus with the 1.8 mm objective. Move the stage micrometer until one end of the scale is at the edge of the field. Count the number of small spaces (0.01 mm each) in the diameter of the field and determine the diameter of the field. The MF is given by the formula (*r* is the radius of the microscopic field):

$$MF = (10{,}000) / (3.1416) \times r^2$$

2) Use pipette to put 0.01 ml milk on the slide; make sure the all the milk is on the slide. Use the needle to spread the milk uniformly over the entire 1 cm^2. Dry films at 40 to 45 °C in about 5 minutes.

3) Submerge the slides in xylene for 1 - 2 minutes. Drain and air-dry the films. Fix the film in 90 - 95% ethyl alcohol for 1 minute by submerging the slide in alcohol kept either in a jar or by gently pouring the alcohol over the film. Allow the slide to drain and air-dry completely. Dip the slides edgewise in alcoholic methylene blue staining solution (in a jar) for 1 - 2 minutes. Slowly remove slides, allowing a few seconds for stain to drain into staining jar. Wash in fresh tap water in a beaker by raising and lowering the slide on its side a number of times to remove excess stain without impairing milk films. Allow stained slides to drain and air-dry gradually.

4) Place one drop of immersion oil on film and examine under objective. Count any isolated single cell, pair of cells or clump of cells on a number of microscopic fields. The fields counted shall be selected at random and represent all parts of the film. The number of field to be count is determined by the density of bacterial clumps: if the average number of clumps per field is under 0.5, 0.5 to 1, 1 to 10 and 10 to 30, the number of fields to be counted will be 50, 25, 10 and 5 respectively. If the number of clumps per field is over 30, then the counter is recorded as uncountable. In such cases, if the actual count is required, the milk sample will have to be diluted suitably and then the microscopic count determined.

Interpretation

Calculate the average number of the clumps per field and multiply by the microscopic factor (MF) to give the Direct Microscopic Clump Count per millilitre. Estimates of bacterial counts by this method may be expected to be relatively more accurate in the case of poor quality milks having high bacterial counts. In the case of low count samples, examination of a large number of fields is necessary to obtain some accuracy in the estimates.

3.6.6. Somatic Cell Count

Use: test for screening or grading, determine number of somatic cells.

Advantages: quick (10 - 15 minutes).

Disadvantages: laboratory equipment and highly skilled staff needed.

Alternatives: California Mastitis Test and other mastitis tests can be used as a screening test.

Principle

Somatic cells (leucocytes, lymphocytes and epithelium cells) are determined by spreading a sample over a slide to form a film, drying and staining of the film and subsequent counting of the stained cells using a microscope. Multiplication of the number of cells counted in a defined area by a working factor gives the number of cells per millilitre.

Materials and equipment

a) 65 ± 5 °C water bath and 35 ± 5 °C water bath.

b) Filter, resistant to the solvents used, pore size 10 - 12 *µm* or less.

c) Microscope (x 500 - x 1,000).

d) Micro-syringe, of capacity 0.01 ml, maximum tolerance 2 %.

e) Clean and dry slides, marked with outline of a shape of a film of dimensions 20 x 5 mm.

f) Hot plate, capable of being maintained at a temperature of 40 ± 10 °C.

g) Fan, hairdryer type.

h) Dye solution (use gloves!): mix 54.0 ml ethanol (95% V/V) and 40.0 ml tetrachloroethane (poisonous!) in a bottle. Heat in the water bath set at 65 °C. Add 0.6 g Methylene blue and mix carefully. Cool in a refrigerator to 4 °C and then add 6.0 ml glacial acetic acid. Pass the solution through an appropriate filter into an airtight bottle.

Procedure

1) Heat the sample in a water bath (35 °C), mix carefully and cool to the temperature at which the micro-syringe has been calibrated, for

example to 20 °C. Use micro-syringe to take 0.01 ml of the sample and place on a clean slide, fill area as evenly as possible. Dry film on a level plate until completely dry. Dip dried film on the slide in the dye solution for 10 minutes. Complete drying with the fan if required. Then dip the film in tap water until all surplus dye is washed away. Dry again and store with protection against dust.

2) Use microscope to count the cell nuclei in the film (at least 400). These are clearly recognizable and at least half should be visible in the microscope field. Count nuclei in vertical strips in the middle third of the film. Avoid counting strips selected exclusively from the peripheral areas of the film.

Interpretation
The length of the strips to be counted is 5 mm each. The width of a strip corresponds to the diameter of the microscope field. With a test portion of 0.01 ml of sample, calculate the Working Factor (*Wf)* using the following calculation:

$$Wf = \frac{20x100}{dxb}$$

d is the numerical value of the diameter, in millimetres, of the microscope field

b is the number of strips counted completely.

The number of somatic cells is multiplied by the Working Factor (*Wf)* to give the number of cells per millilitre of sample. If an udder is diseased (Mastitis), the number of cells (leucocytes and lymphocytes) will increase. The age of the cow and the stage of lactation, also influence the number of cells. In the case of diseased cows, blood clots may be found in the milk.

Mastitis, inflammation of the udder, is contagious and affects milk yields. Mastitis milk clots less easily with rennet, which can affect cheese production.

3.7. Adulteration

3.7.1. Introduction
The most common methods of adulteration of milk are:

- Addition of water
- Addition of preservatives
- Addition of added solids
- Removal of fat by skimming
- Addition of separated milk or skim milk to whole milk.
- Addition of added fats

3.7.2. Detection of added water

The presence of added water in milk is detected by the following:

- Lower density of milk at 27 °C (see 3.5.1, page 21)
- Lower percentage of fat (see 3.4.2, page 17)
- Lower percentage of solids not fat (see 3.4.3, page 19)
- Depression of freezing point (see 3.5.2, page 22 and below)
- Results from rapid AMA tests (see 3.9, page 44)

Freezing point

Water is present if the freezing point of the milk is minus 0.512 °C or closer to 0 °C. If you were reading a scale, it would look like the following table:

Table 6: Freezing point and water added

0 degrees Celsius	=	100% added water
-0.257	=	50% added water
-0.387	=	25% added water
-0.491	=	5% added water
-0.502	=	3% added water
-0.507	=	2% added water
-0.512	=	1% added water
-0.517	=	0% added water
-0.520	=	No added water
-0.525	=	No added water

Some AMAs also calculate the percentage of added water as well as the freezing point (3.9, page 44).

3.7.3. Detection of preservatives

If milk containing preservatives is accepted, processed milk or dairy products when offered for sale may be a hazard to health. It may also be impossible to process the milk into fermented products such as yoghurt and cheese. The most common preservatives found in milk are listed below, together with a short description of a detection test.

Detection of Hydrogen Peroxide

1) Put about 2 ml of milk in a test tube, followed by 5 drops of a solution of para phenyl diamine (2 % w/v).
2) A blue colour indicates the presence of hydrogen peroxide.

Detection of Formaldehyde

1) Mix 5 ml milk with 5 ml water in a graduated test tube.
2) Add one drop 10% ferric chloride solution to 10 ml Gerber sulphuric acid (see 3.4.2, page 17) in another test tube.
3) Gently pour the acid carefully down the side of the test tube with the milk-water mixture so that it forms a layer at the bottom without mixing with the milk.
4) A violet, or blue colour, at the junction of the two liquids indicates the presence of formaldehyde. The test will detect about 1 ml of 40% formaldehyde solution in 100 litres of milk, i.e. about 10 ppm.
5) A green or brown colour indicates formaldehyde is not present.

Detection of Hypochlorite

1) Prepare a stannous chloride solution (0.025 % w/v) in 73.5% sulphuric acid: mix 3 volumes of concentrated sulphuric acid and 1 volume of water. Cool 3 ml of milk in a test-tube to 2 - 5 °C.
2) In another tube, take an equal volume of the stannous chloride solution, similarly cool, and add to milk.
3) Gently shake the tube while in the freezing mixture for 3 minutes.
4) Pour in to a 12.5 ml centrifuge tube and centrifuge for 3 minutes at 2500 rpm.
5) A yellow-green colour indicates the presence of hypochlorite.

Detection of Boric Acid or Borax (Turmeric Paper Test)

1) Acidify milk with hydrochloric acid (7 ml hydrochloric acid to 100 ml milk).
2) Dip a strip of dried turmeric paper and allow paper to dry in the air.
3) If boric acid or borax is present, the paper will colour red.

Detection of Benzoic Acid

1) Acidify milk with hydrochloric acid (5 ml hydrochloric acid to 100 ml milk), then shake until curdled.
2) Filter and extract the filtrate with 50 to 100 ml of ethyl ether. Wash the ether extract layer with two 5-ml portions of water. Evaporate the greater portion of ether in a porcelain dish on a water-bath and allow the remainder to evaporate spontaneously.
3) If benzoic acid is present in large quantity, it will crystallize from the ether in shining leaflets and give a characteristic odour on heating.

4) Dissolve the residue in hot water and add a few drops of ammonium hydroxide, expel the excess of ammonia by evaporation, dissolve the residue in a few ml. hot water and filter if necessary.

5) Then add a few drops of the neutral ferric chloride solution (0.5 % w/v), neutral).

6) A salmon coloured precipitate of ferric benzoate indicates the presence of benzoic acid.

Detection of Salicylic Acid

1) Acidify 100 ml of milk with 5 ml of dilute hydrochloric acid (1:3 by volume).

2) Shake until curdled and filter.

3) Extract with 50-100 ml of ethyl ether. Wash the ether layer with two 5-ml portions of water. Evaporate the greater portion of ether in a porcelain dish on a steam bath; allow the remainder to evaporate.

4) Add one drop of the ferric chloride solution (0.5%, neutral).

5) A violet colour indicates the presence of salicylic acid.

3.7.4. Detection of added solids

There are several ways to raise the density of milk to prevent detection of added water and to increase the total solids:

Detection of Starch

If starch is added, the milk will show a lower fat percentage, lower density, lower SNF percentage and a depression of freezing point.

1) Pour 3 ml milk in a test-tube, bring it to boil over a flame, cool to room temperature and add a drop of a 1% iodine solution.

2) The presence of starch is indicated by the appearance of a blue colour, which disappears when the sample is boiled and re-appears on cooling.

Detection of Cane Sugar

1) Put 15 ml milk in a test tube.
2) Add 1.0 ml of concentrated hydrochloric acid and 0.1 g of Resorcinol and mix.

3) Place the tube in boiling water bath for 5 minutes.

4) A red colour indicates the presence of cane sugar.

Detection of Carbonates

1) Put 5 ml milk in a test tube.
2) Add 5 ml of alcohol, a few drops of an alcoholic solution of Rosalic acid (1% w/v), and mix.
3) If a carbonate is present, a rose red colour appears, whereas pure milk shows only a brownish colouration.

Detection of Urea

A urea content above 70 mg/100 ml in milk indicates milk containing added urea.

1) Prepare a dimethylamino-benzaldehyde solution. Dissolve 1.60 g. of the reagent in ethyl alcohol to which 10 ml of concentrated hydrochloric acid has been added. Make up the volume to 100 ml with ethyl alcohol.
2) Take two 5 ml samples of milk.
3) Add 5 ml of the solution to the first sample and mix well.
4) A distinct yellow colour if observed in sample one indicates milk containing added urea. Sample two, the control, would show a slight yellow colour due to the presence of natural urea in milk.

Detection of Carbohydrates

1) To an aqueous solution of milk, add a little alcoholic solution of Molisch's reagent.
2) Pour concentrated sulphuric acid down the side of the test tube until a separate layer of the acid is formed at the bottom.
3) A red-violet ring at the junction of the two layers will be observed if Carbohydrates are present.

Detection of Maltodextrins

Maltodextrins are produced from starch and usually found as a creamy white hygroscopic powder. They can be cheaply and widely available.

1) Put 20 ml of milk in a beaker, boil and cool.
2) Coagulate the milk using 10% Trichloroacetic acid.
3) Filter through Whatman filter paper no. 42 and collect the filtrate.
4) Add 2 ml of 2% Barium chloride to the filtrate and mix well.
5) Appearance of blue colour indicates the presence of maltodextrins.

3.7.5. Detection of skimming

An indication of removal of fat from milk is given by a lower percentage of fat, a higher density reading of the sample at 27°C, and a higher ratio of SNF to Fat.

3.7.6. Detection of milk mixed with skimmed silk

When separated or skim milk is added to whole milk, it may be detected from a lower percentage of fat in combination with a higher density at 27 °C, a higher percentage of SNF, or a higher ratio of SNF to Fat.

3.8. Drug residues

Introduction

Milk collected from producers may contain drugs (e.g. antibiotics) and/or pesticides residues. These residues, in significant amounts, may inhibit the growth of lactic acid bacteria used in the manufacture of fermented milk, cheese and yoghurt. Besides being a serious health hazard selling milk with, for example, antibiotics is illegal in many countries as it may have harmful effects on people, lead to allergic reactions and resistant strains of bacteria.

3.8.1. General test for drug residues

A milk sample is subjected to a fermentation test with starter culture and the acidity checked after 3 hours. The values of the titratable acidity obtained are compared with titratable acidity of a similarly treated sample, which is free from any inhibitory substances.

Equipment and materials

a) Test tubes.

b) Starter culture.

c) 1 ml pipette

d) Water bath.

e) Kit for determining titratable acidity (3.5.8, page 28).

Procedure

1) Fill three test tubes with 10 ml suspect milk and three test tubes with normal milk.

2) Heat all tubes to 90 °C by putting them in boiling water for 3 - 5 minutes. Cool to optimum temperature of the starter culture (30, 37 or 42 °C), add 1 ml of starter culture to each test tube, mix and incubate for 3 hours.

3) After each hour, the acidity of one test tube from the test sample and the control sample is determined.

Interpretation
If acid production (as measured by the Titratable Acidity Test) in the suspect sample is the same as the normal sample, then the suspect sample does not contain any inhibitory substances. If acid production in the suspect sample is less than in the normal milk sample, this indicates the suspect sample contains antibiotics or other inhibitory substances.

Milk from animals treated with antibiotics, should be rejected for a period of at least 72 hours (or longer if specified on the product label) after treatment. As indicated above, antibiotics should not be present in milk for the following reasons:

- some people are allergic to antibiotics;
- can interfere with the preparation of dairy products;
- can contribute to the emergence of antibiotic resistant bacteria.

Residues of veterinary drugs in milk should not exceed levels that would present an unacceptable risk to the consumer.

3.8.2. ELISA (Enzyme-Linked Immuno-Sorbent Assay) test kits

Many suppliers now make ELISA kits for testing for inhibitors and antibiotics in milk. Though they generally give a result in about 5-10 minutes and can therefore be used at milk reception points, the kits are quite expensive per test. For more information visit: www.genoprice.com/antibiotics_elisa.htm

Other even more rapid testing kits such as the broad-spectrum Delvotest screening test (www.dsm.com/le/en_US/delvotest/html/home.htm) are based on the principle of allowing specific bacteria to grow in a nutrient agar, which already contains a small quantity of milk. After incubation, and under normal circumstances, the bacteria will ferment lactic acid, which will result in a colour change, taking place in the sample from purple to yellow. Still others kits such as TwinsenorBT are rapid receptor-based assays in dipstick format (www.lactoscan.com/acc_antibio.html).

3.9. Automatic milk analysers (AMAs)

Use: test for payment and most milk parameters.

Advantages: quick, results immediately.

Disadvantages: relatively expensive, equipment needs calibration.

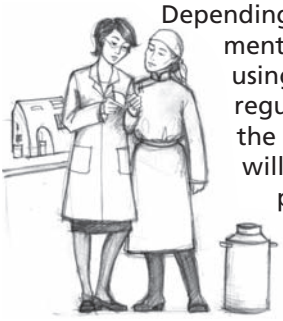
Alternatives: see other compositional and physical quality tests.

Principle

Rapid AMAs use infrared, ultrasonic or digital measurements that are uniquely representative of each milk component analysed.

AMAs are relatively new and powerful tools for facilitating clean milk production, milk screening and milk payment systems, especially when linked to electronic weighing units. They are also powerful tools for improving and maintaining milk quality, e.g. with 12-volt adaptors they can be used by milk collectors and provide instant results, with instant printouts to show to producers.

Calibration



Depending on the accuracy of analysis required, these instruments have to be calibrated regularly (e.g. every week) using reference methods e.g. the Gerber test. Analyse regularly one or more control samples to make sure the results remain within accepted tolerances. You will have to use good quality milk and store the sample with a suitable preservative at 4°C. Because calibration methods vary with each instrument, you will need to refer to the manufacturer for the appropriate calibration method.

3.9.1. Rapid screening of milk

The newer AMAs can test for all the compositional and physical parameters of raw milk important to milk producer groups, such as:

- temperature (3.5.4, page 24)
- fat (3.4.2, page 17)
- SNF and hence TS (3.4.3, page 19)
- density (3.5.1, page 21)
- pH (3.5.5, page 25)
- freezing point (3.5.2, page 22).

Some AMAs, including the lower-cost models, can also test for additional parameters such as protein and added water, important for cheese making and milk producer screening:

- protein percentage
- lactose percentage
- minerals (ash) percentage
- added water percentage.

However, except for measuring pH, AMAs do not perform the rapid hygienic screening tests for measuring the suitability of milk for subsequent processing such as:

- Clot on Boiling Test (3.5.6, page 27)
- Alcohol Test (3.5.7. page 27)
- Titratable Acidity Test (3.5.8, page 28).

The following is a partial list of instruments that can be used:

- Auto Zero (Rajasthan Electronic & Instruments, India): www.reiljp.com
- Dairylab (USA): www.dairylab.com
- Lactoscan (Milktronic, Bulgaria): www.lactoscan.com
- Lactoscope (Delta Instruments, USA): www.deltainstruments.com
- Milkoscan (Foss Electric, Denmark): www.foss.dk
- Milkotester (Milkotester, Bulgaria): www.milkotester.com
- Multispec (Multispec, UK): www.claro.co.uk

Some of these instruments cost less than USD 1,000 each, usually considerably less than equipping a laboratory to carry out individual tests for each parameter, especially if the cost of consumables (glassware and reagents) and staff are taken into account.

Hygienic parameters

AMAs can also be used for determination of hygienic characteristics. Of course, equipment that is more expensive is required and the instruments need to be calibrated. Most instruments work on the principle of fluoro-opto-electronic, disk cytometry or flow cytometry. Some examples of instruments are given below. The manufacturers' user instructions should always be closely followed.

- Bactoscan (Foss Electric, Denmark): www.foss.dk
- Bactocount (Bentley Instruments, US): www.bentleyinstruments.com
- Partec (Germany): www.partec.de

Chapter 4. Milk payment systems

4.1. Introduction

This chapter describes the different approaches for developing milk payment systems. First the necessary steps to introduce a payment system are described (section 4.2), followed by a description of the recording of payments (section 4.3) and the development of payment systems (section 4.4). Examples of payment systems can be found in chapter five. Which milk payment system is chosen depends on:

- **Stage of development of milk collection:** in the initial stages a simple system can be chosen (with low costs), which can be developed to a more sophisticated system later.
- **Trust between the members of the group**: if the group of milk producers you are working with know each other very well and have established a trusting relationship, you might for example decide not to introduce penalties for adulteration practices.
- **Educational level of group members:** it is important to introduce a payments system that is accepted and understood by all member of the group.
- **Readiness of group members to accept payment systems:** all group members should be convinced that the payment system introduced is the most appropriate.
- **Dairy legislation:** the dairy legislation and regulations in your area or country might dictate what you can or cannot do. This is something to carefully study before introducing a payment system.
- **Testing methods:** the payment system should be based on raw milk testing methods that are available and economical (see chapter 3). *It may be necessary to make simultaneous duplicate tests on a sample of milk when using the results for milk payment. If the results differ significantly, then the sample is re-tested until results are, e.g. ± 0.1% for fat content, with the median result recorded.*
- **The hygienic quality of the milk available:** if you are already aware that hygienic conditions during milk collection are low, a payment system based on hygienic quality is a priority. On the other hand, if you know that the hygienic quality is high, testing and paying for hygienic quality might not be the first priority, and you could only do, for example, random testing and sampling.
- **Adulteration practices:** if you know certain adulteration practices exist in your area, then testing and payments systems should be adjusted accordingly.

- **The dairy product(s) to be processed from the raw milk is**: the greater the amount of fat, protein and SNF in milk the greater the yield of dairy products such as cheese Thus you might want to have a payment system based on fat or solids (TS or SNF). If butter is your main product then a payment system based on fat would be appropriate, as milk with a high fat content gives more butter than milk with a lower fat content.

4.2. Introducing a payment system step by step

The steps for introducing a new payment system are indicated in the box.

Step 1. Set objectives

Step 2. Carry out a participatory survey

Step 3. Set base milk price

Step 4. Determine parameters

Step 5. Set acceptance and deduction levels

Step 6. Design testing schedule

Step 7. Determine other payments

Step 8. Determine frequency and mode of payments

A more detailed description of the steps to follow is given below.

Step 1. Set objectives

It is important to consider the objectives before introducing any payment system. The list below sets out a number of possible objectives, most existing payment systems are a combination of these objectives.

- **To increase yield of dairy products**: the yield of dairy products will depend on the amount of total solids present. The greater the amount of fat, SNF and protein in raw milk the greater the yield of, e.g. cheese. Thus, if you are making cheese you might want to have a payment system based on fat or solids (TS or SNF). If your main product is butter, then a payment system based on fat would be appropriate, as milk with a high fat content gives more butter.
- **To promote hygienic quality of the milk:** if this is one of your main objectives, you might want to introduce a payment system based on hygienic quality at an early stage.
- **To avoid adulteration:** if one of your aims is to discourage farmers from adding water or solids to the milk, then your payment system should be designed accordingly.

- **To increase safety of dairy products:** next to promoting the hygienic quality of the milk, safety involves drugs, antibiotics and other residues in the milk. A payment system, which includes testing for these residues, with subsequent rejection and/or penalties, will assist in increasing the safety of dairy products.

Step 2. Carry out a participatory survey

A participatory survey of the situation regarding milk testing and payments in the area can give you useful information. It will assist you in deciding which payment system to choose, as a payment system should be adjusted to the local situation and local composition of milk. The list below gives an overview of the items that can be incorporated in the survey:

1) **Regulations** regarding milk testing and payments.
2) Existing **milk testing and payment systems.**
3) **Cost of milk production**.
4) Existing milk **prices paid to farmers.**
5) **Market prices for** ready-to-drink milk and dairy products.
6) Compositional **quality of milk.**
7) Hygienic **quality of milk.**
8) **Adulteration** practices.
9) Availability and cost of **milk testing equipment.**
10) **Collection** time and costs.
11) **Level of organization** of milk producers.

In the context of this book, participatory methods are not described in detail. Some participatory methods may be found in the FAO Milk Producer Group Resource book and in the other references found in the information sources and references listed in Annex 1 (page 67).

Step 3. Set base milk price

Before deciding on the base milk price, check whether the milk price has to be approved by a milk board or governmental department. In order to determine the base price for raw milk, you will need to calculate all the costs your milk producer group will incur, plus the margin (savings or profit) your want to make. Consider the following cost items:

- transport costs (including insurance, drivers' wages, petrol, etc);
- collection costs;

- testing costs;
- preservation costs;
- processing costs;
- marketing costs;
- stationary, rent of buildings, salaries etc.;
- costs of electricity and water;
- costs of other activities of the milk producer group;
- depreciation costs, e.g. for buildings, transport etc;
- any savings planned.

You will have to make sure the cost of a testing and payment system is not higher than what is gained.

Below follows an example of a calculation for the base milk price based on the fat content for the production of butter and non-fat cottage cheese by your producer group. If you sell bulk milk to a third party processor, then the base price would be negotiated with the processor.

1) Find out what the commercial values or wholesale prices of butter and non-fat cottage cheese are, e.g. 100 ∀ and 15∀ per kg respectively *(∀ is an imaginary money unit we use in this book).*

2) Determine the average fat and SNF content of your milk, say 3.5% and 8.5% respectively.

3) Calculate the approximate commercial value of your whole milk:

   - first the value of the fat: each kg of butter contains 80% fat, therefore each kg whole milk contains fat valued at [3.5% x (100% / 80% x 100 ∀) = **4.4** ∀];
   - second the value of the skimmed milk component of each kg whole milk: assuming 80% of the whole milk is normally recovered as skimmed milk after cream separation, and it requires 8 kg skimmed milk to produce 1 kg cottage cheese, each kg whole milk is valued at [80% x (1 / 8) x 15 ∀ = **1.5** ∀];
   - therefore the value of whole milk is [4.4 + 1.5 = **5.9** ∀];
   - the whey left over from producing cottage cheese could be fed to livestock.

4) Estimate the total volume of milk expected daily, say 500 kg.

5) Calculate all the costs mentioned above per day plus your margin, say 1,400 ∀ per day.

6) Calculate base milk price as follows:

   - commercial value of milk [500 kg x .5.9 ∀ = 2,950 ∀];
   - deduct costs and margin [2,950 ∀ - 1,400 ∀ = 1,550 ∀]
   - if you spread this amount over 500 kg of milk daily**,** the base milk price per kg that you would have to pay on average to your milk producers would be [1,550 ∀ / 500 kg = **3.1 ∀]**.

Step 4. Determine parameters

Below the parameters are described that can be included in a payment system. It is important to consider all parameters and include in the milk payment system those parameters that are most important to you.

The main parameters to be considered in a milk payment system are:

1. Quantity (volume or weight).
2. Compositional quality (fat, protein/SNF).
3. Hygienic quality.

1. Quantity and temperature

Milk payment for quantity forms the base of milk payment systems and can be either by volume or by weight, e.g. a certain payment per litre or per kilogram. Because many payment systems pay for solids as well, it is often more appropriate to pay per kilogram of milk to facilitate calculation. Section 3.2, page 14 explains how to measure milk quantity.

2. Compositional quality

Fat

Fat is often the first compositional quality parameter that is included in a milk payment system (testing for fat is explained in section 3.4.2, page 17 and section 3.9 page 44). There are several ways to pay for the fat content of milk:

- Grade the milk in **fat groups** and pay a certain amount per kilogram of milk with a certain fat percentage range.
- Pay for fat in a **linear payment system**: e.g., a certain amount per percentage or per kilogram of fat (see 5.3, page 60).
- Introduce a **penalty** for low fat or a **bonus** for high fat, e.g. introduction of a penalty for a fat percentage below 3.0 %.

Rather then a percentage, it is better to use quantity of fat (in kg), because this will discourage farmers from adding water. If fat percentages are used, this means that a milk producer would receive more money if she or he adds water to the milk. For example:

Milk price for 3.2 % fat is 5.0 ∀ per kg

Milk price for 4.0 % fat is 5.2 ∀ per kg

A farmer with 20 kg milk with 4% fat (total amount of fat is 0.8 kg) will receive (20 x 5.2 ∀=) 104∀. If this farmer adds 5 kg of water to his milk, his fat percentage will go down to 3.2 % (0.8 kg fat / 25 kg), but he/she will receive more money for his milk (25 x 5.0 ∀ =) 125 ∀ !!!

(∀ is an imaginary currency used in this book)

Solids

Testing for solids is explained in 3.4.3, page 19. Solids in the milk can be expressed either as Total Solids (TS) or as Solids Non-Fat (SNF), which is the amount of total solids minus the fat component. From the density of milk, the SNF can be calculated. The solids in the milk will contribute to the yield of dairy products, for example in cheese making. An example of payment a system in which solids are included is given in 5.4, page 62.

3. Hygienic quality

There are many reasons to include hygienic quality within a payment system. What parameters you include in your payment system often depends on which testing methods are available. Payments for hygienic quality are often bonuses or penalties based on a grading system. The parameters are divided into groups (e.g. from excellent to very bad) and each group will have a certain bonus or penalty per kilogram of milk (see 3.6, page 30).

Step 5. Set acceptance and deduction levels

Once you have set the objectives of the payment system, the base milk price and the main parameters of the payment system, the next step is to set acceptance and deduction levels.

Acceptance levels

Acceptance levels are the minimum requirements for the milk not to be completely rejected. If the milk meets these minimum requirements, the milk can be paid for according to the quantity and / or quality of the milk. These acceptance levels might vary according to the results of the survey on the current compositional and hygienic quality, the type of milk products or local regulations. For example, milk of buffaloes, ewes and some cow and goats species can have a relatively high fat content (see Annex 3, page 71). Of course, testing methods need to be available for the parameter your select.

Please note:
If milk is to be rejected, e.g. because it contains high antibiotic levels, it is important to dispose of it in a manner that removes it from the human and animal food chain.

Deduction or warning levels

For milk that is close to the acceptance levels but can still be accepted, e.g. for further processing, you may consider doing a re-test and introducing a deduction or warning system. Options are to issue warnings or to introduce penalties linked (e.g. Table 7), if possible, to advice from extension or dairy staff.

Suspension

If a producer is repeatedly delivering milk that cannot be accepted, even after a farm visit, you might want to introduce a suspension for delivering milk for a certain period. If a producer's quality standards are consistently poor, a member can be expelled from the milk producer group.

Table 7: examples of rejection and deduction levels for cow milk:

	Rejection level	Deduction level	Unit
Fat	<3.0	3.0 - 3.2	%
SNF	<8.2	8.2 - 8.5	%
Total Solids	>12.0	10.0 - 12.0	%
Water	<1.027	1.027 - 1.028	Density at 15 C
or	>1.036	1.035 - 1.036	Density
or	>-0.520	-0.520 to -0.525	°C freezing point
or	>10	5 - 10	% excessive water
Preservatives	none	none	
Antibiotics	0.0006		i.u. / ml
Temperature			°C
pH	<6.4	6.4 - 6.5	
Clot on boiling	Positive test	-	
Alcohol test	Positive test	-	
Titratable acidity	0.20	0.18	% lactic acid
10 min Resazurin	0 and 1	2 and 3	Disc numbers
Methylene blue	<30	30 - 60	Minutes
Bacterial count	>750	500 - 750	(x1,000 CFU/ml)
Somatic cell count	>1,000	750 - 1,000	(x1,000 CFU/ml)

Note: *these are examples only and should be adjusted to your local situation!*

Step 6. Design testing schedule

As described in chapter two, testing can be expensive and time consuming, and should therefore be reduced to the minimum necessary for acceptable monitoring and payment. In section 2.7, page 11, periodic, random and composite sampling is explained to reduce the number of samples and tests and the associated costs.

Determine other payments

Incentive payments other than for quantity and quality can be considered for inclusion in a milk payment system. Some are described below.

Seasonality

In many countries, whether in temperate or tropical zones, there can be strong seasonal variations in the total of milk volume produced. To stimulate low-season milk production, higher milk prices in the low season can be introduced. In section 5.5, page 63, an example is given of a payment system that includes payments for seasonal milk production.

Other payments

Other payments that can be considered include premium payments for organic or biological milk or bonuses for a certain volume. Any other costs that are not yet included in the base milk price can be deducted from the price of the milk. For example if your group supplies concentrate feed or other services such as breeding and veterinary to group members you can deduct the payment for the feed from the milk price.

Step 7. Determine frequency and mode of payments

The frequency of milk payments can vary according to the preferences of the milk producers that are being paid or the person that pays the milk producers. Common frequencies of payments are:

- Twice daily, payment for the morning milk in the evening and for the evening milk in the morning after.
- Daily.
- At the end of the week or once every two weeks.
- Monthly, e.g. on day 15 for the previous month production.

Where the milk price is based on average composition for a period of two weeks or monthly averages, the interval between payments is normally two weeks (4 to 6 weeks after first delivery). Intervals longer than 6 weeks should be avoided and often small-scale milk producers prefer daily or weekly payments. On the other hand, daily payment for very small quantities of milk increases administration work and raises costs.

The following are different ways in which to pay a milk producer.

Mode of payment

- Contracts with milk producers.
- Cash or cheque.
- Bank credit transfer.
- In kind (fertilizer, concentrates, veterinary medicines).

- Credit, cash or advance payment (coupon / monthly card).
- Deductions for credit repayments.

Smart cards
Smart Cards are credit card-sized plastic cards with a microchip. These cards can store information, carry out local processing on the data stored and can perform complex calculations. Smart cards are used with some milk producer groups in India (see box text below).

Indian Smartcards (see www.akashganga.in)

Each milk producer is given a plastic card as identification, with a photograph. At the counter, he/she drops the card into a box, which reads the card electronically and transmits the identification number to a computer. The milk is then poured into a steel trough on a weighbridge. Instantly, the weight of the milk is displayed to the farmer and communicated to the computer. Then, an operator sitting by the side of the trough takes a 5 ml. sample of milk and holds it up to a tube connected to an electronic fat testing machine, the fat content of the sample is determined in just a few seconds, displayed to the farmer and communicated to the computer. The computer calculates the amount due to the farmer based on a rate chart that indicates the price for milk with different levels of fat content. The total value is printed on a payment slip and the milk producer can collect the payment immediately. Using this system milk records and always authentic and accurate, and make it easy to identify members. The system costs around $2,000.

4.3. Recording of payments

The keeping of proper payment records is essential for a milk producer group, and can be the key to the success or failure of the group. It is important to show members and others how the payments have been made. Keeping financial records is often a legal requirement to provide information to lending institutions or to government agencies.
Table 8 shows an example of a weekly milk collection record for one producer. This includes results of milk testing, in this case the lactometer reading (density) and the fat percentage. Such records may be consolidated by the producer group into a single register for all milk producers, who have their own individual milk book into which their deliveries are recorded.

Table 8: example sheet of weekly milk collection records

Name Producer:						
Code number:						
Sample taken:						
Date	**Day**	**Kg milk**	**Density reading**	**fat %**	**Rate per kg**	**Total amount**
	Sunday morning					
	Sunday evening					
	Monday morning					
	Monday evening					
	Tuesday morning					
	Tuesday evening					
	Wednesday morning					
	Wednesday evening					
	Thursday morning					
	Thursday evening					
	Friday morning					
	Friday evening					
	Saturday morning					
	Saturday evening					
week total:						
Payments made on:						
Remarks:						

Other parameters that can be included in the recording of milk payment systems are:

- Producer identification number.
- Date of sampling, testing, or grading.
- Type of sampling, testing, or grading procedure used.
- Results of sampling, testing, or grading.
- Name of licensed tester, or grader conducting the procedure.

4.4. Development of payment systems

When collection is in the initial stages of development, it may be possible to only screen milk visually and pay on a volume or weight basis. This has the disadvantage that milk of a better quality is not rewarded and that there is no incentive to improve milk quality. Any changes in payment

systems from, for example, payment according to volume to payment according to quality should be introduced gradually.

The box below describes a three-step incentive payment scheme used to reward milk producer groups in Mongolia for improving the quality of their milk. The scheme was part of an overall National Milk Promotion Campaign that also involved three steps, namely:

(i) milk quality improvement;

(ii) import substitution and

(iii) milk publicity and consumer education, including generic milk branding and school milk nutrition schemes.

Mongolia Milk Quality Improvement Scheme
www.mongolia-dairy.mn

Objectives

- *To encourage milk producers to improve earnings through productivity enhancement inputs rather than adding more cows.*
- *To encourage milk quality improvement through clean milk production enhancing measures.*
- *To build on, and improve existing practices, though training and demonstration, awareness raising and incentives.*

Implementation strategy

- *Is market-oriented at Milk Collection Point, Milk Cooling Centre and Milk Processing Unit levels with public and private sector dairy operators (linked to QC kits, training etc)*
- *In three steps at Milk Producer Organisations:*

  Step 1/Year 1: incentive payment based on quantity and hygienic (organoleptic) quality, with seasonal incentives.

  Step 2/Year 2: add incentive based on compositional quality.

  Step 3/Year 3: add incentive based on bacteriological quality.

The Smart Card milk recording and payment systems mentioned above can be scaled up into a fully electronic milk collection and payment system for milk producer groups, which processes, displays, prints and stores all the data required. The system can be programmed to make deductions for other services such as loan repayments, e.g. for a dairy cow, or for animal breeding and health services. The system cost from A PC-based system currently costs under USD 3,500 and a microprocessor-based system about USD 2,600.

Chapter 5. Examples of payment systems

5.1. Introduction

In the context of this book, we will focus on payment systems suitable for small groups of milk producers. The background information from the table below for four imaginary milk producers will be used for the examples in this chapter (The base milk price will be 5 ∀/ kg milk, ∀ is an imaginary monetary unit we use in this book). The data for 10-min Resazurin, organoleptic and sediment tests in the table below are classes and will be explained in the relevant examples.

Table 9: Background information for payment examples

Milk producer	1	2	3	4
kg milk	10	20	20	20
% fat	4.2	4.2	3.5	2.8
Density	1.036	1.036	1.032	1.028
SNF	10.64	10.64	9.49	8.34
10 min Resazurin test	Class I	Class V	Class II	Class III
Sediment test	Class I	Class IV	Class II	Class II
Organoleptic tests	Class I	Class II	Class I	Class II
somatic cell count	120,000	800,000	300,000	550,000
Bacterial count	9,000	10,000	18,000	45,000

In the examples below, we will start with the simplest and cheapest payment systems. The other examples show a possible development into more sophisticated milk payment systems, depending on the objectives of the payment system. To simplify the calculations, standard payment tables can be developed in accordance with the selected parameters. Each example will have suggestions for possible ways to accept or not accept the milk received.

5.2. Example 1: Payment according to quantity of milk

A payment system based only on quantity is the simplest method and easy to calculate. If milk payment is exclusively on quantity, no laboratory equipment is needed; only instruments to measure volume or weight (see 3.2, page 14).

Calculation for example method 1

Producer No.	kg or litre milk	Price/kg	Total price
1	10	5	50 ∀
2	20	5	100 ∀
3	20	5	100 ∀
4	20	5	100 ∀
Total	**70**		**350 ∀**

∀ is the imaginary money unit we use in this book.

In this example, all four milk producers get the same amount of money for the milk per kilogram or litre (5 ∀ per kilogram of raw milk). The total price paid for the 70 kilogram of milk is 350∀.

advantages of method 1:

- simple and easily understood method to calculate the milk price;
- no expensive testing equipment needed.

disadvantages of method 1:

- no incentive to improve quality or composition of milk;
- does not discourage adulteration, e.g. adding water or extracting cream.

options for accepting / not accepting milk:

- density test to check adulteration with water;
- organoleptic tests to check hygienic quality.

5.3. Example 2: Payment according to weight of fat in milk

In this example, a compositional parameter is introduced, fat, one of the most important components of raw milk. This payment method is based on the amount of fat a milk producer delivers. The price for fat is set in such a way that the total amount paid for all the milk is the same as in example 1 (350 ∀), in this case the price for fat is set at 138.9 ∀ per kilogram of fat.

Calculation for example method 2

(Milk price is set at 138.9 ∀ per kg of fat):

Producer No.	kg milk	Fat %	Total kg fat	Price/kg	Total price
1	10	4.2	0.42	5.83	58.3 ∀
2	20	4.2	0.84	5.83	116.7 ∀
3	20	3.5	0.70	4.86	97.2 ∀
4	20	2.8	0.56	3.89	77.8 ∀
Total	**70**		**2.52**		**350.0 ∀**

∀ is an imaginary money unit we use in this book

We have set the price of fat in such a way that the total amount paid for the 70 kilograms of milk is the same (350 ∀). If we compare the price paid to each milk producer we can see that producers 1 and 2 get a higher price for each kilogram of milk (5.83∀ as compared to 5∀), producer 3 gets a slightly lower price (4.86∀ as compared to 5∀) and producer 4 gets a lower price (3.89∀ as compared to 5∀), due to the lower fat content.

advantages of example method 2:

- simple method to calculate the milk price (kg fat x fat price);
- milk producer is rewarded for efforts to increase fat content of milk;
- no incentive for adding water to the milk (increasing water content will not have any benefits).

disadvantages of example method 2:

- fat testing equipment needed;
- costs for sampling and testing for fat;
- no incentive to improve hygienic quality.

alternative payment options include:

- incremental rates for ranges of percentage fat, e.g. 3-4, 4-6 and > 6 %;
- minimum fixed fat level, e.g. 3.0% with penalty rate for milk testing less than fixed level;
- flat price for milk adjusted to 3.5 %, premium for every 1/10th of a percentage point above that.

options for accepting / not accepting milk:

- Density test to check adulteration with water.
- Organoleptic tests to check hygienic quality.

5.4. Example 3: Payment according to fat and SNF in milk

This method is based on the fat and SNF content of milk. The yield of milk products will depend on the amount of total solids present. The higher the amount of fat and solids in milk, the higher the yield of cheese. Milk with a high fat content gives more butter than milk with a lower fat content.

Payment system
The payment system is based on a price for fat and a price for SNF. The price of the milk can be calculated according to a formula:

$$\text{milk price} = \text{kg of milk} \times \left\{ \frac{(\text{fat \%} \times \text{fat price})}{100} + \frac{(\text{SNF \%} \times \text{SNF price})}{100} \right\}$$

Calculation for example method 3
(Price for fat is set at 50.9 ∀ per kg and for SNF at 33.9 ∀ per kg.)

Producer No.	Kg milk	fat %	SNF %	Price / kg	Total price
1	10	4.2	10.64	5.75	57.5
2	20	4.2	10.64	5.75	114.9
3	20	3.5	9.49	5.00	100.0
4	20	2.8	8.34	4.25	85.1
Total	**70**				**357.5**

∀ *is an imaginary money unit we use in this book*

In this example a slightly higher price is paid for the total 70 litres of milk, the differences between the price per kg milk is not as high as in example 2.

advantage of example method 3:
- method provides an incentive for fat and SNF.

disadvantages of example method 3:
- a more complicated method to calculate the milk price;
- need to buy fat testing equipment / density meter;
- costs for testing fat and SNF;
- farmers could try to add other solids to increase the SNF content.

alternative payment options:
- payment could be based on fat and protein content if rapid automatic and digital-based testing unit is available.

options for accepting / not accepting milk:
- density test to check adulteration with water;
- organoleptic tests to check hygienic quality.

5.5. Example 4: Seasonal payment according to milk fat and SNF

This example is similar to example 3 and based on the content of fat and solids-not-fat (SNF) in the milk. In this example however, we will introduce a seasonal variation.

Calculations for examples method 4

(1) Prices of fat and SNF in different seasons

Component	**Price** (in ∀)		
	Lean season	**Flush season**	**Average**
Milk fat (per kg)	55.9	45.9	50.9
SNF (per kg)	36.9	30.9	33.9

(2) Lean season payment

Producer No.	**kg milk**	**fat %**	**SNF %**	**Price/kg**	**Total price**
1	10	4.2	10.64	6.27	62.74
2	20	4.2	10.64	6.27	125.48
3	20	3.5	9.49	5.45	109.17
4	20	2.8	8.34	4.64	92.85
Total	**70**				**390.24**

(3) Flush season payment

Producer No.	**kg milk**	**fat %**	**SNF %**	**Price/kg**	**Total price**
1	10	4.2	10.64	5.21	52.08
2	20	4.2	10.64	5.21	104.16
3	20	3.5	9.49	4.54	90.78
4	20	2.8	8.34	3.86	77.25
Total	**70**				**324.27**

∀ *is an imaginary money unit we use in this book*

In this example we pay a higher price for milk delivered in the lean season, the total price paid for the 70 kilogram is 390.2 in the lean season and 324.3 in the flush season.

advantages of example method 4:

- method provides an incentive for fat and SNF;
- method provides an incentive to deliver milk in the lean season.

disadvantages of example method 4:

- a more complicated method to calculate the milk price in each season;
- need to buy fat testing equipment / density meter;
- costs for testing fat and SNF.

alternative payment options

- could use a simpler seasonal payment systems based on quantity only (see example 1 above).

options for accepting / not accepting milk:

- density test to check adulteration with water;
- organoleptic tests to check hygienic quality.

5.6. Example 5: Payment according to compositional and hygienic quality

In this example we use the same payment system for compositional quality based on fat and SNF (see example 3), but introduce a grading system for hygienic quality. Table 10 shows the grading system that combines the 10-minute Resazurin Test, the Sediment test and Organoleptic tests (smell and taste).

Table 10: Grading system for hygienic quality

Test	Class/Rating	Score
10-min Resazurin test	I (excellent/very good)	4
	II (good)	2
	III (fair)	0
	IV (poor/bad)	-2
	V (very bad)	-4
Sediment test	I (excellent)	4
	II (good)	2
	III (fair)	0
	IV (bad)	-2
	V (very bad)	-4
Organoleptic test	I (good)	2
	II (fair)	0
	III (bad)	-2

The highest score is 10, the lowest minus 10. Score minus 2 to 2 receives the basic price and for every point, a certain amount of money is added or deducted. Score 0-6 receives basic price, 6-10 receives a small bonus, 10-14 receives substantial bonus.

Table 11: Bonus / penalty system for hygienic quality

Score from	To	Bonus / penalty
10	7	Base price + 0.60
6	3	Base price + 0.30
2	-1	Base price
-2	-5	Base price - 0.30
-6	-10	Base price - 0.60

Calculation for example method 5:

(See example 3 for calculations of the milk price per kg based on fat and SNF)

Producer	Weight of milk kg(	Price based on fat + SNF / kg	Score	Bonus or Penalty /kg	Price / kg	Total price
1	10	5.75	10	+ 0.60	6.35	63.50
2	20	5.75	-6	- 0.60	5.15	103.00
3	20	5.00	6	+ 0.30	5.30	106.00
4	20	4.25	2	0.00	4.25	85.00
Total	**70**					**407.00**

∀ *is an imaginary money unit we use in this book*

The compositional quality of the milk delivered by milk producers 1 and 2 is the same, but the hygienic quality is different, resulting in a significantly lower price per kilogram in this example.

advantages of example method 5:

- method provides an incentive for fat and SNF;
- method provides an incentive to deliver milk of good hygienic quality.

disadvantages of example method 5:

- a more complicated method to calculate the milk price for the hygienic quality classes;
- need to buy fat testing equipment / density meter;
- costs for testing fat, SNF and hygienic quality parameter.

alternative payment options:

- for incentive reasons, it may be better to introduce bonuses rather than penalties, or to talk about deductions instead of penalties;
- omitting the sediment test would reduce the sample size and cost.

Annex 1. Information sources and references

General

1. FAO dairy information page: http://www.fao.org/ag/againfo/themes/en/dairy/home.html
2. FAO Directory of Small-scale Dairy Processing Equipment: http://www.fao.org/ag/againfo/themes/documents/LPS/DAIRY/SDE/Suppliers.htm
3. Codex Alimentarius for definitions of milk: www.codexalimentarius.net
4. FAO Milk Producer Group Resource Book (2002): ftp://ftp.fao.org/docrep/fao/007/y3548e/y3548e00.pdf
5. International Organisation for Standards (ISO) 67:100 Milk & Dairy Products http://www.iso.org/iso/iso_catalogue/catalogue_ics/catalogue_ics_browse.htm?ICS1=67&ICS2=100
6. Guide to Good Dairy Farming Practice 2004 (FAO/IDF): ftp://ftp.fao.org/docrep/fao/006/y5224e/y5224e00.pdf
7. FAO small-scale dairy farming manual (1993): http://www.fao.org/ag/againfo/resources/documents/Dairyman/Dairy/Title1.htm
8. For a list of developing countries, see Development Assistance Committee (DAC) list: http://www.oecd.org/dataoecd/32/12/41751233.pdf
9. Dugdill, B.T. and Kurwijila, L.K., 2004. *Guidelines on Food Safety and HACCP Based Quality Assurance Systems for Small and Medium Scale Dairy Establishments in Developing Countries.* FAO Working Paper
10. Employment generation through small scale dairy marketing and processing: http://www.fao.org/docrep/007/y4860e/y4860e00.htm
11. FAO Dairy Outlook Information Network, a discussion list to disseminate and exchange information on the world dairy economy: http://www.fao.org/es/esc/en/15/162/highlight_168.html

Milk Testing

12. Resubal, Lourdes E. 1975*. Dairy Microbiology Practicals.* FAO Regional Dairy Development and Training Centre for Asia and the Pacific, Dairy Training and Research Institute, University of the Philippines at Los Baños College, Laguna.
13. O'Connor C.B. 1995. *Rural Dairy Technology.* ILRI Training Manual 1. ILRI (International Livestock Research Institute), Nairobi, Kenya. 119 pp. ISBN 92-9146-000-1. http://www.ilri.org/html/trainingMat/Manual.pdf

14. Dugdill, B.T., Petricic, A. and Yli-Sepala, M., 1978. *Milk and Dairy Products Testing Procedures, Parts 1 and 2.* FAO/UNDP Cooperative Dairy organisation and Extension Programme, Bangladesh.

15. Codex Alimentaius, 2008. Maximum Residue Limits for Veterinary Drugs in Food. *CAC/MRL 02-2008. http://www.codexalimentarius.net/download/standards/45/MRL2_e.pdf*

16. International Dairy Federation *(IDF). http://www.fil-idf.org/Content/Default.asp?*

Milk Payment

17. Shri Kamdhenu Electronic Pvt. Ltd., 2008. *Modern Rapid Automatic and Digital-based Milk Collection System.* Personal Communication

18. FAO, 1972. *Payment for Milk on Quality*.

19. Panayotova, Milena and Jens Adler, 1999. *Development and future perspectives for Bulgarian raw milk production towards EU Quality Standards.*

20. Ruuskanen, S., 1987. *FAO Report on the Feasibility of basing the payment of milk on fat content in the Arusha/Kilimanjaro Regions of Tanzania.*

21. Berg, J.C.T. van den. 1990. *Strategy for Dairy development in the tropics and subtropics* ISBN 90-220-10005-8, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, the Netherlands.

Annex 2. Weights and measures

Throughout the world, different terms are in use for measuring weight, length and volume. The following tables give the terms that you may need to know while working with milk payment and testing systems.

Metric	**Metric**	**Imperial**	**Imperial**
1 tonne	1,000 kilogram	2,204.62 pounds	157.00 stones 6.62 pounds
1 kilogram (kg)	1,000 grams (gm)	2.20 pounds	35.2740 ounces
1 gram (gm)	1,000 milligrams (mg)	0.0353 ounces	
1 litre (l)	1,000 millilitres (ml)	1.76 pints (UK)	2.11 pints (US)
1 litre (l)	1,000 millilitres (ml)	0.26 gallons	
1 metre (m)	100 centimetres (cm)	3.28 feet	
Imperial	**Imperial**	**Metric**	**Metric**
1 stone	14 pounds (lbs)	6.35 kilograms	
1 pound (lb)	16 ounces (oz)	0.45 kilograms	453.59 grams
1 pint (pt, UK)	20 fluid ounces	0.57 litres	5.92 decilitres
1 pint (US)	0.12 gallons	0.47 litres	
1 gallon	4.00 quarts	3.79 litres	
1 gallon	6.67 pints (UK)		
1 quart	2 pints (UK)	0.95 litres	
1 foot (ft)	12 inches (ins)	0.30 metre	30.48 centimetres
1 yard (yd)	3 feet (ft)	0.91 metres	91.44 centimetres

Celsius	Fahrenheit	Celsius	Fahrenheit
0	32.00	15	59.00
1	33.80	16	60.80
2	35.60	17	62.60
3	37.40	18	64.40
4	39.20	19	66.20
5	41.00	20	68.00
6	42.80	21	69.80
7	44.60	22	71.60
8	46.40	23	73.40
9	48.20	24	75.20
10	50.00	25	77.00
11	51.80	26	78.80
12	53.60	27	80.60
13	55.40	28	82.40
14	57.20	29	84.20
15	59.00	30	86.00

Annex 3. Milk composition

The average figures below are for normal raw milk, at a temperature of 20 °C.

	Cow	Goat	Ewe	Buffalo	Camel
Water (%)	85.5 - 89.5	87.3	80.9	82.4	87.7
Fat (%)	3.2 - 5.5	4.2	8.0	7.4	3.0
SNF (%)	8.2 - 10.0	8.5	11.1		9.3
TS (%)	10.5 - 14.5	12.7	19.1	17.6	12.3
Protein	2.6 - 3.6	3.5	5.4	4.7	3.5
Lactose	4.6 - 5.0	4.2	4.8	4.6	5.2
pH	6.6 - 6.7		6.5-6.7		6.5-6.7
Acidity (%)	0.14 - 0.18				
Specific gravity	1.032	1.033	1.036	1.031	0.96-1.04
Freezing point (°C)	-0.512 to -0.550				
SCC	100,000 - 300,000				

Annex 4. Glossary

In the list below, you will find an explanation of the text used in the context of this book.

Acid	A compound containing hydrogen that can attack and dissolve many substances. *Example:* hydrochloric acid (HCl). An acid in water can react with a base to form a salt and water.
Acidity	A general term for the strength of an acid in a solution.
Acidity test	Quality test that measures lactic acid in milk.
Adulteration	Addition of other substances to milk, which affects the quality of the milk (e.g. water).
Alcohol	an organic compound that contains a hydroxyl (OH) group. *Example:* ethanol (CH_3CH_2OH), also known as ethyl alcohol.
Alcohol test	A rapid (platform) that uses alcohol to check milk quality.
Alkali/alkaline	A base in (aqueous) solution. Alkalis react with, or neutralize hydrogen ions in acids and have a pH greater than 7.0 because they contain relatively few hydrogen ions. *Example:* aqueous sodium hydroxide (NaOH).
AMA	Automatic Milk Analyser.
Anhydrous	Not hydrated with water.
Aqueous	A solution in which the solvent is water. Usually used as 'aqueous solution'. *Example:* aqueous solution of sodium hydroxide (NaOH).
Autoclave	A strong, pressurised, electrically heated vessel for sterilising laboratory equipment.
Bacteria	Tiny organisms, invisible to the eye, belonging to the vegetable kingdom.
Boiling point	The temperature at which a liquid boils, changing from a liquid to a gas. Boiling points change with atmospheric pressure. *Example:* the boiling point of pure water at standard atmospheric pressure is 100 °C.
Bronopol	A non-corrosive preservative in tablet or granular form (2-Bromo-2-Nitro propane-1,3 diol) for preserving milk samples for subsequent testing.
Buffer (solution)	A mixture of substances in solution that resists a change in the acidity or alkalinity of the solution when small amounts of an acid or alkali are added.
Burette	A long, graduated glass tube with a tap at one end. A burette is used vertically, with the tap lowermost. Its main use is as a reservoir for a chemical during titration.
Butterfat	See also *fat*
°C	Degrees Celsius, see also *Celsius scale*.
Carbohydrate	A compound containing only carbon, hydrogen and oxygen. Carbohydrates have the formula $C_n(H_2O)_n$, where n is variable. *Example:* sugars and starches.
Carbonate	A salt of carbonic acid. Carbonate ions have the chemical formula CO_3^{2-}. *Examples:* calcium carbonate $CaCO_3$ and sodium carbonate Na_2CO_3.
Catalyst	A substance that speeds up a chemical reaction, but itself remains unaltered at the end of the reaction. *Example:* copper in the reaction of hydrochloric acid with zinc.
Celsius scale (°C)	A temperature scale on which the freezing point of water is at 0 degrees and the normal boiling point at standard atmospheric pressure is 100 degrees.

Centrifuge	An instrument for spinning small samples very rapidly. The fast spin causes the components of a mixture that have a different density to separate.
Clot on boiling test	Hygienic quality test through heating the milk to see if the milk coagulates.
cm	centimetre.
Coagulation	A term describing the tendency of small particles to stick together in clumps.
Compound	A chemical consisting of two or more elements chemically bonded together. *Example:* Calcium can combine with carbon and oxygen to make calcium carbonate ($CaCO_3$), a compound of all three elements.
Cryoscope	A handheld device for measuring the freezing point of milk.
Crystal	A substance that has grown freely so that it can develop external faces.
Crystalline	A solid in which the atoms, ions or molecules are organized into an orderly pattern without distinct crystal faces. *Examples:* copper sulphate and sodium chloride.
Crystallisation	The process in which a solute comes out of solution slowly and forms crystals.
Cytometry	Counting of cells.
Delvotest	Test used for the detection of antibiotics.
Density	The mass per unit volume (e.g. g/cm^3).
Desiccant	A substance that absorbs water vapour from the air. *Example:* silica gel.
Desicator	A glass bowl and lid containing a shelf. The apparatus is designed to store materials in dry air. A desiccant is placed below the shelf and the substance to be kept dry is placed on the shelf. The lid makes a gas-tight joint with the bowl.
Developing country	For a list of developing countries, see Development Assistance Committee (DAC) list: www.oecd.org/dac/htm/daclst2000.htm.
Direct microscopic somatic cell count	Microscopic count of the actual number of somatic cells in milk. (This system is used to check and verify electronic cell count machines).
Disinfectant	A chemical that kills bacteria and other microorganisms.
Dissolve	To break down a substance in a solution without causing a reaction.
Distillation	The process of separating mixtures by condensing the vapours through cooling.
Distilled water	Distilled water is nearly pure water and is produced by distillation of tap water. Distilled water is preferred in the laboratory because the distillation process removes many of the impurities that may influence the chemical reactions for which the water is used.
Dye	A coloured substance that will stick to another substance so that both appear coloured.
ELISA	Enzyme-Linked Immuno-Sorbent Assay, test used for the detection of antibiotics in milk.
FAO	Food and Agriculture Organization of the United Nations.
Fat	In milk is a complex mixture of triglycerides containing numerous fatty acids. Milk fat is one of the components of milk, which provides the basis for differential pricing of milk. Milk fat also is referred to as butterfat.
Filtrate	The liquid that has passed through a filter.
Filtration	Separation of a liquid from a solid using a membrane with small holes (e.g. filter paper).
Flame	A mixture of gases undergoing burning. A solid or liquid must produce a gas before it can react with oxygen and burn with a flame.
Freezing point	The temperature at which a substance undergoes a phase change from a liquid to a solid. It is the same temperature as the melting point.
g	gram.

Gerber test	Test to determine amount of fat in milk.
Glucose	The most common of the natural sugars ($C_6H_{12}O_6$). It occurs as the polymer known as cellulose, the fibre in plants. Starch is also a form of glucose.
Glycerol	A three-carbon sugar forming the backbone of triglycerides and other fats.
Hydrate	A solid compound in crystalline form that contains water molecules. Hydrates commonly form when a solution of a soluble salt is evaporated.
Hydrous	Hydrated with water.
Indicator (acid-base indicator)	A substance or mixture of substances used to test the acidity or alkalinity of a substance. An indicator changes colour depending on the acidity of the solution being tested. Many indicators are complicated organic substances. Some indicators used in the laboratory include Universal Indicator, litmus, phenolphthalein, methyl orange and bromothymol.
ISO	International Organization for Standardization.
i.u.	International Units.
kg	kilogram.
l	litre.
Laboratory sample	Sample as prepared for sending to the laboratory and intended for inspection or testing.
Lactose	Average milk contains just under 5 percent lactose. Lactose is the sugar in milk. It is converted to lactic acid in sour milk and is used in the production of various cheeses and buttermilk. Little variation in lactose content exists among cows or breeds.
Linear score	Linear scores for somatic cell counts (SCC) convert SCC logarithmically from cells per millilitre to a linear score from 0 to 9. The linear score has a straight line, inverse relationship with milk yield. An increase of one in the linear score is associated with a 400-pound decrease in lactation milk yield or a 1.5-pound drop in daily yield.
Lovibond comparator	Used for the comparison of colours, named after the founder Joseph Lovibond.
m	metre.
Maltodextrins	Linear polymers of glucose molecules, a mixture of glucose, maltose, oligosaccharides, and polysaccharides.
Mastitis	Inflammation of the mammary gland.
mg	milligram.
Milk	The lacteal secretion from one or more dairy animals (from cows, goats, sheep, yaks, buffaloes, camels and mares).
Milk collection	Collection of milk from more than one farmer to a collection point or centre.
Milk composition	Average composition of dairy cow milk includes the following constituents: 87 percent water, 3.5 percent protein, 5 percent sugar (lactose), 3.7 percent fat and 0.8 percent minerals and vitamins.
Milk cooling	Lowers milk temperature to increase keeping time.
Milk hygiene	Making sure milk is clean and safe for consumption.
Milk payment	Either in currency or in kind.
Milk processing	Transformation of raw milk into milk and dairy products.
Milk producer groups	Group consisting of milk producers with, as a main activity, collecting milk from members in order to sell directly, process, cool or transport the milk.
Mixture	A material that can be separated into two or more substances using physical means.
ml	millilitre.

Opaque	A substance that will not transmit light so that it is impossible to see through it. Most solids are opaque.
Organoleptic tests	Tests based on taste, smell or visual observations.
Oxidation	Combination with oxygen or a reaction in which an atom, ion or molecule loses electrons to an oxidising agent. An oxidising agent does not have to contain oxygen. The opposite of oxidation is reduction.
Oxide	A compound that includes oxygen and one other element. *Example:* copper oxide (CuO).
Pasteurisation	Destroying any potential pathogenic germs by heating milk at a minimum of 63 °C for 30 minutes, known as the LTLT (low temperature-longtime) process; or 72 °C for 15-20 seconds, known as HTST (high temperature-shorttime) process.
Petri dish	A shallow glass or plastic dish with a lid.
pH	A measure of the hydrogen ion concentration in a liquid. Neutral is pH 7.0; numbers greater than this are alkaline; smaller numbers are acidic.
Pipette	A long, slender, glass tube used to draw up and then transfer accurately measured amounts of liquid.
Potassium dichromate	A preservative in tablet or granular form used to preserve milk samples for testing.
Preservation	Increasing keeping time of milk.
Preservative	A compound used to stabilize and to prevent decomposition of milk samples sent to laboratories for component analysis.
Protein	A complex chemical substance in milk and other foods, which upon hydrolysis breaks down to amino acids. Protein increases cheese yield and enhances milk flavour.
Raw milk	Milk that has not been treated in any way. Raw milk is not pasteurized, separated, standardized or homogenized.
Reaction	The recombination of two substances using parts of each substance to produce new substances. *Example:* the reactants sodium chloride and sulphuric acid react and recombine to form the products sodium sulphate, chlorine and water.
Reagent	A commonly available substance (reactant) used to create a reaction. Reagents are the chemicals normally kept on chemistry laboratory benches. Many substances called reagents are most commonly used for test purposes.
Reduction	The removal of oxygen from, or the addition of hydrogen to, a compound. The opposite of reduction is oxidation.
Representative sample	A sample of milk obtain by thoroughly mixing or agitating the total quantity of milk produced by a cow. Milk meters are designed to collect automatically a representative sample from the total quantity of milk.
Resazurin	Used as a redox indicator in the reductase test of milk.
Rosalic acid	Red crystalline powder used in the detection of carbonates.
Sampling	Taking representative small amounts of milk for analysis later.
SCC	Somatic Cell Count.
Sediment	Material that settles out at the bottom of the milk when it is still.
SNF	Solids Non Fat, the solids portion of the milk minus the fat component represents about 8.5 to 9.2 percent of the total milk solids e.g. protein, lactose and minerals. Sometimes referred to as non-fat solids.
Solids-Not-Fat (SNF)	See SNF.
Solution	A mixture of a liquid (the solvent) and at least one other substance of lesser abundance (the solute). Mixtures can be separated by physical means, for example, by evaporation and cooling.
Somatic Cell	The Somatic Cell content of milk is composed of 75 percent white blood cells and 25 percent epithelial cells from the secretory tissue of the udder.

Somatic Cell Count	A measurement of the number of somatic cells present in a sample of milk. A high concentration of more than 500,000 somatic cells per millilitre of milk indicates an abnormal condition in the udder.
Tetra-Chloro-Ethane	A non-flammable solvent for fats, oils, waxes, resins, etc.; used in the manufacture of paint and varnish removers, photographic films, lacquers and insecticides.
TS	Total Solids.
USD	United States Dollar ($).
V/V	Volume / Volume.
W/V	Weight / Volume.
Whatman filter	Specific brand of filter papers.
Whey	Watery part remaining after milk has curdled; contains chiefly lactose and whey proteins.
Yoghurt	Fermented milk product, fruit, flavours and sugars may be added. Milk solids content is commonly 15 percent. Most yogurts are high in protein and low in calories.