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Dairy and Food Process and Products Technology

PROF. TRIDIB KUMAR GOSWAMI
AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT
IIT KHARAGPUR

Lecture 41

What is milk pasteurization? milk pasteurization is the process of heating milk (or **milk products**) to a predetermined temperature for a specified period **without** re-contamination during the entire process.

The **predetermined temperature** usually depends on the heat resistance of spoilage microorganism that the pasteurization program is targeting to destroy.

Why **pasteurization is necessary? (1)** There is a public health concern since the public is going to consume the product. Pasteurization kills all the pathogenic bacteria that may cause infections to consumers.

(2) There is need to ensure that the product can keep for longer periods without expensive storage equipment. Pasteurization will eliminate spoilage **bacteria and enzymes** and extend the shelf life of the product.

The amount of heat and the length of time used in pasteurization depends on the **Thermal Death Time** of the target microorganism. The minimum **combination** should target the most resistant **pathogen** such as *Coxiellae burnettii*.

When deriving the thermal death time of any microorganism, the temperature **must remain constant** and holding time is **varied** to kill the specified number of cells.

Thermal death time (D-value) is the duration it takes to kill a certain bacteria at a given temperature.

What is the difference between D-value, Z-value, and F-value?

The decimal reduction time, *D-value*, is the **amount** of time under specified conditions to reduce microbial population by one decimal. This time varies and is dependent on the temperature and the target microorganism. **One decimal reduction** (**1D**) is equivalent to a population **drop** by one log cycle or **90% reduction**.

For example, if the population of microbe 'X' is reduced to 10% by exposing it to 121 °C for 4 seconds. We Denote the D-value of microbe 'X' as **$D_{121°C}$ = 4 seconds.** For spore formers like *Clostridium botulinum*, the treatment should achieve 12 log cycle reduction in original bacterial population.

Z-value is the measure of change in the rate of death **due to** change in temperature. It is the change in temperature required to change the decimal death time by one log cycle or one decimal (1D).

In other words, Z-value is the measure of bacterial sensitivity to heat treatment. It is the change in temperature that will reduce the D-value by a factor of 10. A Z-value can be obtained by plotting two D-vales **against temperature**.

F-value is the **duration it will take** to kill a known bacterial population. It is usually set at 12 log cycles (12D) to kill the **most resistant mesophilic spores** in a food sample.

Different microorganisms have different D-values. However, these D-values follow **a negative slope** when **plotted** on a graph.

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Lecture 42

Thermal death time of microorganisms in food processing: -

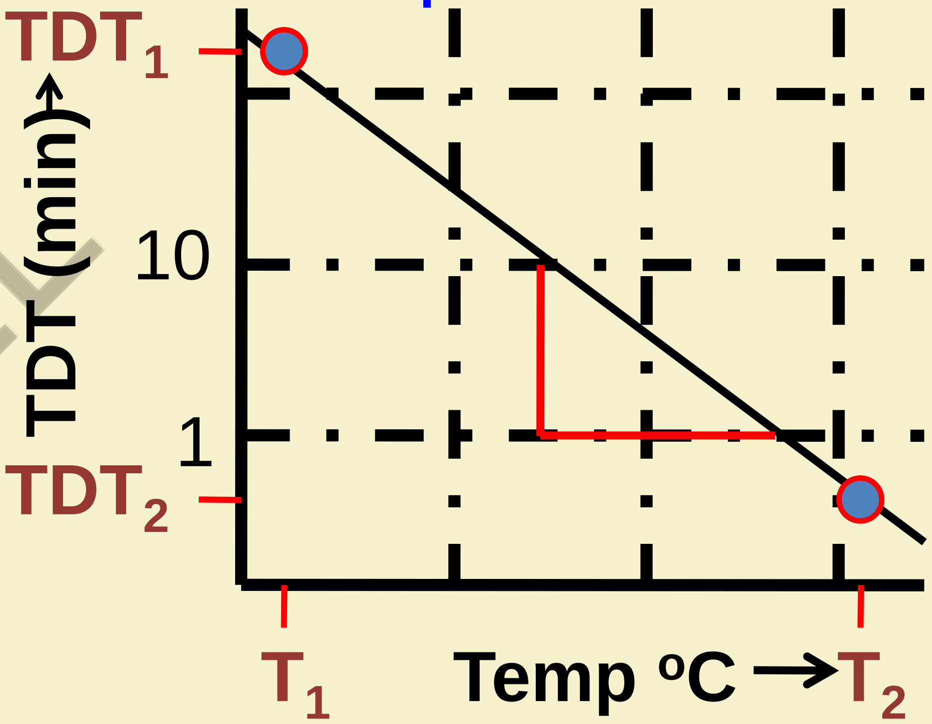
Thermal death time is the minimum time to accomplish a total destruction.

Slope for TDT line is $-\dfrac{\log(TDT)_1 - \log(TDT)_2}{(T_2 - T_1)}$

Slope using z value $-\dfrac{\log(10) - \log(1)}{(z)} = -\dfrac{1}{z}$

$$or,\ \frac{\log(TDT)_1 - \log(TDT)_2}{(T_2 - T_1)} = \frac{1}{z}$$

$$or,\ or,\ \frac{\log(TDT)_1}{\log(TDT)_2} = \frac{(T_2 - T_1)}{z}$$



Replacing TDT with symbol F

$$or, \frac{\log F_1}{\log F_2} = \frac{(T_2 - T_1)}{z}$$

$$or, \log \frac{F_1}{F_2} = \frac{(T_2 - T_1)}{z}; \quad or, \frac{F_1}{F_2} = 10^{=\frac{(T_2 - T_1)}{z}}; \quad or, F_1 = F_2\, 10^{\frac{(T_2 - T_1)}{z}}$$

If we assume F_2 to be the reference temperature, then

$$F_1 = F_{ref}\, 10^{\frac{(Tef\; - T_1)}{z}}$$

F depends on temperature and is specific for a microorganism

Broadly, **pasteurization** can be **categorized** as either **low** or **high** temperature pasteurization **methods**. Both of these can either be batch or continuous processes.

Low temperature pasteurization is majorly concerned with food safety and aims at killing all pathogenic microorganisms and reducing spoilage types in a food sample. Milk that has undergone low temperature pasteurization is suitable for making cheese because it encourages syneresis.

Low temperature pasteurization can assume various temperature / time combinations such as 63 °C / 30 minutes or 72 °C / 15 seconds. Mild heating kills all pathogenic bacteria and reduces the load of spoilage bacteria but preserves most physico-chemical properties of the milk.

On the other hand, **high temperature pasteurization** aims at killing the vegetative pathogenic and spoilage bacteria as well as denaturing as much serum protein as possible. High temperature pasteurized milk is more suitable for making yogurt because Syneresis will not occur. The serum proteins are denatured hence they will not separate.

The choice of the pasteurization method depends on several factors, which may not be limited to:

- Intended purpose of the pasteurized milk,
- Access to sophisticated equipment,
- Volume of milk to be pasteurized,
- Target microorganism, etc

Whatever the case, one can choose to carry out normal pasteurization or ultra pasteurization. Normal pasteurization will preserve milk for about two to three weeks while **ultra pasteurization** will preserve milk for even up to one year.

Different types of thermal processing methods

Thermization: Heat the milk to between 57°C to 68°C and hold for 15 minutes. Thermization targets pathogenic bacteria while leaving the good bacteria in the product. The low temperatures do not alter the **structure** and **taste** of the milk.

Batch pasteurization: Also known as low temperature long time (LTLT) pasteurization. Heat the milk to 63°C for 30 minutes. The extendend holding time causes alteration in the milk protein structure and taste.

Flash pasteurization: also known as high temperature short time (**HTST**) pasteurization. Heat the milk to between 72°C to 74°C for 15 to 20 seconds. Targets **resistant pathogenic bacterial spores** (***Clostridium botulinum*** **spores**).

Ultra-high temperature (UHT) pasteurization: Heat the milk to between 135°C to 140°C for 2 to 4 seconds. The extreme heat targets *Coxiella burnetii*, which causes **Q-fever**. The heat **kills all the vegetative** forms of bacteria and the milk can survive for **9 months**.

Canned sterilization: This is a wet treatment of canned milk products in an autoclave / specialized treatment chambers. Heat to between 115°C to 121°C for **10 to 20** minutes.

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Lecture 43

How to test for the effectiveness of milk pasteurization:-

High temperature pasteurization **denatures peroxidase** enzyme. The **enzyme** is more resistant to heat treatment than all pathogenic microorganisms found in milk. **If** the heat treatment is **sufficient** to denature this enzyme, it is a confirmation that all the pathogenic microorganisms have been killed in the process.

Properly pasteurized milk should, therefore, produce a negative result for peroxidase test.

Alkaline phosphatase may not be **very reliable** because research has shown that it can be **reactivated**, especially if the **pasteurized** milk has **high fat** content.

HTST:-This type of pasteurization is also known as **flash pasteurization**. Flash pasteurization involves heating milk to **71.7°C for 15** seconds to kill ***Coxiella burnetii***, which is the most heat resistant pathogen in raw milk.

Since it is technically impossible to bring the milk to that exact temperature, it is always safe to work with a range of temperatures. To be safe, you can heat the milk to between **72°C to 74°C** for 15 to 20 seconds. This will ensure that the milk is heated uniformly to the required temperature.

This method is most suitable in continuous pasteurization systems.

Flash pasteurized milk will keep for between 16 and 21 days. For commercial reasons, some manufacturers intentionally reduce the number of days to push the products out of the shelves.

A standard milk pasteurization system consists of the following parts:

Balance tank: maintains a constant head for the incoming milk

Milk feed pump: creates suitable pressure that is necessary for efficient flow

Flow control system: ensures that sufficient amount of fluid is in the conduits at any given time

Filters and clarifiers: removes dirt from the products

Homogenizer: divides fat globules into micro globules to avoid fat separation in standing milk

PHE with regeneration, heating, holding and cooling sections: facilitates efficient pasteurization

Flow diversion valves: Ensures that all the conditions for pasteurization have been met before the milk asses through.

Instrumentation and control equipment: Increases system efficiency and reliability

Peripheral sources of utilities such as steam, air, and water: Provides the necessary utilities for heating, cooling, and pressurized environments

Conduits/piping system: Facilitate flow of milk and utilities from one point to the next

Each of the pasteurizer sections has been designed to increase the efficiency of the PHE.

Movement of milk through the PHE for an effective pasteurization:

Chilled milk from the bulk milk tank at 4°C moves into the balance tank from where it is pumped into the regeneration section of the PHE.

At the regenerative heating section of the PHE, chilled milk receives heat from the already pasteurized milk leaving the system. Heat exchange occurs across the PHE plates in a counter current motion of the two fluids of different temperatures (the video below illustrates this motion). The regenerative heating raises the temperature of milk to about 40°C to facilitate easy standardization. Heating then continues to 60°C to facilitate easy homogenization of the fat globules.

After clarification, standardization, and homogenization, milk passes into the heating section where milk exchanges heat with steam across the PHE plates. The steam heats the milk to over 72°C, which is the perfect HTST pasteurization condition.

Once the milk has attained the pasteurization temperatures, it moves into the holding tubes. The length of these tubes have been calibrated with the flow rate to ensure that the milk stays at that temperature for at least 16 seconds. This time is sufficient to destroy the target pathogen according to the D-values.

If the milk fails to attain the required temperatures, the flow diversion valve diverts its flow back to the heating section to ensure that the temperatures are sufficient to kill all the target pathogens and their spores.

Once the milk is fully pasteurized, it moves back to the regenerative heating section to raise the temperatures of the incoming chilled milk. In the process, the temperatures of the outbound pasteurized milk drops to about 32°C.

The pasteurized milk then moves to the cooling section of the pasteurizer where chilled water (or PHE coolant) further lowers its temperatures to 4°C.

Advantages of regenerative heating

Utilization of the incoming chilled milk to cool the outgoing hot pasteurized milk increases the efficiency of the PHE.

A smaller amount of heat energy is required to heat the milk to pasteurization temperatures since the heating does not start from 4°C of the chilled milk.

Reduces the amount of time required to pasteurize milk.

Note: When starting the process of pasteurization in the PHE, milk is circulated in the heating section until it attains the required temperatures before regenerative heating begins.

Low Temperature Long Time (LTLT) pasteurization:-

Here, the temperatures used for pasteurization are reduced to 63°C and held for 30 minutes. The prolonged holding period alters the structure of the milk proteins making it better suited for making yogurt.

This method is best for batch pasteurization where the milk is held in a jacketed vat for effective pasteurization. There are many designs of batch pasteurizers in the market that are suitable for both domestic and commercial use.

let us look at some of the best batch pasteurizers for home use. We'll also review an ice cream mix / cream pasteurizer that is capable for commercial use.

Ultra High Temperature (UHT) Pasteurization:-

This is a completely closed pasteurization method. The product is never exposed even for a fraction of a second during the entire process.

It involves heating milk or cream to between 135°C to 150°C for one to two seconds, then chilling it immediately and aseptically packaging it in a hermetic (air-tight) container for storage.

UHT milk can keep for nine months without refrigeration.

Despite the risk of Millard browning, UHT pasteurization remains the most popular milk preservation method for safe and stable milk.

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Lecture 44

Disadvantages of high temperature pasteurization

There is a possibility of alteration of milk proteins. This can affect the properties of such milk when used to make other food products.

High temperatures inactivate the enzymes that protect the product increasing the risk of spoilage.

Elevated temperatures cause **Maillard reaction**, which discolors the product making it undesirable to consumers.

High temperatures alter the protein structure and imparts a cooked flavor to the milk.

- **Browning:**
  - **Fruits and vegetables**

- Enzymatic
- Non-enzymatic

Oxidation of phenolic compounds

Sensory properties
- Color
- Flavor

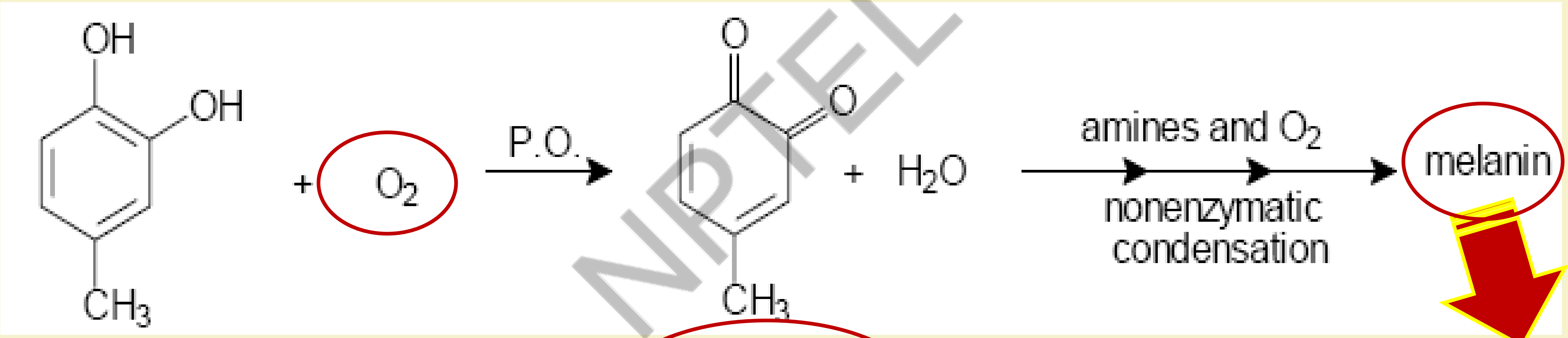
Bad

Good

Polyphenoloxidase (PPO): Enzyme that catalyze browning reaction

- **Examples: Apples, avocados, lettuce, potatoes**

The reaction:



4-methyl-catechol

Quinones

Soluble or Insoluble brown polymers

M
AI
LL
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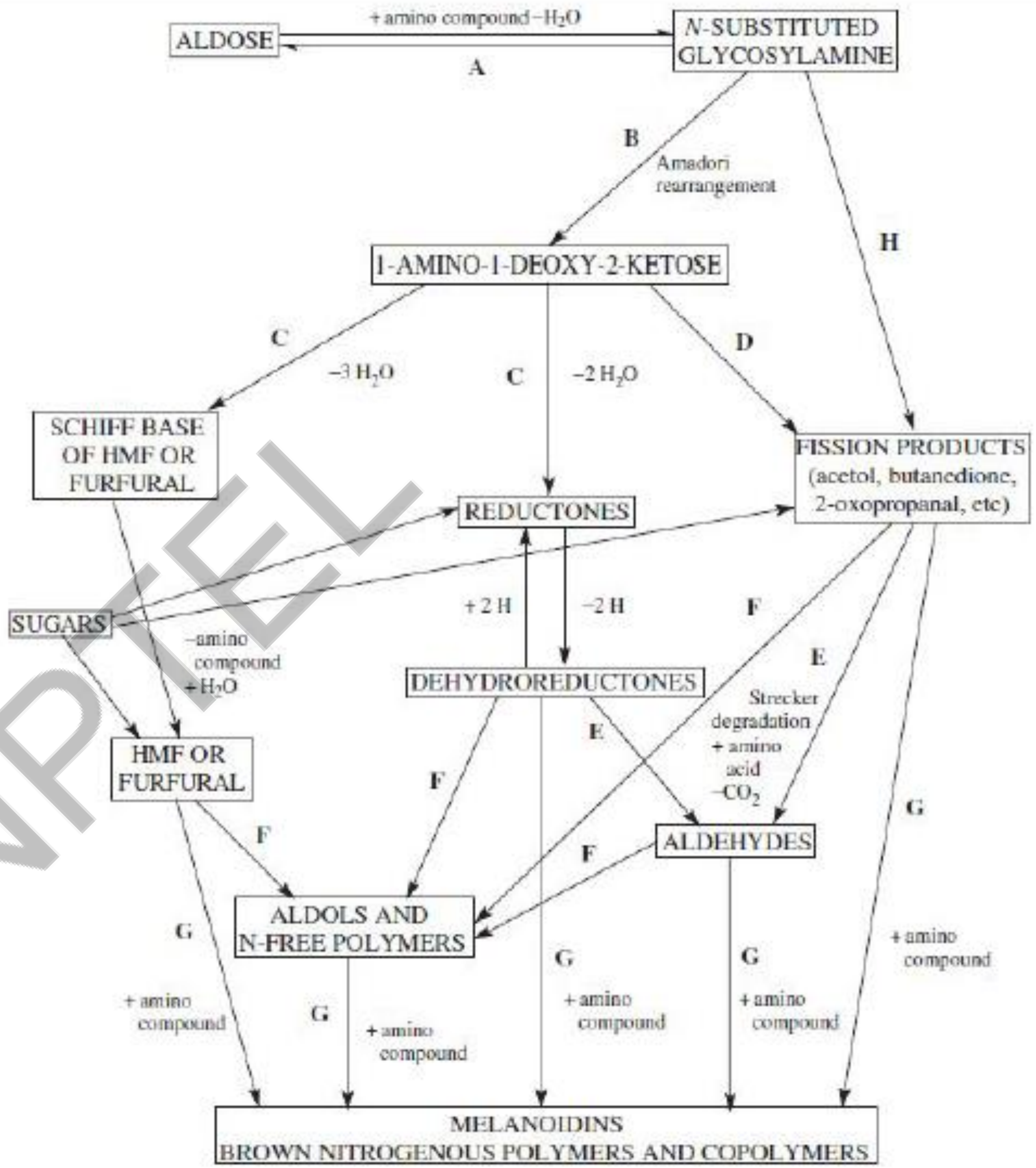
Maillard reaction – general schema

Preconditions and participating compounds -complexity:

glucose-glycine – more than 24 products found;

xylose-glycine – more than 50 products found.



According to:
J. E. Hodge, Chemistry of browning reactions in model systems, J. Agric. Food Chem.,1953, 1, 928–943.

Application of high temperature pasteurization

Pasteurizing fluid milk

You can heat the milk to 63° C for not less than 30 minutes (low temperature long time pasteurization). Alternatively, heat the milk to 72° C for not less than 16 sec (high temperature short time pasteurization) or equivalent.

These temperature-time combinations have been proven to be sufficient for the destruction of pathogens and the enzyme phosphatase. A negative test result for the alkaline phosphatase test confirms the efficacy of pasteurization.

Frozen dairy dessert mix pasteurization

Very many frozen dairy products exist in the market. When pasteurizing ice cream or ice milk, heat the product to at least 69° C for not less than 30 min or 80° C for not less than 25 sec. Any other time-temperature combinations must be approved (e.g. 83° C/16 sec).

Pasteurization of enriched milk products

Milk based products with 10% butterfat or higher, or added sugar (e.g. cream, chocolate milk, etc) should be heated to 66° C/30 min or 75° C/16 sec for effective pasteurization.

Objectives of milk pasteurization

The chief objective of milk pasteurization is to destroy pathogenic bacteria that could have a public health concern. By destroying these microorganisms, the product becomes safe for public consumption.

Secondly, pasteurization eliminates destructive bacteria and enzymes that could cause spoilage of the product. This leads to a prolonged shelf life of the milk.

Pasteurized milk is commercially sterile, which means that they are not entirely rid of bacteria. One should compound their preservation with another method (usually refrigeration).

In modern milk processing plants, the PHE is connected to a separator and a homogenizer in the same line. The milk separators help in butter fat standardization while the homogenizer breaks down fat globules into tiny microglobules that remain suspended throughout the milk. It prevents formation of cream layer when the milk is left standing for long.

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Lecture 45

Steps of pasteurization

Before you begin pasteurization, chances are high that you will be bulking milk to attain an economically viable volume. Milk being a highly perishable product, it requires extreme care to avoid incurring losses. For this reason, it is necessary to chill the milk to avoid spoilage.

a). Milk chilling

Chilling is not a pasteurization process but it is a necessary step when dealing with large volumes of milk. Milk leaves the cow's udder at temperatures above the ambient, which encourages rapid bacterial multiplication that speeds up spoilage.

However, reducing the temperatures to between 2° C to 5° C arrests bacterial growth and metabolism. This provides a head start at keeping the quality before proper pasteurization commences.

Chilling may affect the quality of the product negatively if it is kept for long. Psychrotrophic bacteria will cause proteolysis of protein, which leads to bitter flavor attributed to the released polypeptides.

Prolonged chilling introduces alterations to the structure of the casein micelles and increases the coagulation time. This leads to formation of less firmer curd and consequently low quality cheese.

Effects of chilling on milk

Impeding rennet/acid coagulation:

Lowering the temperatures to 2°C causes the milk not to coagulate even after rennet/acid treatment. This phenomenon has been utilized in continuous cheese making process in which the temperatures are raised after addition of acid/rennet. Coagulation begins when the temperatures reach 15°C to 30°C.

No coagulation of milk at isoelectric point:

Even after adjusting the pH of casein to isoelectric point (IP), the milk will not coagulate if its temperature ranges between 2°C and 5°C.

Low temperatures encourage the formation of many diffusible inorganic salts that distorts the micellar structure of casein leading to formation of more non-micellar (soluble) casein.

Consequently, one you have to lower the pH of the medium further to achieve complete coagulation. However, acid coagulation leads to formation of a less rubbery coagulum.

Chilling increases viscosity of milk:

Viscosity of milk largely depends on its colloidal components, of which proteins forms the bulky part. Chilling changes the structure of milk proteins leading to an increase in their bulk hence the increase in milk viscosity at chilled temperatures.

Chilling decreases in cheese curd firmness:

Milk chilling affects the ratio of calcium:phosphate hence their interaction in the colloid solution. A drop in this ratio leads to an increase in the duration it takes for the milk to coagulate. To counter this problem, add calcium chloride to cheese milk before cold aging starts.

Increases hydrolytic rancidity in milk:

Chilling exposes the casein micelle and release the lipases into the medium. As the temperatures rise gently or when the medium is gently agitated, the lipases get active and attack the fat globules and release the fatty acids leading to rancidity.

Increases foaming in milk:

Chilled milk foams easily due to the increased activity of ß-lactoglobulin, which is a surfactant. Milk proteins coalesce at the surfaces/lamellae of the protein, which also traps air leading to formation of air bubbles.

Chilling leads to an increased clustering of fat

Chilling milk encourages change formation in the surface of fat globules, which encourages the globules to stick together. The clustering of fat globules leads to an increased creaming rate in cold milk.

Pre-heating (regeneration) and standardization stage

After bulking, the chilled milk is heated to about 40°C to facilitate easy separation of butter fat during standardization.

The system uses regenerative heating, i.e., it uses the heat of the already pasteurized milk to heat up the incoming chilled milk. The chilled milk, in a counter current flow, cools down the pasteurized milk.

The purpose of standardization is to obtain a product with uniform content of butter fat. Different products can be obtained from this process e.g. skimmed milk, standardized milk, low fat milk, high fat milk, etc.

After determining the type of product you are making, you can use a computer program or any standardization method to determine the amount of cream to separate. This will leave you with the desired amount of butterfat to standardize the milk.

c). Clarification stage

Clarification is essential for removing all foreign matter from the product. Large solid particles are removed by straining the milk through tubular metallic filters. A centrifugal clarifier (not the one used for standardization) is used to remove all soil and sediments from milk.

The filters, usually fitted in parallel twins permits continuous processing as one can be cleaned while the other is running. Clean the filters regularly (between 2 to 10 operational hours depending on the level dirt) to avoid growth of bacteria.

Standardization stage

It is important to standardize milk fat to ensure that you end up with a product of consistent quality in the market. Different consumers prefer different products.

There are customers who will consume skim milk only while there are those who will take low fat milk. There are those who will take standardized milk while there are those who prefer high fat milk.

Standardization is necessary to ensure that all the customers are catered for. Again, it is during the process of standardization that you get to separate the butterfat that is used for making cream and other fat based products such as butter and ghee.

Types Of Cream: Their Uses And How To Make Each:-

Cream is a rich fat-based dairy product that you obtain by skimming milk with 4% fat content. Different types of cream depend on the type of separation/cream concentration used. After separating the cream, concentrate it to 10% – 75% fat content depending on your intended purpose. On the average, most creams have about 40% fat content.

Cream is a rich fat-based dairy product that you obtain by skimming milk with 4% fat content.

You can also obtain cream from milk by scalding, i.e. warming the milk and separating the fat as it rises to the top.

After separation, cool the cream to below 5°C to avoid spoilage by inherent enzymes such as lipases. Concentrating the cream causes rapturing of the fat globule membrane (FGM), which facilitates an easier access to the fat nucleus.

In addition to preventing spoilage, cooling also slows down the microbial growth, which minimizes spoilage considerably. Again, cooling avoids oiling off. The butterfat at the center of the globules are liquid, which oozes out during separation.

Generally, you can use different types of cream for the following purposes:- Consumptions as:

Manufacturing butter and ghee.

Used in the confectionery industry.

Standardizing other products (recombined milk).

Manufacturing butter oil and ice cream.

Categories / types of cream

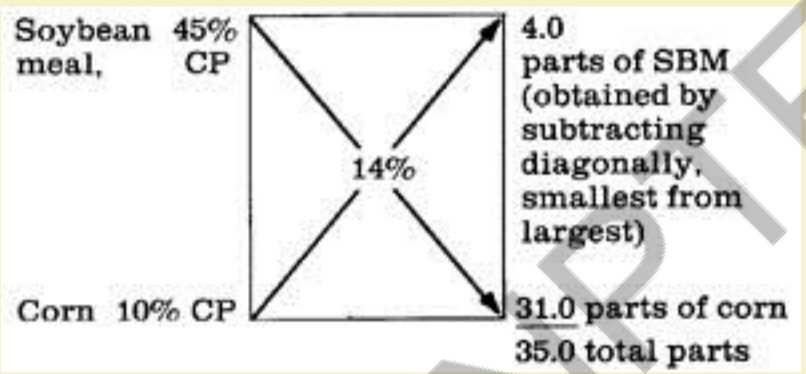
The fat content of the cream determines the category of the cream. They include:

Half cream, *minimum fat content of 12%*

Single cream, *minimum fat content of 18%*

Whipped cream, *minimum fat content of 35%*
Double cream, *minimum fat content of 48%*
Plastic/clotted cream, *minimum fat content of 55%*

Milk Standardization: How to Use the Pearson's Square Method



To use **Pearson's Square**: 1. Subtract the nutrient requirement (middle of **square**) from the nutrient concentration (on left of **square**) in the feed across the diagonal (top left – middle = bottom right; bottom left – middle = top right). Repeat this for both feeds.

Milk standardization is important in the dairy industry because it is used to ensure that every consumer gets milk with constant fat content and consistency. Primarily, milk may be separated into two products; cream with high fat content (about 40% fat) and skimmed milk (about 0.03% fat) using a centrifugal separator.

The process of standardization involves reduction of fat content in milk from the natural minimum of 3.25%. The cream extracted from the standardization process facilitates processing of other dairy products such as ice cream, butter, and **ghee**.

Milk standardization can take two forms i.e. either partial separation or mixing of skimmed and whole milk. Mass balancing plays a key role in successful standardization of milk.

Example 1

2000 kg of milk (with 87.6% water, 3.8% fat, 3.2% protein, 4.6% lactose, and 0.7% ash content) has to be reduced in fat content from 3.8% to 2.5% by removal of cream with 40% fat content from the milk. How much milk will have to be removed?

Solution.

TM Balance: $2000 = C + M$ [C – Cream; M – Milk]

MF Balance: $2000 \times 0.038 = 0.4 \times C + 0.025 \times M$

2000 X 0.025 = 0.025 X C + 0.025 X M; C – cream & M - Milk
Solving the equations will give the values of C = 69.3 kg and the remaining milk M = 1930.7 kg.

Example 2

If 3000 kg of the same milk used in the previous example is separated into cream with 45% fat and skimmed milk with 0.05% fat, how much cream and skimmed milk are expected assuming no losses?

Solution

TMB: 3000 = C + M

FMB: 3000 X 0.038 = 0.45 X C + 0.0.0005 X S

Solving the equations will give C = 250.3 kg and S = 2749.7 kg

Thank You!!