Unit V - Topic 5

Condensed Milk – Milk Powder Manufacturing – Drying Equipment -Drum Drier And Spray Drier

Introduction

Condensed milk is a milk product obtained by evaporating part of water of whole milk, or fully or partly skimmed milk, with or without the addition of sugar. They are intended for use as such or for pre-condensing the fluid milk or fluid milk by–product preparatory to the manufacture of dried milk products.

The term 'condensed milk' is commonly used when referring to full cream sweetened condensed milk whereas the term evaporated milk is generally used while referring to full cream unsweetened condensed skim milk. Skimmed milk products are known as sweetened condensed skim and unsweetened condensed skim milk respectively.

6.2 Sweetened Condensed Milks

Sweetened condensed milks are milk products which can be obtained by the partial removal of water from milk with the addition of sugar, or by any other process which leads to a product of the same composition and characteristics. The fat and/or protein content of the milk may have been adjusted, only to comply with the compositional requirements by the addition and/or withdrawal of milk constituents in such a way as not to alter the whey protein to casein ratio of the milk being adjusted.

It may sometimes contain added refined lactose, calcium chloride, citric acid and sodium citrate, sodium salts of orthophosphoric acid and polyphosphoric acid not exceeding 0.3 per cent by weight of the finished product.

Such kind of addition need not be declared on the label. Sweetened condensed milk should contain not less than 9.0 percent milk fat, and not less than 31 per cent milk solids and 40.0 per cent cane sugar.

They may be

1. Sweetened condensed milk

2. Sweetened condensed skimmed milk

3. Sweetened condensed partly skimmed milk

4. Sweetened condensed high-fat milk

6.3 Evaporated Milks

Evaporated milks are milk products which can be obtained by the partial removal of water from milk by heat, or by any other process which leads to a product of the same composition and characteristics. The fat and/or protein content of the milk may have been adjusted, only to comply with the compositional requirements by the addition and/or withdrawal of milk constituents in such a way as not to alter the whey protein to casein ratio of the milk being adjusted.

It may contain added calcium chloride, citric acid and sodium citrate, sodium salts of orthophosphoric acid and polyphosphoric acid not exceeding 0.3 per cent by weight of the finished product. Such addition need not be declared on the label. Unsweetened condensed milk should contain not less than 8.0 percent milk fat, and not less than 26 per cent milk solids.

They may be

1. Evaporated milk
2. Evaporated skim milk
3. Evaporated partly skimmed milk
4. Evaporated high-fat milk
5. Evaporated Filled Milk : Evaporated filled milk is a prepared blend of skim milk, vegetable oil, stabilizers and vitamins.

Because of its concentrated form, evaporated milk is a multipurpose, convenient dairy product ready for every milk use. Pouring directly from the can, evaporated milk can be used in countless applications: creaming coffee or tea, poured on cereals and fruits, providing consistency in meat patties and loaves, coatings for baked or fried meats, or in place of milk in the manufacture of candies, frostings and pies.

6.4 Advantage of Condensing Milk in Vacuum

The chief advantages of condensing milk in vacuum over evaporation under atmospheric pressure are three fold. They are

1. Economy of operation

The total heat units expended when condensing in vacuum pan at the usual temperature of about 55 to 60°C are slightly greater than the total heat units required for evaporation under atmospheric pressure. There is no saving in total heat units due to evaporation under reduced pressure. However evaporation in vacuum has the distinct advantage of making possible the economical utilization of steam at low temperature and of exhaust steam. Hence where exhaust steam is available there is opportunity for a considerable saving in fuel by its use.

The fact that under reduced pressure milk boils at relatively low temp (55 to 60°C) makes possible the use of low pressure steam such as exhaust steam, without sacrificing the rapidity of evaporation. This assists in saving fuel and reduces operating cost. In short, it helps reutilization of steam used in condensing and adoption of double and triple system of condensing. Other advantages are:

- About 90% of the water contained in the milk is removed in the evaporator and only 10% in the spray dryer. However, the energy required per Kg water evaporated in the spray dryer is 16-20 times the energy required per Kg water removed in the evaporator.
- In absolute terms, the energy consumption of the dryer is approximately twice that of the evaporator if a six effect evaporator is used. If a 4 effect evaporator is used the energy consumption of the evaporator and the dryer will be approximately the same. The above illustrates that although only 10 % of the water is removed in the dryer, this should not lead to the assumption that the efficiency of the dryer is of minor importance.

- In an effort to improve the overall efficiency of the process, the tendency has been to concentrate the milk as much as possible prior to drying. The importance of such tendency is illustrated by the fact that if for a given milk throughput, the evaporator concentration falls from 50 to 48%, the dryer evaporative load is increased by 8.7%, while if the evaporator concentrations increases to 52% the dryer load is reduced by 7.5%. Since, the energy supplied to the dryer is about 60% of the total required for drying process; these variations have a marked effect on the overall economy.
- In modern plants, skim and whole milks are concentrated to 48-50 % solids and whey to 55-60 %.
- In view of the above, it has been suggested that evaporators and dryers should be developed that can handle milk of higher total solids. However, the use of higher concentrations is not an engineering problem related to the design of evaporators and dryers, it is a technological problem.

2. Rapidity of evaporation

The fundamental factor that determines the rapidity of evaporation is the rate of heat transmission or the amount of heat transmitted by the steam to milk per unit area of heating surface per hour. The rapidity of heat transmission in turn depends largely upon the temperature difference between steam and milk. The greater the difference, the more heat is transmitted. The rapidity of evaporation also depends upon surface area available and viscosity of the product. The rapidity of evaporation is necessary:

(1) To check the growth of microorganisms that may have survived higher heat treatment.

(2) To have economy of evaporation.

(3) To protect the milk against heat damage.

3. Protection of milk against heat damage during operation

Condensing in vacuum pan makes possible evaporation at a relatively low temperature (55 to 60°C). With present evaporating equipment, milk temperature of 52 to 57°C is usually maintained. Exposure to high evaporating temperatures hampers the quality. The low boiling point saves the milk from heat damage.

In addition, it widens the gap between temperature of steam and milk, so steam of low pressure and hence of low temperature, protects the milk from a shock from heating surface which would have been the case in atmospheric pressure.

POWDERED MILK:

Milk destined for the production of powder must be of high chemical, organoleptical, and bacteriological quality. Acidity of milk must be below 0.15% (expressed as lactic acid), otherwise the solubility of the milk powder is reduced. Stored raw milk is not good even when it is kept under refrigerated conditions because it may lead to an increase in free fatty acidy in the resultant dried milk causing many fold increase in lipolysis in the powder produced from such milk. High bacterial counts increase the susceptibility of fat to oxidation during storage of the powder. Oxidation of milk fat reduces the shelf life of the resulting milk powder. Fat oxidation is accelerated by the presence of metals such as copper or iron. Care must be taken that all equipments,pipelines and accessories coming into contact with milk and cleaning solutions are made of stainless steel exclusively.

The basic operations in milk powder production consists of receiving and selecting milk, filtration/clarification, cream separation/standardization, preheat treatment, condensing, homogenisation, drying, packaging and storing of powder. Production of skim milk powder differs slightly from whole milk powder production.

i. Standadization

The objective of standardization is to adjust the ratio of milk fat and total solids to the level required in the final product. Production of skim milk powder differs slightly from whole milk powder production. For skim milk powder, it is necessary to reduce fat in skim milk to less than 0.1%.

ii. Preheat Treatment

The preheating of milk before condensing in the manufacture of dried milks is done for the production of safe and better stable milk powders and also for inducing in it other desirable attributes. Pasteurization at 72oC for 15 s is sufficient to address the safety requirements associated with processing of raw milk, though, higher temperatures and longer holding times may be necessary to meet requirements relating to ther moduric pathogens and specific food spoilage organisms. For milk powder solubility, which mostly depends on the state of the milk protein system, the high temperature short time (HTST) regime is more convenient when compared to prolonged thermal treatment at low temperatures, and has the same microbiological effect. The temperature most frequently used is in the range of 88-95oC for 15-30 sec. HTST regimes with direct or indirect heating are also used with temperatures ranging up to 130oC.

Preheat treatment contributes significantly to the shelf life of dried milks (e.g. whole milk powder) primarily through development of antioxidant or reducing substances.The formation of reactive or free sulphydryl groups, resulting from the heat treatment of milk, are responsible for preventing oxidized flavour development by acting as free radical scavengers, and thus as antioxidants. Products of Maillard reactions also contribute to the overall antioxidant effect in milk powders.

Milk may be heat-treated at temperatures to achieve various levels and types of protein denaturation, according to final product requirements. Skim milk powder is commonly graded according to the amount of undenatured whey protein nitrogen present in non-fat milk solids expressed by the whey protein nitrogen index (WPNI), which is defined as the amount of undenatured whey protein nitrogen measured in mg/g powder. Table 14.1 shows the heat classifications for skim milk powders as was introduced by the American Dry Milk Institute (ADMI) in 1971.

Class of powder	WPN Index (mg/g powder)	Typical heat treatment conditions for milk
Low heat	Not less than 6.0	75°C, 20 s
Medium heat	Above 1.5, but below 6	85 -105°C, 1-2 min
High heat	Not more than 1.5	120-135°C, 2-3min

Heat classification of skim milk powders and associated heat treatmet

iii. Condensing

For spray drying, the milk is concentrated in multiple effect evaporators to 40-50 % total solids. For roller drying, the milk is concentrated to 18% total solids. Further concentration for spray drying would increase viscosity and cause difficulties during atomisation of the milk. During roller drying, a higher concentration of milk would form a thicker layer on the rollers, followed by inhibited drying and intensive irreversible changes to proteins, lactose and fat. Evaporators use much lesser thermal energy than driers for removal of equivalent amount of moisture from milk.

iv. Homogenization

Homogenization is not an obligatory operation in milk powder manufacture, but is usually applied to decrease free fat content. Higher free fat content in powder is,however, demanded in certain confections. Homogenization also helps to prevent clumping of fat during reconstitution and improves the keeping quality of powder.Homogenization is conducted after evaporation, or in partly concentrated milk, the concentration rate being not more than 3:1. At higher concentration, homogenization destabilizes milk proteins, thus decreasing powder solubility. The customary homogenization is 2500 to 3000 psi at 62.8 to 76.7oC.

v. Drying

Though a number of drying systems are available, practically only spray drying and roller drying are commercially used in dairy industry. Since the product quality and process economy are much better and are being constantly improved, spray drying has the highest potential today and in the foreseeable future.

Drum Drying

The drum dryer is an indirect type dryer in which the milk to be dried is maintained in a thin film on a rotating steam heated drum. The milk being dried is spread over the outside surface of the dryer. Clinging to it and drying continues as the hot drum rotates. At the end of a revolution, the drum comes to a ‘doctor blade’ which scrapes the dried film from the drum, when the product has made about three-quarter of a complete rotation on the drum surface. The process is also known as roller drying or film drying. Drum drying requires less space and is more economical than spray dryers for small volumes. The ratio of steam consumption to water evaporation is from 1.2 to 1.6:1. The major disadvantages are that the product may have a scorched flavour, and solubility is much lower (85%) because of protein denaturation.

12.2.1 Classification of drum dryers

The drum dryers may be classified according to:

1. Number of drums (a) single drum, (b) double drum, or (c) twin drum.
2. Pressure surrounding the product (a) atmospheric, and (b) vacuum.
3. Feeding arrangement: (a) nip feed, (b) splash feed, (c) dip feed or (d) roller feed.
4. Material of construction: (a) alloy steel, (b) stainless steel, or (c) chrome, or nickel plate steel Fig. 12.1; 12.2; 12.3; 12.4; 12.5; 12.6; & 12.7 shows different types of drum dryers and their feed mechanisms.

12.2.2 Construction of drum dryers

The double drum atmospheric dryer is most commonly used in the dairy industry (Fig. 12.1). Liquid is fed at about 70 ºC from a trough or perforated pipe into a pool in the space above and between the two rolls. Heat is transferred by conduction to the liquid, which is partly concentrated in the space between the rolls. Subsequently, all the liquid is vapourized as the drum turn, leaving a thin layer of dried product which is scraped off by doctor blades into conveyor below.

Water vapour above the dryer has a lower density than the air surrounding the unit, and will rise. Vaporized moisture is removed through a vapour hood above the drums. The lower edge of the hood is formed into a trough to drain away moisture which may accumulate because of condensation. Adequate air flow must be over the drum surface to carry away moisture.

The different feeding arrangements are shown in Fig: 12.2 . Dip feed is the most simplest type of feed, suitable for materials with a high rate of sedimentation. Dip feed is used for certain suspensions of solids, usually with recirculation of material in the tray. Roller feed is suitable for glutinous materials such as starch. The product may be placed in its natural form or condensed before it is fed to the dryer. Milk is usually precondensed (not more than 30%) for single drum units, and preheated for double drums.
The doctor blade, a sharp hard flexible knife, scrapes the dried material from the drum. The blades are made of spring steel if the surface of the drum is hard and for soft drum bronze is used. The blades are positioned at an angle of 15 to 30º with the surface. The conveyor for each drum discharges the product into for sizing the dried product.

The inside of drum is heated with steam at 3-6 kg/cm2. Drum temperatures of below 130 ºC is suggested, as the product temperature approaches the temperature of the steam. The drums used are 60 to 120 cm in diameter, and upto 360 cm in length. Drums are carefully machined, inside and outside, otherwise a difference in thickness will change heat transfer rate and drying will not be uniform. The speed of the drums is adjustable from 6 to 24 rpm. The speed is important as it affects the thickness of milk film and the time of solid contact with metal. The speed of the drum depends upon the concentration of the milk and the final moisture content. Both drums turn at the same speed.

The time that the solid is in contact with metal is 3 s or less. The product is removed after 3/4 to 7/8 of a revolution of the drum has taken place. The thickness of the film is quite critical in controlling the operation. It is important that the material be spread evenly over the drum in order to have a uniform product. The surface tension and the rheological properties of the material controls this.

The spacing between the drum affects the film thickness. One drum of a double drum dryer is mounted on a stationary bearing and the other on a movable bearing to adjust the spacing between the drums. The spacing between the drums is about 0.5 to 1.0 mm. If the clearance is below this, there will be product damage.

As the heat is removed from steam, it is condensed. The condensate moves to the bottom of the drum and must be removed by a pump or siphon. Flooding of the inside with condensate reduces the heat transfer rate. The drying capacity is proportional to the active drum area.

Fig. 12.1 Twin drum dryer

Fig. 12.2 Roller dryers with (a) dip feed (b) application by roller and (c)thin layer application with dip feed roller and transfer roller

Fig. 12.3 Twin roller dryer with spray film feed

Fig. 12.4 Single roller dryer with feed rollers fitted on top

Fig. 12.5 Twin roller dryer with reservoir

Fig. 12.6 Steam inlet in to drum for heating and the condensate discharge in roller driers

Fig. 12.7 Roller dryer with fluidized bed

12.2.3 Rate of evaporation in drum dryers

The rate of moisture removal by a drum dryer is essentially a constant rate of water evaporation as the product is continuously fed between the drums and the dried product is removed. The equation governing the rate of evaporation in a drum dryer is:

Where, = ts - ta
latent heat of vaporization.
the mean temperature difference between the roller surface and the product.

The overall coefficient is from 1000 to 1800 kcal/hr m2 c under optimum condition, although it may be only 1/10th of these values when conditions are adversed. Since the thickness of drum wall is small compared to the diameter of the drum, the area A can be regarded simply as the outer surface area of the drum. The U depends on hs , k and hp and other coefficients.

Where, hs : equivalent film coefficient of steam, Kcal/ hr m2c

x: thickness of metal , m
k : thermal conductivity of metal, kcal/ m hr c
hp : equivalent film coefficient of product
hc : convection coefficient
hr: radiation coefficient
he : evaporation film coefficient

The factor having the greatest effect on U is the condition of the liquid film and the drum speed. Drying rates for drum dryers can be extremely high when thin film of low viscosity is evaporated, and it is thus permissible to use high temperature. In addition to assuring the adequate heat transfer the drying system must provide for removal of water vapour. If the speed of a particular drum is measured, then the U value and the moisture content of the product will be increased, if the conditions are unchanged. The overall thermal efficiency of drum dryer is 35 – 80 %.
The moisture content x of a milk product containing mw amount of water and ms amount of dry matter including fat is given by:

The proportion of dry matter (TS) is given by :

During the evaporation of a product from the original moisture content x0 containing amount of water mwo to a final moisture content x containing an amount of water mw, the following amount is removed.

Calculated as a fraction of the water originally present, the following is obtained:

12.3 Spray Drying

Spray drying is the transformation of feed from a fluid state into a dried particle form by spraying the feed into a hot drying medium. Spray drying is considered to be one of the best methods for drying of food materials. This method is applied to fluids of high moisture content and high viscosity or of a slightly paste like character. The major advantages of spray drying are:

(i) High production rate
(ii) Gentle drying
(iii) Short drying period
(iv) Superior flavour, appearance, and solubility of product
(v) Continuous single step operation
(vi) Uniform product
(vii) Plant can be easily automated
(viii) No product contamination
(ix) High thermal efficiency

A conventional spray dryer consists of the following main components **(Fig. 12.8)**

(1) Drying chamber
(2) Hot air system and air distribution
(3) Feed system
(4) Atomizing device
(5) Powder separation system
(6) Pneumatic conveying and cooling system
(7) Fluid bed after-drying/cooling
(8) Instrumentation and automation

In a spray dryer, the milk is pumped to a nozzle or rotary valve disc atomizer which sprays the feed in fine droplets into a drying chamber. The droplets are subject to a stream of hot air flowing either counter-currently or cocurrently in relation to the falling droplets. Thereby, the droplets of milk are dried so the dry matter remains as powder particles, which fall down towards the bottom of the chamber from where it is removed more or less continuously, as shown in the Fig. 12.8. On account of the large liquid surface created by atomization, the evaporation takes place very quickly, usually at a very low temperature, irrespective of whether drying air of a very high temperature is used. The hot air applies heat to the droplets and carry away the vapour evolved. The temperature of the milk droplets is kept down to the wet bulb temperature and does not exceed the calculated value of 49-54 ºC. The **(Fig. 12.9)** shows heat recuperate type air-liquid-air, while Fig-12.10 shows single stage spray dryer with heat recuperator type air-liquid-air., **(**shows animation of condensing and drying plant.

Fig-12.10 Single stage spray dryer with heat recuperator type air-liquid-air.

The spray dryer consists of mainly four components:

1. Heating of the drying air: air heaters with accompanying fans, air filters dampers and ducts.
2. Atomization of feed into a spray: atomizer with feed supply system of pumps, tanks and feed pretreatment equipment
3. Contacting of air and sprays and drying of sprays: drying chamber with air disperser, product and exhaust air outlets.
4. Recovery of dried products and final air cleaning: complete product recovery with product discharge, transport and packing, air exhaust system with fans, wet scrubbers, damper and duct.

12.4 Classification of Spray Dryers

Spray dryers are mainly classified according to:

1. Method of atomization:(a) pressure atomization (b) centrifugal atomization, (c) pneumatic atomization
2. Method of heating air (a) steam (b) furnace oil, (c) electricity
3. Position of drying chamber (a) vertical (b) horizontal
4. Direction of air flow in relation to product flow (a) counter current (b) co current (c) mixed current
5. Pressure in dryer (a) atmospheric (b) vacuum
6. Shape of the bottom of the chamber (a) flat bottom (b) conical bottom