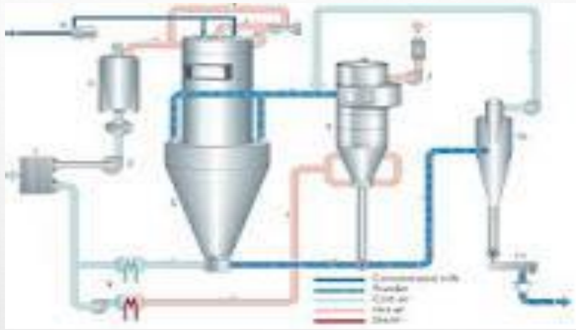
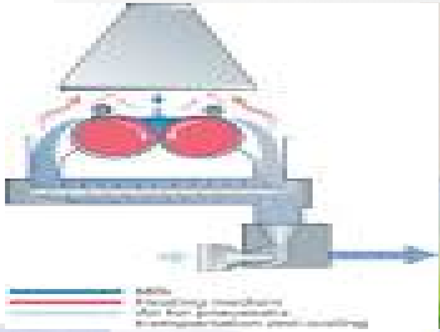
COURSE TITLE: FOOD AND INDUSTRIAL MICROBIOLOGY
COURSE NO. - DTM-321: CREDIT HRS-3 (2+1)

MICROBIOLOGY OF MILK POWDER

RAKESH KUMAR
ASSOCIATE PROFESSOR (DAIRY MICROBIOLOGY)
FACULTY OF DAIRY TECHNOLOGY
S.G.I.D.T., BVC CAMPUS,
P.O.- BVC, DIST.-PATNA-800014





Milk powder – Desiccated form of milk
Degree of concentration – Nearly whole of the moisture removed
Product – Less perishable, less space for packaging and storage and transportation is easier

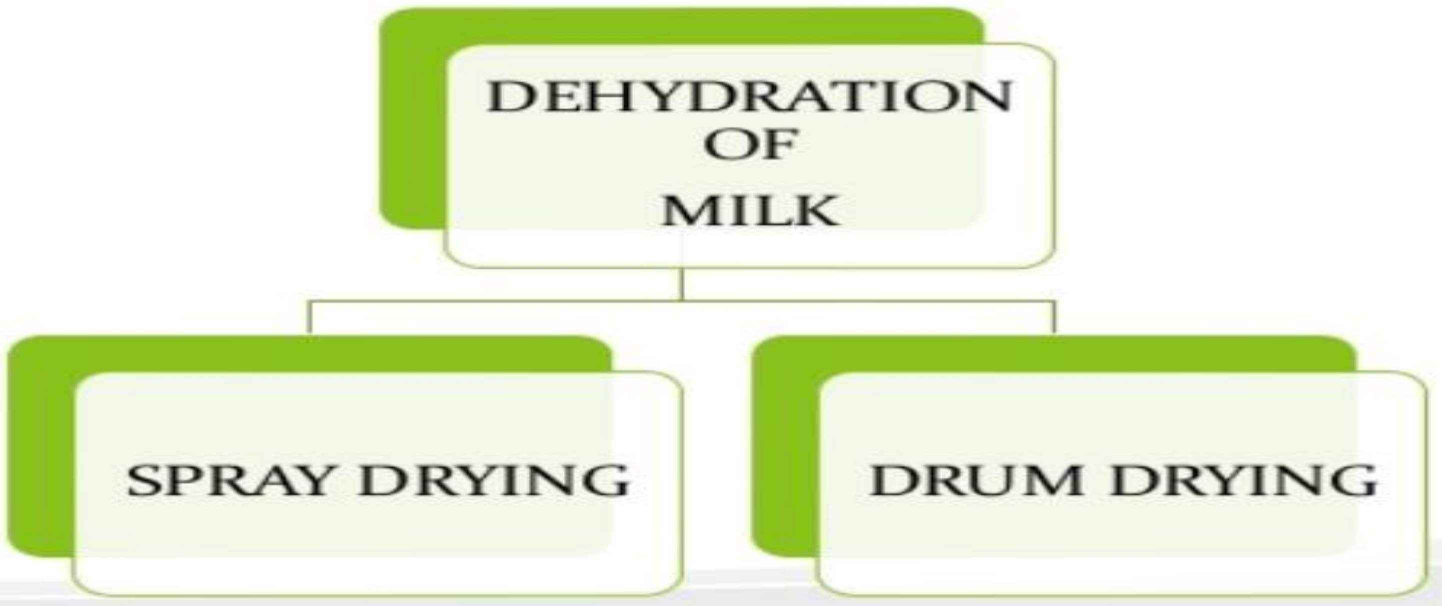
- ✓ Excess milk supply during flush season
- ✓ Conservation of natural characteristics of fresh milk
- ✓ Dependable keeping quality of finished product
- ✓ Reduction in volume / easy to transport
- ✓ Provide a product to be used in different foods

Whole Milk Powder
Skim Milk Powder
Infant Foods
Malted Milk Foods
Dairy Whitener
Dried Cream
Dried butter
Dried Ice-Cream Mix
Dried Sweetened Condensed Milk
Dried Whey
Butter Milk Powder
Cheese Powder
Khoa Powder
Channa Powder
Srikhand Powder
Dry Sodium Caseinate

INTRODUCTION - Milk is highly perishable in nature, so it is desirable to preserve it for later consumption. Drying is the most important method of preservation. The advantage is that using modern techniques, it is possible to convert the milk to powder without any loss in nutritive value, i.e. milk made from powder has the same food value as fresh milk. The disadvantage is that drying consumes require lot of energy and no other product processing in the dairy industry require higher energy than this for per tonne of final produce.

Components	Whole Milk	SMP	WMP
Moisture	87.4	3.0-4.0	2-4.5
Fat	3-4	0.6-1.25	26-28.5
Lactose	3.5	49.5-52.0	36-38.5
Protein	3.5	34.0-37.0	24.5-27
Ash	0.7	8.2-8.6	5.5-6.5

(g Per 100g)



APPLICATIONS OF DRIED MILK POWDER

- ✓ Baked products, snacks and soups
- ✓ Cheese milk extension (powder is added to local fresh milk to increase the yield of cheese)
- ✓ Chocolates and confectionery
- ✓ Sweets and Dairy desserts
- ✓ Direct consumer / household use (reconstitution)
- ✓ Ice cream
- ✓ Baby foods / Infant formulae
- ✓ Nutritional products for immune compromised persons, invalids, athletes, hospital use etc.
- ✓ Recombined "fresh", UHT, evaporated and sweetened condensed milks
- ✓ Recombined cheeses, mainly "soft" or "fresh"
- ✓ Recombined coffee and whipping creams
- ✓ Recombined yoghurts and other fermented products

INTRODUCTION

MILK POWDER

Milk powder manufacturing is a process carried out on a large scale. It involves removal of water under stringent hygiene conditions while retaining all the desirable natural properties of the milk i.e. colour, flavour, solubility, nutritional value. During milk powder manufacturing, water is removed by boiling the milk under reduced pressure at low temperature and the concentrated milk produced is then sprayed in a fine mist into hot air to remove further moisture and so produce milk powder. Whole (full cream) milk contains about 87% water and skim milk contains about 91% water and approximately 13 kg of whole milk powder (WMP) or 9 kg of skim milk powder (SMP) can be made from 100 L of whole / skimmed milk respectively.

Constituent	Whole Milk	Skim Milk	Whey	Sweet-Cream Buttermilk
•Fat	26	1	1	5
•Lactose	38	51	72-74	46
•Casein	19.5	27	0.6	26
•Other proteins	5.3	6.6	8.5	8
•'Ash'	6.3	8.5	8	8
•Lactic acid	—	—	0.2–2	—
•Water	2.5	3	3	3

Comparative Typical Composition of Dry Milks*

	Nonfat Dry Milk	Dry Whole Milk	Dry Buttermilk
Protein (%)	36.00	26.50	34.00
Lactose (%)	51.00	38.00	48.00
Fat (%)	0.70	26.75	5.00
Moisture (%)	3.00	2.25	3.00
Total Minerals (%*)	8.20	6.00	7.90
Calcium (%)	1.31	0.97	1.30
Phosphorus (%)	1.02	0.75	1.00
Vitamin A (I.U./100g)	36.40	1,091.30	507.10
Thiamin/Vitamin B_1 (mg/100g)	0.35	0.26	0.26
Ribofalvin/Vitamin B_2 (mg/100g)	2.03	1.48	3.09
Niacin/Vitamin B_3 (mg/100g)	0.93	0.68	0.99
Niacin Equivalents (mg/100g)	9.30	6.75	8.95
Pantothenic Acid (mg/100g)	3.31	2.87	3.09
Pyridoxine/Vitamin B_6 (mg/100g)	0.44	0.33	0.44
Biotin (mg/100g)	0.04	0.04	0.04
Ascorbic Acid/Vitamin C (mg/100g)	2.00	2.20	5.00
Choline (mg/100g)	111.20	88.18	110.20
Energy (calories/100g)	359.40	498.20	379.80

Source: American Dairy Products Institute.

Milk Powder (IS: 1165-2002):

Sl. No.	Characteristics	Requirements
1	Moisture, % by mass, Max.	4.0
2	Total milk solids, % by mass, Min.	96.0
3	Fat, % by mass, Min	26.0
4	Insolubility index, Max.	2.0 ml
5	Total ash (on dry basis), % by mass, Max.	7.3
6	Titratable acidity (lactic acid), % by mass, Max.	1.2
7	Bacterial count per gm. Max.	40,000
8	Coliform count	Absent in 0.1 g
9	Coagulase positive *Staphylococcus aureus*	Absent in 0.1 g
10	Salmonella	Absent in 25 g
11	Shigella	Absent in 25 g

Partly skimmmed milk Powder (IS: 14542-1998)

Sl. No.	Characteristics	Requirements	
		Type I	Type II
1	Moisture, % by mass, Max	4.0	4.0
2	Total solids (milk solids and added salts), % by mass, Min	96.0	96.0
3	Milk fat, percent by mass, More than Less than	 1.5 26.0	 1.5 26.0
4	Insolubility index, ml, Max. a) Roller dried b) Spray dried	 15.0 1.5	 - -
5	Total ash (on dry basis), % by mass, Max.	8.2	8.2
6	Titratable acidity (as lactic acid), % by mass, Max.	1.5	1.5
7	Bacterial count per gm. Max.	50,000	50,000
8	Coliform count	Absent per 0.1 g	Absent per 0.1 g

i) Standard Grade (IS: 13334 (Part I) : 1998)

Sr. No.	Characteristics	Requirements
1	Moisture % by mass, Max.	4.0
2	Total solids (milk solids and added salts), % by mass, Min	96.0
3	Milk fat % by mass, Max.	1.5
4	Insolubility index, ml, Max. a) Roller dried b) Spray dried	 15.0 1.5
5	Total ash (on dry basis), % by mass, Max.	8.2
6	Titratable acidity (as lactic acid), % by mass, Max.	1.5
7	Bacterial count per gm. Max.	50,000
8	Coliform count	Absent per 0.1 g

ii) Extra Grade (IS: 13334 (Part 2) : 1992)

Sr.No.	Characteristics	Requirements
1	Moisture % by mass, Max.	3.5
2	Total solids (milk solids and added salts), % by mass, Min	96.5
3	Fat % by mass, Max.	1.25
4	Insolubility index, Max.	0.5 ml
5	Total ash (on dry basis), % by mass, Max.	7.3
6	Titratable acidity in ml of N/10 NaOH, Max.	19.5
7	Lactate content, mg/g, Max./100g	1.5
8	Scorched particles, Max. 100g	15 mg
9	Bacterial count per gm. Max.	40000
10	Coliform count	Nil in 0.1 g
11	Coagulase positive *Staphylococcus aureus*	Absent in 0.1 g
12	Salmonella	Absent in 25 g
13	Shigella	Absent in 25 g

The heat processing of milk reduces the water activity, subsequently destroy pathogenic and spoilage microorganisms and Inactivate enzymes. Heating / Drying induced chemical interactions leading to reduction of redox potential and helps in extending the shelf life of dried milk powder under the ambient temperature storage.

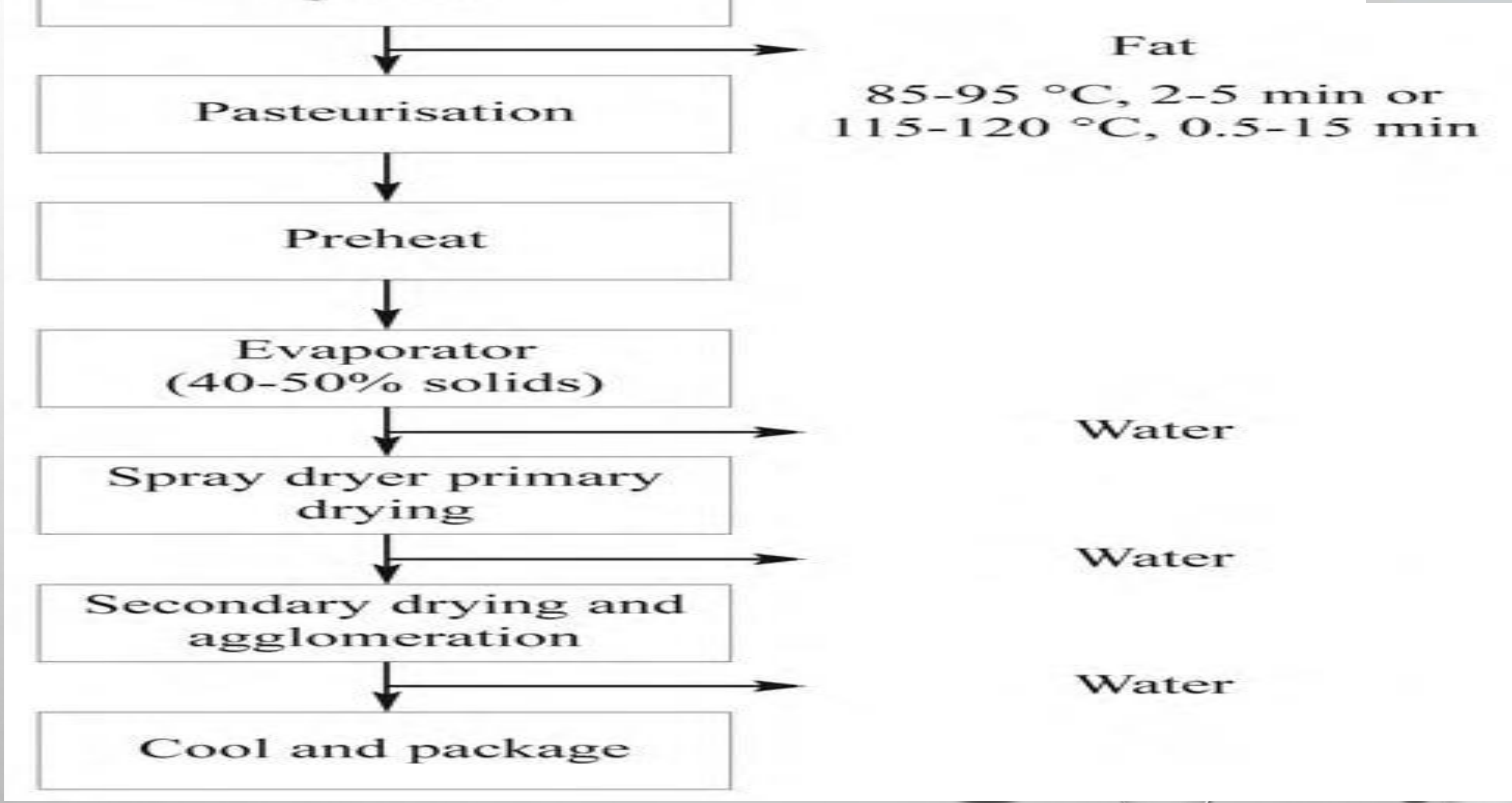
Dried milk powder made with whole milk or skimmed milk dehydrated to about 97% by spray drying / vacuum drying. It showed good shelf life, highly hygroscopic and can be reconstituted to fluid milk for further use. Skim milk powder: Skim Milk Powder is obtained by removing water from pasteurized skim milk. It contains 4% or less moisture (by weight) and 1.5% or less milkfat (by weight) and a minimum milk protein content of 34%.

RECEIVING AND SELECTION

- Cooling to 4°C.
- Milk should be of high chemical, bacteriological and organoleptic quality.
- Presence of antibiotic and pesticides in raw milk reduce the quality.
- If the titratable acidity is higher than 0.15%, solubility of the product will be reduces.
- Clarification by centrifugation or filtration.
- Standardization: to adjust the ratio of fat and Total Solids.

Preheating -- Standardized milk is heated to temperatures between 75°C and 120°C and held for a specified time from a few seconds up to several minutes (pasteurization: 72°C for 15s). Preheating causes a controlled denaturation of the whey proteins in the milk and it destroys bacteria, inactivates enzymes, generates natural antioxidants and imparts heat stability. The exact heating/holding regime depends on the type of product and its intended end-use. High preheats in Whole Milk Powder is associated with improved keeping quality but reduced solubility. Preheating methods are indirect (via heat exchangers), or direct (via steam injection or infusion into the product), or sometimes a mixture of the two.

Production of skimmed milk powder



Receiving milk

Pre-heating (35–40°C)

Separation (SMP)

Filtration/Clarification (35–40°C)

Standardization (WMP)

Forewarming (85°C/10 min)

Condensing

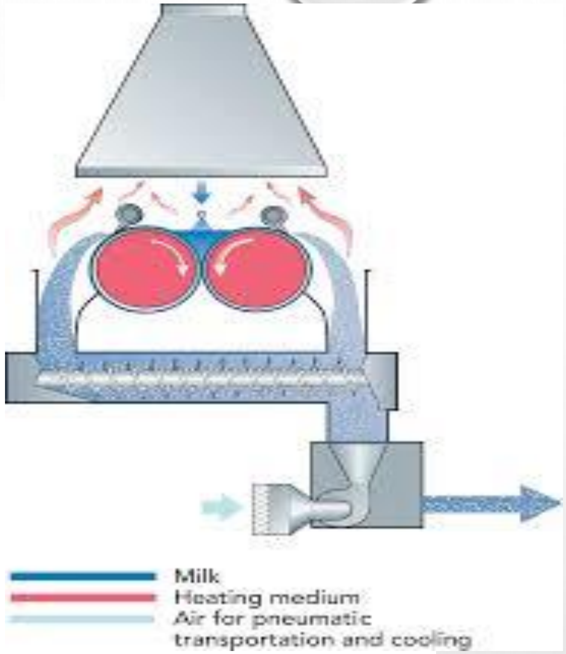
(SMP) Homogenization (WMP) — 2500 psi- I Stage / 500 psi-II Stage (63–77°C)

Pre-heating (74–85°C)

Drum drying

Packaging

Storage (Room temperature)



Heat treatment -- Different pasteurisation methods 1 Low-temperature-longer time(LTLT) - 65°C for 30 minutes, called the Holding or Batch method 2 High-Temperature-Short-Time (HTST) - heat treatment of 72°C for 15 seconds is applied followed by rapid cooling to below 10°C. Also called the continuous system or flash pasteurisation. 3 Ultra High Temperature (UHT) - 149.5°C for 1 second or 93.4°C for 3 sec.

Heat treatment effect -- Higher than pasteurization (88-95°C/15- 30sec) 1. Destroy all pathogens. 2. Inactivate enzymes (especially lipase). 3. Activate SH groups (antioxidant). HTST produces better powder quality. De-aeration of milk before heating protects vitamin C.

Condensing / Evaporation -- The preheated milk gets concentrated in stages from around 9.0% total solids content for skim milk and 13% for whole milk, up to 45-52% total solids. This is achieved by boiling the milk under a vacuum at temperatures below 72°C in a falling film on the inside of vertical tubes, and removing the water as vapour. This vapour, which may be mechanically or thermally compressed, is then used to heat the milk in the next effect of the evaporator which may be operated at a lower pressure and temperature than the preceding effect. More than 85% of the water in the milk may be removed in the evaporator. Modern plants may have up to seven effects for maximum energy efficiency.

Condensing --- In spray drying, milk is concentrated to 40-50% and for roller drying, to only 33- 35%. Highly concentrated milk will form a thick layer on the roller and create difficulties during atomization which inhibits further drying process.

Homogenization --- to prevent creaming or the rising of fat to the top of the container of milk. The process of homogenization permanently emulsifies the fine fat globules by a method that pumps milk under high pressure [2000–2500 lb/in2 (psi)] through small mesh orifices of a homogenizer. Homogenization mechanically increases the number & reduces the size of the fat globules. The size is reduced to 1/10 of their original size. Resulting in the milk that maintains more uniform composition with improved body and texture, a whiter appearance, richer flavor, & more digestible curd.

Heating – Before entering the drying chamber, concentrated milk feed is slightly heated to reduce its viscosity and to increase the energy available for drying.

Air Filtration – Air filter is used to prevent contamination due to dust or any other particulate matter.

Feed Pump – Three piston pump with pressures upto 300-400 bar is used for pumping feed.

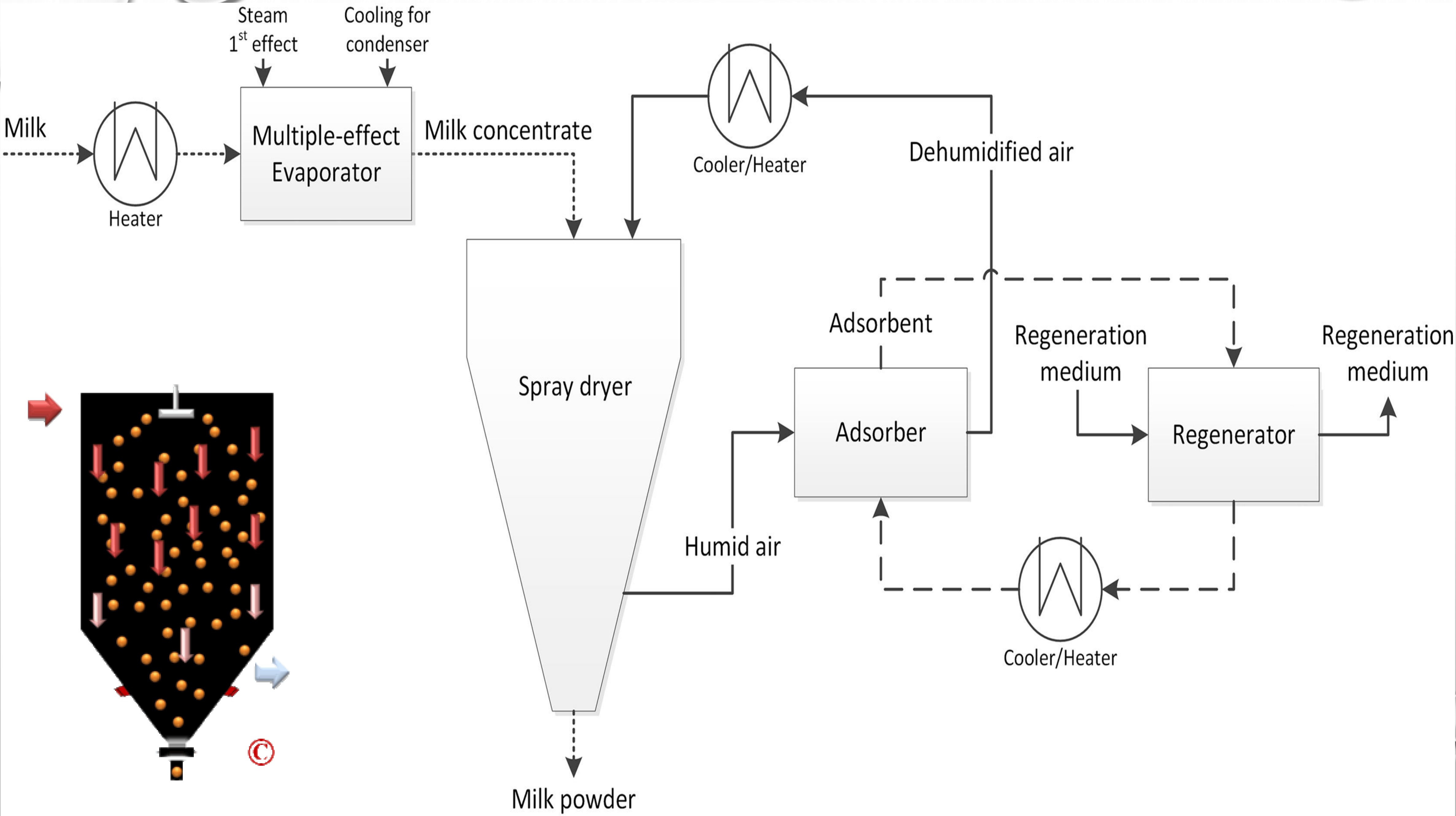
SPRAY DRYING

Atomization – Atomization of the concentrated milk is the principle of the spray drying process. The atomizer may be either a pressure nozzle or a centrifugal disc. By atomization the concentrate is converted into droplets of size 10-200um, with the greatest portion in the range 40-80um. Smaller droplet size results in higher surface area which helps in drying.

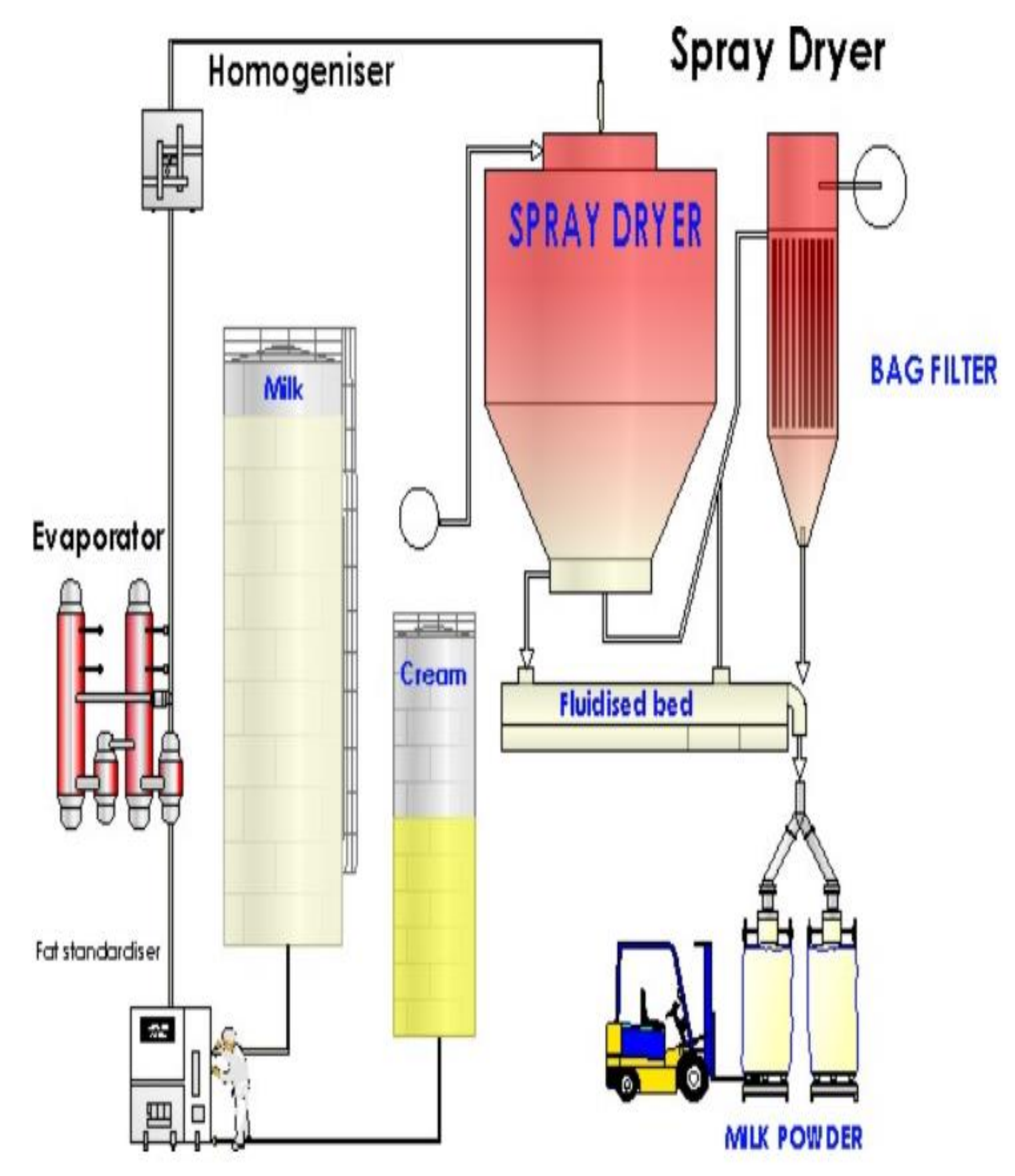
Drying Chamber – Concentrated milk feed comes in contact with hot air here and is dried (Inlet Air Temperature 130-200°C; Outlet Air Temperature 65-90°C and atomization pressure 150-300 kPa).

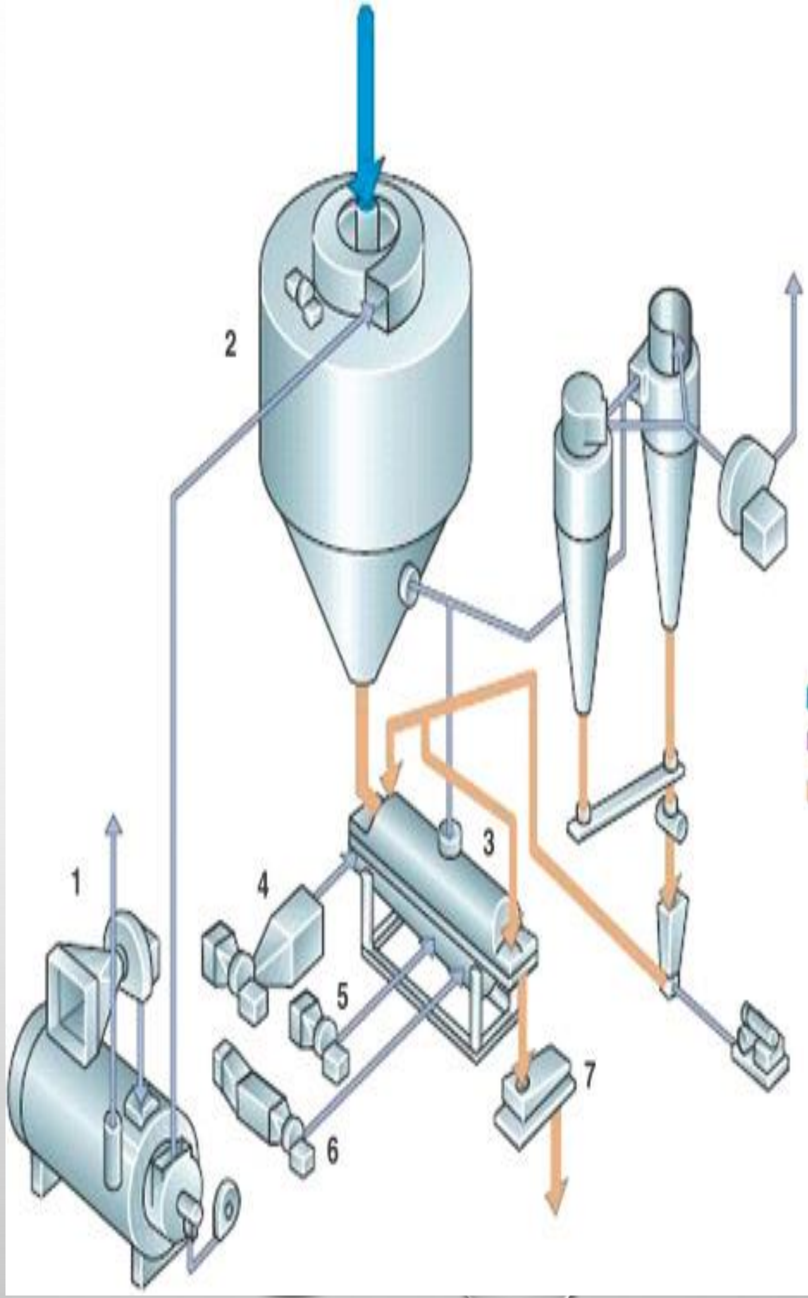
Co-current flow of hot air is preferred. By controlling the size of the droplets, the air temperature, and the airflow, it is possible to evaporate almost all the moisture while exposing the solids to relatively low temperatures. External hammers are used on the cone to avoid build-up of dried particles.

Cyclone Separator – The principle of cyclone separation is based on the centrifugal force exerted on a particle. It separates particles based on their density. Fines are sent forward to the filters.



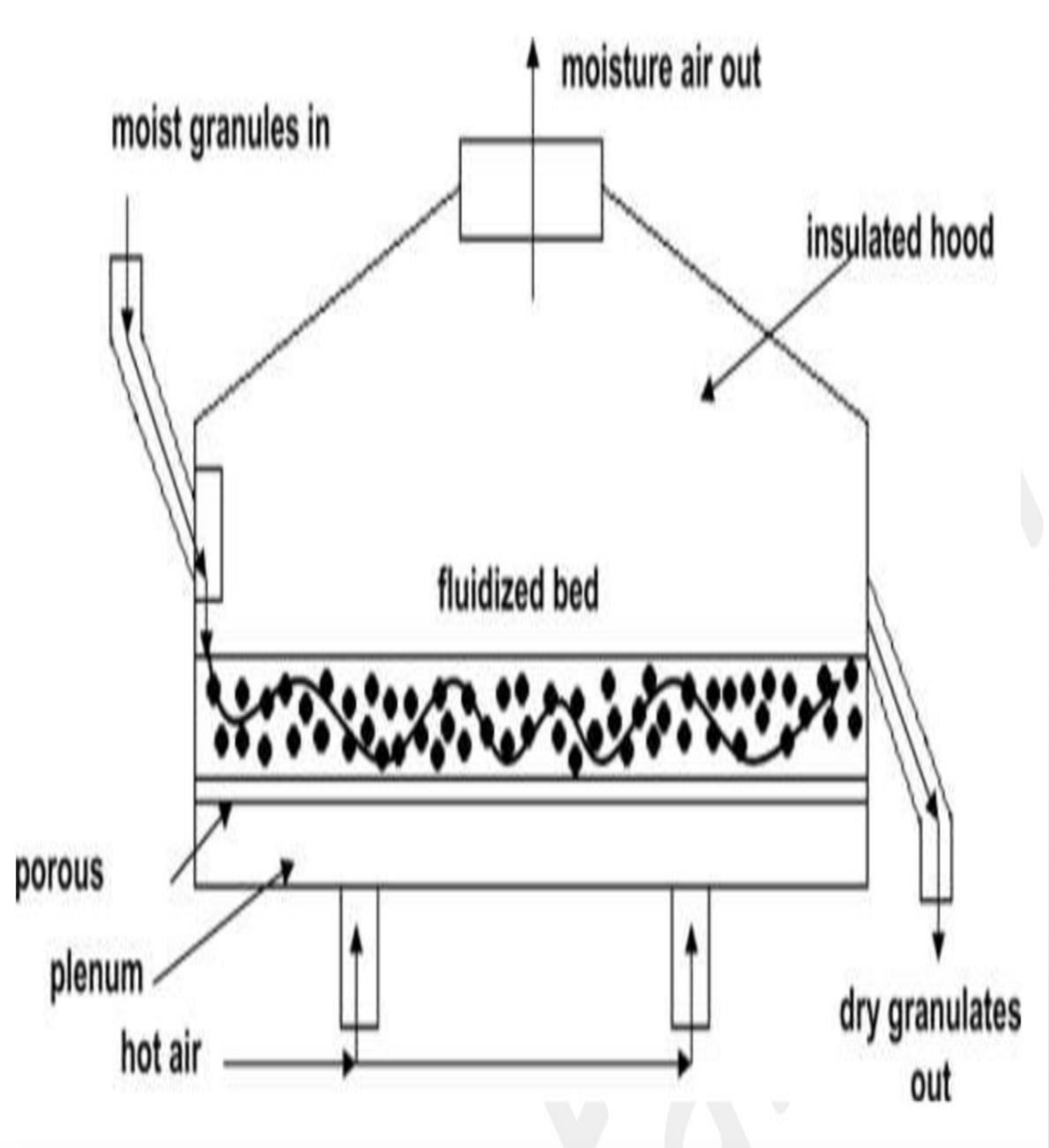
Steam
1st effect
Cooling for
condenser
Milk
Heater
Multiple-effect
Evaporator
Milk concentrate
Cooler/Heater
Dehumidified air
Spray dryer
Adsorbent
Regeneration
medium
Regeneration
medium
Adsorber
Regenerator
Humid air
Cooler/Heater
Milk powder

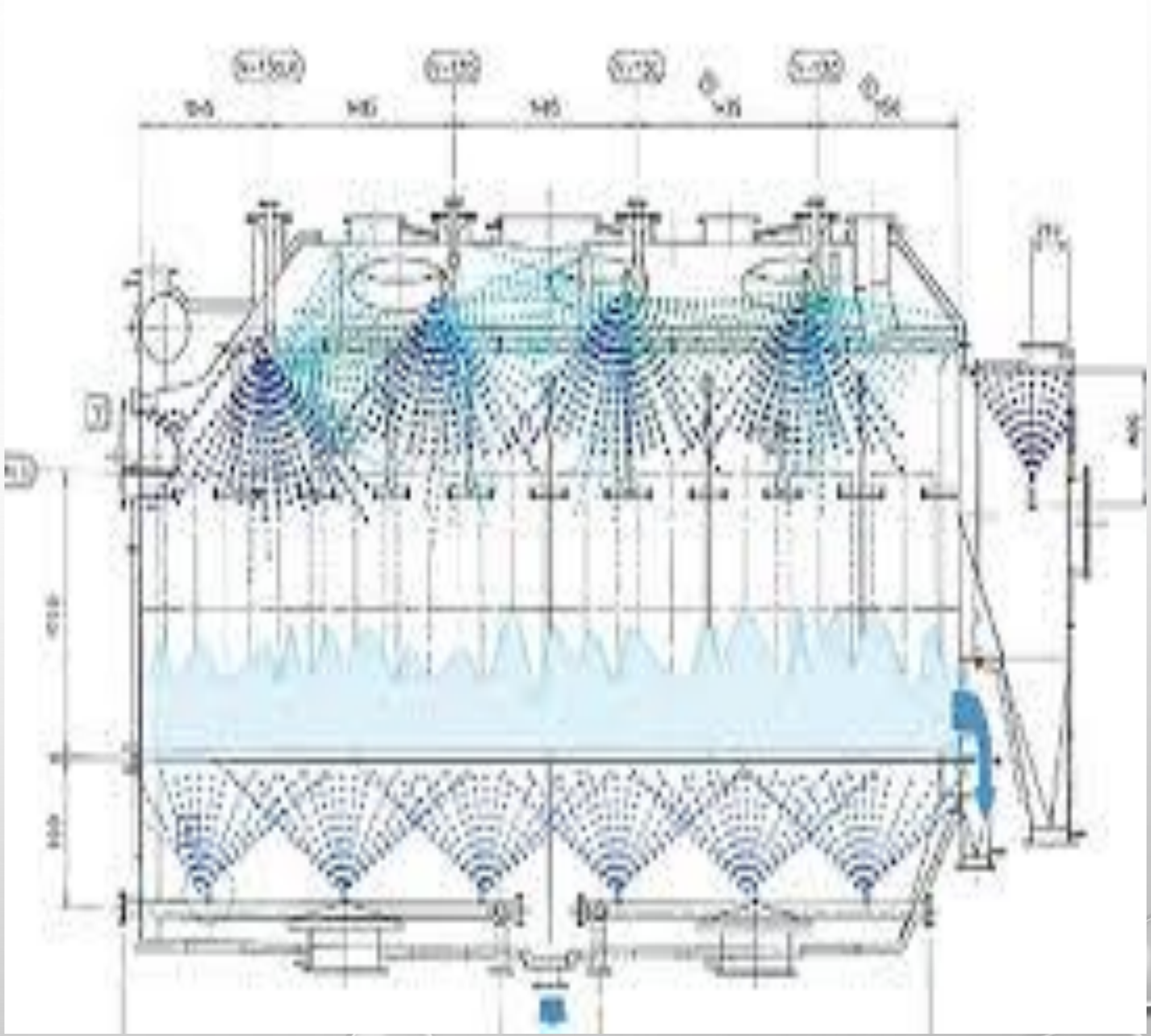




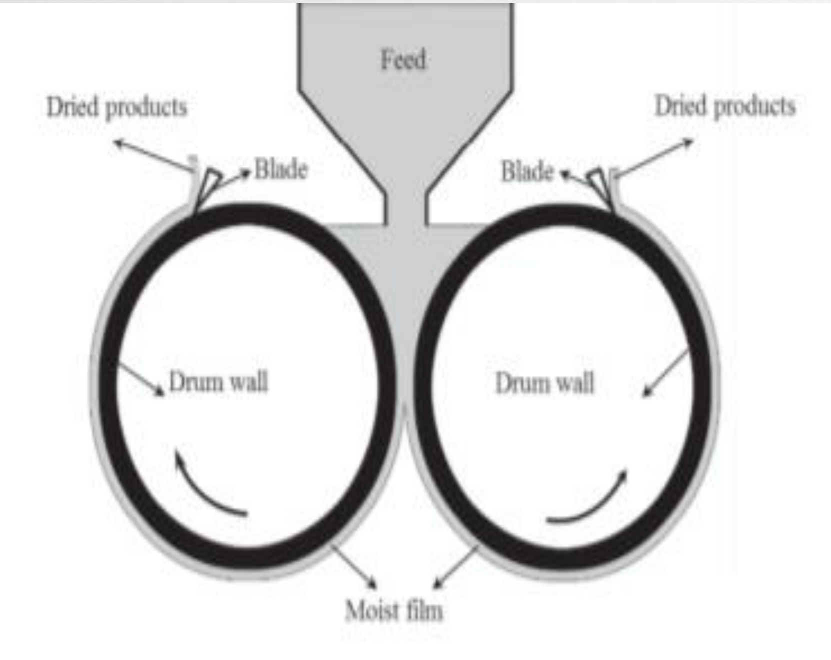
Spray dryer with fluid bed attachment (two-stage drying).

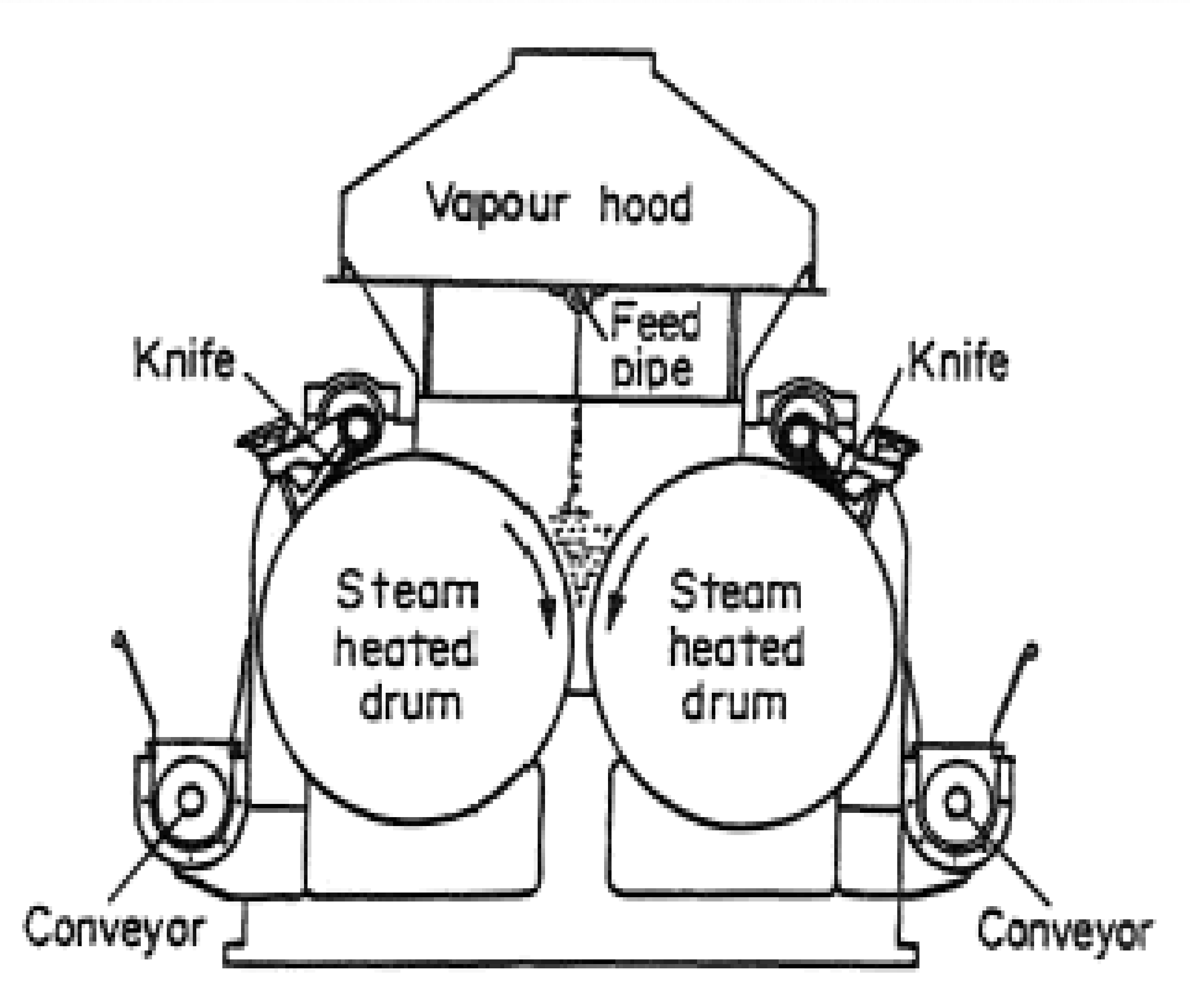
1 Indirect heater
2 Drying chamber
3 Vibrating fluid bed
4 Heater for fluid bed air
5 Ambient cooling air for fluid bed
6 Dehumidified cooling air for fluid bed
7 Sieve


moisture air out
moist granules in
insulated hood
fluidized bed
porous
plenum
hot air
dry granulates out



Drum drying ---- Roller drying involves direct contact of a layer of concentrated milk with the hot surface of rotating rollers or drums. The drum body of the drum dryer is heated on the inside by steam. Feed used for roller drying contains 45-50% solid content. Depending on the design of the drum dryer, the product is applied continuously as a thin film at the bottom or top of the main drum. As the drum rotates and is heated on the inside, the product dries on the outside of the drum surface. The moisture evaporates and leaves the process at the top. If necessary, the vapor can also be removed by suction locally around the drum. The dried product film finally reaches the knife and is scraped off. It often causes irreversible changes such as lactose caramelization, Maillard reaction and protein denaturation.


Feed
Dried products
Blade
Dried products
Blade
Drum wall
Drum wall
Moist film


Vapour hood
Feed pipe
Knife
Knife
Steam heated drum
Steam heated drum
Conveyor
Conveyor

Packaging and storage --- Milk powder is packed into either plastic-lined multi-wall bags (25 kg) or air tight bulk bins (600 kg). WMPs are often packed under nitrogen gas to protect the product from oxidation and to maintain their flavour and extend their keeping quality. Packaging is chosen to provide a barrier to moisture, oxygen and light. Bags generally consist of several layers to provide strength and the necessary barrier properties. Retail milk powder is usually packed in tin containers.

Agglomeration of milk powders --- Standard powders, because of their fine dusty nature, do not reconstitute well in water. "Agglomerated" and "instant" powders were specifically developed to counter this. The manufacture of an agglomerated powder initially follows the standard process of evaporation and drying, described earlier. However, during spray drying small particles of powder leaving the drier (the "fines") are recovered in cyclones and returned to the drying chamber in the close proximity of the atomiser. The wet concentrate droplets collide with the fines and stick together, forming larger (0.1-0.3 mm), irregular shaped "agglomerates". Agglomerated powders disperse in water more rapidly and are less dusty and easier to handle than standard powders.

Microbiology of Dried milks

Roller dried milks always show lower counts (approximately 1000 / gm) while low heat spray dried powders –few thousand to one million

Variation in count is mainly due to two reasons i) Degree of contamination; ii) Difference in temperature employed at different stages of processing.

As we live in microbial world, there are ample opportunities for the milk to get contaminated at different stage of food chain. Microbes such as *Aspergillus*, *Bacillus*, *Enterococcus*, *Micrococcus*, *Mucor*, *Penicillium*, *Rhizopus* and *Streptococcus* can cause spoilage of dried milk powder. High microbial load in milk and dairy products leads to spoilage, and economic losses to the producers. Although, pathogens such as *Escherichia coli*, *Listeria monocytogenes*, *Salmonella*, and *Shigella* must be absent in dried milk powder.

Relatively low numbers of microorganisms survive processing. Heat resistant organisms (spore-formers and non-spore-formers) and mould are responsible for deterioration of milk powders, if the product is allowed to absorb moisture during prolonged storage. The aw of dried milks is otherwise too low to support microbial growth and a general decrease in microbial counts occurs during storage.

Although dried milk products have been implicated in a number of foodborne disease outbreaks, these have usually been the result of post-pasteurisation contamination by pathogens. Foodborne pathogenic bacteria are unable to grow in dried milk powders, but may survive for long periods.

Before evaporation and drying, the milk is standardised, if required, and heat treated. Vegetative bacteria, including *Enterobacteriaceae* and *Listeria monocytogenes* have been shown to survive the drying process, and therefore all raw milk should receive a process at least equivalent to pasteurisation. Skimmed milk may also be subjected to low, medium and high heat processes to give varying degrees of protein denaturation as required. Typically, a low heat process will be 74°C for 30 seconds, a medium heat process 80-100°C for 1-2 minutes, and a high heat process may be equivalent to an ultra high temperature (UHT) treatment (140-150 °C). Milk for dried whole milk powders is heated at 85-95°C for several minutes. UHT heating units result in products that have excellent microbiological quality, which is important when dried milk is to be used as an ingredient in baby food.

Salmonella spp.

There have been several significant salmonellosis outbreaks associated with dried milk powders, and *Salmonella* contamination has come to be regarded as a serious potential hazard in dried milk products. It was found that contamination was widespread in both product and this finding gave rise to a number of improvements in hygiene, sanitation and process control. The organism is thought to have originated in raw milk and then spread through the plant. It seems to have entered the insulation material of the dryer through small cracks in the dryer wall, and this then acted as a reservoir from which *Salmonella* could repeatedly contaminate the finished product. In 2005, powdered infant formula contaminated with *S. agona* was implicated in an outbreak involving 104 infants in France. Such outbreaks are often linked to contamination in equipment that is poorly designed and difficult to clean effectively, and the *Salmonella* strains involved are often found to be lactose-positive.

Staphylococcus aureus

- Contamination of dried milk powders with staphylococcal enterotoxins was a significant problem in the 1950s, and several outbreaks were recorded, often caused by growth and toxin production in the concentrated milk prior to drying. Improvements in temperature control and hygiene prior to drying have largely eliminated this problem. More recently, in 2000, a very large outbreak of staphylococcal food poisoning was reported in Japan, which affected over 13,420 people. This outbreak was associated with consumption of semi-skimmed liquid milk, which was manufactured using dried skimmed milk powder. It was thought that some temperature abuse could have occurred during production of the dried milk, allowing *Staph. aureus* to grow and produce heat-stable toxin, which then persisted through to the finished product and cause intoxication, even though the thermal processes had destroyed the organism .

Listeria monocytogenes

No cases of listeriosis associated with dried milk products have been reported. However, the ubiquity of *Listeria* spp. in dairy plants and other wet processing areas and the cases of listeriosis linked to other dairy products suggest that contamination of dried products is possible. The survival of *L. Monocytogenes* during spray drying and storage of product has been investigated. Spray drying was found to give a small reduction in numbers, and the viable count continued to decline during storage, but viable *L. monocytogenes* could still be isolated from some samples after 12 weeks.

Bacillus spp.

Bacillus cereus has been found to be a common contaminant in dried milk. In the US, 62.5% of samples of milk powder were found to be positive, and, in Brazil, the organism was isolated from 80% of samples examined. Although there have been many reports of *B. cereus* food poisoning associated directly with dried milk consumption, in 2005, milk powder contaminated with *B. licheniformis* and *B. subtilis* was the cause of an outbreak in Croatia involving 12 children. Reconstituted milk that was held for 2 hours prior to consumption, without boiling, was identified as the caus. *B. cereus* spores can survive for many months in dried milk powders.

Enterobacter spp.

Enterobacter spp. are not normally regarded as food borne pathogens, but there have been a number of outbreaks of neonatal meningitis caused by *Enterobacter sakazakii* associated with dried milk consumption, with fatality rates as high as 30 – 80%. Powdered infant formulae contaminated with *C. sakazakii* was responsible for outbreaks among infants. These outbreaks are thought to have been due to growth of the organism in the reconstituted powder. The presence of any members of the *Enterobacteriaceae* in infant formulae may therefore be a cause for concern. Studies have shown that *C. sakazakii* can survive spray-dying when inoculated into skimmed milk powder.

Toxins

The mycotoxin aflatoxin M l has occasionally been found in dried milk. The drying process has been found to reduce the concentration, but a significant amount is able to survive processing and storage of finished product for long periods.

THANK YOU