

History, status, scope and legal standards of condensed milks in India and abroad

HISTORY

- The evaporation of milk – year 1200 - Marco Polo described - milk concentrate in Mongolia which was used by mixing with water
- Nicolas Appert - condensed milk in France in 1820
- Gail Borden, Jr. developed afterwards in the United States in 1856
- Borden was able to produce a usable milk derivative that was long-lasting and needed no refrigeration
- By 1858 Borden's milk, sold as Eagle Brand
- The basic principle of the process of sterilization by heat was introduced by Mr. John B. Meyenbarg

- Meyenbarg conceived the idea of making condensed milk without the addition of cane sugar or other preservatives and without the necessity of refrigeration
- Originally the unsweetened sterilized condensed milk was sold under the trade name of Evaporated Cream
- The Federal Food & Drug act of 1906 changed the name “Evaporated Cream” to “Evaporated Milk”
- The vacuum pan that was developed in 1883 has undergone marked improvement
- In 1911, Nestlé constructed the world's largest condensed milk plant in Dennington, Victoria, Australia
- In 1914, Professor Otto F. Hunziker, head of Purdue University's dairy department, published a book titled Condensed milk and milk powder

DEVELOPMENT OF CONDENSING PROCESS

- The simplest evaporator is an ordinary open pan heated with steam or direct gas - evaporation takes place at ambient pressure - long time
- Milk - exposed to high temperature - deterioration of the proteins and chemical reactions such as the Maillard reaction or even coagulation results
- Development - forced recirculation evaporators and multi stage evaporators
- For the separation of liquid and vapours, centrifugal separators are preferred
- Unsweetened condensed - Evaporated Milk - Fortification with vitamins of either or both A and D3

The improvements in modern equipment are:

1. Change of metal from copper to stainless steel
2. Double and triple effect or combination of single effect evaporator with thermo-temperature control
3. Plate type evaporators were developed in 1958

USES OF CONDENSED MILKS

- Bakeries
 - Confectionaries
 - Ice Cream manufacture
 - Making prepared food products such as creaming coffee or tea and as flavouring
 - Topping on chocolate or similar cream flavor snowball.
 - Pouring on cereals and fruits
 - Used in meat patties and loaves for consistency
 - Coatings for baked or fried meats
 - In place of milk in the manufacture of candies, frostings and pies.
 - Brazilian candy Brigadeiro
 - Use on toast.
 - Mixed with sugar and some butter and baked to form a popular sweet candy called Tablet (confectionery) or Swiss-Milk-Tablet.
 - Mixed with some evaporated milk and eggs, to make a stiffer and more filling version of crème brûlée known as Leche Flan.
 - Boiling a can of condensed milk in water for about 2 hours, resulting into product called Kaymak- sweet semi-liquid substance which can be used as a cake icing or put between dry wafers.
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Table -1.4: Raw material cost of dairy products as % of sale price

No.	Products	Raw material cost as % of sale price
1	Market Milk (bulk vended)	90
2	Market Milk (packaged)	80
3	Milk Powder / Butter	70
4	Paneer	58
5	Sandesh	42
6	Peda/Burfi/Kalakand	52
7	Gulabjamun	33
8	Rasogolla	33
9	Shrikhand	43
10	Dahi	60
11	Mishti Doi	40

(Source: Dairy India 2007-6th edition, p-33)

Status in World

Table -1.6: Global trade in dairy products

Product	Million tonnes			
	Intra-EU Trade	World Trade	World Production	World Trade as % of Production
Condensed Milk, retail pack	0.2	0.5-0.6	4	10-15
Whole Milk Powder	0.25	~1.3	2.5	50
Skim Milk Powder	0.5	~	3.5	30

(Source: CFCE / IDF, Rabobank International, Dairy India-2007, P-47)

Fonterra, a New Zealand based multinational company, is the world's largest producer of milk powder controlling 40 percent of the global whole milk powder.

Table -1.7: Market size of condensed & dried milks

'000 tonnes

Year	Butter	Ghee	Milk Powders	Malted milk food	Condensed milk	Cheese
1991	130.0	942.6	150	41	8.1	2.5
2001	500.0	1830.1	235	68	12.0	8.0

(Source: FAOSTAT for butter & ghee (FAO 2005); Ministry of Food Processing Industries (2002). Dairy India-2007, P-63)

FSSR, 2011 for Evaporated Milk

No.	Product	Milk Fat	Milk Solids	Milk Protein in milk solids not fat
	(1)	(2)	(3)	(4)
(i)	Evaporated milk	Not less than 8.0 percent m/m	Not less than 26.0 percent m/m	Not less than 34.0 percent m/m
(ii)	Evaporated partly skimmed milk	Not less than 1.0 percent and not more than 8.0 percent m/m	Not less than 20.0 percent m/m	Not less than 34.0 percent m/m
(iii)	Evaporated skimmed milk	Not more than 1.0 percent m/m	Not less than 20.0 percent m/m	Not less than 34.0 percent m/m
(iv)	Evaporated high fat milk	Not less than 15.0 percent m/m	Not less than 27.0 percent m/m	Not less than 34.0 percent m/m

FSSR, 2011 for Sweetened Condensed Milk

No.	Product	Milk Fat	Milk Solids	Milk Protein in milk solids not fat
	(1)	(2)	(3)	(4)
(i)	Sweetened condensed milk	Not less than 9.0 percent m/m	Not less than 31.0 percent m/m	Not less than 34.0 percent m/m
(ii)	Sweetened condensed skimmed milk	Not less than 1.0 percent m/m	Not less than 26.0 percent m/m	Not less than 34.0 percent m/m
(iii)	Sweetened condensed partly skimmed milk	Not less than 3.0 percent m/m and Not more than 9.0 percent m/m	Not less than 28.0 percent m/m	Not less than 34.0 percent m/m
(iv)	Sweetened condensed high fat milk	Not less than 16.0 percent m/m	Not less than 30.0 percent m/m	Not less than 34.0 percent m/m

The legal standards as per The Food Safety and Standards Regulations can be referred on web site <http://www.fssai.gov.in>

BIS specifications for Condensed Milk

Sr. No.	Characteristic	Full Cream Sweetened	Full Cream Unsweetened	Skim Sweetened	Skim Unsweetened
1	Total Milk Solids, % by Wt., Min.	31.0	31.0	26.0	20.0
2	Fat, % by Wt.,	NLT 9.0	NLT 9.0	NMT 0.5	NMT 0.5
3	Sucrose, % by Wt., Min.	40.0	-	40.0	-
4	Titratable Acidity (as lactic acid), % by Wt. Max.	0.35	0.30	0.35	0.30
5	Colour	Whitish to light brown	Whitish to light cream	Whitish to light brown	Whitish to light cream
6	Bacterial Count, per g, Max.	500	-	500	-
7	Test for Coliform Organisms	Negative	-	Negative	-
8	Yeast & Mould Count per g., Max.	10	-	10	-

NLT- Not Less Than, NMT- Not More Than

INTERNATIONAL STANDARDS

The international standards:

- American Dairy products Institute (ADPI) - <http://www.adpi.org>
- Codex Alimentarius - <http://www.codexalimentarius.org>

FSSR, 2011 for Milk powder

No.	Parameter	Whole Milk Powder	Partly Skim Milk Powder	Skim Milk Powder
1	Moisture	Not more than 4 percent m/m	Not more than 5 percent m/m	Not more than 5 percent m/m
2	Milk Fat	Not less than 26.0 percent m/m	Not less than 1.5 percent m/m and Not more than 26.0 percent m/m	Not more than 1.5 percent m/m
3	Milk Protein in Milk Solids Not Fat	Not less than 34.0 percent m/m	Not less than 34.0 percent m/m	Not less than 34.0 percent m/m
4	Titratable acidity (ml 0.1 N NaOH / 10g Solids Not Fat)	Not more than 18.0	Not more than 18.0	Not more than 18.0
5	Insolubility Index	Not more than 2.0 ml	Not more than 2.0 ml	Not more than 2.0 ml
6	Total Ash on dry weight basis	Not more than 7.3 per cent	Not more than 8.2 per cent	Not more than 8.2 per cent

FSSR, 2011 for Infant milk food

1	Moisture, per cent by weight (not more than)	4.5
2	Total milk protein, per cent by weight (not less than)	12.0
3	Milk fat, per cent by weight (not less than)	18.0
4	Total ash, per cent by weight (not more than)	8.5
5	Ash insoluble in dilute Hydrochloric acid, per cent by weight (not more than)	0.1
6	Solubility:	
	Solubility Index maximum	2.0 ml
	Solubility per cent by weight (not less than)	98.5
7	Vitamin A (as retinol) μg . per 100 g. (not less than)	350 μg
8	Added Vitamin D (expressed as Cholecalciferol or Ergocalciferol) μg per 100g. (not less than)	4.5 μg
9	Vitamin C, mg per 100 g. (not less than)	35 μg
10	Thiamine, μg per 100 g. (not less than)	185 μg
11	Riboflavin, μg per 100 g. (not less than)	275 μg
12	Niacin, μg per 100 g. (not less than)	1160 μg
13	Pyridoxine μg per 100 g. (not less than)	160 μg
14	Folic acid, μg per 100 g. (not less than)	20 μg
15	Pantothenic acid, mg per 100 g. (not less than)	1.4 mg
16	Vitamin B12, μg per 100 g. (not less than)	0.7 μg
17	Choline, mg per 100 g. (not less than)	32 μg
18	Vitamin K μg per 100 g. (not less than)	18 μg
19	Biotin, μg per 100 g. (not less than)	7.0 μg
20	Sodium mg per 100 g. (not less than)	90 μg
21	Potassium, mg per 100 g. (not less than)	370 mg
22	Chloride, mg per 100 g. (not less than)	250 mg
23	Calcium, mg per 100 g. (not less than)	230 mg
24	Phosphorous, mg per 100 g. (not less than)	115 mg
25	Magnesium, mg per 100 g. (not less than)	22 mg
26	Iron, mg per 100 g. (not less than)	5.0 mg
27	Iodine, μg per 100 g. (not less than)	20 μg
28	Copper, μg per 100 g. (not less than)	280 μg
29	Zinc, mg per 100 g. (not less than) and not more than	2.5 mg 5.0 mg
30	Manganese, μg per 100g. (not less than)	20 μg
31	Selenium, μg per 100 g. (not less than)	14 μg
32	Bacterial count, per g. (not more than)	10,000
33	Coliform count absent in	0.1 g
34	Yeast and mould count absent in	0.1 g
35	Salmonella and Shigella absent in	25 g
36	E. coli absent in	0.1 g
37	Staphylococcus aureas absent in	0.1 g

FSSR, 2011 for Infant formula

1	Moisture, per cent by weight (not more than)	4.5
2	Total milk protein, per cent by weight (not less than) and not more than	10.0 16.0
3	Total fat, percent by weight (not less than) Milk Fat, percent by weight (not less than) Linoleate per 100 gram (not less than)	18.0 12.0 1.398g
4	Total ash, per cent by weight (not more than)	8.5
5	Ash insoluble in dilute Hydrochloric acid, per cent by weight (not more than)	0.1
6	Solubility: (a) Solubility Index maximum (b) Solubility per cent by weight (not less than)	2.0 ml 98.5
7	Vitamin A (as retinol) µg. per 100 g. (not less than)	350 µg
8	Added Vitamin D (expressed as Cholecalciferol or Ergocalciferol) µg. per 100g. (not less than)	4.5 µg
9	Vitamin C, mg per 100 g. (not less than)	35 µg
10	Thiamine, µg per 100 g. (not less than)	185 µg
11	Riboflavin, µg per 100 g. (not less than)	275 µg
12	Niacin, µg per 100 g. (not less than)	1160 µg
13	Pyridoxine µg per 100 g. (not less than)	160 µg
14	Folic acid, µg per 100 g. (not less than)	20 µg
15	Pantothenic acid, mg per 100 g. (not less than)	1.4 mg
16	Vitamin B12, µg per 100 g. (not less than)	0.7 µg
17	Choline, mg per 100 g. (not less than)	32 mg
18	Vitamin K µg per 100 g. (not less than)	18 µg
19	Biotin, µg per 100 g. (not less than)	7.0 µg
20	Vitamin E (as a-tocopherol compounds) IU per 100g. (not less than)	3.15 IU
21	Sodium mg per 100 g. (not less than)	90 mg
22	Potassium, mg per 100 g. (not less than)	370 mg
23	Chloride, mg per 100 g. (not less than)	250 mg
24	Calcium, mg per 100 g. (not less than)	230 mg
25	Phosphorous, mg per 100 g. (not less than)	115 mg
26	Magnesium, mg per 100 g. (not less than)	22 mg
27	Iron, mg per 100 g. (not less than)	5.0 mg
28	Iodine, µg per 100 g. (not less than)	20 µg
29	Copper, µg per 100 g. (not less than)	280 µg
30	Zinc, mg per 100 g. (not less than) and not more than	2.5 mg 5.0 mg
31	Manganese, µg per 100g. (not less than)	20 µg
32	Selenium, µg per 100 g. (not less than)	14 µg
33	Bacterial count, per g. (not more than)	10,000
34	Coliform count absent in	0.1 g
35	Yeast and mould count absent in	0.1 g
36	Salmonella and Shigella absent in	25 g
37	E. coli absent in	0.1 g
38	Staphylococcus aureas absent in	0.1 g

FSSR, 2011 for Malted milk food

Sr. No.	Parameter	Malted milk food without Cocoa powder	Malted milkfood with cocoa powder
(a)	Moisture	Not more than 5 per cent by weight.	Not more than 5 per cent by weight
(b)	Total protein (N x 6.25) (on dry basis)	Not less than 12.5 per cent by weight.	Not less than 11.25 per cent by weight.
(c)	Total fat (on Dry basis)	Not less than 7.5% by weight	Not less than 6% by weight
(d)	Total ash (on dry basis)	Not more than 5% by weight	Not more than 5% by weight.
(e)	Acid insoluble ash (on dry basis) (in dilute HCl)	Not more than 0.1 per cent by weight	Not more than 0.1 per cent by weight
(f)	Solubility	Not less than 85% by weight.	Not less than 80% by weight.
(g)	Cocoa powder (on dry basis)	-	Not less than 5.0% by weight.
(h)	Test for starch	Negative	-
(i)	Bacterial count	Not more than 50,000 per gram.	Not more than 50,000 per gram.
(j)	Coliform count	Not more than 10 per gram	Not more than 10 per gram.
(k)	Yeast and mould count		absent in 0.1 gm
(l)	Salmonella and Shigella		absent in 0.1 gm
(m)	E.Coli		absent in 0.1 gm
(n)	Vibrio cholera and V.Paraheamolyticus		absent in 0.1 gm
(o)	Faecal streptococci and Staphylococcus aureas		absent in 0.1 gm

FSSR, 2011 for Malte based food

A	Moisture	Not more than 5 per cent, by weight
B	Total Protein (N x 6.25) (on dry basis)	Not less than 7.0 per cent, by weight
C	Total ash (on dry basis)	Not more than 5 per cent, by weight
D	Acid insoluble ash (in dilute HCl)	Not more than 0.1 per cent, by weight
E	Total plate count	Not more than 50,000 per gram
F	Coliform count	Not more than 10 per gram.
G	Yeast and Mould Count	Not more than 100 per gram.
H	E Coli	Absent in 10 gram.
I	Salmonella and Shigella	Absent in 25 gram
J	Alcoholic Acidity (expressed as H ₂ SO ₄) with 90 per cent alcohol (on dry weight basis)	Not more than 0.30 per cent.
k	Vibrio cholera and V.Paraheamolyticus	absent in 0.1 gm
l	Faecal streptococci and Staphylococcus aureas	absent in 0.1 gm

INTERNATIONAL STANDARDS

The international standards:

- American Dairy products Institute (ADPI) - <http://www.adpi.org>
- Codex Alimentarius - <http://www.codexalimentarius.org>

Quality of raw milk for manufacture of condensed milks

Quality of raw milk used for manufacture of condensed milks and milk powders has the following significance:

- It decides the ease with which it can be handled during processing and manufacture
- It influences the processing parameters and their effects on powder characteristics
- It influences quality specifications of the finished product
- It affects the functional and physico-chemical properties of the finished product

Quality of raw milk for manufacture of condensed milks

- The received milk checked for organoleptic qualities along with other platform tests like clot on boiling (COB), alcohol / ethanol test to determine the suitability of milk for heat processing
- The following criteria are used to define high quality raw milk:
 1. It has a normal taste and appearance.
 2. It has a normal chemical and physical composition.
 3. It does not contain harmful chemical contaminants or residues.
 4. It has a low total count of bacteria and somatic cells.

Quality of raw milk for manufacture of condensed milks

- The milk should be fresh and stored at maximum 5°C for maximum 48 hours after milking, and should not have had any pre-treatment other than:
 1. Separation of cream / desludging by means of a centrifuge.
 2. One heat treatment at max. 72°C and 15 s.
 3. Standardization of fat content by separation of cream and or addition of skim milk.

The milk should be of a very good quality and be free from any additives (apart from fresh cream for standardization) and suspended solids (filtered 100 μ).

Table-3.1: Quality of raw milk in relation to manufacture of condensed milks and milk powders

No.	Parameter	Suggested / Desirable Level	Relevance to Milk Powder
1	Appearance, Smell and Taste	Normal – Absence of flakes, clots, blood	Influence appearance, flavour of finished product
2	Sediment	0.5 – 3.0 mg/Litre	Scorched particles level may increase
3	Milk Fat	Normal – As per local and/or legal requirements	Influence on yield, composition
4	MSNF	-do-	-do-
5	Acidity	≤ 0.15 % LA	<ul style="list-style-type: none"> <li data-bbox="1083 919 1862 1090">▪ Problems with protein stability during processing – early fouling of evaporator <li data-bbox="1083 1105 1862 1262">▪ Influence on basic standards of products made - e.g. S.I., Total acidity <li data-bbox="1083 1276 1862 1376">▪ Poor shelf life – colour, flavour, more free fat
6	pH	6.6 – 6.8	-do-

7	Heat Stability	10 min at 140 ⁰ C, Alcohol test – Negative	Heat processing of milk becomes problematic <ul style="list-style-type: none"> - Early fouling of evaporators - Poor solubility and other related problems
8	Copper	0.10 mg/kg	Catalyze oxidation of fat – poor shelf life
9	Iron	1.0 mg/kg	-do-
10	Heavy metals, Pesticides, Insecticides, Mycotoxins	Absent	Hazardous to human health
11	Antibiotics	0.02 IU/ml	Public health view point undesirable, product will be unsuitable for fermented milk products
12	Somatic cell count	5,00,000 /ml	<ul style="list-style-type: none"> - Poor stability – early fouling of evaporator - High Solubility Index - Poor shelf life – tallowy flavour

13	Free Fatty Acids	1 m mol/100 g fat	Appearance, flowability, reconstitutability and shelf life of powder
14	Non-condensable gases	0.01 to 0.02 % by wt., max.	Can affect the working of evaporator
15	Total Bacterial Count	1,00,000–5,00,000 CFU/ml	<ul style="list-style-type: none"> - Bacteriological quality of finished product - Basic standards – S.I., Total Acidity
16	Thermoresistant Bacteria	5,000 CFU/ml, Max. 25,000 CFU/ml	Bacteriological quality of finished product especially LHP
17	Psychrotrophic Bacteria	2×10^6 CFU/ml	End use of powder in recombined sterile products.

Pre-treatments for Concentrated Milks

- Filtration and/or centrifugation
- Standardization
- Forewarming /Preheating
- Concentration / Concentrate heating
- Homogenization

Filtration

- Weigh can strainers, strainers and filters in the milk line or a duplicate filter unit with by-pass connection are general filtration techniques
- **Bactocatch** method developed by Alfa-Laval Co., Sweden - filtration of milk - **ceramic filters** prior to pasteurization - **microfiltration** technique **removes 99.6% of the bacteria**
- **The advantages of this process are:**
 - Economical
 - Bacillus cereus level is reduced appreciably
 - Absence of disagreeable flavour that sometimes is present in overheated milk
 - Excellent quality low heat powder for cheesemaking, least adverse effect on rennetability, curd characteristics etc.
 - Low heat powder having extended shelf life.

Centrifugation

- There are three types of centrifugal processes to which milk may be subjected during manufacture of dried milks.
 1. Separation proper i.e. Skimming
 2. Clarification
 3. Bactofugation

A clarifier removes leucocytes, cellular debris and particles from earth or fodder gaining entry into milk which might act as a catalyst for chemical reaction during storage of powders

Centrifugation

- The **Bactofugation** process - Professor Simonart - remove bacteria by means of centrifugation
- Basically the bactofuge is a clarifier - one inlet and one outlet
- Additionally, there are two nozzles of about 0.4m diameter fitted into the bowl wall for the discharge of skim milk or what is called 'bactofugate' rich in protein and bacteria
- Size and density of the bacteria being the criteria of their removal
- Bactofugation of milk is always applied in combination with heat treatment, a temperature of 55-65°C offering the optimum bactofugation effect
- Bactofugation of milk by single pass process is less effective (90% removal of bacteria) than two pass process where two bactofuges are arranged in series (bacterial reduction may be up to 99.9%)
- Heating (130 – 140°C) the bactofugate and remixing it with treated milk can eliminate the losses due to bactofugation

Centrifugation

Influences of centrifugation of milk on quality of milk powders :

1. Centrifugation prior to concentration improves casein dispersion and heat stability.
2. Improved shelf life of powder due to reduced tendency of oxidation and lipolysis due to removal of slime, foreign materials (which may act as chemical reaction catalyst), leucocytes, lipolytic bacteria and enzymes etc.
3. Improved solubility to powder (1.8-2.0%) when clarification is applied at 35- 40°C.
4. Decrease in sediment formation.
5. Better organoleptic quality of resultant powder.
6. Improved bacteriological quality of finished product.

Standardization

- Standardization - to meet the legal standards and to optimize yield and profit
- In manufacture of dried milks, the milk fat and SNF are so standardized that the finished product will meet the standards
- The fat to SNF ratio adjustment is done by addition of calculated amount of cream or skim milk to the milk
- This purpose is accomplished in the present day industry by use of tri-purpose separator which has the standardizing device too

PREHEATING / FOREWARMING OF MILK

In manufacture of milk-powders milk is subjected to heat treatment in two stages-

- (A). Prior to concentration
- (B). After concentration, before atomization.

Heating prior to concentration has the following objectives:

- Preheating of milk to at least the boiling temperature of the first effect evaporation is essential, so that evaporation can start immediately the milk enters the heating tubes
- The most common boiling temperatures of the first effect in the food industry are between 40-100°C
- Heating of milk to a temperature exceeding the boiling temperature of the first effect are required for the purpose of:
 - (a) Enzyme inactivation, e.g. lipoprotein lipase.
 - (b) Pasteurization effect - improved microbiological quality of resultant product due to microbial inactivation. Heat treatment employed in manufacture of low and high heat powders had profound effect on bacterial profile
 - (c) To lengthen the running time of evaporators (as most of the whey proteins are denatured when milk is preheated before evaporation).
 - (d) To generate specific properties in the resultant milk powders, e.g. heat stability, viscosity, etc. by altering the characteristics of some of the components of milk such as casein, whey protein, mineral balance etc.
 - (e) To improve oxidative stability of whole milk powder during storage. This is due to production of -SH groups and other reducing substances in milk on account of heating.
- To produce skim milk powder of various heat classification.

Table- 4.1: Classification of Non-Fat Dry Milk on the basis of Heat Class

No.	Heat Class	Heat / Casein Number, %	WPNI (ADMI) mg/g	Cysteine Number
1	Extra Low Heat	-	-	26-33
2	Low Heat	< 80.0	> 6.0	34-41
3	Medium Heat	80.1-83.0	4.5-5.99	-
4	Medium High Heat	83.1-88.0	1.5-4.49	-
5	High Heat	> 88.1	< 1.5	-

Table- 4.2: Typical time-temperature combinations for different types of powders

Type	Temperature	Time
Low Heat	74 ⁰ C	15 Sec
Medium Heat	79 ⁰ C	3 min
High Heat	82 ⁰ C	30 min

Concentrate heating

- The viscosity of the concentrate has bearing on drying efficiency as well as certain properties of the dried milks
- High concentrate viscosity - increase the likelihood of blockage of feed lines and in the calandria of evaporators
- Concentrate has to be heated to 70-75°C prior to atomization

Advantages of pre-heating concentrate

- Saving of energy as it is more efficient to heat the concentrate by means of steam or hot water than to use heat from the air supplied to the dryer
- The evaporation capacity of the dryer is increased by ~ 5% when the concentrate is supplied to the atomizer at 70°C instead of 50°C
- The average size of the droplets into which the concentrate is atomized is reduced due to the lower viscosity - facilitates the drying making it possible to reduce the air outlet temperature and still maintain the specified moisture content of the powder
- The lower outlet temperature results in increased capacity and gentler drying which results in improved powder quality - especially solubility

Advantages of pre-heating concentrate

- As the temperature conditions in the last stages of the evaporator and in the feed tank for the dryer can be favorable for growth of micro organisms, heat treatment of the concentrate immediately before drying will contribute to safeguard the bacteriological quality of the powder
- Heating of the concentrate must be done in such a way that no holding takes place, i.e. The concentrate heater must be placed immediately before the atomizer
- This is necessary in order to avoid the so called "age-thickening" which occurs very rapidly at temperatures above 60°C - irreversible and results in very high viscosity

Table 4.3: Changes in viscosity of concentrated skim milk (39 % TS) held for different periods at 75⁰C

No.	Holding time (min)	Viscosity (cP)
1	0	14
2	15	41
3	30	90
4	45	168
5	60	360
6	75	460

Table 4.5: Influence of the heating on the characteristics of whole milk powder concentrate (Non-homogenized, Dry matter content: 49.5%)

Temperature of concentrate, °C	Moisture, %	Viscosity cP	ADPI Solubility Index (ml)	Degree of homogenization, %	Free-fat content, %	Bulk Density, g/cm³	N₂ penetration cm³/100 g	Mean particle density
50	3.18	3610	1.20	50	13.8	0.58	2.95	1.05
60	2.87	2945	0.60	52	14.5	0.57	3.18	1.04
70	3.04	1510	0.30	55	15.9	0.55	4.00	1.01
80	3.02	1150	0.20	58	21.1	0.54	5.08	1.00

Homogenization

- Homogenizing milk/concentrate prior to spray drying - reduce the size of the fat globules and low free fat content in powder

Table 4.7: Influence of the concentrate homogenization on v whole milk powder

Concentrate	Dry Matter, %	Moisture Content, %	Viscosity, cP	ADPI Solubility Index (ml)	Free-fat content, %	Bulk Density, g/cm³
Non-homogenized	43.2	2.73	1380	0.05	23.7	0.49
	49.1	3.18	1635	0.40	12.0	0.54
	54.7	3.52	3040	1.20	5.2	0.62
Single –stage homogenized	43.2	2.57	800	0.10	7.3	0.50
	49.1	3.07	1630	1.80	4.8	0.55
	54.7	3.41	5960	2.20	4.6	0.61
Two-stage homogenized	43.2	2.58	700	0.05	7.1	0.49
	49.1	3.09	1000	0.30	6.3	0.53
	54.7	3.46	3260	0.70	5.1	0.62

Microbial quality of milk powders

- Microbial deterioration a_w should increase to over 0.6 (and for the majority of microorganisms much higher); such a high a_w can only be reached if the powder is exposed to fairly moist air
- Enzymatic hydrolysis of fat has been observed at a $w \geq 0.1$, although extremely slow
- Accordingly, whole milk powder must be free of lipase
- Milk lipase will always be inactivated by the intense pasteurization of the milk as applied in the manufacture of whole milk powder
- This is by no means ensured, however, for bacterial lipases. Hence, not too many lipase-forming bacteria should occur in the raw milk
- However, enzymic deterioration of liquid products made from the milk powder can occur if enzymes are present before the drying, as drying usually does not cause substantial inactivation of enzymes

Microbial quality of milk powders

Table 47.1: Lowest values of water activity at which organisms grows

No.	Organisms	a_w	No.	Organisms	a_w
1	Bacteria	0.98–0.90	4	Halophilic bacteria	down to ~ 0.75
2	Yeasts	~ 0.9	5	Osmopholic yeasts	down to ~ 0.6
3	Molds	0.92–0.80	6	Xerophilic molds	down to ~ 0.6

Microbial quality of milk powders

- The causes for milk powder to be bacteriologically unacceptable or even unsafe can be of three kinds:
- In the fresh milk, bacteria are present that are not killed by the heat treatments to which the milk is subjected before and during drying.
- Conditions during the various process steps until the product is dry do allow growth of some bacterial species.
- During manufacture, incidental contamination may occur. The level of contamination is generally low and remains low if the bacteria involved cannot grow.

Microbial quality of milk powders

- In the regeneration section of pasteurizers and possibly in the part of the evaporator, *S. thermophilus*, in particular, can develop. The bacterium grows fastest at 45C but scarcely multiplies at temperatures over 50C
- It generally does not grow in the evaporator, because the temperature is too high in the first effects, whereas in the later effects aw will be too low
- Because *S. thermophilus* is moderately heat resistant, relatively high counts may result, especially in low-heat milk powder
- In medium and high-heat powder the bacterium is killed during manufacture
- Determination of the count of *S. thermophilus* in the milk just before the preheater may give a good indication of the fouling of the heating section of plant and of the moment at which it should be cleaned

Microbial quality of milk powders

- In some drying plants that employ a wet washer to recover powder fines, the outlet air is brought into contact with a film of milk rather than water, thereby preheating the milk and saving energy; this implies that the preheated milk acquires the wet bulb temperature (~ 45C, *S. thermophilus* . C)
- In the second half of the evaporator and in the balance tank Enterococci (*E . faecium*), in particular, will start to grow
- If the milk is properly preheated and the plant is satisfactorily cleaned and sterilized, it will take a rather long time, however, before substantial counts of *E . faecium* have developed
- In actual practice, these prerequisites are not always met and in milk powder with a relatively high count, *E . faecium* often is the predominant species

Microbial quality of milk powders

- Likewise, the conditions in the second part of the evaporator and in the balance tank are favorable for growth of *Staphylococcus aureus*
- The bacterium generally is killed by pasteurization, and strains of *S. aureus* in milk powder have been shown to have phage characteristics different from the strains in raw milk
- Presumably, they originate from direct or indirect human contamination
- Although *S. aureus* is not heat resistant, the conditions during drying appear to be such that complete killing is not achieved

Microbial quality of milk powders

- *Bacillus stearothermophilus* (ssp. *calidolactis* in particular) can readily grow at higher temperatures. Its growth range is from 45C to 70C, with an optimum near 60C
- It can also grow in concentrated milk and therefore throughout the equipment between preheater and drier
- Moreover, the bacterium can form spores under these conditions, which further limits its killing during drying
- Obviously, some growth of *B. stearothermophilus* will always occur during manufacture, even in a well-cleaned and disinfected plant. However, under most conditions this will not cause problems.

Measures to control bacterial growth

- Special attention should be paid to the temperature and the time for which the product stays in the equipment, and to matching of the capacities of the various parts of the plant
- Multiple effect falling-film evaporators are more satisfactory
- It is recommended that the volume of the concentrate balance tank be kept as small as possible. Mostly, there are two tanks, making possible a change every 2 h or so, and the cleaning of one while the other is in use.
- Contamination of the product flow from outside should be prevented, with particular reference to *S. aureus*.
- The concentrated milk may be pasteurized just before it enters the drier, and this is increasingly being done. It is especially successful with regard to the killing of *E. faecalis* and *E. faecium*, provided that the temperature applied is high enough. Heating for 45 s at 72 C has little effect; 45 s at 78 C causes a considerable reduction.

Defects in dried milks – causes and prevention

Name of defect	Cause	Prevention
Flavour		
Stale / Old	Long storage	Short storage
	Storage at high temperature	Storage at low temperature (24°C) or below
	Excessively high pre-heating temperature	Optimum high pre-heating temperature
	Delayed cooling and removal of dried product from drying chamber	Prompt cooling and removal of dried product from drying chamber
	High moisture content during storage	Optimum moisture content during storage
Rancid	Low pre-heating temperature (lipase not inactivated)	Optimum pre-heating temperature (inactivate lipase)

Name of defect	Cause	Prevention
Oxidized/Tallowy	Storage at high temperature	Storage at low temperature
	Action of sunlight (transparent packaging material)	Avoid action of sunlight (opaque packaging material)
	High acidity in milk	Using fresh, sweet milk
	Metallic (copper and iron) contamination (direct contact with milk)	Using stainless steel or aluminium alloy contact surfaces only
	Delay in cooling and removal of dried product from drying chamber	Prompt cooling and removal of dried product from drying chamber
	Higher oxygen content in the head space of the container	Vacuum or inert gas packaging (reduce head space oxygen content less than 2 percent)
		Use of permitted anti-oxidants

Name of defect	Cause	Prevention
Scorched/Burnt	Excessively high temperature of drying (roller drying)	Optimum high temperature of drying (roller drying)
	Drum surface has pits	Drum surface kept smooth
	Scraper knives dull	Scraper knives kept sharp
Body and texture (fineness and homogeneity)		
Lumpy	Insufficient drying	Sufficient drying
	Absorption of moisture (exposure to humid atmosphere)	Preventing absorption of moisture
	Drippage from pressure spray nozzle	Use centrifugal disc atomizer
Caked	Absorption of moisture (exposure to humid atmosphere)	Preventing absorption of moisture

Name of defect	Cause	Prevention
Colour and appearance		
Browning and darkening of colour	Long storage	Short storage
	Storage at high temperature	Storage at high temperature
	Delay in cooling and removal of dried product from drying chamber	Prompt cooling and removal of dried product from drying chamber
	High moisture content during storage	High moisture content during storage
Lack of uniformity in appearance	Partial scorching during manufacture (drum process)	Careful control of operations
	Partial discoloration after packaging	Careful control of storage conditions influencing discoloration

Infant milk food

- 30% children suffer from malnutrition in developing countries
- Human milk – ideal for infant feeding or children below one year age
- Several reasons – mother's ill health, unwillingness due to profession, income group etc. led to deprivation of children for mother's milk
- Infant need to be fed either wholly or partly with milk from other sources
- Other milks – generally diluted with water and added with sugar for infant feeding
- Developed countries – modified Cow milk successfully dried – reconstituted

Infant milk food

- In India, CFTRI, Mysore and Amul Dairy, Anand started investigation in 1957
- 1960 – standardized a process for commercial production of Amul infant/baby food from buffalo milk in 1960 by Roller Process
- Since 1967, Amulspray babyfood has been in the market

Infant milk food

- Infant Milk Food means the product prepared by spray drying of the milk of cow or buffalo or a mixture thereof. The milk may be modified by the partial removal/substitution of different milk solids; carbohydrates, such as sucrose, dextrose and dextrans/maltodextrin, maltose and lactose; salts like phosphates and citrates; vitamins A, D, E, B Group, Vitamin C and other vitamins; and minerals like iron, copper, zinc and iodine.
- It shall be free of lumps and shall be uniform in appearance.
- It shall be free from starch and added antioxidants.
- It shall also be free from dirt, extraneous matter, preservatives and added colour and flavour and from any material which is harmful to human health.
- It shall not have rancid taste or musty odour.

Table-45.1: Chemical composition of human, cow and buffalo milks

No.	Components, g/100 ml	Human	Cow	Buffalo
1	Proteins	1.2	3.3	4.2
2	Fat	3.8	4.1	7.0
3	Carbohydrate	7.0	4.5	5.1
4	Ash	0.21	0.72	0.82

Table-45.2: Major differences in the make up of different constituents of human, cow and buffalo milks

No.	Components	Human	Cow	Buffalo
1	Proteins			
	▪ Caseins, % of total protein	40	82.3	75.6
	▪ Whey proteins, % of total protein	60	17.7	24.4
	▪ Immunoglobulins (g/100 ml)	1.0-1.5	0.5	NA
	▪ Lactoferrin (mg/ml)	1.39	0.09	0.32
	▪ Lysozyme (mg/100 ml)	40	0.013	NA
2	Lipids			
	▪ Oleic acid (mg/lit)	14.9	10.3	9.5
	▪ Linoleic acid (mg/lit)	3.4	0.8	0.5
	▪ Linolenic acid (mg/lit)	Traces	0.2	0.3
	▪ Arachidonic acid (mg/lit)	0.33	Traces	NA
	▪ Cholesterol (mg/lit)	0.2	0.14	NA
3	Lactose	6.9	4.8	5.1
4	Minerals			
	▪ Total (%)	0.21	0.68	0.82
	▪ Ca (mg/100 ml)	31	128	210
	▪ P (mg/100 ml)	15	87	128
	▪ Fe (mg/100 ml)	0.15	0.14	6.2
5	Vitamins & Growth factors			
	▪ Vit A (mg/100 ml)	0.05	0.03	0.05
	▪ Vit E (mg/100 ml)	0.54	0.07	NA
	▪ Nicotinic acid (mg/100 ml)	0.24	0.08	0.1
	▪ Bifidus factor (units)	40	1	NA

Human milk vs other milks

Carbohydrates

- Human milk - higher carbohydrates (lactose) 40% of the total energy of human milk is supplied by this constituent - only 29% in case of cow milk
- Moreover, presence of non-lactose oligosaccharides such as bifidus stimulating factors in human milk enables the growth of healthy microflora in the intestines

Fats/lipids

- Fat present in human milk provides essential fatty acids (required for nervous system development and prostaglandin synthesis), fat soluble vitamins and sterols
- Almost an equal amount of fat is present in cow and human milks; however, qualitatively they differ widely in their fatty acid make-up

Table 45.3: Fatty acid composition (% wt.) of human and cow milks

No.	Fatty acid	Human milk	Cow milk
1	4:0 Butyric	-	3.3
2	6:0 Caproic	Trace	1.6
3	8:0 Caprylic	Trace	1.3
4	10:0 Caprolic	1.3	3.0
5	12:0 Lauric	3.1	3.1
6	14:0 Myristic	5.1	14.2
7	16:0 Palmitic	20.2	42.9
8	16:1 Palmitoleic	5.7	3.7
9	18:0 Stearic	5.0	5.7
10	18:1 Oleic	46.4	16.7
11	18:2 Linoleic	13.0	1.6
12	18:3 Linolenic	1.5	1.8
13	Unsaturated / Saturated Ratio	1.92	0.32

- Human milk fat - rich in polyunsaturated fatty acids (PUFA) (notably linoleic acid- an essential fatty acid- about 7 to 8 times higher) - brain development
- Human milk fat – more oleic acid - easily digestible; cow milk fat - excess of butyric acid - fatty diarrhea
- Higher content of 18:1 (Oleic acid) in human milk also enables improved retention of calcium in breastfed infants
- All infant foods should contain PUFA rich vegetable oils so as to provide a minimum of 300 mg/k cal of linoleic acid in the formulas

Proteins

- Whey proteins are richer in essential amino acid content (PER = 3.11) compared to caseins (PER=2.50) - good quality proteins, typical of human milk
- Higher proportion of α -lactalbumin but no β – lactoglobulin - α -lactalbumin serves as a source of essential amino acids for the infant as well as acting as a crucial component of an enzyme system that biosynthesizes lactose.
- Antimicrobial proteins of human milk (lactoferrin, lysozyme and IgA) account for 75% of the protein in human colostrum, versus 39% in mature human milk and less than 0.1% in cow milk
- Taurine more in human milk and traces in cow milk - play a major role in fat utilization and brain development

Minerals

- Human milk - mineral content is less than one third than in cow/buffalo milk

Host - resistant factors

- **Immunoglobulins (Ig) (Milk antibodies):** The most abundant Ig of human milk is **IgA** versus Ig G in cow milk. It provides the infant with protection against enteric infection and serves as an "**intestinal paint**" to prevent the passage of various foreign proteins and bacteria from the intestinal tract into circulation
- **Lactoferrin (LF):** Human milk contains from **3 to 100 times** as much iron binding protein LF as cow milk. LF is active against enteropathogenic *E. coli* , *Vibrio cholerae*, *St. mutans* and *Candida albicans*, presumably by chelating iron and making it unavailable for microbial growth
- **Lysozyme:** It cleaves the cell wall peptoglycan of a number of Gram positive and Gram negative microorganisms and appears to act with complement to potentiate the activity of IgA against *E. coli*, and with peroxide and ascorbate to lyse *E. coli* and salmonella.
- Human milk contains **~ 3000 times** as much lysozyme as cow milk

- **Bifidobacteria:** Protect the infant against disease by producing volatile acids which inhibit the proliferation of pathogenic microorganisms in the gut
- **Oligosaccharides and glycoproteins:** Stimulate the growth of *B. bifidum* var: *pennsylvanicus* .
- Human milk contains ~ 30 to 100 fold more stimulatory activity than cow milk.

Infant milk food

Receiving milk
↓
Pre-heating (35-40°C)
↓
Filtration/clarification
↓
Chilling and storage (5°C)
↓
Standardization (Fat:SNF = 1:3.227)
↓
Addition of ferrous sulphate and sugar
↓
Pre-heating (80°C/ No hold)
↓
Condensing (43-48% TS)

Homogenization (I - 50 kg/cm² and II- 25 kg/cm²)
↓
Chilling and storage (5°C)
↓
Pre-heating (70°C)
↓
Drying
↓
Sifting
↓
Fortification (with amino-acids, vitamins and minerals)
↓
Gas packaging (Nitrogen)
↓
Storage (<24°C)