Quality Management in Powder Manufacture

For skim milk and whey permeate

Presented by: Eddy Bronsveld

Tetra Pak®
PROTECTS WHAT'S GOOD

Content overview

Introduction - line solution team for powder

Eddy Bronsveld
Line Solution Expert

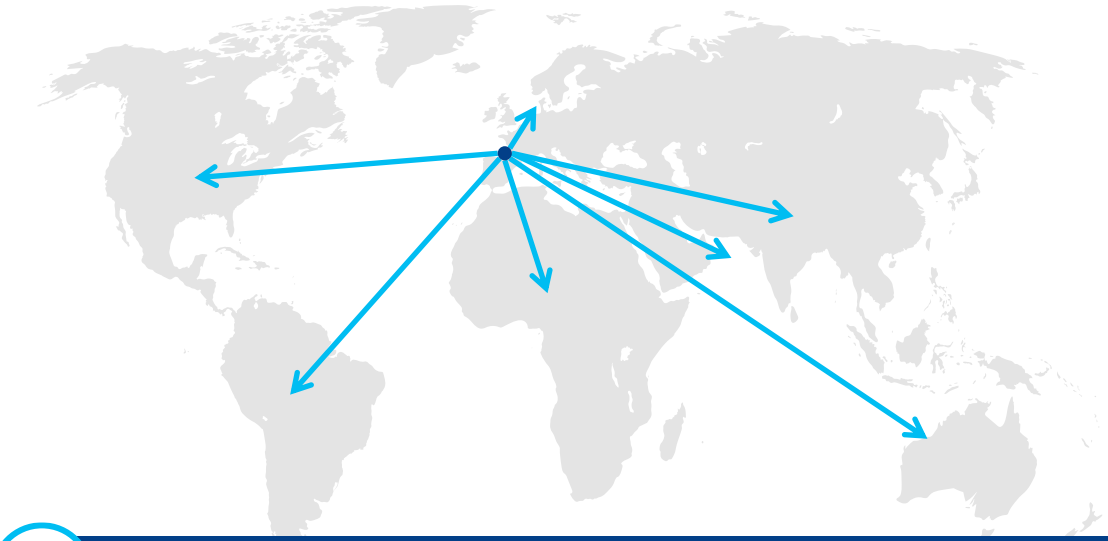
- Specialist in spray drying
- >30 years experience in evaporation and spray drying
- Line solution specials for E2E powder business: 7 years

Introduction - line solution team for powder

Eddy Bronsveld
Line Solution Expert

Evonne Brooks
Line Solution Expert

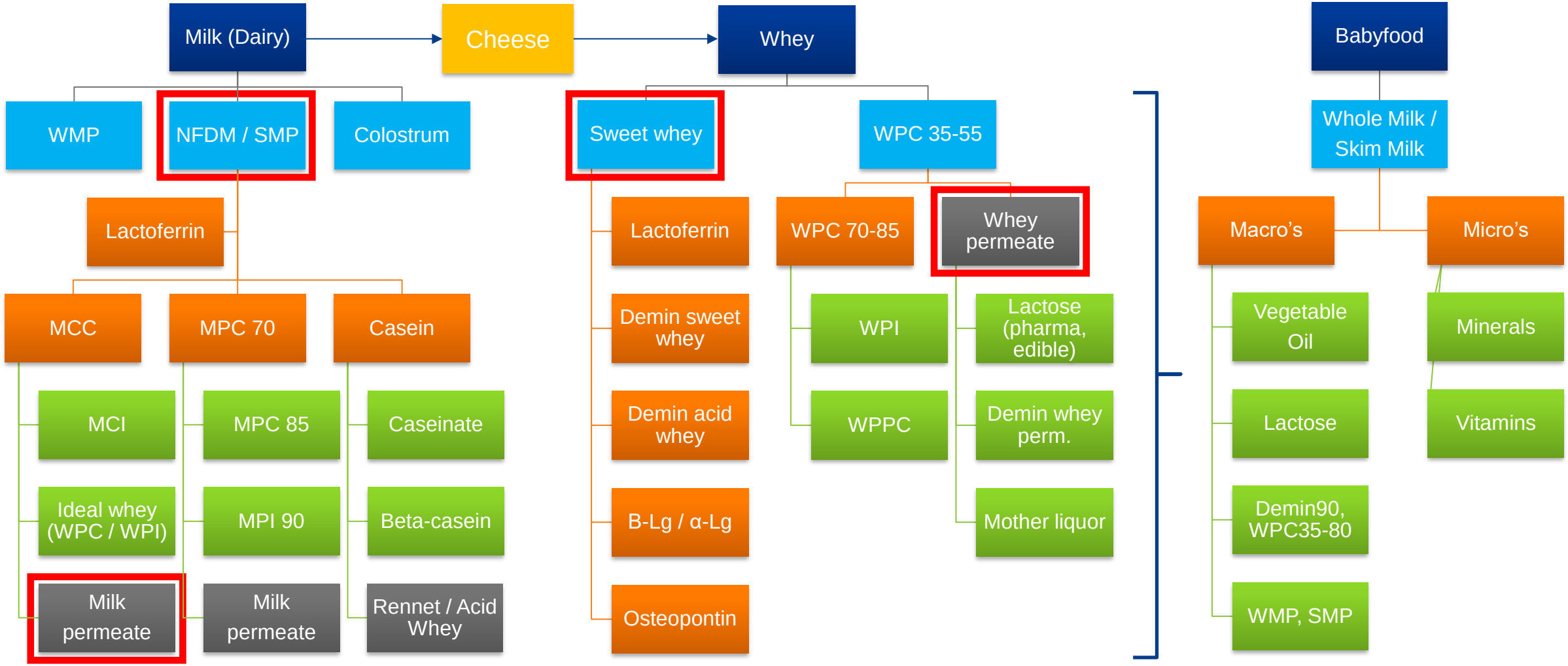
Nanne van Dijk
Line Solution Expert



- Supporting **27 market organisations** in TP
- Defining **conceptual designs** for powder lines
- Mass balances, process block charts, PTS
- Expertise in powder manufacture and properties

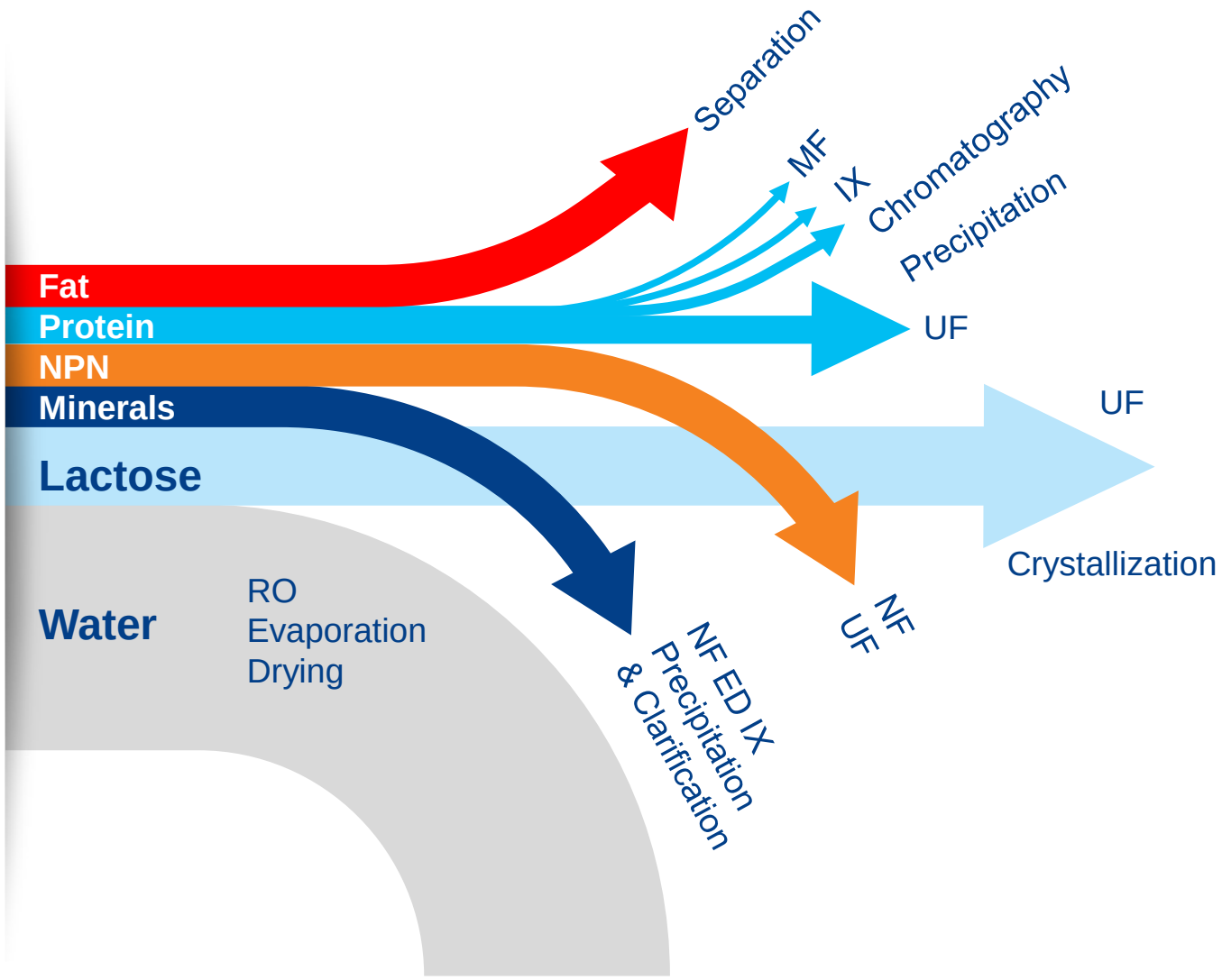
Powder line solutions for milk and whey

Milk and whey derivatives



Key processing unit operations for fractionation

- Pre-treatment / HEX & Separation
- Filtration, MF / UF / NF / RO / DF
- Precipitation
- Decoloring
- Chromatography
- Electrodialysis ED
- Ion exchange IX
- Decanting
- Crystallization
- Evaporation
- Dryers



Spray drying of dairy products

Two main reasons for spray drying

1. To reduce the weight and bulk of food products, **making transportation and storage more economical.**

2. To **prevent or inhibit the growth and activity of micro-organisms,** thereby preserving the food

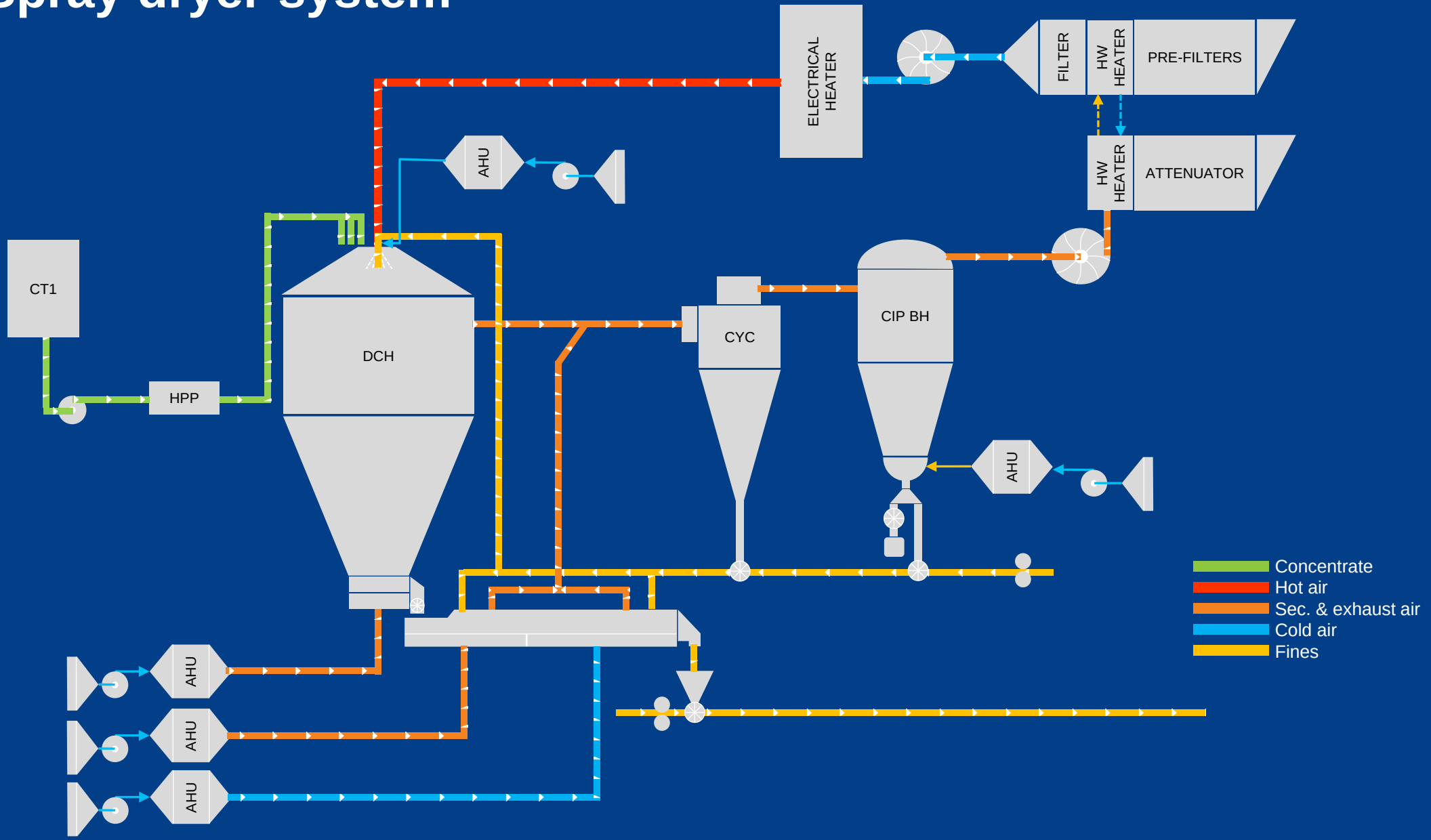
- When drying is performed correctly, rehydrated dried foods retain nearly the **same nutritional quality, color, flavor, and texture** as fresh food.
- However, improper drying can lead to significant loss in nutritional and sensory qualities, and more significantly, pose a **risk of microbial spoilage** and potential foodborne illness.

Dryer key design considerations

Key considerations for design

- Raw materials
- Product composition
- Product types
- Plant capacity (daily volume)
- Powder properties
- Climatic conditions

Spray dryer system



Wide Body and Tall Form Bustle spray dryer

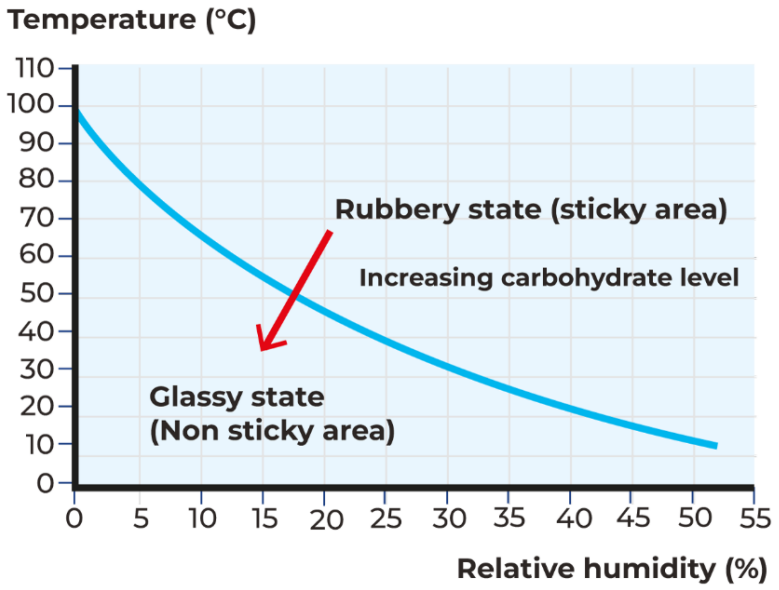
Wide Body dryer

Tall Form Bustle dryer

Spray drying of thermoplastic products

- **Powder build-up** on drying chamber walls is a well-known phenomenon
- Cause of buildup: **Stickiness of product**
- **Contributor:** Glass Transition Temperature of constituents
- Product stickiness exhibited in spray drying is **related to product composition, type of constituents, particle moisture and particle temperature**.

As carbohydrates in **milk powder increases**, the glass transition takes place at a **lower temperature and relative humidity**.



Stickiness

Composition | Constituents | Moisture | Temperature

Quality management

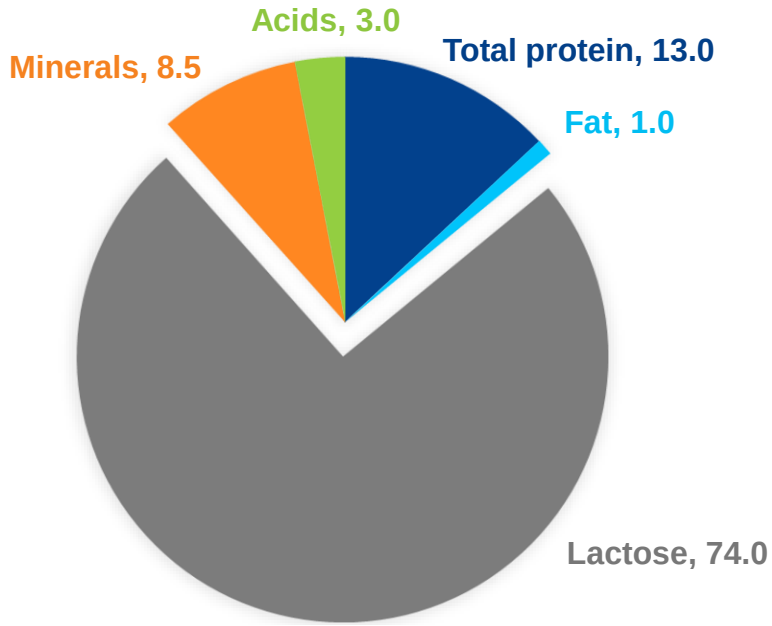
Powder characteristics

- **C** Chemical Characteristics
- **P** Physical characteristic
- **F** Functional characteristics
- **M** Microbiological characteristics

Chemical characteristics

- Protein
- Fat
- Carbohydrate
- Ash / Minerals
- Water
- Free fat
- Titrable acidity
- Whey Protein Nitrogen Index

COMPOSITION SWEET WHEY (%DM)



Physical characteristics

- Scorched particles
- Objectionable matter
- Solubility index
- Bulk density
- Particle size distribution
- Average particle size
- Color / Flavor
- Mechanical stability

Functional characteristics

F

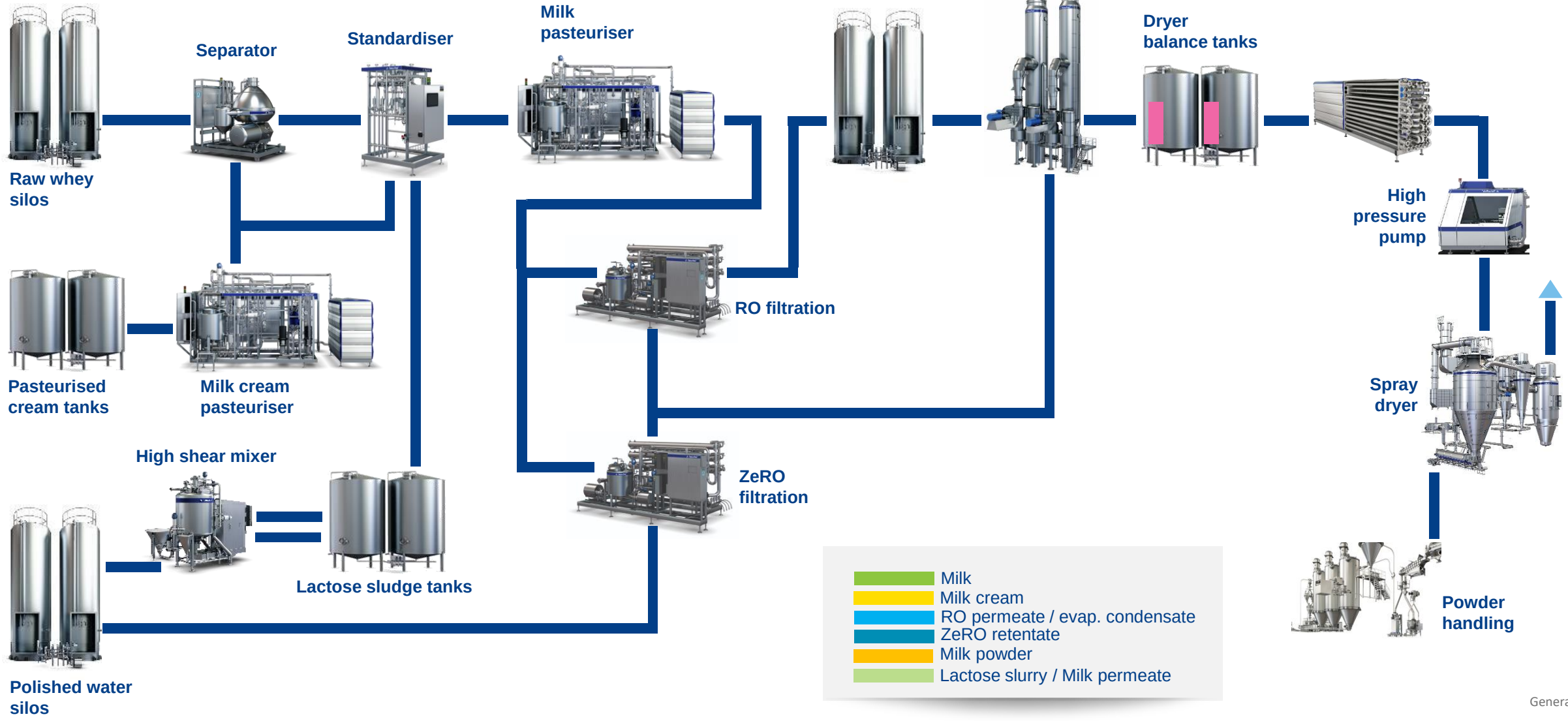
- Flowability
- Wettability
- Dispersibility
- Slow dissolving particles (SDP)
- Hot water sediment
- Coffee sediment / Coffee Test
- White fleck number (WFN)
- Hygroscopicity, Cakiness

Microbiological characteristics

- Total Plate Count
- E. Coli
- Coliform
- Coagulase Pos. Staphylococcus
- Thermophiles
- Mesophilic & Thermophilic Spores
- Yeast, Molds
- Salmonella, Listeria

Skim milk powder manufacture

Skim / whole milk powder production line



Product info skim milk powder (ADPI)

	Product		NFDM (extra grade)	NFDM instant (extra gr)	SMP regular
Chemical	**Protein (SNF)**	%	as is (36 – 40)	as is (36 – 40)	34.0 min.
	Fat	%	1.25 max.	→	1.50 max.
	Moisture	%	4.0% max.	4.5 max.	5.0 max.
	Titrable acidity	0%	0.15 max.	→	0.18 max.
	WPNI	mg/g	LH (6.0 min.), MH (1.51-5.99), HH (1.5 max.)		
	Scorched particles	mg/25g	15.0 max. (22.5 max)	→	→
Physical	**Bulk density**	g/cm^3	0.65 – 0.75	0.45 – 0.50	0.65 - 0.80
	Solubility index	ml	1.2 max. (2.0 max.)	1.0 max.	1.0 max.
	Dispersibility	%	--	85 min.	--
	Color	--	White to cream	→	→
	Flavor	--	sweet and desirable	Sweet and pleasing	Bland, clean
Microbiological	**SPC / TPC**	cfu/g	10,000 max.	10,000 max.	30.000 max.
	Coliform	cfu/g	10 max.	→	--
	Bacillus Cereus	cfu/g	100 max.	→	→
	Enterobacteriaceae	cfu/g	10 max.	→	→
	Coag. Pos. Staph.	cfu/g	Not detected (10 max.)	→	→
	Yeast and Mold	cfu/g	100 max.	→	→
	Salmonella / Listeria	125/g	Not detected	→	→

Skim milk powder specification ADPI & Codex

AMERICAN Dairy Products INSTITUTE

Skim Milk Powder (SMP) Standard

Product Definition

Skim Milk Powder (SMP) is the product resulting from the partial removal of fat and water from pasteurized milk. The fat and/or protein content of the milk may have been adjusted, only to comply with the compositional requirements below, by the addition and/or withdrawal of milk constituents in such a way as not to alter the casein-to-whey protein ratio of the milk being adjusted. Milk products permitted for such adjustment purposes are defined in the Permissible Additives section of this Standard.

Skim Milk Powder complies with all provisions of the U.S. Federal Food, Drug, and Cosmetic Act.

Composition

Parameter	Units of Measure	Limits
Protein	%, solids non-fat basis[1]	34.0 minimum
Fat	%	1.50 maximum
Moisture[2]	%	5.0 maximum

1 - Solids non-fat includes lactose water of crystallization.

2 - Moisture content does not include lactose water of crystallization.

Other Characteristics

Physico-chemical Properties		
Parameter	**Units of Measure**	**Limits**
Scorched particles	mg/25g	15.0 maximum
Titratable acidity	%	0.18 maximum
Solubility index	mL	1.0 maximum
Color	visual	white to cream
Flavor	sensory	bland, clean

Microbiological Analysis		
Parameter	**Units of Measure**	**Limits**
Standard plate count	CFU/g	30,000 maximum
Yeast and mold	CFU/g	100 maximum
Coliforms[3]	CFU/g	10 maximum
Enterobacteriaceae[3]	CFU/g	10 maximum
Salmonella	CFU/sample[4]	not detected
Staphylococcus (coagulase positive)	CFU/g	not detected[5]
Listeria genus	CFU/g	not detected

3 - The food industry is trending toward *Enterobacteriaceae* ("EB") as the most commonly used category of indicator organisms for gauging general process sanitation. For compliance to this Standard, either coliforms and/or EB shall be utilized, at the discretion of the manufacturer.

4 - Typical minimum sample size for *Salmonella* testing is 25 g, but the exact sample size and methodology is left to the discretion of the manufacturer.

5 - Where the effective limit of quantitation for the test is 10 CFU/g (such as when a dilution factor of 10 is applied) then the test result must be not detected in order to comply with this Standard. Where the testing method is capable of quantifying microbial counts below 10 CFU/g, then a compliant result must be a value less than 10 CFU/g.

Permissible Additives

The protein content of milk used to manufacture Skim Milk Powder may be adjusted ("standardized") by the addition of the following milk products only:

- Milk retentate: the product obtained by concentrating milk protein by ultrafiltration of milk, reduced fat milk, or skim milk;
- Milk permeate: the product obtained by removing milk proteins and milkfat from milk, reduced fat milk, or skim milk by ultrafiltration; and
- Lactose.

Methods of Analysis

Parameter	Reference Method
Protein	ISO 8698-1 / IDF 20 part 1
Fat	ISO 1736 / IDF 9C
Moisture	ISO 5537 / IDF 26
Scorched particles	ISO 5739 / IDF 107
Titratable acidity	ISO 6091 / IDF 86
Solubility index	ISO 8156 / IDF 129
Microbiological tests	FDA BAM

https://www.adpi.org/

Skim milk powder specification ADPI & Codex

1. SCOPE

This standard[i] applies to milk powders and cream powder intended for direct consumption or further processing, in conformity with the description in Section 2 of this standard.

2. DESCRIPTION

Milk powders and cream powder are milk products which can be obtained by the partial removal of water from milk or cream. The fat and/or protein content of the milk or cream may have been adjusted, only to comply with the compositional requirements in Section 3 of this standard, 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.

3. ESSENTIAL COMPOSITION AND QUALITY FACTORS

3.1 Raw materials

Milk and cream

The following milk products are allowed for protein adjustment purposes:

- milk retentate: Milk retentate is the product obtained by concentrating milk protein by ultrafiltration of milk, partly skimmed milk, or skimmed milk;
- milk permeate: Milk permeate is the product obtained by removing milk proteins and milkfat from milk, partly skimmed milk, or skimmed milk by ultrafiltration; and
- lactose.[ii]

3.2 Composition

Cream powder

Minimum milkfat	42% m/m
Maximum water[(a)]	5% m/m
Minimum milk protein in milk solids-not-fat[(a)]	34% m/m

Whole milk powder

Milkfat	Minimum 26% and less than 42% m/m
Maximum water[(a)]	5% m/m
Minimum milk protein in milk solids-not-fat[(a)]	34% m/m

Partly skimmed milk powder

Milkfat	More than 1.5% and less than 26% m/m
Maximum water[(a)]	5% m/m
Minimum milk protein in milk solids-not-fat[(a)]	34% m/m

Skimmed milk powder

Maximum milkfat	1.5% m/m
Maximum water[(a)]	5% m/m
Minimum milk protein in milk solids-not-fat[(a)]	34% m/m

[(a)] The water content does not include water of crystallization of the lactose; the milk solids-not-fat content includes water of crystallization of the lactose.

[i] This standard replaced the *Standard for Whole Milk Powder, Partly Skimmed Milk Powder and Skimmed*

APPENDIX

ADDITIONAL INFORMATION

The additional information below does not affect the provisions in the preceding sections which are those that are essential to the product identity, the use of the name of the food and the safety of the food.

Additional quality factors

	Whole milk powder	Partially skimmed milk powder	Skimmed milk powder	Method
Titratable acidity	max 18.0	max 18.0	max 18.0	See CXS 234-1999
(ml-0.1 N NaOH/ 10 g-solids-not-fat)				See CXS 234-1999
Scorched particles	max Disc B	max Disc B	max Disc B	See CXS 234-1999
Solubility index (ml)	max 1.0	max 1.0	max 1.0	See CXS 234-1999

NOTES

[1] FAO and WHO. 1995. *General Standard for Food Additives*. Codex Alimentarius Standard, No. CXS 192-1995. Codex Alimentarius Commission. Rome.
[2] FAO and WHO. 1995. *General Standard for Contaminants and Toxins in Food and Feed*. Codex Alimentarius Standard, No. CXS 193-1995. Codex Alimentarius Commission. Rome.
[3] FAO and WHO. 1969. *General Principles of Food Hygiene*. Codex Alimentarius Code of Practice, No. CXC 1-1969. Codex Alimentarius Commission. Rome.
[4] FAO and WHO. 2004. *Code of Hygienic Practice for Milk and Milk Products*. Codex Alimentarius Code of Practice, No. CXC 57-2004). Codex Alimentarius Commission. Rome.
[5] FAO and WHO. 1997. *Principles and Guidelines for the Establishment and Application of Microbiological Criteria Related to Foods*. Codex Alimentarius Guideline, No. CXG 21-1997. Codex Alimentarius Commission. Rome.
[6] FAO and WHO. 1985. *General Standard for the Labelling of Pre-packaged Foods*. Codex Alimentarius Standard, No. CXS 1-1985. Codex Alimentarius Commission. Rome.
[7] FAO and WHO. 1999. *General Standard for the Use of Dairy Terms*. Codex Alimentarius Standard, No. CXS 206-1999. Codex Alimentarius Commission. Rome.
[8] FAO and WHO. 2021. *General Standard for the Labelling of Non-Retail Containers of Foods*. Codex Alimentarius Standard, No. CXS 346-2021. Codex Alimentarius Commission. Rome.
[9] FAO and WHO. 1999. *Recommended Methods of Analysis and Sampling*. Codex Alimentarius Standard, No. CXS 234-1999. Codex Alimentarius Commission. Rome.

https://www.fao.org/fao-who-codexalimentarius/

Wide Body and Tall Form Bustle spray dryer

Wide Body dryer

Tall Form Bustle dryer

Risk management regular skim milk powder production

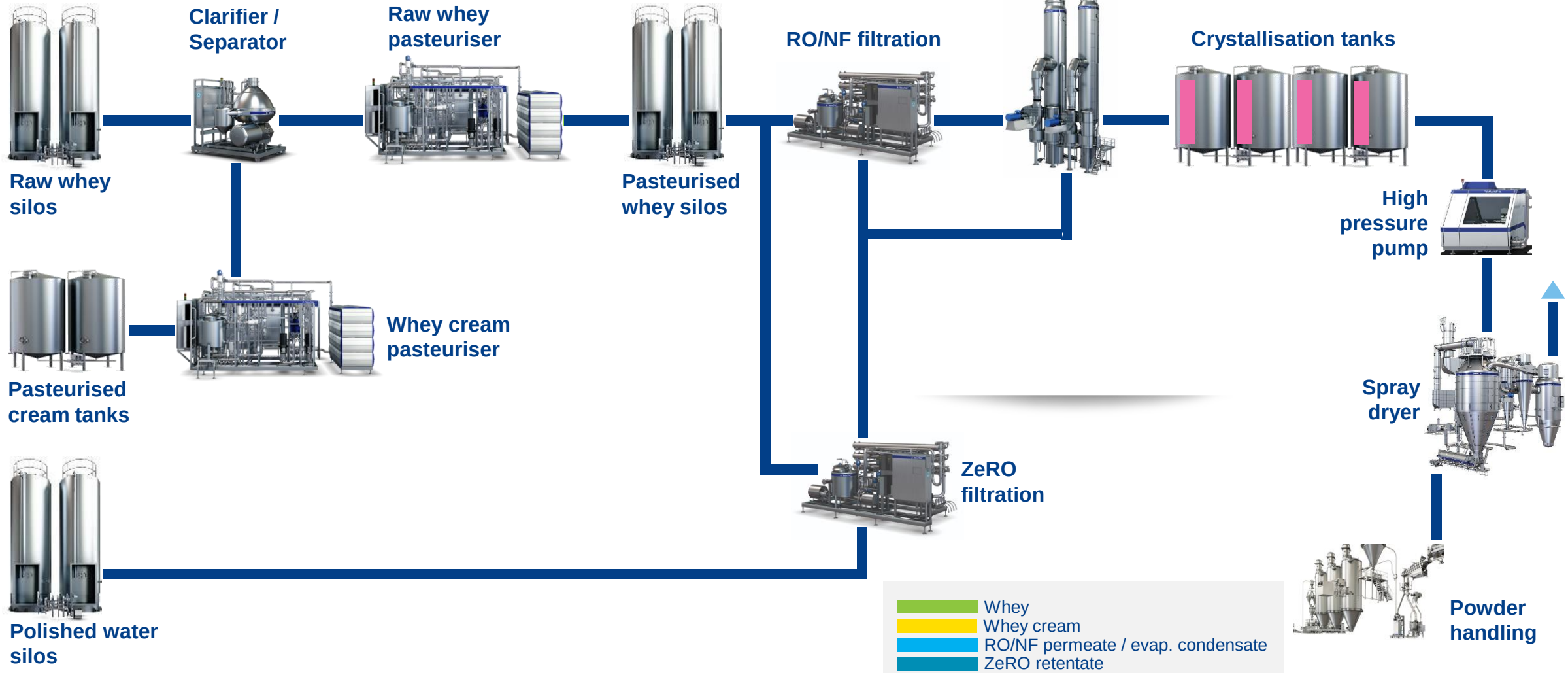
Chemical spec.	Value (typical)	Issue / Risk	Focus areas / Control parameters
Protein	34.0% SNF max	Too low	Standardisation with lactose or permeate
Fat content	1.0% max.	Too high	Separation efficiency
Water	4.0% max.	Too high	Ambient / dryer process conditions, dryer and fluidbed temperature / airflow profile
WPNI	2.5 – 4.5	Out of spec	Pasteurisation, pre-heat conditions evap.
Scorched particles	7.5 (mg/25g)	Maillard reaction → Combustion hazard	Equipment condition, powder accumulation hot zones. Blockages, Maintenance / Cleaning
Solubility index	0.1 – 0.2 ml	Too high	Heat treatment, drying air temperatures, denaturation, moisture/Aw, fat content, protein level, lactose crystallisation.
Bulk density	0.60 – 0.75	Out of spec	Dryer temperature profile, particle density, atomisation (viscosity, droplet size, nozzles type & position, agglomeration (primary, secondary), Single- / multi-stage drying, etc.
Flowability	85	Too low	Large mean particle size, narrow particle size distribution, spherical shape, smooth surface, agglomeration

Microbial risk overview and preventive measures

Step	Typical temp (°C)	Microbial risk	Likely bacteria	Preventive measure
Concentrate tanks	50 – 60	Warm, moist → biofilm and thermotolerant growth risk.	Thermophilic Bacillus spp.	CIP every 4 – 6 hours.
Concentrate feed line	65 – 85	Warm, moist → biofilm and thermotolerant growth risk.	Thermophilic Bacillus spp.	CIP every 20 – 24 hours.
Spray drying inlet	160 – 240	Lethal to vegetative cells; spores survive.	Bacillus spp., thermophiles, molds	Use filtered air. Avoid condensation or wet spots. Minimize production stops or restart. Perform dry cleaning.
Spray drying outlet	75 – 95	Drying complete, but residual hot spots possible.	Bacillus spp., thermophiles, molds Cronobacter E-saki	Maintain outlet air >80–90°C; avoid wet spots; ensure drying chamber is clean and dry.
Powder cooling	20 – 30 ambient	If air not filtered, risk of airborne contamination.	Listeria, Staphylococcus, molds	Use filtered air (HEPA), Ensure positive air pressure.
CIP	40 – 85	Incomplete removal of biofilms	Bacillus cereus, thermophilic spore formers	Validate CIP cycles; inspect hard-to-clean areas (gaskets, joints)

Whey and permeate powder manufacture

Whey / permeate powder production line



Product info whey and permeate powder

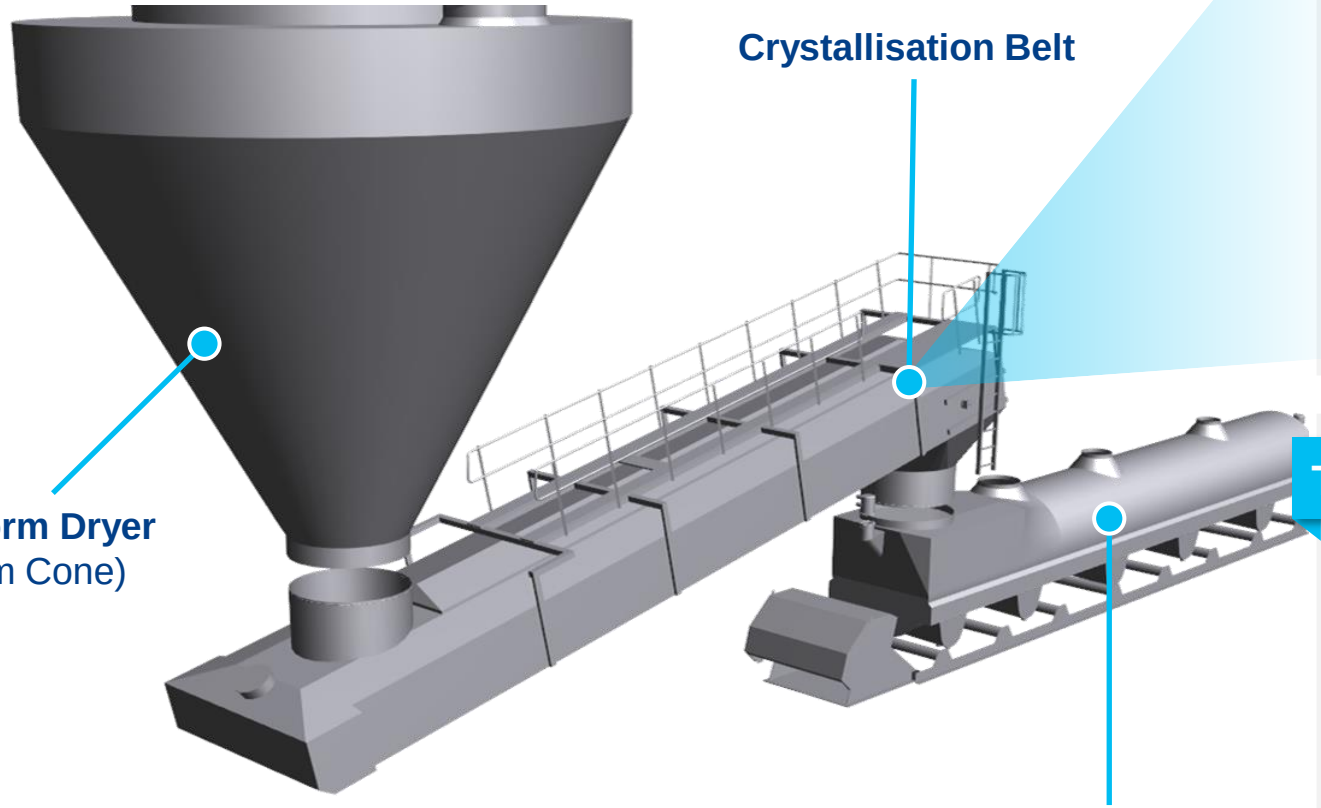
	Product		Dry whey (extra grade)	Milk permeate (ADPI)	Whey permeate (ADPI)
Chemical	**Protein (SNF)**	%	11.0 min. (ADPI/Codex)	2.0 min (typ. 3 - 5)	7 max. (typ. 2 – 7)
	Fat	%	1.5 max	1.5 max. (typ. 0 – 1.0)	1.5 max. (typ. 0 – 1.0)
	Moisture	%	5.0 max.	5.0 max. (typ. 3 – 4.5)	5.0 max. (typ. 3 – 4.5)
	Lactose	%	65.0 min. (Codex)	76 min (typ. 78-88)	76 min. (typ. 76 – 85)
	Ash	%		14.0 max (typ. 8 -11)	14.0 max (8 – 11)
	TA / pH	%	0.16 max.	5.5 – 6.6	→
Physical	**Scorched particles**	mg/25g	15.0 max	→	→
	Bulk density	g/cm^3	0.70 – 0.80	0.70 – 0.80	0.70 – 0.80
	Solubility index	ml	< 1.0	-	-
	Dispersibility	%	-	-	-
	Color	--	Off white to cream	White to cream	→
	Flavor	--	Whey flavor	Bland, clean	→
Microbiological	**Standard Plate Count**	cfu/g	30,000 max.	30,000 max.	→
	Coliform	cfu/g	10 max.	10 max.	→
	Enterobacteriaceae	cfu/g	10 max.	10 max.	→
	Coag. Pos. Staph.	cfu/g	10 max.	-	-
	Yeast and Mold	cfu/g	100 max.	100 max.	→
	Salmonella / Listeria	cfu/g	Not detected	Not detected	→

Wide Body and Tall Form Bustle spray dryer

Tall Form Bustle dryer
Non-caking whey or permeate powder

Wide Body dryer
Semi caking whey powder

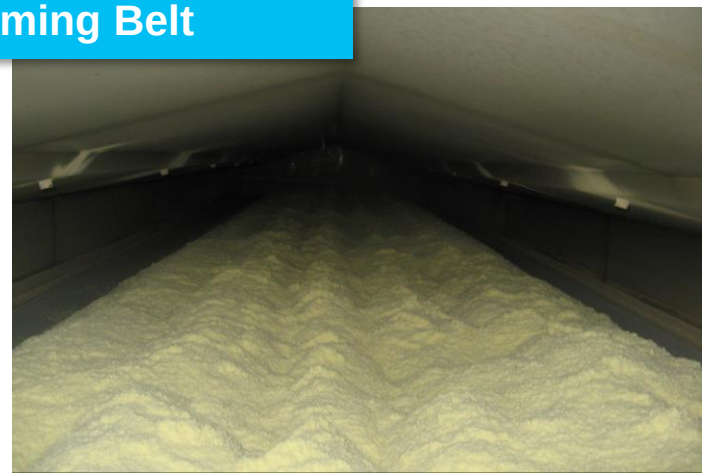
Spray dryer



Dryer cone outlet

9 - 12% moisture

Timing Belt



Hygroscopicity and cakiness

- **Hygroscopicity:** The ability to adsorb moisture during storage in a conditioned room (controlled RH and temperature).
- **Caking:** The amount of powder remaining on a sieve after storing the powder in a conditioned room followed by drying in an oven

Non-caked product

Caked product

0 - 10%	=	Non-caking
10 - 20%	=	Slightly caking
20 - 50%	=	Caking
50 - 90%	=	Very caking
90 - 100%	=	Extremely caking

0 - 10%	=	Non hygroscopic
10 - 15%	=	Slightly hygroscopic
15 - 20%	=	hygroscopic
20 - 25%	=	Very hygroscopic
>25%	=	Extremely hygroscopic

Risk management whey and permeate powder production

Chemical spec.	Value	Issue / Risk	Focus areas / Control parameters
Total moisture	4.5 – 5.0%	Caking, decoloring	Degree of crystallisation, drying
Free moisture	< 1.5%	Caking, decoloring	Drying
Water activity (Aw)	< 0.2	Caking, decoloring	Drying, Conditioning
Bulk density	600 – 800 g/ml	Atomisation, Milling	Viscosity, Milling
Scorched particles	15 mg/25g	Dryer performance	Dryer performance
Solubility Index	0.3 ml	Dryer performance	Dryer performance
Cakiness	0 – 20%	Poor powder handling	Degree of crystallisation, Crystal size, Composition (sticky components), Low free moisture.
Hygroscopicity	0 – 20%	Poor powder handling	
Colour	Stable	Maillard reaction	Free moisture, temperature, composition (reducing sugars)