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National Dairy Development Board
For Efficient Dairy Plant Operation

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DAIRY INGREDIENTS FROM WHEY

The theme of this issue is ***"Dairy ingredients from whey".*** It may be understood that the information given here is by no means complete.

This bulletin includes technical information based on latest developments on products, systems, techniques etc. reported in journals, companies' leaflets and books and based on studies and experience. The technical information in different issues is on different areas of plant operation. It is hoped that the information contained herein will be useful to readers.

In this issue:

INTRODUCTION

Whey is the liquid fraction remaining after the manufacture of cheese, chhana, paneer and casein. World whey output is majorly contributed by cheese whey to about 95%. In India, the major source of whey is from the production of chhana and paneer. A rule of thumb is that the amount of milk used for the production of cheese equals almost the amount of whey recovered. Whey still contains about 50% of the nutrients present in the milk, comprising milk sugar (lactose), serum proteins, some minerals, a small amount of fat and most of water soluble minor nutrients from milk such as vitamins. Whey and whey products are used by the food industry in wide variety of applications because of their excellent nutritional and functional properties.

The composition of whey and whey by-products varies considerably, depending on milk source and the manufacturing processes involved. Whey is a good fermentation medium for a number of fermented products. In many applications, lactose in whole or de-proteinised whey is hydrolysed to glucose and galactose.

Nutritional characteristics of whey: In general, whey is rich in lactose, proteins, minerals and vitamins. Lactose is a source of energy with high calorific value. Numerous studies have demonstrated that lactose increases calcium absorption and retention. It may also improve the absorption of magnesium and zinc. In animal studies,

lactose extended life expectancy and reduced the accumulation of body fat.

The proteins in whey are complete and of exceptional quality. They contain, in varying amounts and in the right proportion, all the amino acids required by humans, among which sulphur amino acids are particularly valuable owing to their anticancer activities. They are also readily digestible and completely bio-available. Whey proteins are among the most valuable component of whey. Whey proteins, though present in small quantities, have high protein efficiency ratio (3.6), biological value (104) and net protein utilisation (95).

Whey is also a rich source of Calcium (Ca), Phosphorous (P) and water soluble vitamins. As the pH of milk decreases, more of the salts dissociate. This results in higher concentrations of soluble calcium, magnesium, zinc and phosphorous in acid whey. The concentration of calcium and other minerals may be altered during whey processing. The ratio of Ca:P is about 0.8 in whey (Modler, 2000); this is a high Ca:P ratio compared with other food products. Whey minerals are involved in the regulation of the water flow by osmosis between different regions of the body. Further, the composition of whey salts reveals a low ratio of sodium/potassium, which is important for preventing elevated blood pressures (hypertension). It also contains copper, zinc and iron as minor constituents. Zinc performs many functions, like the stimulation of the insulin activity

for the absorption of glucose from blood. Iron is part of several metallo-proteins such as haemoglobin, lactoferrin, lactoperoxidase, catalase and supports several important functions as a carrier of oxygen.

Glyco-macro peptide derived from *k*-casein induces production of cholecystokinin, a hormone associated with satiety. It also inhibits the adhesion of oral actinomycetes and streptococci to erythrocytes, and binding of cholera toxins to its receptor. It is free from aromatic amino acids, and therefore a suitable protein substitute for those suffering from hereditary disorder of aromatic amino acid metabolism, such as phenylketonuria (*Handbook on whey and whey products by Dr. J.N. de Wi*).

Other benefits of whey protein:

They provide a number of benefits in areas including sports nutrition, weight management, immune support, bone health, and general wellness.

- Whey proteins also have the highest levels of BCAAs (Branched Chain Amino Acids), which results in building and retaining muscle tissue
- Boost immune system functioning and also helpful in blood sugar control.
- They have potential positive impact in other areas including appetite suppression, cholesterol reduction, and the inhibition of dental plaque and dental caries.

- It enhances the production of glutathione, one of the body's most powerful natural antioxidants. Therefore, whey proteins aid in improving the body's immune system, by acting as an antioxidant.

WHEY PROCESSING

Whey is a by-product during cheese manufacturing and approximately 9 pounds of whey is produced for every 1 pound of cheese. Cheese may be produced through use of enzymes, such as rennet, that clot casein or addition of acid to lower the pH of the milk so that casein will precipitate. Some types of cheese use both methods to clot the casein.

The quality and characteristics of whey depend upon the process used:

- Whey drawn from curd that is clotted by rennet only will have a higher pH and is considered to be sweet whey. Sweet whey cheeses – most cheese types including Cheddar, Swiss and Brick.
- Whey drawn from curd that has formed through the use of acid (with or without added rennet) will have a lower pH and is referred to as acid whey. Acid whey cheeses – Cottage, ricotta, quark and cream cheese and industrial casein made by acid coagulation.
- Fermented whey – sweet whey that has a lower pH due to the action of cheese starter culture. Fermented whey

is not typically produced but rather results from undesired continued acid production by starter cultures.

Fig.1 Composition of Milk and Whey

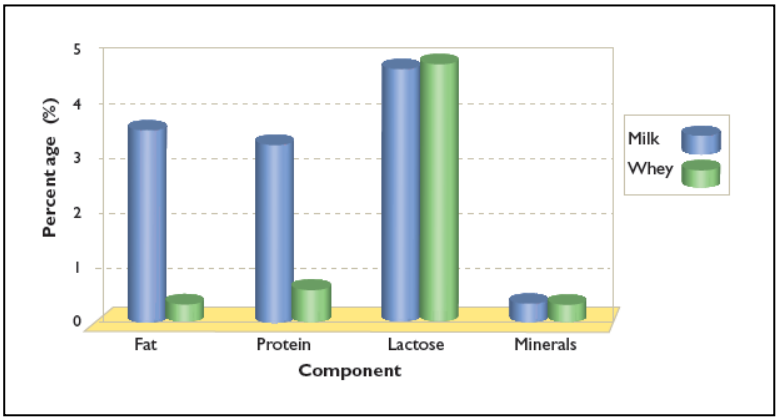


Table 1 Comparison of composition of milk with sweet and acid whey

Component	Milk	Sweet whey	Acid whey
	%		
Total solids	12.5	6.5	6.5
Protein	3.5	0.8	0.7
Lactose	4.6 to 4.8	4.8	4.4
Ash	0.7	0.5	0.6
Fat	3.5	0.3	0.3
Lactic acid	-	0.1	0.5
mg/100g			
Calcium	120	45	103

Phosphorous	9	45	78

Ref: *Karen Smith, Ph.D. Dairy Processing Technologist at Wisconsin centre for dairy research, Dried dairy ingredients; 2008*

Compositional differences:

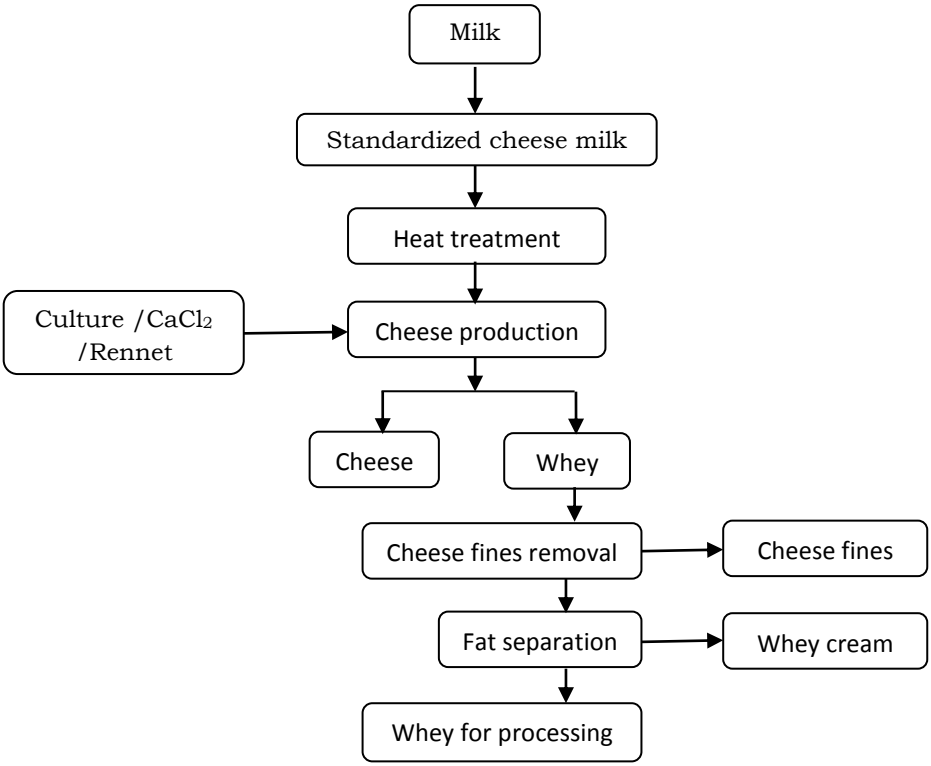
The composition of the resulting sweet and acid whey will differ because of the pH when the whey is removed from cheese curds and the use of rennet.

- Sweet whey will contain glycomacropeptide. Rennet cleaves κ-casein thereby producing a protein fragment known as glycomacropeptide. It can be 20% of the protein in sweet whey and it is not present in acid whey unless rennet is used.
- Coagulating agents typically used include: glucono-δ-lactone, lactic, phosphoric, citric and hydrochloric (casein production).
- Acid whey will have higher levels of calcium than sweet whey.

  Note: Calcium phosphate is more soluble at lower pH therefore the lower pH of acid whey will draw more calcium from the cheese curd.
- Sweet or acid whey that was produced from cheese, where the pH was reduced by microbial cultures will contain by-products of the fermentations such as galactose and lactic acid.

  Note: Fermented whey will not have higher calcium levels but will contain by products of starter culture fermentations.

FC 1: Production of Whey for processing



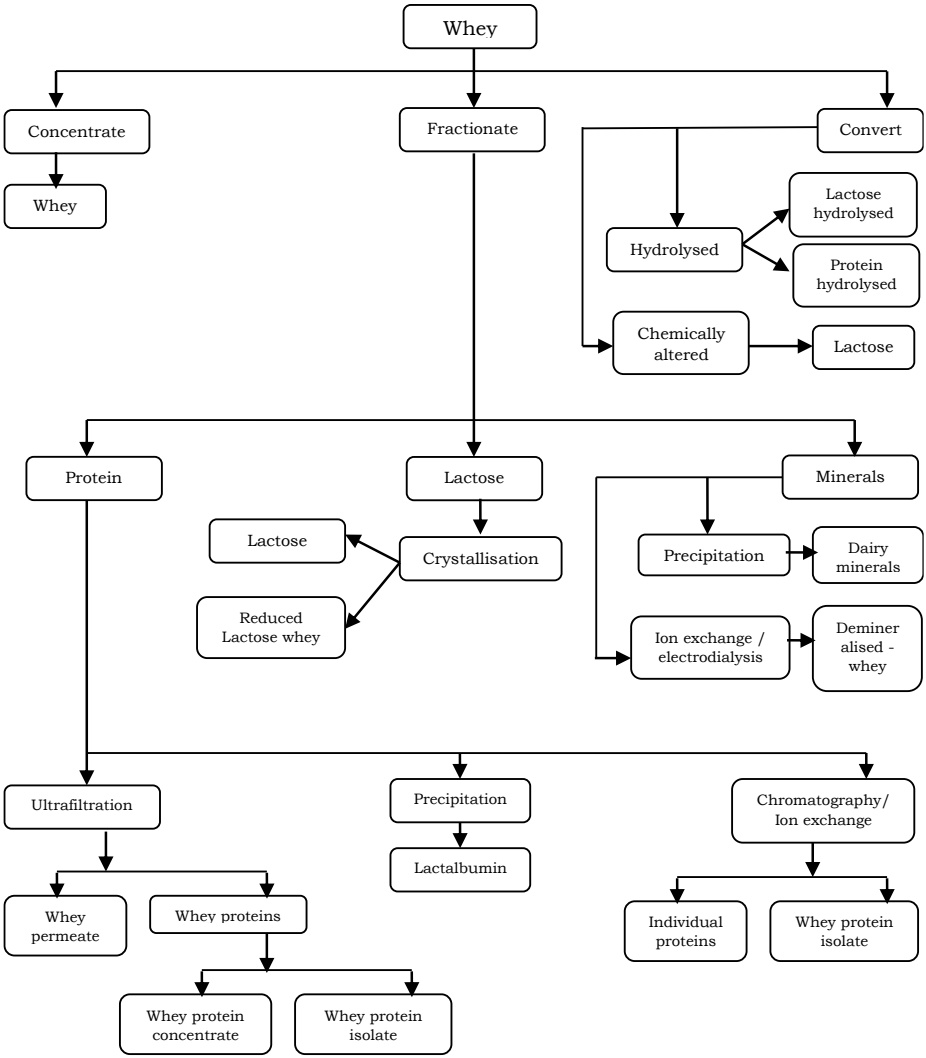
- **Cheese fines:** These are small pieces of cheese that were not captured in the curd and it consist of coagulated casein which are not soluble, therefore their presence in whey is not desired.
- **Whey cream:** They consists of small fat globules that were not trapped within the cheese matrix. These fat globules can cause off flavours during storage of whey

based powders; therefore, it is important that as much of the whey cream be removed as possible.

Optional steps:

- **Bleaching**: benzoyl or hydrogen peroxide may be added to reduce the yellow/orange colour of whey resulting from the use of annatto colour during cheese manufacture.
- **Neutralizing**: addition of caustic to increase the pH of the whey and typically would be used only for acid or fermented whey.
- **Crystallization**: concentrated whey is allowed to cool so that lactose crystallizes.

FC 2: The different products that can be manufactured using whey &process involved



WHEY POWDER

Whey powder is the dried form of whey that contains relatively high concentration of all whey constituents including lactose and protein. In the presence of moisture, lactose and protein readily participate in the maillard reaction. This interaction may result in a decrease in protein quality, which is accompanied or followed by undesirable colour changes. During drying, high heat denatures whey proteins, destroying some bioactive compounds, such as the amino acid cystine.

Acid whey powder from Cottage cheese or paneer and related products contains approx. 65 % lactose, 12 %protein, 6 % lactic acid, 2.5 % moisture and large quantities of calcium; in fact, all of the calcium that originally existed in the milk. Furthermore, acid whey powder contains the vitamin B complex, vitamin C, and the natural milk fermentation flavour compounds, like diacetyl.

Type of dryers used:

Whey powder functionality is affected by the type of dryer used. Majority of whey powder is produced by spray drying which is a less severe process than roller drying. Roller drying is relatively uncommon because of the amount of protein denaturation that results. Roller dried product will

have a flaked appearance, browner colour and more cooked flavour as compared to sprayed dried powder.

Table 2 Essential mineral content in acid and sweet whey powder

Minerals	WHO recommended daily intake * (Adult male)	Sweet Whey Powder content/100g**	Acid whey powder content/100g**
Calcium, mg	500	796	2054
Zinc, mg	22	1.97	6.31
Magnesium, mg	300	176	199
Phosphorous, mg	-	932	1348

*World Health Organization 1974
**Potosi and Orr,1976

Because of low concentrations of sodium, potassium and chloride, but high lactose and high-quality whey proteins contents, demineralised whey powder at 90% demineralization level is eminently appropriate for the preparation of infant formulae for meeting the nutritional requirements of infants.

FC 3: Manufacture of Sweet and Acid Whey Powder

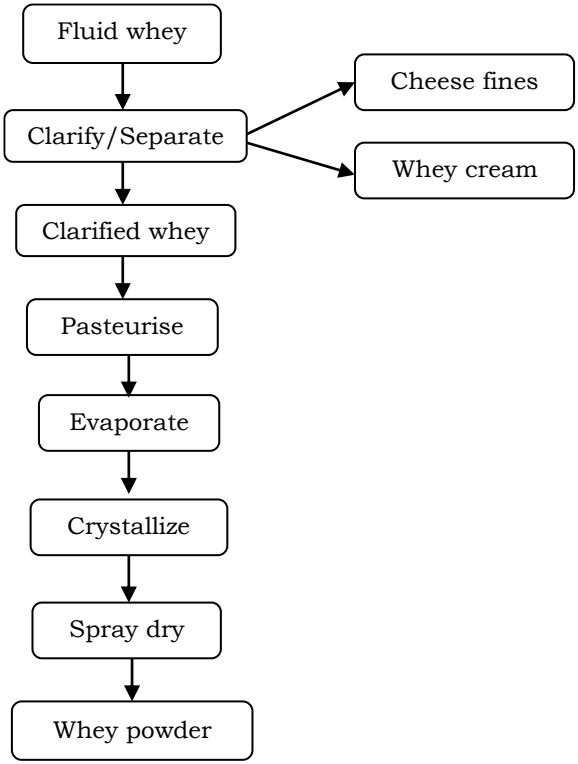


Table 3 FSSAI specification for Whey Powders

Parameter	Whey Powder (sweet)	Acid whey Powder
Moisture, max, %, (m/m)	5.0	4.5
Milk fat, max, %, (m/m)	2.0	2.0
Milk protein, min, %, (m/m)	10.0	7.0

Lactose content as anhydrous lactose, min, %, (m/m)	61.0	61.0
pH (in 10% solution)	more than 5.1	max. 5.1
Total ash, max, %, (m/m) on dry basis)	9.5	15.0
Ref: 2.1.12 (C) Standard for whey powder: FSSRs. (Food Products Standards & Food Additives)		

DEMINARALIZED OR REDUCED MINERALS WHEY

The salts in whey have significant effect on its taste, and may hamper the use of whey in food products. In de-lactosed whey (mother liquor) the lactose content is reduced to 50% and the protein content increased from 13 to 28%, but the mineral content is also increased about 20% on total solids. This makes mother liquor still more unfavourable for applications in human food, a problem may that be solved by desalting.

Processes such as precipitation, ion exchange, electrodialysis and membrane filtration may be used to remove the minerals. Membrane filtration, ion exchange and electrodialysis do not denature proteins thereby preserving protein solubility in demineralized whey produced by such methods. The exact process used will determine the mineral profile of the final product. Demineralized whey often will have a less salty flavor because of the removal of minerals.

Electrodialysis is a cheaper and more current demineralization process for whey.

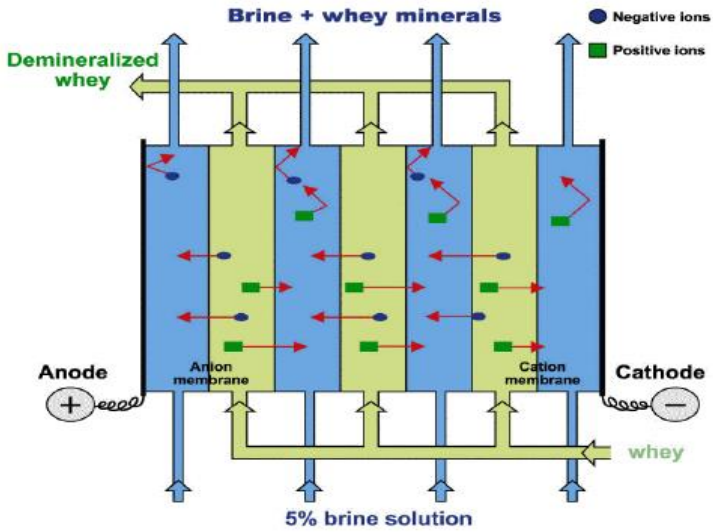


Fig.2 *Dr. J.N de Wit; Principle of demineralisation through electrodialysis.*

Electrodialysis unit, consisting of a number of compartments separated by alternate cation and anion membranes at mutual distance of about 1mm. Negative ions can pass through a (positively charged) anion membrane, but stopped by a (negatively charged) cation membrane, as indicated by the red arrows. Conversely positive ions can pass through a cation membrane but not through an anion membrane. Direct current electrodes are placed in the end compartments as anode and cathode.

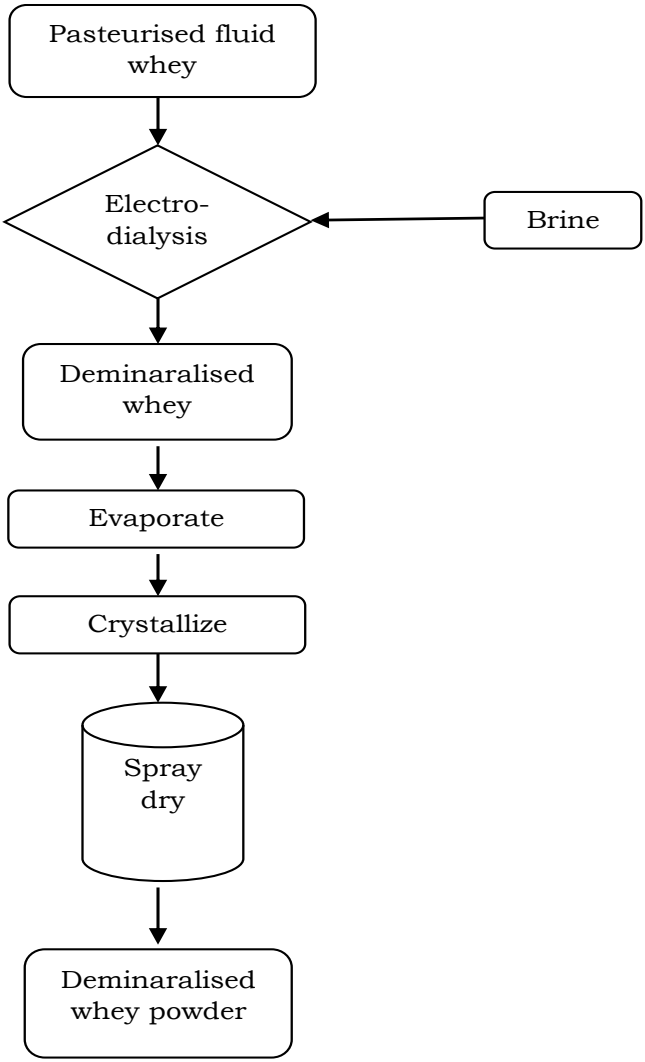
Whey is circulated through the dilution cells and whey salts are carried off through a 5% brine solution in the concentration cells. When direct current is applied across the cells, cations attempts to migrate to the cathode and anions to the anode. However, completely free migration is not possible because the membrane acts as barriers to ions of like charge.

Table 4 General composition of demineralised whey powder

Component (%)	25% Demineralized whey	50% Demineralized whey	90% Demineralized whey
Protein (dry basis)	11.4	11.5	13.7
Lactose	78	80	80
Ash	5	3	1
Fat	1	1	1
Moisture	5	5	5

Ref: *Karen Smith, Ph.D. Dairy Processing Technologist at Wisconsin centre for dairy research, Dried dairy ingredients; 2008*

FC 4: Manufacture of Demineralized Whey Powder



REDUCED LACTOSE WHEY

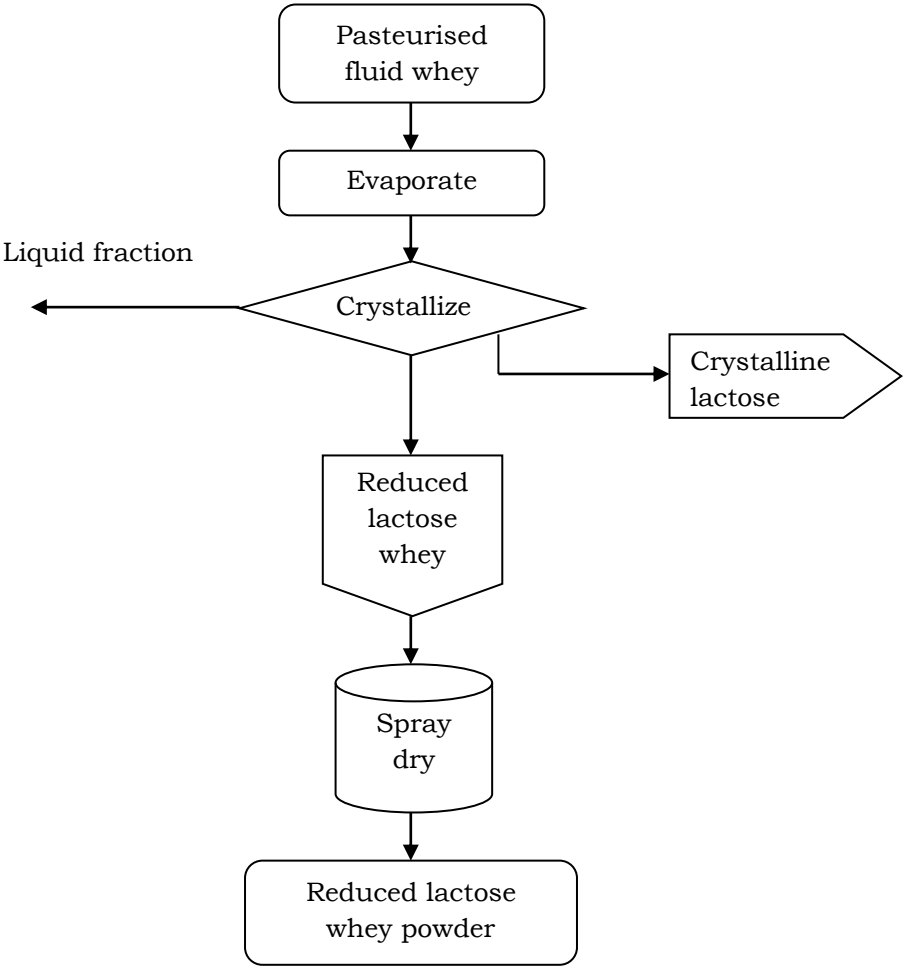
Reduced lactose whey is the substance obtained by the removal of lactose from whey. The lactose content of the finished dry product shall not exceed 60 percent (Code of Federal *Regulations (CFR) title 21 volume 3 April 1 2020).* Removal of the lactose is accomplished by physical separation techniques such as precipitation, filtration, or dialysis. As with whey, reduced lactose whey can be used as a fluid, concentrate, or a dry product form. The acidity of reduced lactose whey may be adjusted by the addition of safe and suitable pH-adjusting ingredients.

Crystalline lactose is a by-product. The mineral components of the whey are not altered. Reduced lactose whey differs from whey protein concentrate (WPC) in that the minerals are not removed while production of WPCs involves removal of both lactose and minerals. Because only lactose is removed, lactose reduced whey may also be referred to as mineral concentrated whey or fractionated whey.

Table 5 CFR specifications for reduced lactose whey*

Component (%)	Not less than	Not greater than
Milk fat	1	4
Protein	16	24
Lactose	-	60
Ash	11	27
Moisture	1	6
** 21 CFR (Code of Federal Regulations)184.1979 (2007)*		

FC 5: Manufacture of Reduced Lactose Whey Powder



LACTOSE / PROTEIN HYDROLYSED WHEY

Lactose Hydrolysed Whey:

Lactose hydrolyzed whey is produced by hydrolyzing a portion of the lactose to glucose and galactose by addition of lactase enzyme. The product will have increased sweetness and decreased tendency for lactose crystallization as compared to whey. The amount of lactose converted to glucose and galactose depends on product specifications.

Lactose hydrolysed whey is difficult to dry and the powder may tend to become sticky with storage.

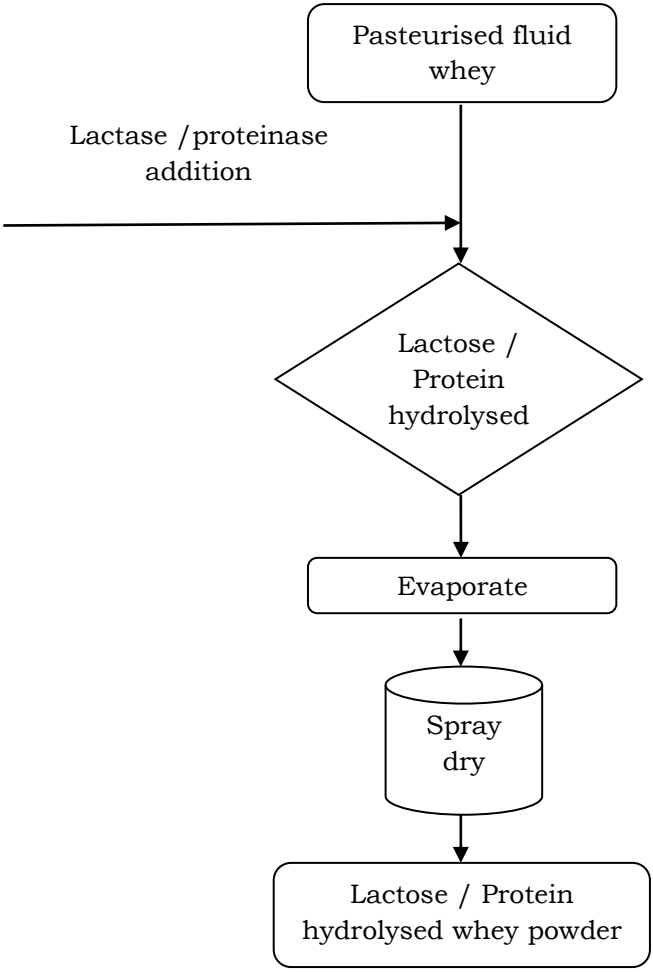
Protein Hydrolysed Whey:

Protein hydrolysed whey has a portion of the whey protein hydrolysed into smaller fragments. Enzymes such as trypsin, chymotrypsin, etc. are used.

There is considerable variation in the product profile. The specific enzymes used, sequence of enzymes, reaction time, reaction temperature, etc. are all important and can affect the type of protein fragments produced.

Manufacturers currently are using Whey Protein Concentrates (WPC) as starting material to produce protein hydrolysed products with higher protein contents.

FC 6: Manufacture of Lactose / Protein Hydrolysed Whey Powder



WHEY PROTEIN CONCENTRATE (WPC)

Whey protein concentrate means a product obtained by removing non-protein constituents (lactose and minerals) from whey by means of physical separation techniques such as precipitation, filtration, dialysis and other relevant techniques, followed by drying. WPC produced by ultra-filtration process uses semipermeable membrane.
Higher protein WPCs require the use of water, in a process known as dia-filtration (DF), to remove greater amounts of lactose and ash. Proteins are not denatured by the UF process therefore WPCs can be very soluble.

Sweet or acid whey may be used, however, WPCs typically are produced from sweet whey- where lactose, minerals and non-protein nitrogen compounds are removed thereby concentrating the protein fraction.

Table 6 General composition of whey protein concentrate

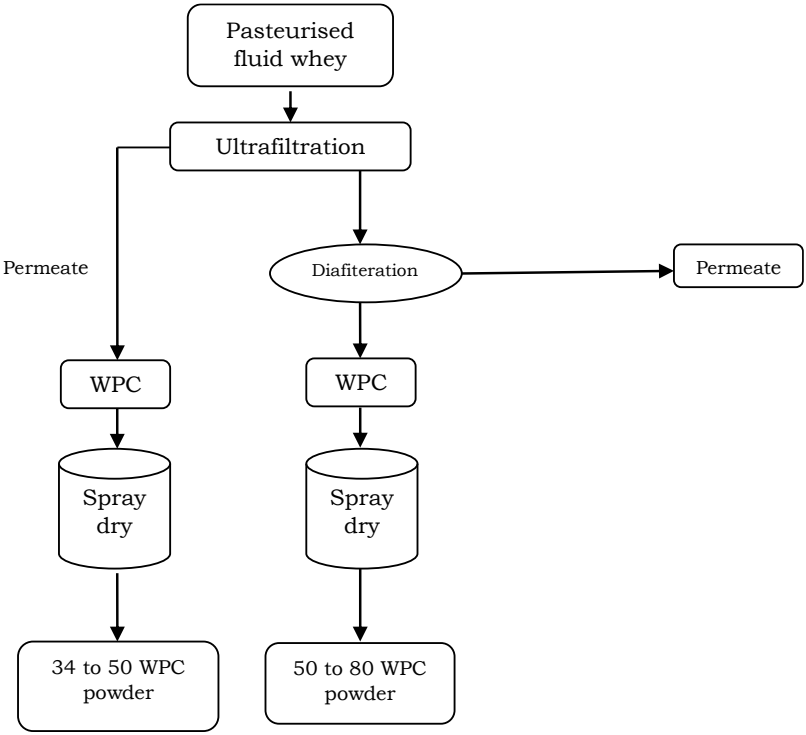
Component (%)	WPC 34%	WPC 55%	WPC 80%	WPC FSSAI
Protein	33	53	77	min 35
Lactose	52	31	9	-
Ash	7	6	4	-
Fat	4	6	6	max 10
Moisture	4	4	4	max 6
Scorched particles	-	-	-	max disc B (15 mg)

Ref: *Karen Smith, Ph.D. Dairy Processing Technologist at Wisconsin centre for dairy research, Dried dairy ingredients; 2008*

Whey protein concentrates (WPC) contain up to 35-85% protein by weight and are indeed very rich in high quality whey proteins. Besides having functional properties, WPC improves the nutritional attributes of the product. The PER (Protein Efficiency Ratio) value of whey protein concentrates is similar to that of egg protein, i.e. it is higher than that of milk powder and of other milk protein products (caseinates, co-precipitates).

The high protein and low fat content of whey protein concentrates makes them particularly suitable for incorporation into special diets which are thereby enriched with high quality protein. These products have been recommended for slimming diets, diets for patients suffering from hyperlipoproteinaemia and generally for feeding patients, particularly those suffering from liver and/ or gall bladder diseases and from diabetes. They are especially suitable for addition to baby foods as well as to the diets of sportsmen, children and elderly people who can also have benefit from a product rich in high quality protein.

FC 7: Manufacture of WPC 34 to 50 and WPC 50 to 80:



WHEY PROTEIN ISOLATE (WPI)

Whey protein isolate in its purest form contains 90-98% protein, but no fat, lactose or cholesterol. It is packed with loads of essential and non-essential amino acids. They contain higher levels of bioactive compounds.

WPIs are produced by one of two methods:

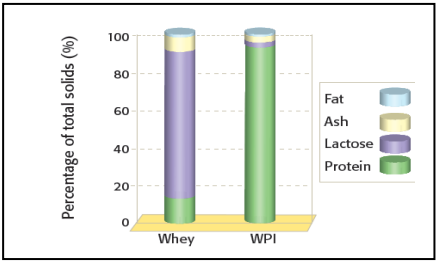
- Micro Filtration/Ultra Filtration
- Ion exchange

Protein composition of the WPI will depend on the method used. The greatest difference is the presence of glycomacropeptide, a protein fragment resulting from the action of rennet on casein during cheesemaking.

The ion exchange process does not capture glycomacropeptide and therefore it is absent from WPI produced by ion exchange unless it is added back. MF/UF process retains the same.

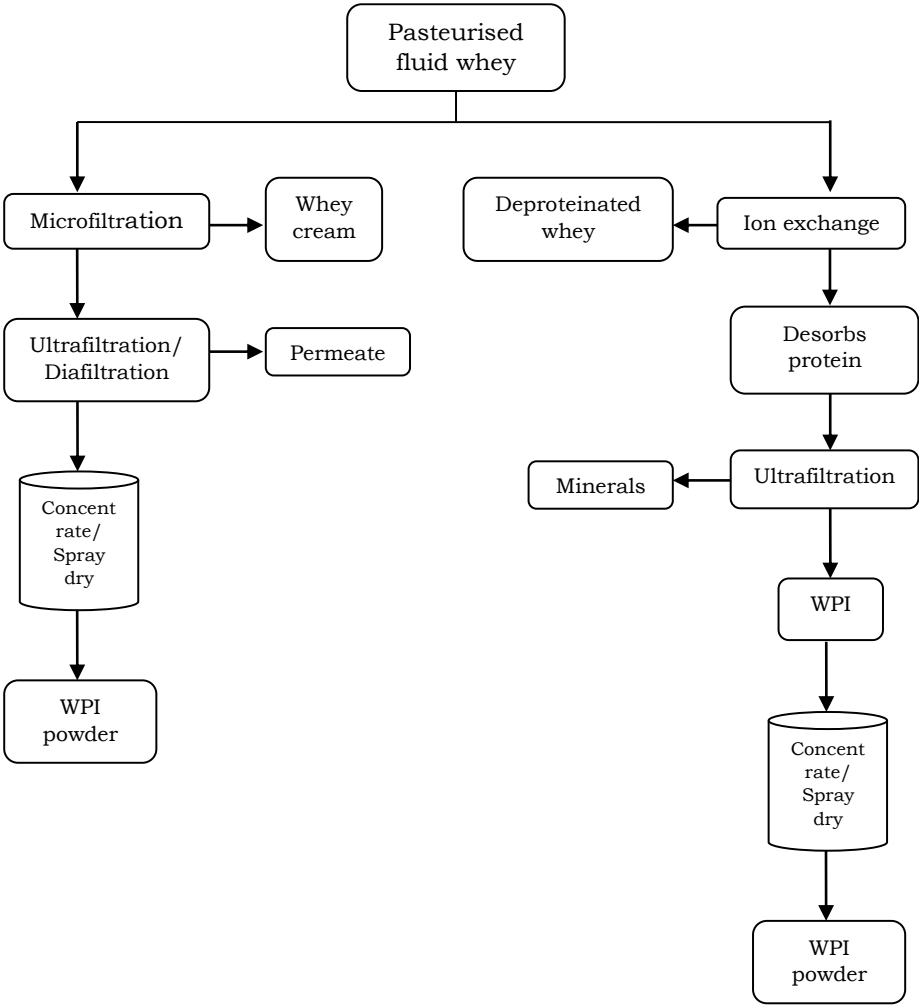
Fig.3 General Composition of whey protein isolate

Component (%)	WPI
Protein	89
Lactose	2
Ash	3
Fat	1
Moisture	5



Ref: *Karen Smith, Ph.D. Dairy Processing Technologist at Wisconsin centre for dairy research, Dried dairy ingredients; 2008*

FC 8: Manufacture of Whey Protein Isolate (WPI):



CONDENSED WHEY

Condensed whey contains whey constituents in more concentrated form. Whey solids in the form of condensed whey is a cheap source of high-quality proteins and carbohydrate and the fat is generally removed by centrifugation. Sweetened condensed whey contains sugar equal to the weight of solids in whey which is a source of energy.

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DAIRY INGREDIENTS FROM WHEY

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