



MANUFACTURE OF WHEY PROTEIN CONCENTRATES BY MOLECULAR SEPARATION PROCESS



- The aim of manufacture of whey protein products is to separate proteins from whey in such a form that they remain, as far as possible, fully undenatured and thus retain their functionality.
- Ultrafiltration is a molecule separation process where components of a liquid are separated based on their difference in size.
- It is low energy consuming process and is being widely used in the dairy industry to recover whey proteins.
- The dairy industry typically uses membranes with a molecular weight cut off of 10,000 daltons.
- Thus, any component smaller than 10,000 daltons will be part of the permeate fraction.
- Ultrafiltration retains (in the liquid product termed retentate) any insoluble material or solutes larger than about 20,000 Da molecular weight.

- The rest of the whey stream passes through the membrane, driven by the applied pressure and is called permeate.
- Ultrafiltration of whey enables the whey protein to be separated from the lactose, mineral and other water-soluble low-molecular-weight species.
- By 1981, Ultrafiltration (UF) had become the most widely used process for recovery of soluble whey protein concentrates (WPC).
- It is now a major means of WPC production throughout most of the dairy countries of the world. With this process, 90-95% of the proteins in the whey is recovered.
- WPC is commonly characterized by its protein content on dry basis (e.g.WPC-80 has 80% protein on dry basis).
- The development of robust, synthetic and cleanable membranes and the refinement of continuous operation using multi-stage recycle loops, and diafiltration have been significant factors contributing to the success of this process.
- Another procedure for the separation of whey proteins from whey is by gel filtration.

Ultrafiltration Process

- Membrane configurations designed to date have included tubular, plate and frame, spiral wound, hollow fiber, and flat leaf. Examples of each type are in commercial operation.
- The hollow fiber membranes, manufactured from synthetic polymers such as polysulphone or polyamide, are normally used in the dairy industry.
- Although UF is currently the method of choice for the commercial production of whey protein concentrates of varying protein concentration, several major problems limit its operational performance including: high capital cost and operating cost; membrane fouling and concomitant loss of permeate flux rate; incomplete removal of low molecular solutes unless diafiltration is used; cleaning, sanitation and related microbial problems; disposal of large volumes of permeate.
- The permeation behavior and the characteristic of WPC obtained by ultrafiltration, widely vary with the type of feed stream, pH, ionic strength and various other constitutional makeup of the system.
- It is low energy consuming process.
- The economy of the process and the characteristics of the resultant WPCs are dependent on the permeation behavior of the constituents during ultrafiltration.

- The upper limit to fractionation will be set by the design of the plant, but commercially dried WPC products produced by UF may contain 30 to 80% protein.
- In order to achieve higher protein values (up to 90% of dry matter), one or more diafiltration steps may follow.
- Diafiltration means that water is added to the retentate, thereby the viscosity is reduced, and the concentration of lactose, ash, and NPN is decreased by further UF.
- Both sweet and acid whey may be used in the production of WPC.
- The protein content of product is achievable with a given UF plant without diafiltration is tied to the hydrodynamics of the special system design.
- In essence the higher the total solids level attainable in the concentrate, the higher the protein purity achievable without diafiltration.
- The range of various suppliers is 50-65% purity without diafiltration.

Pre-treatment of whey to increase the permeate flux rate

- During ultrafiltration process, fouling of membranes is normally observed.
- This can be caused by concentration polarization and by progressive accumulation of materials, such as calcium phosphate, on UF membranes during processing.
- The design of modern UF plants is directed toward better control of concentration polarization, primarily through maximizing shear at the membrane surface.
- To minimize progressive fouling in continuous plants (e.g., at constant concentration factor), pre-treatment techniques can be sequestration of calcium, demineralization, heating plus calcium precipitation or pH adjustment, replacement of calcium with sodium, clarification and filtration.
- Other pre-treatments include protein interaction, which aids in larger aggregates or precipitates formation, which are non-fouling.

- There is an increase in flux by 50% when cheese whey is heated to 80°C/15 sec instead of pasteurization temperature.
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- Whey, regardless of type, usually must be filtered or centrifuged to remove suspended cheese or casein particles and for cheese whey, to remove fat also.
- A method, which claims to provide complete removal of lipoproteins, lipids, and colloidal calcium phosphate, is based on cooling cheese whey to 0-5°C, adding calcium chloride, adjusting to pH 7.3, warming to 50°C, and removing the insoluble precipitate that is formed by centrifugations or decantation.
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- UF permeate flux rate of pre-treated whey was about double than that for control whey; pre-treated whey was essentially turbidity-free, contained 85% less milk fat, 37% more calcium and 40% less phosphorus than whey.

Manufacture of whey protein concentrates

- The whey produced during cheese production is separated for fat and fines, pasteurized, cooled to 55°C and transferred to balance tank (Fig. 32.1).
- The balance tank should have residence time of 30-60 min that will serve not only to balance flow, but also to preconditioning the whey to maximize capacity of UF plant.
- The preconditioning is quite complex and consists at least of modification of the form of the calcium complexes and deaeration.
- Whey is then pumped into UF plant, from which WPC is produced.
- Also, a protein depleted permeate (the stream which passes through the semi permeable membrane) is produced, from which a variety of different products can be produced profitably.
- The protein content of the retentate stream will depend on the volume of permeate removed from the whey.
- This can be regulated readily.

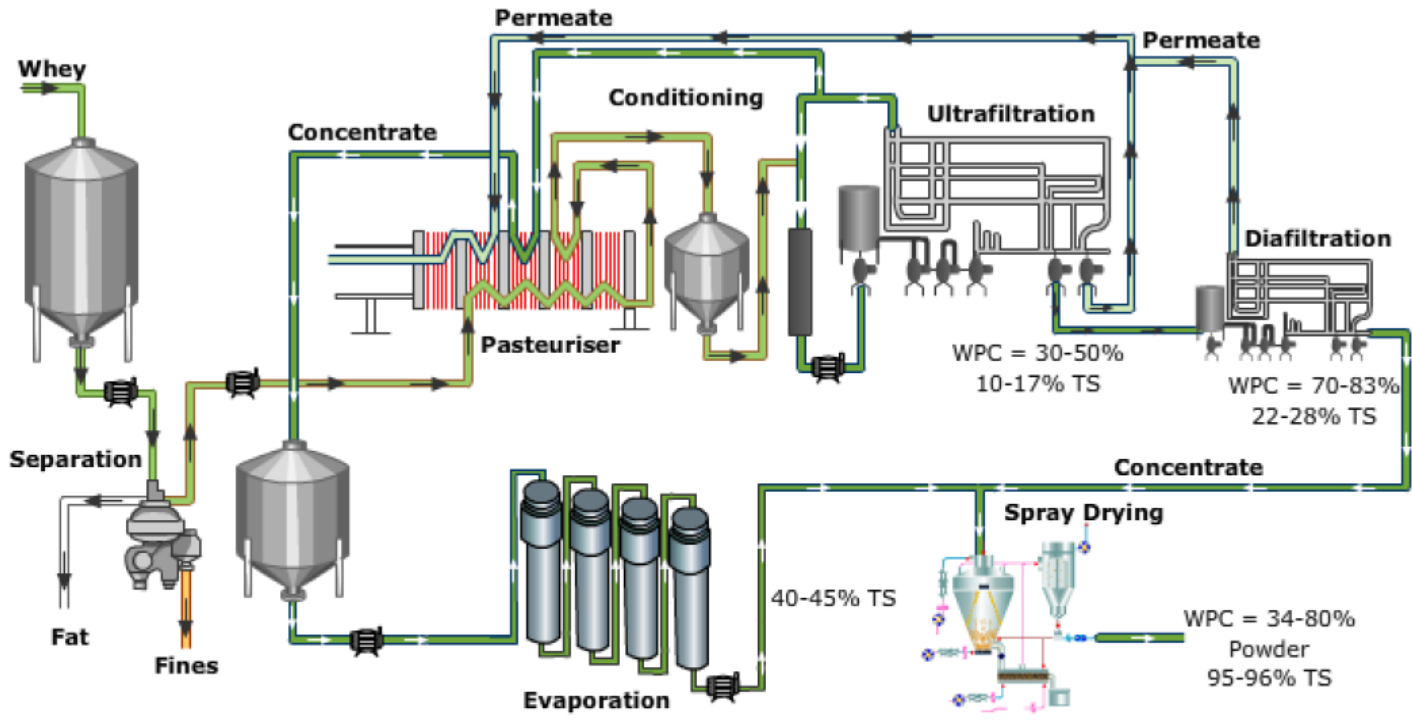
- Gupta and Reuter (1987) investigated the manufacture of WPC from sweet cheese whey. Clarification of cheese whey, prior to Ultrafiltration (UF), was found essential for the effective operation of an UF plant.
- UF permeation rates were greater with higher UF temperature and with pre-holding of the whey for 30-40 min at temperatures (68-72°C), higher than the UF temperature (50°C).
- Probably, holding of whey at a temperature higher than the UF temperature causes the main precipitation of calcium phosphate to take place in the balance tank itself.
- Therefore, there is much less tendency for the precipitation of calcium phosphate in the membrane system.
- The increase in total solids concentration in the retentate was slow during early UF stages, but improved considerable in advanced stages. 15, 20 and 25% TS WPC were obtained at about 92.5, 95.35 and 96.8% whey volume reduction (WVR), respectively, irrespective of the preheating and UF temperatures used.
- In diafiltered concentrates, 15, 20, and 23% TS were achieved at greater WVR, i.e. 95.2, 96.7 and 97.35%, respectively.
- Preheating and UF temperatures treatment affects the constituents of concentrates. The effect was most distinguished on calcium content.
- The preheating treatment of 68-72°C for 30-40 min, before ultrafiltration of whey at 50°C, increased calcium/TS of concentrates considerably higher with increased UF concentration compared to lower preheating temperatures (equivalent to UF temperatures).

- In addition, concentrates produced at higher UF temperatures had higher calcium/TS. Ash/TS of concentrates decreased during ultrafiltration and further with diafiltration.
- The decrease was more rapid in cases, where lesser calcium was retained. During both UF and diafiltration, lactose/TS of concentrates reduced drastically.
- Protein purity of whey protein concentrates improved greatly with increased UF concentration, but at a diminishing rate during later UF stages. 50, 60, 70 and 75% protein/TS in concentrates were obtained at about 12, 15.5, 21 and 25.5% TS concentration, respectively.
- As the protein content increases, the fat content increases and lactose, moisture, and ash contents decrease.
- The membranes not only retain the protein, but also the fat.
- On the other hand, in this process lactose and minerals are lost in the permeate resulting in their proportional decrease in the remaining solids.
- With diafiltration, the protein purity of the product improves significantly.
- Thus, by manipulating the UF conditions, it is possible to produce WPC with different protein: lactose: calcium ratios.
- The acidity/TS of concentrates showed a slight decrease during UF.
- The diafiltration, however, reduced acidity/TS of concentrates significantly.

Manufacture of spray dried WPC

- If the UF plant has a constant feed and concentration capacity, WPC can be evaporated and dried directly.
- UF plant concentrate is evaporated to 25 to 40 percent solids, depending on the concentrate composition.
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- To achieve acceptable powder densities (0.35 to 0.5 g/cm³), it is normally necessary to concentrate in evaporators the WPCs 35-50% prior to spray drying.
- WPCs 50-80% often has 27-30% TS and can be pumped directly to spray drying.
- WPC is evaporated to 25-40% solid concentration depending upon the concentrate composition. Concentration for 35% protein powders is typically evaporated to 40% solids.

- Concentration for 75% protein powders is evaporated to 25% or less TS.
- Evaporated WPC is then spray dried (typically to 4% moisture or less).
- The spray drying process for this product is conventional. Nozzle atomization is preferably used.
- The typical inlet drying air temperature is 175-190°C.
- Between 90 and 95% of the protein in the whey is recovered.
- The resulting powder may be blended to ensure good product uniformity, and then bagged.
- Low-temperature processing is necessary because of the heat sensitivity of the product, but suitable equipment is readily available.

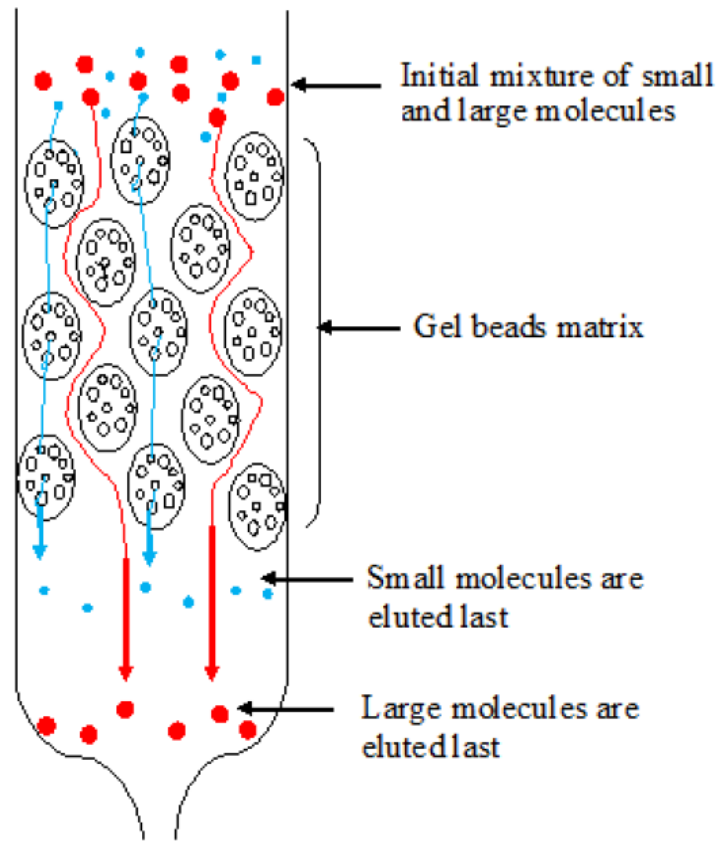


Manufacture of whey protein concentrates (WPC) by ultrafiltration process

Gel Filtration Process

- This useful technique for separation of whey components is essentially a batch process.
- Gel filtration separates molecules on the basis of size.
- The solid support used in gel filtration is called media or matrix that consists of spherical gel beads, whose size and porosity are carefully controlled by swelling in an appropriate buffer.
- The gel filtration matrix in the name of Sephadex G-10, Sephadex G-25, Sephadex G-50, Sephadex G-75 etc are used for separating different range of molecular size constituents. G-25 has the molecular sieving ability of 1KDa - 5KDa and is suitably used after packing in a column for separation of whey proteins from other constituents of whey.
- Generally, whey is retreated to remove lipids and fine particles, concentrated by RO or evaporators to about 20% total solids, centrifuged and filtered to remove precipitated solids and applied to the gel.

- When the whey is passed through a column or bed of porous Sephadex G-25 beads, various whey constituent molecules diffuse into the beads to varying degrees.
- Smaller molecules of lactose, minerals etc. diffuse further into the pores of the beads and are forced to follow a circuitous path before later exiting the beads, resulting in their movement through the bed more slowly.
- By contrast, large molecules of whey proteins flow around the resin beads, taking a relatively direct path through the column resulting in their movement through the bed more quickly.
- This causes the larger molecules of whey proteins to elute earlier than the other smaller molecules of lactose, minerals etc.
- The difference in the flow rates of large and small molecules allows the faster-flowing macromolecules of whey proteins to get recovered separately from the slower small molecules of other whey constituents as the whey travels the distance of the sephadex porous beads packed in the column.



Gel Filtration Process

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- It is subjected to fouling and microbial contamination also.