Paper No.: 07

Paper Title: TECHNOLOGY OF MILK AND MILK PRODUCTS

Module – 33: Technology of dairy byproducts-2: whey protein products

INTRODUCTION

By far the single largest use of whey solids on global basis is in the form of whole dry whey and it continues to grow. Whey is a dilute, highly perishable and largest by-product of dairy world from the manufacture of cheese, casein, *chhana, paneer, chakka* and co-precipitates. In view of the low solids content of whey, there has been a gross lack of interest in its utilization compared to other fluid by-products of dairy industry. Due to the presence of high organic matter (6-7% total solids) in the form of protein, lactose, fat minerals and water-soluble vitamins, its disposal causes environmental pollution.

COMPOSITION OF DIFFERENT TYPES OF WHEY

Chemical composition and acidity of whey varies depending upon the source viz. cheese, casein, *chhana, paneer, chakka* and co-precipitates whey (Table 1).

It, in general, contains about half of the total solids of milk, and is a source of precious nutrients like lactose, whey proteins, minerals and vitamins. Whey proteins, though present in small quantity, have high protein efficiency ratio (3.6), biological value (104) and net protein utilization (95) and are next only to egg protein in terms of nutritive value.

Table 1: Composition of different whey systems

Constituents	Cheddar cheese	Acid casein	Rennet	*Chhana* and *paneer*	Coprecipitates
Total solids (%)	7.0	7.0	6.8	6.5	6.2
Fat (%)	0.3	0.1	0.1	0.5	0.1
Protein (%)	0.9	1.0	1.0	0.4	0.3
Lactose (%)	4.9	5.1	5.1	5.0	5.1
Ash (%)	0.6	0.7	0.5	0.5	0.6
T.A. (%)	0.2	0.4	0.2	0.4	0.3

UTILIZATION OF WHEY

Utilization of whey has been of great concern in the dairy industries engaged in manufacturing of cheese and coagulated milk products. The techno-economic problems associated with the utilization of whey have been receiving considerable attention and remarkable advancements have been made.

MANUFACTURE OF CONDENSED WHEY

Whey concentration is carried out with the following objectives:

- Volume reduction for transport to other processing facilities
- Pre-concentration for drying into whey powder
- Manufacture of condensed whey: plain or sweet

Clarification

The whey always has Curd fines, which confer serious risk of blocking heat exchangers' channels or fouling Ultrafiltration or RO membranes. These curd fines also adversely affect the solubility properties and flavour of end product. These curd fines are usually removed by a combination of settling, screening and clarification.

Separation and Pasteurization

In order to obtain flavour stability in concentrated whey, the whey is separated to remove fat. Then the whey is pasteurized for optimum microbiological quality, to inactivate rennet and storage stability and stored at 5°C till concentration and drying.

Concentration

The whey may be concentrated economically with the integration of Reverse osmosis (RO) for pre-concentration, and multi effect evaporator. The long tube falling film evaporators used for this purpose are characterized by short residence time (5-30 sec.), high heat transfer coefficients and efficient energy use.

Plain Condensed Whey: The desirable degree of concentration of plain whey is 35- 50% total solids. Whey condensed to higher solids content (more than 55% T.S.) forms a gel after cooling and is not recommended to be used in any food or feed products due to its coarser texture and low solubility.

Plain condensed whey is also made as an intermediate product for whey powder making. The whey is concentrated and pre-crystallized before drying.

Sweetened Condensed Whey: For its preparation sweet cheese whey is mixed with sugar equal to the weight of solids in whey (about 6.7 Kg sugar for 100 Kg whey). The mixture is concentrated using multistage evaporators to at least 76% T.S. The specific gravity of sweetened condensed whey at 50°C is 1.360 (38.4°Be'). The concentrate is always cooled to 30°C using flash coolers and served with lactose crystals. The seeds mixture is stirred for 1 to 3 hr to crystallize the lactose. It may then be packed in barrels or cans. The product does not require any refrigeration for storage.

Lactose crystallization

To avoid the very undesirable caking properties of ordinary whey powder, it is of great industrial importance to get the major part of the lactose content in a crystalline form. The advantage of this lies both in energy savings and in improved powder properties. In the spray drier, it is possible to dry whey concentrate containing up to around 60 % TS, when the lactose content has been subjected to a crystallization degree of 85-90 %. On the other hand, for non-crystallized concentrate, it is not possible to attain more than 42-45 %, TS for drying. Obviously this low degree of concentration has negative effect on the process economics. Controlled crystallization can be initiated by immediate flash cooling of condensed whey after evaporation to about 30°C. As far as possible slow agitation should start immediately; fine grained α-lactose monohydrate at a level of about one Kg. per ton of concentrate should be added. The holding time under these conditions should be 3-4 hours. Cooling of the concentrate should then start; the rate being about 3°C/h until 10°C is reached.

Spray drying

Recent trend in drying of milk and a milk product is extensive use of spray drier that may be single stage, two-stage and more recently three-stage drying.

WHEY PROTEIN CONCENTRATES

There has been a continuous increase in the production of whey protein concentrates (WPC) since the introduction of the latest ultrafiltration process. It is now a major means of WPC production throughout most of the dairy countries of the world. Presently, WPC constitutes a very small proportion (10%) of protein utilization in food industry. The largest potential use of WPC is as a replacement for non-fat dry milk (NFDM) in the food industry. WPC with 35% protein is perceived to be a universal substitute for NFDM, because of the similarity in

gross composition and its dairy character. Superiority of WPC over NFDM is also due to cost advantage.

MANUFACTURE OF WHEY PROTEIN CONCENTRATES

Procedures for the manufacture of whey protein products are based on known behaviour of whey components under defined conditions. Properties that have been exploited commercially include: molecular size differences (Ultrafiltration, gel filtration), insolubility of protein at high temperature, charge characteristics (demineralization, protein removal by ion exchange), aggregation by polyphosphates, and crystallization of lactose.

Ultrafiltration Process

By 1981, Ultrafiltration (UF) had become the most widely used process for recovery of soluble whey protein concentrate (WPC). 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. With this process, a highly functional WPC is produced for a wide variety of applications.

After ultrafiltration, concentrate is heat-treated, after which it is cooled and then preheated again for drying. To achieve acceptable powder densities (0.35 to 0.5 g/m^3), it is normally necessary to concentrate in evaporators the WPC 35-50% prior to spray drying. UF plant concentrate is evaporated to 25 to 40% solids, depending upon the concentrate composition. The evaporated concentrate is then spray dried. The typical inlet drying air temperature is 175°-190°C.

Gel Filtration Process

This process has been used commercially for recovery of WPC. The hydrated gel acts as a molecular sieve in that small molecular weight components are able to enter the solvent phase within the gel beads. Protein molecules remain in the solvent phase surrounding the beads. High and low molecular weight fractions then can be recovered. Products of 30 to 80% protein can be manufactured. The process is expensive to install and operate, and the yield, at 65% of the proteins in whey, is low. It also is subject to fouling and microbial contamination. It is no longer used in commercial operation.

Heat Precipitation Process

Whey proteins may be precipitated with heating of whey at acid or near-neutral pH. Acid whey must be heated to at least 90°C and maintained at such temperatures for at least 10 min

to achieve maximum yields. For sweet whey, good yields can be obtained by heating at pH between 6.0 and 6.5, although products so derived have higher mineral concentrations than those of acid whey unless pH is adjusted to 4.6 prior to protein removal.

The precipitate so formed is firmer and more readily separated than that formed in non-acidified whey. Precipitated protein is removed by settling (static or accelerated), washed, re-separated, and dried. In modern plants, high-speed centrifuges such as clarifiers and decanters are used for separation. The product is dried using ring, fluid bed, roller or spray driers.

Precipitation by Complexing Agents

This process is also called the cold precipitation process. Numerous complexing agents can be used to recover protein from whey; of these, polyphosphates appear to be the only group to be used commercially for this purpose. Long-chain polyphosphates precipitate protein from whey at low pH e.g., 3.5. Typically, potassium polymetaphosphate and sodium hexametaphosphate are used. The precipitates so formed are removed by centrifugation, washed, and then subjected to pH alteration and calcium addition to remove the phosphate. Removal of calcium prior to phosphate addition reduces the amount of phosphate required and results in recovery of up to 90% of the original whey proteins. Further modification of this process is also possible.

Adsorption Method

Since whey proteins are amphoteric, solid phase charged adsorption media can be used to remove them from solution under appropriate conditions. Media used for this purpose are regenerated cellulose, titania plus alumina and silica.

In case of regenerated cellulose process, whey is first decationized and then mixed with resin in a stirrer tank reactor. After separation of the protein-resin complex from the deproteinated whey, the protein is desorbed at pH 9.0. Ultrafiltration is used to concentrate the protein solution, which is then spray dried. The dried whey protein concentrate may contain as high as 95% protein.

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