Unit V - Topic 4
Whey manufacture – techniques –equipment – ice cream freezers

MANUFACTURE OF DRIED WHEY

22.1 Introduction

The trend in Western Europe is to preserve whey solids in the form of demineralised and delactosed whey powders. Whey powder is essentially produced by the same method as other milk powders. Whey powder production consists of three main operations: evaporation, crystallization, and drying. During evaporation whey is concentrated to 42-60% total solids. Lactose crystallization prior to drying for whey powder production is inevitable because amorphous lactose is sticky. This causes problems during drying as it results in a hygroscopic product, but this can be overcome by converting most of the lactose into crystalline α-hydrate form.

When dried conventionally without lactose crystallization, whey concentrates yield powder that are very hygroscopic and the manufacturer runs the risk of the powder caking on storage, or even in the drier. In addition, the efficiency of the drying is reduced, since it is not possible to concentrate whey to solids content greater than 42-45% total solids for a non-crystalline product. To avoid the caking properties of ordinary whey powder it is industrially important to encourage the majority of the lactose to crystallize into the non-hygroscopic α-lactose hydrate form. The advantage of lactose crystallization lies both in energy savings and in improved powder properties.

22.2 Drying of Whey

Recent trend in drying of whey is extensive use of spray drier that may be single stage, two-stage and more recently three-stage drying. The moisture content of whey powder ranges between 3.5-5%. Processes pertaining to the spray drying of whey for the manufacture of various types of whey powder are depicted in.

Whey can be transformed into powder by using different technological processes, with the final product quality depending on applied technology. Powders produced by different methods vary considerably. Characteristics essential to powder quality are powder hygroscopicity and caking tendency. Since 100% lactose crystallization cannot be achieved, the target in whey powder production is to gain the largest possible portion of lactose in crystalline form, such as 90-95% α-lactose monohydrate.

Increased lactose crystallization in procedures 2, 3, and 4 (Fig 22.1) results in a decreased quantity of amorphous lactose and drying is performed at higher outlet air temperatures, allowing intensified evaporation of up to 60% total solids. The increase in the inlet air temperature by 10°C raises the outlet air temperature by 1°C.

22.2.1 Single-stage process

In single-stage drying, the product is dried to its final moisture content in the spray-drying chamber alone; sometimes pneumatic conveying system is adopted with one-stage drying system. Ambient air provides both the conveying and cooling of powder. If climatic conditions prevent powder temperature/residual moisture contents to be achieved with ambient air, the conveying air must be dehumidified and cooled to usually 8°C. In procedure 1 (Fig.22.2), concentrated whey is pumped into the spray drying chamber. Both spraying methods are used with a pressure or a centrifugal (rotating) atomizer. Inlet air temperature varies from 150 to 200°C with different procedures. Outlet air temperature is 85°C. As a general rule, outlet air temperature should be as low as possible, but high enough to prevent the powder from sticking and leaving a deposit ("fouling") in the spraying chamber. Air, evaporated materials, and powder fines are directed through the system of cyclones, where powder particles are separated and returned into the process. Most of powder obtained at the chamber bottom and joined to the powder derived from the cyclone is cooled with cold air and pneumatically transported to sifting and packaging equipment. Powder obtained in such a way is very hygroscopic, with a high caking tendency. Hygroscopic whey powder exposed to room conditions has a strong tendency to absorb moisture from the air and form hard cakes or lumps. For these reasons, careful control of drying conditions is necessary to reduce the production of undesirable hygroscopic product. Air flows, which permitted product to contact high temperature surfaces, such as the lip of inlet air duct, results in excessive scorched particles in the finished product.

Procedure 1, in addition to resulting in a highly hygroscopic product, is disadvantageous from an energy-saving point of view, because whey can be concentrated in evaporated only up to 45% total solids. However, since water evaporation in a multieffect vacuum evaporator is significantly cheaper than in a spray drier, the steam consumption for this procedure is 6.6 kg/kg whey powder.

By introducing lactose crystallization between the evaporation and drying process (Procedure 2) powder quality and process economy are improved. 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 and fine-grained α-lactose monohydrate at a level of about one kg per tonne 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. Crystal size in the final crystallized concentrate should be mostly in the range 20-30 µm with the largest crystals not exceeding 50 µm.

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%. Direct evaporation and drying costs in procedure 2 are thus lowered to 5.5 kg steam/kg of whey powder.

22.2.2 Two-stage process

The principle of two-stage drying is a combination of spray drying as the first - stage drying and fluid bed drying at the second stage. Final drying in the integrated fluid bed dryer ensures that the desired residual moisture is achieved. After final drying, the powder is cooled in a pneumatic cooling and conveying duct. The installations can be operated with both nozzle and centrifugal atomizers.

By two stage drying, it has been possible to obtain good quality powders and also with advantage regarding drying economy in the manufacture of non-agglomerated products. In this process normally, powders leave the chamber and enter the attached vibrating fluid bed drier with a moisture content of 5-7%. In the fluid bed, the air blown into the first section has an ambient temperature to stabilize the agglomerates, thus avoiding lumping of the thermoplastic powder. Air temperature in the second section is 100°C, where the excess moisture is removed from the powder, while in the third section the powder is cooled down with conditioned air of approximately 11°C, to prevent additional moisture absorption. This lowers drying costs. Fines are recovered in the spray drier and fluid bed cyclones collected and returned to the atomizing zone for agglomeration. This agglomeration gives a free flowing powder. In this process typical drying conditions are: feed preheating to 80°C, feed concentration of 50-60%, crystallization, and then drying at an inlet temperature of approximately 185°C.

22.2.2.1 Advantages

Two-stage drying allows for gentler handling of the product, thereby reducing product degradation. The biggest advantage over single-stage drying is the improved efficiency achieved by increasing the temperature difference between supply air and outgoing air. The energy required for drying is about 10 – 15 % lower than in the single-stage process. The cost of whey drying is reduced to 5.0 kg steam/kg of powder by application of two-stage processing.

22.2.3 Three-stage drying

The three-stage dryer involves transfer of the second drying stage into the base of the spray drying chamber and having the final drying and cooling conducted in the third stage located outside the drying chamber. It consists of a main drying chamber, static integrated bed chamber and vibro fluidized bed chamber. In the main chamber primary drying of the droplets takes place in the main chamber as they fall from the atomizer to the base of the chamber. The second drying stage takes place as drying air is sucked through the powder layer. The moisture content of the powder falling on the integrated bed is 12–20 % depending upon the type of product. This second drying stage reduces the moisture content to 8-10 %. The moisture content is very important to achieving the exact degree of agglomeration of the product and porosity of the powder layer. The third and last drying stage takes place in the vibro fluidized bed dryer where the moisture contents of the powder reduces to 3 to 5%. Fluidized bed chamber is supplied with heating and cooling section. Only a small amount of powder leaves the plant together with the drying and cooling air as fines. This powder is separated from the air in a cyclone. The powder is recirculated, either to the main chamber or to a point in the process appropriate to the type of product and the agglomeration required.

22.2.3.1 Advantages

This configuration allows the supply air temperature to be increased and the outgoing air temperature to be lowered. This reduces the specific energy requirement by a further 10-15%, improves particle agglomeration and reduces product degradation by using lower drying air temperatures compared with two-stage drying. A large number of plants installed work to this principle. Mass-produced products such as skim milk powder and whey powder are manufactured cost-effectively in this way.

22.2.4 Belt process

Lactic acid in dry form is very thermoplastic even at low temperature and difficult to dry by conventional spray drier. This means that this type of powder is extremely sticky during the spray drying process. The belt process is especially advantageous in drying lactic acid whey. The high moisture content of powder leaving the spray drying chamber ensures that crystallization will continue in the powder to an even greater extent than in the two-stage process using fluid bed drier. This crystallization is improved if the wet powder is kept at high moisture content for 10-15 minutes. This is conveniently done on a belt conveyor mounted between the chamber outlet and a fluid bed, where the final drying takes place. The resulting powder consists of large agglomerates, which has a low bulk density, but is extremely instant and have excellent non-caking properties. In order to avoid condensation in the cyclones, hot air is introduced into the exhaust system of the spray dryer to increase the relative humidity.

A spray belt dryer is shown in. It consists of a main drying chamber and three smaller chambers for crystallisation, final drying and cooling. Typical drying conditions involve preheating to 80°C, feed concentration to 50%, spray drying at inlet temperature of 150°C and outlet temperature of 55°C to a moisture content of 12-15%.

22.2.5 Filtermat concept of drying

In filtermat drying system, the concentrate is atomized by pressure nozzle in a low profile drying chamber. Here the conveyor belt collects powder from bottom of the chamber. The conveyor belt contains three sections. First section for agglomeration and crystallization, second section contains warm air for drying and third section for cooling of powder.

22.3 Roller Drying of Whey

The technologically simpler and much less expensive roller drying technique can sometimes be used economically for the production of lower-quality whey powders (Peters, 2005), but its harsh heat treatment effects diminish the utility of this traditional technique for producing high quality whey-based powders.

Whey powder obtained by the roller drying method is very hygroscopic since most of the lactose is in amorphous form. It has a dark colour caused by the maillard reactions between proteins and lactose. Considering that the amino group in lysine takes part in these reactions, the quantity of available lysine is decreased by 30%. In addition, roller-dried whey powder is not easily soluble and has other negative characteristics. In spite of these negative effects the roller drying also have some advantages, such as low cost investment, relatively small space necessary for the operation, economical processing, and easy operation and maintainance. Some of the problems encountered in conventional roller drying may be eliminated by vacuum roller drying. In this type of drying the whey is dried at a temperature below 100°C at 91-98 KPa means that the effects of oxygen and high temperature are markedly reduced. The product has better properties than the whey powder obtained from roller drying under atmospheric pressure.