Handbook on Spray Drying Applications for Food Industries

M. Selvamuthukumaran

Spray Drying of Dairy and Cereal Food Products

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3.0 INTRODUCTION

Milk is a highly perishable commodity that requires preservation. It contains moisture content of around 89%–90%. Therefore, it deteriorates under ambient temperature condition quickly and after a time period at controlled storage conditions. Therefore, water needs to be removed from the milk in order to facilitate longer time periods of usage. To carry out this process, drying is essential. There are various drying methods available that remove water efficiently from milk. Among them, spray drying is one technique that can be successfully adopted to remove moisture from the product. The product quality, i.e., both physico-chemical and microbiological properties, are highly dependent on the processing conditions that are being adopted during spray drying. The various parameters viz. inlet air temperature, outlet air temperature, atomizer speed, concentration of slurry feed, have a prominent role in maintaining the quality of end product.

Spray drying also exerts a great influence over nutritional properties. Various changes that occur during spray-drying conditions include the destruction of vitamins and denaturation of proteins. For developing certain powders, especially whey powder and milk protein concentrate powder (MPCP), a few additional processing steps are required. For example, before spray drying whey powder the slurry needs to undergo a process of crystallization and in the case of MPCP, adopting membrane technology to purify the concentration of protein is needed before the drying processes to get a good yield. Spray dryers are available in various sizes to efficiently handle enormous volumes of the dried product.

3.1 ICE CREAM MIX POWDER

Ice cream mix powder is used in popular, delicious, frozen desserts liked by consumers of different age groups. It is prepared from its dairy products source. It’s developed using the spray-drying process, which is considered to be one of the most novel techniques used for enhancing the shelf life of the final product. The spray-drying process helps to microencapsulate a fat, protein, and lactose matrix. It’s a popular technique used for converting ice cream into solid powder form (Vega et al. 2005). It’s an instant product that can be easily reconstituted for preparing ice cream at any time. The product is very easy to pack and very convenient for handling during transportation. It reduces the space of packaging material
needed, thereby reducing the cost of the pack and also the costs that are incurred during transportation. The moisture content of the product is low; therefore, the stability is increased and when a shortage of milk production occurs, it can be used to solve the crisis of milk product shortage. It can be utilized during a lean season period.

### 3.1.1 Preparation

The major ingredients used for manufacturing instant ice cream mix powder are fat, which can be either obtained from dairy product sources, i.e., cream or from other sources, such as palm kernel oil/sunflower oil/peanut oil, along with skimmed milk powder, corn syrup, solid sugar, protein, emulsifier, stabilizer, flavorings, and colorings. The addition of polyoxyethylene sorbitan mono-oleate improves the textural properties of ice cream. It also leads to production of ice cream with more stiffness and enhanced melting properties. Stabilizers like pregelatinized potato starch and emulsifier like Tween-80 can also be used for its preparation.

#### 3.1.1.1 The Two Stages of the Production Process

The first stage is the spray drying of the liquid premix and the second stage is the dry blending of ground sugar. The final product is prepared by reconstituting 1:2 ratios of instant mix powder and water. Finally, the reconstituted mix is kept in the freezer to maintain a tasty and well-textured product.

The detailed process for manufacturing instant ice cream mix powder is given in Figure 3.1a. The different ingredients were blended (see Table 3.1) and the mix was preheated to 50°C using a plate heat exchanger. The preheated mix was then subjected to a homogenization process in two stages; firstly, at 2000 psi and secondly, at 500 psi, for the uniform distribution of fat particles and also to avoid the separation of the fat layer rising to the top during subsequent stages. Once the mix was homogenized, the pasteurization was carried out in a vat at 68°C for a period of half an hour. The pasteurized mix was atomized into a fine and very tiny droplet form using a disk atomizer at a speed of 16,000 rev/minute, these droplets get exposed to incoming hot air and dried quickly and then the particles are separated through a cyclone separator and the fine powder which is collected is packed in metalized polystyrene pouches under nitrogen or any inert gas to prevent oxidative rancidity. Sudden cooling of powder is important to reducing the cooked and stale flavor of powder. The dry
blended mix powder can accelerate oxidation, rancidity because of exhibiting free fat on the surface of powder particles.

Higher moisture content, metallic contamination, and high storage temperature severely affect the quality of powders to a greater extent. Therefore, the product has to be properly packed and stored at a low temperature to enhance its quality. The finished product contains 31.6% fat, 25.5% SNF (solid nonfat), 40.5% sucrose, and 1.85% moisture.

For preparing soft ice cream from the instant spray-dried powder (see Figure 3.1b), it is reconstituted in water at 1:2, cooled, aged at 5°C for 15
spray drying of dairy and cereal food products

hours, optional flavors are added, it is frozen in a batch freezer, and finally hardened at \(-24^°\) C for 18 hours to get delicious and stiff ice cream.

Fazaeli et al. (2016) optimized ice cream powder using a spray-drying process. They used black mulberry juice to flavor the final product. They used a mixture of solep and k-carrageenan as a stabilizer. The inlet air temperature used was 120°–160° C, the feed flow rate was (5%–15%) and the juice concentration was 15%–45%. The parameters, namely drying yield, melting rate, and overrun was obtained from reconstituted powder. The optimum conditions used for preparing ice cream powder was inlet air temperature of 138° C, feed flow rate of 8%, juice incorporation level of 35%, with melting rate of 1.52 g/minute, and overrun of optimized product was found to be 74.5%.

### 3.2 MILK PROTEIN CONCENTRATE POWDER (MPCP)

Milk Protein Concentrate Powder (MPCP) is a product obtained through the spray-drying process and can be manufactured by separating protein from milk by adopting separation techniques before drying. The separation process removes most of the carbohydrates and leaves only minerals like calcium, phosphorus, and magnesium behind, which are then bound with proteins. The product contains both kinds of proteins, i.e., whey proteins and caseins. It is a rich source of protein when compared to products like skimmed milk powder and whole milk powder.

#### 3.2.1 Constituents of MPCP

MPCP contains an abundant protein content of around 90%. The moisture content of the dried product is around 3%–4%, lactose 4%, fat 2.5%, ash 6%,
and contains minerals, such as calcium at 2000 mg/100 g, sodium at 125 mg/100 g, and energy at 1500 kj/100 g.

The product may vary significantly in protein content depending upon the manufacturers; the protein content of various commercial products may vary from 40%–90%. The casein is present in the form of micellar like milk, therefore it contains a greater matrix of protein bound minerals.

### 3.2.2 Development of MPCP

The detailed steps for developing MPCP are represented in Figure 3.2. Milk is received, preheated to 40°C–50°C, and passed through the cream separator to obtain cream and skim milk. The obtained skim milk is

(Milk)

↓

Preheating

↓

Clarification

↓

Centrifugal separation

↓

Skim milk

↓

Pasteurization

↓

Ultrafiltration

↓

Diafiltration

↓

Spray drying

↓

Powder packing and storage

**Figure 3.2** Detailed procedure for preparing MPCP.
further pasteurized at 75°C to inactivate the enzyme lipase and to kill microorganisms, then passed through a stainless steel membrane tube inbuilt with spiral wound membrane with a pore size of 20 nm. 1.60 bar pressure was maintained as membrane inlet pressure and 1.00 bar was kept as a membrane outlet pressure during the ultrafiltration process. The macro size molecules of casein, whey protein, and residual fat are retained and the microsize molecules of lactose and dissolved solids pass through the membrane and are removed to a certain extent. In order to achieve high protein content in the final end product, i.e., before spray drying, the ultrafiltered sample is again passed through the same membrane in a process known as diafiltration, which efficiently removes most of the lactose constituents and some dissolved salts. This process helps to get the required ratio of protein solid concentration. The skimmed milk is passed through the membrane at 50°C to get the volume concentration ratio of 3:1. After the diafiltration process the soluble solid concentration of approximately 16%–17% is reached. It is increased further to 26% using the evaporation process with the help of a thin film evaporator at 65°C to avoid whey protein denaturation. The feed is spray dried using an inlet air temperature of 175°C and an outlet air temperature of 75°C to get MPCP powder with good physico-chemical properties. The product is packed and stored in airtight pouches. In food industries, people use this product for creating protein-rich foods and nutraceutical formulations (see Figure 3.3).

**Figure 3.3** Uses of MPCP.
3.2.3 Functional Properties of WPCP

The products functional properties include:

- Good water binding capacity
- Gel forming capacity
- Foaming capacity
- Whipping capacity
- Excellent emulsification properties
- Possession of good heat stability properties
- Highly viscous, so it can be used as a thickener
- Enhancement of the milky flavor of the final product

3.3 WHEY POWDER

Whey powder is a product that is obtained as a by-product of the cheese industry, i.e., from whey using a spray-drying process.

3.3.1 Raw Material for Whey Powder Processing

3.3.1.1 Whey

The raw material used for developing whey powder is whey. It’s a coproduct of cheese manufacturing industries that is obtained by coagulating milk with enzymes, such as pepsin and rennet to yield a greenish to yellow colored solution with a tart flavor. In the cheese industry, for making one part of cheese product, approximately eight parts of whey is obtained, and it is being underutilized in most of the dairy processing industries. The whey can be classified into three kinds; one is sweet whey, the name itself indicates a very low acidity of not more than 0.16% acidity (in terms of lactic acid), while the second one is acid whey with higher acidity of greater than 0.35%, and the last kind is casein whey.

It’s an abundant source of minerals, such as calcium and phosphorus. From a nutritional point of view, it contains 50% of solids similar to whole milk (Pasin and Miller, 2000). The major constituent of whey solid is lactose. It’s a fair source of vitamins A and D. It can’t be used as such but it can be converted into powder form, which has a greater shelf life. Commercial dried forms available in on the market include dried whey powder, whey protein concentrate, whey protein isolate, etc. (Westergaard, 2004).

Whey contains major proteins, such as α-lactalbumin, β-lactoglobulin, and lactoferrin (Kumar et al., 2008). Lactoferrin has a lot of bioactive
properties, such as, antibacterial activity, anti-inflammatory activity, etc. It has the property of binding well with iron (Darewicz et al., 2014).

### 3.3.2 Development of Whey Powder

Figure 3.4 illustrates the detailed methodology for preparing whey powder from acid whey. The acid whey is received then filtered to separate the suspended fat and tiny cheese particles. It is then pasteurized immediately at 70°C for a few seconds to kill microbial organisms and live enzymes. After pasteurization, the whey is subjected to evaporation using a vacuum evaporator to achieve 30% total soluble solids (TSS). Next, it is cooled immediately by using flash coolers (Pisecky, 1997; Shrestha et al., 2008; Nijdam et al., 2007), and kept in tanks equipped with agitators at a low temperature for a period of 4–24 hours. During this period β-lactose is converted into a α-lactose form so that it may reduce the hygroscopicity properties of the dried product, and it also further enhances the free-flowing nature of the powder to a greater extent. After an effective crystallization process (Norgaarda et al., 2005), the slurry is subjected to spray drying at inlet temperature of 155°–175°C and outlet temperature of 80°–95°C to get the final product, which is packed and kept in airtight containers.

![Figure 3.4 Production steps involved in manufacturing whey powder from acid whey.](image-url)

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3.3.3 Composition and Uses of Whey Powder

Whey powder is found to be a rich source of lactose and protein (see Figure 3.5). It’s a poor source of fat, therefore it can be ideal for suiting the needs of cardiac patients. The moisture content is very low, i.e., less than 4%, which helps in enhancing the product stability to a great extent. The ash content of the powder varies from 8%–9%. The product has enormous fortification applications in several food processing industries, such as the meat, dairy, confectionery, and bakery industries (see Figure 3.6). The whey powder fortification in food products helps to enhance the overall product quality; it improves texture, color, flavor, and dispersibility of the fortified end products.

![Nutritional composition of whey powder.](image)

![Applications of whey powder.](image)
3.4 CHEESE POWDER

Cheese powder is a product prepared by spray drying melted hot cheese slurry after incorporating emulsifiers, stabilizers, colors, etc. It can be prepared from a wide variety of cheeses that are available commercially, such as cheddar, swiss, camembert, gouda, etc. It has been used immensely in the food processing industries as a flavor enhancer, improves functional properties of the foods, such as, texture, structure, mouth feel, cooking quality, etc. It is widely used during food product formulations and also in culinary preparations, such as, soups, sauces, biscuits, dressings, etc. It can be fortified at the rate of 5%–10%.

3.4.1 Production of Cheese Powder

The detailed production process for development of cheese powder is given in Figure 3.7. Cheese powder can be manufactured from a wide variety of ready to eat or consumable cheeses that are commercially available. Among them, the cheese powder prepared from cheddar cheese is quite a popular product. The cheese of different varieties were blended, cut into sizes of $3 \times 3 \times 3$ cm, other optional ingredients were mixed with it, such as, emulsifier salt, i.e., sodium phosphate, edible color; modified starch, flavors, anticaking agents; and milk solids, i.e., casienates/whey/skim milk, etc. The addition of sodium phosphate as an emulsifier develops an emulsion that will stabilize the product until the drying process. It can be added at 1.5% in solution form for uniform suspension. Water and cheese are added at a ratio of 2:3, mixed well using an agitator at a mixing speed of 1400 rpm for 50 seconds and it is heated for 120 seconds at 60°–70°C until all the solid constituents are dissolved properly. This process is known as a creaming reaction, which is an important step in the cheese powder production process that represents/indicates uniform suspension of cheese fat in water with the help of an emulsifier.

The creaming reaction is greatly influenced by protein-protein reaction during processing, and final product quality is correlated with dispersion levels of protein. The mechanical treatment, i.e., shear stress that occurs during mixing/agitation helps to reduce the size of fat globules, which can further provide a larger surface area for fat–protein interaction and it ultimately results in a more stabilized cheese feed.

The hot slurry was prepared through the application of steam to dissolve the constituents at 70°–80°C to get thick slurry with a concentration of 20%–40%. The slurry was homogenized to subdivide the fat particles
and to give uniform appearance and finally spray dried using inlet air temperature of 175° C, outlet air temperature of 80° C, atomization pressure of 350 kPa, and inlet concentration feed speed of 25 ml/minute to get aesthetic cheese powder.

The operating conditions of spray drying greatly influence the quality of cheese powder production. Commercially, it is manufactured using a two-stage drying system. A tall form drying system is used, which gives good flavor retention with good powder flowability and large particles. The single-stage dryer provides higher outlet air temperature, which is not recommended for use because it adversely affects the product quality. Two-stage drying improves color and flavor retention. If single-stage drying is used the maximum outlet air temperature should be kept below 90° C to prevent browning, to decrease product wettability, which may

Figure 3.7 Detailed production process for developing cheese powder.
occur as a result of protein denaturation, to prevent volatile component loss, to prevent formation of residual free fat during drying processes, thereby drastically reducing flow problem, lump formation, and flavor destructions. The reduction in outlet air temperature helps in increasing the moisture content of the final product; however, it adversely affects the longevity of the product. To extend the stability of cheese powder to more than a year, it is recommended to pack the product in modified atmospheric packing.

The cheese powder contains 27% fat, 4%–5% moisture, 28% protein, and 5%–10% salt. The salt content of the product varies significantly depending upon the type of cheese used during the manufacturing processes.

3.5 SPRAY DRYING OF CEREAL PRODUCTS

Spray drying can be successfully adopted for preparing instant ready to use food products from cereal grains, which have been used widely as an ingredient in several food processing industries. They can also be blended with milk to yield specific beverages to suit consumer needs.

3.5.1 Malt Extract Powder (MEP)

Malt extract powder (MEP) manufactured by spray drying the malt extract slurry or concentrated wort under optimized drying conditions to get a dark brown colored product. MEP has appreciable amounts of B vitamins and proteins and it is used as an ingredient in several food processing industries. It has a good, slightly sweet flavor with positive digestion properties. It can be used as a substitute for sugar in a beer manufacturing formulation, which provides body to the final product.

Figure 3.8 depicts the detailed process for development of malt from barley grains. Barley grains are received, cleaned to remove the foreign particles, washed with 0.1% aqueous lime solution, and then the grains are soaked for a period of one day. Excess water can be removed after soaking and the barley grains undergo induced germination for a period of three days. During this period the natural enzymes, i.e., α, β amylases present in the barley grains are activated and induce the germination process. The nutrients are enhanced to a greater extent as a result of germination. Water can be sprinkled over the grains every 2–3 hours, which were kept as heaps and the heaps were also turned in between to increase the moisture content up to 46% after three days. Once the germination is
over, the rootlets are removed by bruising easily, dried in hot air oven at 55° C for 15–18 hours to give a pleasant aroma, and it is finally packed in pouches for further use.

Figure 3.9 illustrates the detailed process for developing spray-dried MEP from sprouted barley grains. The dried and sprouted barley grains are received, milled in reduction roller or by using hammer mills, mashed under controlled conditions, and during this process the starch gets broken down into simpler sugar units. Separation is achieved by diluting the mashed contents with hot water in order to remove spent grains from the extract. It is achieved using a centrifugal separation process or by using vibratory sieves. The liquid obtained after spent grain removal is known as wort. It is further concentrated by boiling to achieve 14%–20% TSS. During this process the proteins get coagulated, therefore it can be removed again by centrifugation process. The boiled wort is again further concentrated using a vacuum evaporator to increase the TSS concentration.
to 30%, fortified with maltodextrin as a carrier material, spray dried using processing conditions as shown in Table 3.2 to get spray-dried MEP, and then packed and stored in airtight containers. The use of higher inlet air temperature leads to the destruction of vitamin B content of the MEP. The
best powder can be obtained by using inlet air temperature of 170°C, outlet air temperature of 85°C with slurry or feed TSS concentration of 25% (see Table 3.2).

3.5.1.1 Applications of MEP
MEP has been applied widely in several food processing industries.

- It is extensively used in bakery products, such as buns, cakes, etc., to provide malty flavor to the enriched products.
- It is a color enhancer that gives specific color to the end products.
- It is a substitute for malt liquid extract used in the fermented beverage processing industries because of its high amount of fermentable sugars.
- It is a major ingredient in several functional food formulations and nutraceuticals.
- It is also used in soda pop, ice cream, pastry, milk shakes, and other products.

3.5.2 Malted Milk Powder
Malted milk powder is a product that is prepared by spray drying whole milk under standard processing conditions after blending with malt powder obtained from raagi seeds. The raagi seeds, known as finger millet, are widely harvested in India and Africa and are found to be an excellent source of minerals like calcium and phosphorus, fibers, and phenols, etc. They are considered to be the staple food of the low-income groups in India and Africa. It’s an apt food for feeding children because of its nutrient content, especially its mineral content. The malting process makes it even easier to digest. The blending of milk with raagi malt and subsequent drying enhances the nutritional intake of the consumers to a greater extent while also further increasing the storage stability.

Figure 3.10 depicts the flow steps for preparing malted milk powder from raagi. Raagi seeds are received, cleaned, malted (i.e., germinated, oven dried, rootlets are removed), pulverized, and sieved to get fine powder. The malted raagi powder is blended with whole cow milk at 15%–25%, homogenized, and spray dried using processing conditions, i.e. inlet air temperature of 160°C–170°C, outlet air temperature of 80°C–85°C, air pressure of 3.5 kg/cm² to get free-flowing raagi-based malted milk powder. The product can be reconstituted in hot water, fortified with sugar, and can be served as a beverage. Similar commercial products are available in India under the names of Horlicks, Milo, etc., which is prepared from
malted barley grains, wheat flour, milk solids, sugars, cocoa powders, and enriched minerals. It is flavored and dried, then ready to use in instant food products with prolonged stability.

3.6 CONCLUSIONS

Through using optimized spray-drying conditions, various instant dried food products, such as, ice cream powder, MPCP, whey powder, cheese powder, MEP, and malt-based milk food powders can be prepared. These products have the advantage of minimizing the packaging space, being easy to handle, and reducing the transportation cost. If proper packaging conditions are adopted, the products can be stored for a prolonged period.

REFERENCES


