Reconstituting Dairy Powders

AMERICAN Dairy Products INSTITUTE™

The rehydration or reconstitution of dairy powders is an important process for the production of many products and incomplete reconstitution can lead to quality problems. While reconstitution of dairy powders appears straightforward it is in fact influenced by many factors. Changing one or two properties of the powders or rehydration conditions can significantly alter reconstitution.

Reconstitution factors

Reconstitution refers to ability of powders to go into solution. To go into solution powders must wet, sink, disperse and dissolve. Said another way, powders need to have wettability, immersibility (ability to sink), dispersibility and solubility.

Many factors influence the ability of a powder to wet, sink, disperse and dissolve. Among these factors are physical properties of the powder, chemical properties of the powder and recombining methods.

Physical properties of the powder include: composition; particle size; surface structure of the particle; particle density; bulk density; air content; uniformity and; additives used.

Chemical properties of the powder include: protein denaturation and; proteolysis

Recombining methods include: water temperature; water quality; type of agitation and; time.

Powder properties

The physical and chemical properties of the powder particles strongly influence reconstitution. These properties are influenced both by drying conditions and the type of dairy product to be dried.

Physical properties

Physical properties include composition: particle size; particle shape; surface structure of the particle; particle density; bulk density; air content; uniformity and; additives used.

Composition

Some constituents of dairy powders are not soluble in water. Lactose, some minerals and undenatured whey proteins are soluble in water while fat is not. Products such as whole milk powder (WMP) will be difficult to reconstitute without the use of additives since fat on the surface of the powder particle will repel water.

Lactose and proteins are the more hydrophilic components of dairy powders and attract water as opposed to fats that are hydrophobic and repel water. Skim milk powder (SMP) and nonfat dry milk (NFDM) which consist largely of proteins and lactose, therefore, will more readily attract water as compared to whole milk powder (WMP).

Particle size

Fine powder particles (<100 µm) are more difficult to rehydrate as compared to larger particles. Water must make contact with the particle surface to initiate the reconstitution process. Interfacial tension between particle and water must be overcome to wet powder particles and because of this tension small particles prefer to associate with themselves rather than be wetted by water.

Particle shape

The shape of powder particles ranges from spherical to irregular. The method of manufacture determines particle shape.

Roller dried powders, which typically are used for animal feed applications, have an irregular, compact shape with sharp edges. There is very little or no occluded air (air within the particle) in roller dried powders.

Spray dried powders tend to be spherical with a solid and dense surface layer. They have occluded air or vacuoles within the particles.

By contrast, freeze dried powders, which are not common in dairy applications because of cost, have the most porous structure.

Surface structure

The surface structure of powder particles depend on how the powder was dried. Powder surfaces that are more open or porous allow water to readily penetrate the particle. Smooth surfaces contribute to higher bulk densities.

Conditions during drying such as preheat temperature, dryer type, type and configuration of the atomizer, number of dryer stages, and feed concentration are dryer factors that determine porosity of the powder particle.

<u>Particle density</u>
Particle density is the density of the individual powder particle. Density of product components and amount of occluded air, that is, air trapped within the particle, determine particle density. Fat, for example, is a lighter material as compared to components like lactose, therefore, whole milk powder particles will have a lower particle density as compared to skim milk powder particles. Large amount of occluded air also will result in a lower particle density. Factors determining amount of occluded air include: air in the feed; spray dryer system conditions; product composition and; feed properties (state of proteins, denatured whey proteins, feed concentration and feed temperature).

There are many processing factors influencing density. Some of these factors include preheat temperature, feed velocity, atomizer method, air in feed and drying conditions. Variations in density occur due to the relationships between milk composition, inlet and outlet temperatures of the dryer and process conditions.

Increased occluded air occurs with higher protein content (especially undenatured whey proteins), low heat treatment, aeration of the feed and higher total solids in the feed to the dryer.

The presence of fat and lactose also affect particle density. Fat is the least dense component in milk therefore whole milk powder (WMP) particles will have a lower density than skim milk powder (NFDM/SMP) particles. Less lactose and conversely more protein results in a more porous structure because of increased occluded air and results in a lower particle density.

<u>Bulk density</u>
Bulk density refers to the weight of a given volume of powder. Interstitial air, which is the air between particles, is a complex property that is important in bulk density. Other important factors determining bulk density include particle size, particle size distribution, particle shape, particle surface structure and presence of occluded air. The method of manufacture influences many of these factors.

Particle shape rather than particle size is more important when the highest bulk density is desired. Highest bulk density is achieved with air free particles having a spherical shape and a smooth surface. A range of particle sizes also contributes to higher bulk densities because smaller particles can fill the space between larger particles to increase bulk density.

Although roller dried powders have little or no occluded air, their irregular shaped particles have a lower bulk density because the particles do not easily slide past each other and therefore do not pack tightly.

Spray dried powders have uniform, smooth surfaces and as compared to roller dried powders, spray dried powders will have a higher bulk density.

Agglomeration of a powder changes the bulk density. The type agglomerate determines the bulk density of the powder. Types of agglomerates and their affect on bulk density is discussed in the following section.

Bulk density also can change with handling of the powder. Powders can break apart as they move through handling systems. Some powders are more friable or breakable than others. Loose and packed density are measures of changes in bulk density with handling. Loose density is a measure of powder density as produced. Packed density is a measure of powder density after the powder has be subjected to tapping which breaks apart friable powder particles.

<u>Air content</u>
The effect of air both within the particle (occluded) and between particles (interstitial) has been discussed as a factor in bulk densities.

<u>Uniformity</u>
Uniformity is important in composition, surface structure and particle density. When higher bulk density is desired a range of particle sizes is required so that smaller particles can pack in between the larger particles thereby increasing the bulk density. Powders may reconstitute unevenly when there is a lack of uniformity, whether with composition, structure or density.

<u>Additives</u>
Some dairy powders require additives to help wet the particles. Products such as whole milk powder (WMP), that have fat on the surface of the particles, need additives such as lecithin, to attract water so that the particle will wet.

Chemical properties
Chemical properties important in reconstitution of powders include protein denaturation and proteolysis.

Protein denaturation

Denaturation is a change in the structure of a protein that often is not reversible. There are a number of ways to denature protein but heat is the method of concern when discussing reconstitution of powders.

Caseins are stable to heat and therefore are not subject to denaturation. They will, however, interact with whey proteins. Whey proteins denature with heat. Initially whey proteins unwind exposing reactive sulfur groups. As whey proteins continue to unwind the sulfur groups interact with each other. When only whey proteins are present they interact with each other to form clusters (flocculate) of protein. If casein is present, whey proteins will combine with casein to form casein/whey protein complexes.

The amount of whey protein that is denaturated is characterized by the Whey Protein Nitrogen Index (WPNI). The WPNI test measures the amount of undenatured whey protein that remains in the powder, therefore, the higher the WPNI number, the less denaturated whey protein in the powder. Nonfat dry milk (NFDM) powder is classified as low, medium, or high heat based on the amount of undenatured whey protein present (Table 1).

Table 1. Classification of nonfat dry milk (NFDM) powders.

Type of Powder	Undenatured Whey Protein (mg/g powder)
Low heat	≥ 6.0
Medium heat	1.51 - 6.0
High heat	≤ 1.5

Solubility of whey proteins decreases with increasing denaturation. Hydration times and amount of occluded air also are effected by protein denaturation.

Proteolysis

Proteolysis involves breaking large proteins into smaller pieces often through the use of enzymes known as proteases. Depending on the conditions, the pieces may be large or small or anything in between. Whey proteins that have been denatured and are insoluble will go into solution if they are cut into small enough pieces.

Pieces of protein that are very small are referred to as peptides. Pieces that are larger than 10,000 daltons are known as polypeptides.

Agglomeration and instantizing

The terms agglomeration and instantizing often are used interchangeably, however, they actually are two different processes.

Agglomeration

Agglomeration is the process of taking smaller powder particles and sticking them together with other powder particles to make bigger particles or agglomerates. Vapor and solutions made from sugar, maltodextrin and product to be agglomerated may be used to hold the particles together.

The goal of spray drying is to efficiently remove water without causing heat damage to the final product. Product droplets as sprayed into the dryer should have a large surface area but small mass. Small powder particles are the result. Spray dryers therefore start with small liquid droplets that dry rapidly and gently leading to small powder particles that have negligible heat damage.

Although small particles are more efficient for spray drying they have high density, poor flowability and are difficult to rehydrate. Larger particles produced by spray drying are more readily hydrated, however, their method of production can negatively affect solubility. The agglomeration process is able to produce larger particles that rehydrate well but do not have issues with solubility.

Agglomerates have:

- Changes in bulk density
- Altered particle density
- Fewer fines, less dusty
- Improved wettability
- Improved reconstitution
- Improved flowability
- Typical particle size of 130 to 300 µm

There are a number of ways to produce agglomerates with the method determining agglomerate properties. The types of agglomerates are onion, raspberry, compact grape and loose grape (Figure 1).

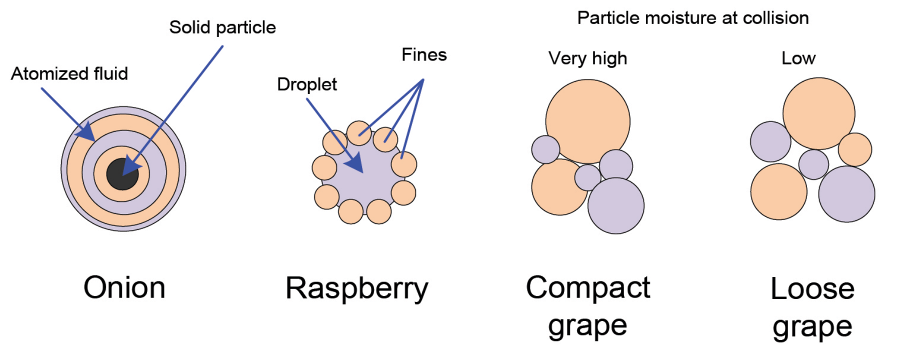

Figure 1. Types of agglomerates.

Agglomerates differ in properties such as mechanical stability, bulk density before and after handling (loose and packed density), amount of slowly dispersible particles and dispersibility of the powder after handling. Dairy powders often are conveyed by air. Some types of agglomerates more easily break apart when conveyed and therefore their properties can change after handling. The tendency of a solid to break into smaller pieces is known as friability.

Onion agglomerates, for example, are rather resistant to mechanical damage as compare to compact grape. Dispersibility is an important property in reconstitution and handling can significantly alter dispersibility of an agglomerated powder.

A comparison of the properties of several types of agglomerates is given in Table 2. It is important to consider several properties when agglomeration is used to improve reconstitution of dairy powders. Mechanical stability refers to how well the agglomerate will maintain shape with transportation and handling during processing. Some types of agglomerates break apart with handling thereby changing bulk density and dispersibility. Slowly dispersible particles are especially undesired in a product sold directly to the consumer.

Onion agglomerates are relatively large and have very good mechanical stability. This type of agglomerate is difficult to dissolve and tends to have many slowly dispersible particles.

Raspberry agglomerates also have good mechanical stability. Raspberry agglomerates have a higher bulk density but are poorly dispersible and have poor solubility.

Grape type agglomerates are good for dairy applications. Compact grape agglomerates have very little air in between particles, low bulk density and good mechanical stability. Loose grape agglomerates, by comparison, have higher bulk density and lower mechanical stability. Loose grape agglomerates also have the best dispersibility and a fast rate of rehydration. The optimum grape type agglomerate for dairy powder rehydration lies between compact and loose giving the agglomerate good mechanical stability without significant loss of desired reconstitution properties.

Table 2. Properties of several types of agglomerates.

Property	Onion	Raspberry	Compact grape	Loose grape
Mechanical stability	high - low			
Bulk density (before handling)	high - low			
Bulk density (after handling)	high - - - - - - - - - - low - - - - - - - - - - - high			
Slowly dispersible particles	many - few			
Dispersibility after handling	poor - - - - - - - - - - good - - - - - - - - - - poor			

Instantizing

Instantizing is the process of adding a compound to assist in the wetting of powder surfaces. Instantizing is required for powders, such as whole milk powder (WMP), that have fat on the particle surface. Water must contact the surface of the particle to rehydrate the powder and fat on the surface repels the water. Addition of a surfactant to the particle surface is needed.

Surfactants are molecules that have both water loving and water repelling areas. One section of the surfactant is hydrophobic (water hating) and another section is hydrophilic (water loving). Together these areas are able to bring water into contact with the surface of the particle despite the presence of water repelling fat.

Lecithin is a surfactant typically used to instantize dairy products such as whole milk powder (WMP). Lecithin is a phospholipid derived from soy or sunflowers. A generalized structure for lecithin is given in Figure 2.

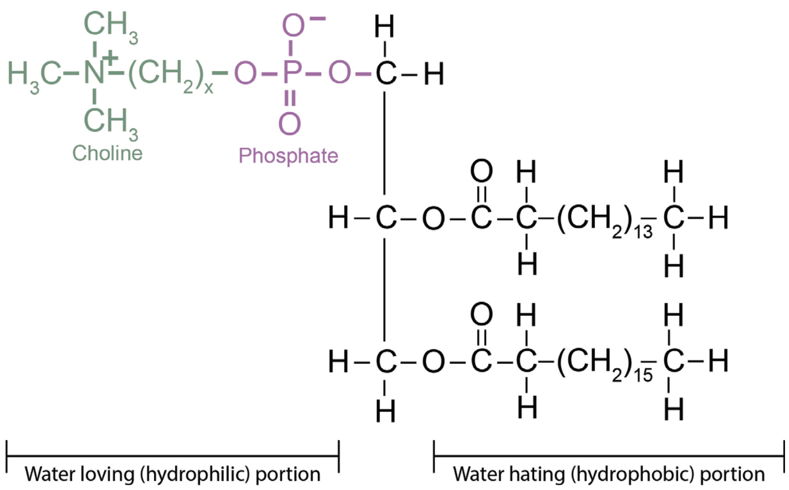

Figure 2. General structure of lecithin.

An example of the process of lecithination of whole milk powder (WMP) is given in Figure 3. The process can be done as one continuous process or the powder can be stored after drying and lecithinated later. Powder produced at one facility also could be lecithinated at another facility in a manner similar to powder produced and stored within the same facility.

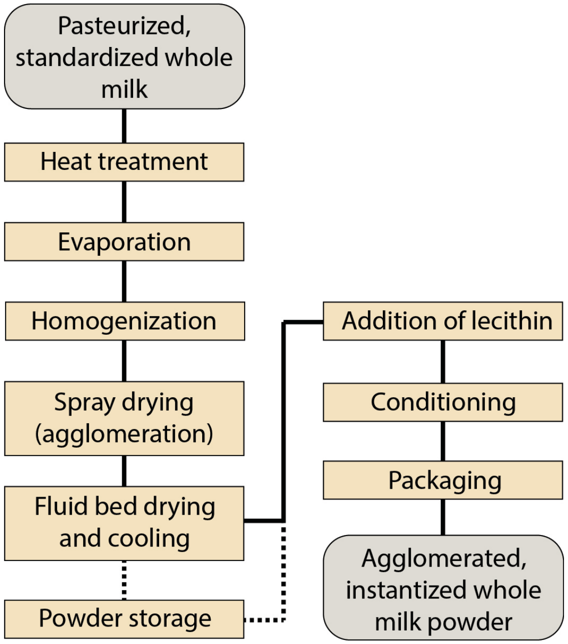

Figure 3. Process for production of lecithinated whole milk powder.

Powder characteristics

Wettability, immersibility (ability to sink), dispersibility and solubility are affected by the physical and chemical properties of the powder and recombining methods. Changing one or two of these properties can markedly change rehydrating behavior.

Wettability

Wettability refers to the ability of water to make contact with the particle surface. Wetting is a time controlling step and is the first step in the reconstitution process.

Wetting of a surface ranges from excellent to non wetting with the angle that the water droplet forms when in contact with the surface determining degree of wetting. Figure 4 is an illustration of the range of surface wetting with corresponding water droplet shape.

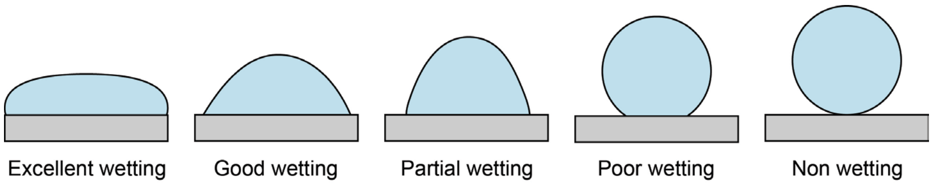

Figure 4. Range of surface wetting by water.

Wetting requires non agglomerated particles to adsorb water on their surface and for agglomerates to pull water between the individual agglomerated particles (Figure 5). It would appear that water could more easily wet small, non agglomerated particles, however, this is not the case.

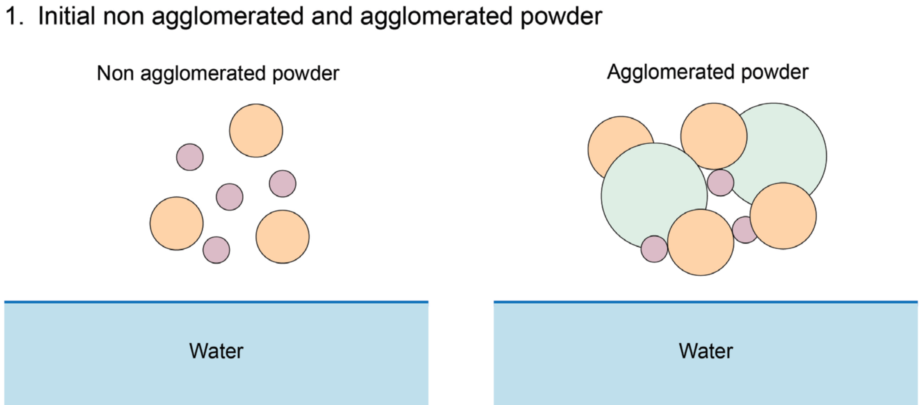

Figure 5. Non agglomerated and agglomerated powder before wetting.

Wetting depends largely on particle size. Small particles have a large specific area (surface area to mass ratio) and may not be wetted individually. In other words, the powder particle may be too small for the large water droplet to contact enough surface to wet the particle. To avoid problems with small particles failing to wet manufacturers can either increase the particle size and/ or agglomerate the powder (Figure 6).

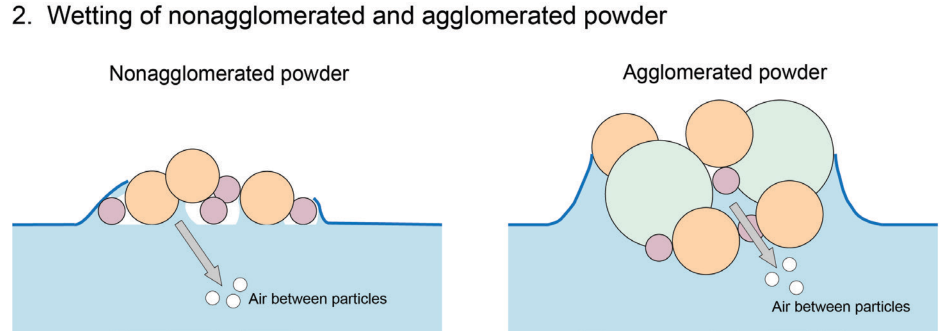

Figure 6. Wetting of non agglomerated and agglomerated powders.

During wetting, air that is in between the powder particles (interstitial air) must be replaced by water so that the powder can both be wetted and sink. Powders that have larger amounts of interstitial air will have decreased wettability. Small particles with a symmetrical shape which results in increased packing density (more powder in the bag) also will have decreased wettability.

Proteins may start to swell as they are wetted and adsorb water into their structure. Water around lactose may become more viscous as lactose is wetted and begins to dissolve.

If the particle surface contains fat then it will not readily wet and instantizing with something such as lecithin may be required.

Good wettability is define as occurring in less than 30 seconds as determined by ADPI's Standards for Grades of Dry Milk.

Factors that make for good wettability include:

- Agglomeration
- Use of lecithin
- Greater particle density
- Gentle handling
- Packaging warm after lecithination

Immersibility (ability to sink)

Immersibility, or the ability to sink, refers to the powder particle quickly becoming completely immersed in the water. Particle size and volume (density) are important factors both for non agglomerated and agglomerated powders.

Larger and denser powder particles sink more quickly. Large amounts of air incorporated within the particle (occluded air) will cause a powder to have poor ability to sink regardless of particle size. In all cases, the particles must loose their entrained air to properly sink and rehydrate. Agglomerated powders typically are better at sinking than non agglomerated powders.

Figure 7 illustrates the process of powders sinking and loosing their entrained air. The process is essentially the same for agglomerated and non agglomerated powders.

3. Sinking of powder

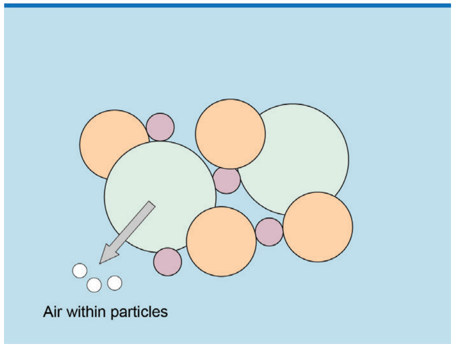

Figure 7. Sinking of powder particles.

Dispersibility

Dispersibility is the ease with which powder is distributed as single particles throughout water. Lumps should not be apparent.

Undenatured whey proteins and lactose will disperse/dissolve in the water to help separate the particles. Dispersibility is illustrated in Figure 8.

4. Dispersing of powder particles

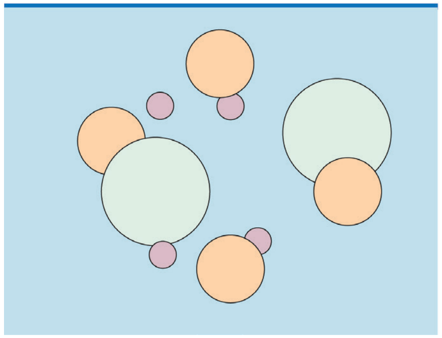

Figure 8. Dispersing of powder particles.

Powders that sink well will have better dispersibility. Powders that have high levels of denatured protein (low WPNI value) or tend to clump will be hard to disperse. A dispersibility of $\geq$ 90% is best for milk powders.

Solubility

Solubility refers to the rate and extent to which powder constituents dissolve in water. Chemical composition and physical state are the most important factors affecting solubility.

Solubility is the final step in the reconstitution process and involves groups of powder particles dispersing as single particles (Figure 9.)

5. Dissolving of powder particles

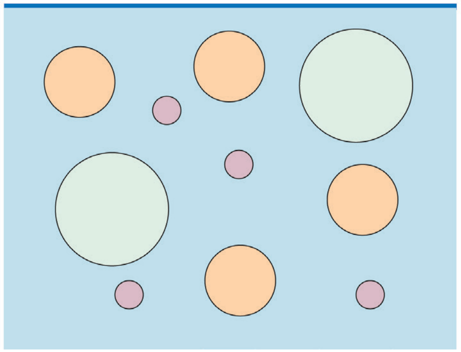

Figure 9. Dissolving of powder particles.

The method of production determines solubility. Denatured whey proteins and whey proteins that have combined with casein to form casein/whey protein complexes will decrease the solubility of the powder. Calcium that has precipitated during heating processes such as evaporation can be difficult to bring back into the solution and can result in a hazy appearance to the rehydrated solution.

Solubility and flowability are closely related powder characteristics. Typically powders that have good flowability also rehydrate easily.

A good solubility index should be as low as 0.25 ml undissolved sediment/50 ml of reconstituted milk.

How agglomerates dissolve

All powders follow the previously discussed steps of wetting, sinking, dispersing and solubilizing when they dissolve. Dissolving of agglomerates illustrates the process.

Agglomerates are designed to readily wet as the particles are larger and easier for water to envelope. When water contacts the particle, lactose rapidly dissolves and the structure of the powder starts to change. Water initially penetrates the pores in the agglomerate rather than the capillaries of individual particles as is the case with non agglomerated powders. The particles get smaller and then swell as the water penetrates the agglomerate. Eventually the rate of water flowing through the pores slows as the dissolved solids increase the viscosity of the surrounding water. Sinking occurs after air within pores and between particles escapes. Agglomerates then disintegrate into individual particles and constituents.

Reconstitution challenges

There can be a number of challenges to reconstituting dairy powders. Some of the challenges are due to product components, some are a result of powder production processes and others are caused by rehydration methods.

Physical characteristics influencing reconstitution

There are a number of physical characteristics that affect the reconstitution of powders.

Among these characteristics are:

- Greater amounts of occluded air decrease the ability to reconstitute
- Greater bulk density and/or decreased porosity increase sinking
- Smaller particles with a symmetrical shape result in increased packing density and decreased water penetration

Lumping by particles

Fine powder particles may form lumps during wetting that require mechanical stirring to disrupt. Small particles prefer to associate with themselves rather than be wetted by water which results in the particles forming ball-like shapes. The ball-like shapes occur when the outer layers of the powder contact water and make a thick outer layer that resists further penetration of water thereby stopping the wetting process.

Powders that wet poorly remain at the water surface with some of the particles actually resting above the surface of the water. Loss of air from between the particles is slow and often incomplete with poorly wetting powders. Very viscous solutions result in areas that do wet. In addition, air remains in non wetting areas resulting in lumps that are wet on the outside and dry in the inside. Such lumps are impervious to water even with agitation.

Denatured powders and insoluble residue

Powders containing denatured protein have lower amounts of occluded air (air within particles). Protein denaturation results in increased hydration times. For example, low heat NFDM that has very little denatured protein, hydrates faster than high heat NFDM which has significant amounts of denatured whey proteins.

Excess heat causes the formation of insoluble complexes, denatures proteins and is the major cause of poor reconstitutability. The insoluble complexes can appear as an insoluble residue or scum on the container surface when the powder is rehydrated.

Air in rehydrated dairy solutions

Excessive amounts of air in rehydrated dairy solutions can cause significant problems in subsequent processes. Rehydration conditions can affect the amount of air present during and after reconstitution.

Nonfat dry milk powder/skim milk powder (NFDM/SMP) can contain approximately 40% air by volume (occluded and interstitial). Nonfat dry milk rehydrated at 122°F (50°C) and 14 to 18% total solids will have the same amount of air in the solution as regular fluid skim milk.

When nonfat dry milk (NFDM) is rehydrated at 86°F (30°C) the solution after 1 hour can have an air content 50 to 60% higher than nonfat dry milk (NFDM) rehydrated at 122°F (50°C). When rehydrated to 41% total solids at 122°F (50°C) the air content in the solution can be 10x's higher than regular fluid skim milk.

Excessive air in rehydrated dairy solutions can cause a number of processing problems. Among them are:

- Foaming
- Burn on in heat exchangers
- Cavitation in the homogenizer leading to ineffective homogenization
- Wheying off of cultured products
- Increased risk of fat oxidation

One method to decrease air in the final rehydrated product is rehydrating at 104°F (40°C) with agitation until all of the powder has dissolved. Agitation then is stopped and the solution allowed to rest for 20 minutes. In large operations where continuous rehydration is required vacuum treatment to deaerate the rehydrated solution may be required.

Milk protein concentrates (MPCs)

Milk protein concentrate 70s (MPC70) and above are very slow to absorb water. Increased time for hydration is needed so that the slow rate of water absorption does not lead to inadequate hydration that can cause the MPC to perform poorly in the food application.

Storage temperature and mineral composition of the MPCs also influences rehydration. Solubility of MPCs decreases as storage temperature increases. Reducing the mineral concentration of a MPC improves rehydration when lower temperature water is used.

Defects caused by poor reconstitution/hydration

The defect that can occur depends on the application and type of powder used. Some typical defects include:

- Loss of heat stability
  - protein aggregation and settling
  - chalky mouthfeel
- Loss of yield
  - cheese, beverages and yogurt
- Lack of clarity
  - WPI drinks

How to reconstitute dairy powders

Factors important in reconstituting dairy powders include: water quality; water temperature; mixing conditions; and time. Reconstitution conditions are similar for many dairy powders with some exceptions for high protein products.

Water quality

Water quality is very important when reconstituting dairy powders. Filtered or reverse osmosis (RO) water is best.

If reverse osmosis (RO) water is not available then the water should have low hardness, especially as regards calcium carbonate ($CaCO_3$). Calcium carbonate is also known as limestone. Calcium has low solubility, precipitates with heat and increases in pH and interacts with proteins when heated. Calcium can be responsible for haziness in rehydrated solutions. Hardness should be <100 mg $CaCO_3$/liter or ~5.5°dH. The unit °dH is Degree of Hardness with 1 °dH equivalent to 10 mg/L CaO (calcium oxide) or 17.8 ppm CaO.

The presence of copper (Cu) and iron (Fe) can result in oxidized flavors in rehydrated dairy powders during storage. It is recommended that copper (Cu) be less than 0.05 mg/L and iron (Fe) less than 0.1 mg/L to avoid quality problems.

Water should be potable and free from harmful bacteria, chemicals and off odors/flavors.

Water temperature
The solubility of dairy powders increases as water temperature increases from 50 to 122°F (10 to 50°C). There is no increase in solubility with water temperatures above 122°F (50°C).

Powder also can be rehydrated at 50°F (10°C) overnight. There may be more undissolved particles when mixing powder and water at 50 to 68°F (10 to 20°C) versus 95 to 113°F (35 to 45°C) even when stored for 24 hours, however, the difference in amount of undissolved particles is not significant for solutions at 8% total solids. Heating to 104°F (40°C) dissolves the particles even for solutions at 26% total solids.

Air content of the resulting liquid dairy product increases at lower mixing temperatures.

Low heat milk powders are easier to dissolve than high heat milk powders.

Powders should dissolve in 20 minutes or less when using water at 104 to 122°F (40 to 50°C).

Milk for cheese production should hydrate for 2 hours.

Mixing powder and water
The method of mixing powder and water can be very important.

Agglomerated powders will more readily wet and reconstitute as compared to non agglomerated powder. The choice of mixing equipment, therefore, can be more critical with non agglomerated powders that do not reconstituted as easily as agglomerated powders.

Small, batch operations often use a jacketed tank with heating/cooling. A two speed shearing agitator is used to reconstitute and mix the powder.

Large operations typically use a heat exchanger to heat the water before it enters the mixing tank. A high shear mixer at the bottom of the tank both shears the powder to help with hydration and circulates the water/powder mixture out the bottom of the tank and back to top of the tank. An agitator in the tank helps with mixing. A vacuum deaerator may be needed to remove air from the solution before homogenization/pasteurization. Some systems are designed to mix/rehydrate powder under vacuum to help with air removal.

WPC/WPI
WPC/WPI powders should be mixed with a high-speed mixer. Allow 30 minutes of additional mixing with slow agitation so that the powders can fully hydrate. Optimum water/milk temperature is <140°F (<60°C).

MPC70 and higher
Mix MPC powders with a high-speed mixer. Hydrate for 12 hours at 40°F (4°C) or 1 hour at 122°F (50°C).

Reconstituting to original concentrations
There are applications that require the powder to be rehydrated to the total solids of the starting product. An example would be reconstituting NFDM for consumption as fluid milk. Below is a table giving approximate powder/water amounts to produce the original liquid product.

Table 3. Reconstituting to starting product total solids.

Product	Powder (g)	Water (ml)	Final total solids (%)
NFDM/SMP	10	90	10
Whole milk	13	87	13
Buttermilk	10	90	10
Whey	7	93	7

Testing reconstitution properties

There are a number of factors and steps in the reconstitution process and it can be important to determine how a powder will perform before large scale use. Troubleshooting also may be required when powders do not perform as expected. Several tests are available to evaluate specific properties of a powder.

Wettability
Wettability tests typically are used for agglomerated or instantized powders. Wettability tests, in general, measure the time necessary to achieve complete wetting of a specific amount of powder when dropped into water at a specified temperature.

IDF has a method for instant NFDM and whole milk powder (WMP). GEA Niro has a similar method that can be used for skim milk, whole milk and whey.

The IDF method defines wettability as the time in seconds required for all the particles in an instant milk powder to become wetted (defined as sinking below the water surface or have a ‘typical’ wet appearance) when placed on the surface of water.

The GEA Niro method defines wettability of powder as the time needed to completely wet a specified amount of powder, when the powder is dropped into water at a specified temperature.

The surface of the particles determine wettability. Fat on the particle surface will repel water unless the particle is treated with lecithin. Particles that are too small do not allow water to properly contact their surface. Particles that wet very quickly can form a film consisting of dissolved components such as lactose that actually hinder further wetting of the powder.

Methods

- IDF Standard 87:1979. Determination of the dispersibility and wettability of instant dried milk.
- GEA Niro analytical method A 5 a. Wettability.

Dispersibility

The ADPI method uses a hydrometer to measure the degree to which instant NFDM disperses in water.

The IDF method defines dispersibility as the ability of a powder in water to break down into particles that can pass through a 150 µm sieve. The method can be used with any dry dairy product although it is especially applicable to NFDM/SMP and whole milk powder (WMP).

A powder sample is evenly spread on the surface of water. The solution is stirred and then filtered through a sieve. The total solids of the water passing through the sieve is measured and compared to the solids of the starting powder sample.

Powders that have poor wettability will not perform well in the dispersibility test. Agglomeration with minimal fines improves dispersibility of a powder.

Methods

- ADPI Ingredient standards book - Methods of analysis. Determination of dispersibility of instant nonfat dry milk (Modified Moats-Dabbah Method).
- IDF Standard 87:1979. Determination of the dispersibility and wettability of instant dried milk.
- GEA Niro analytical method A 6 a. Dispersibility.

Solubility

ADPI has a method for determining the solubility of many dairy powders. Included in the testing method are NFDM/SMP, buttermilk, whey, WPC, WPI WMP, MPC, MPI and micellar casein.

The amount of powder, temperature of water used and mixing time varies depending on the product to be tested. Powders are blended, placed in a conical tube, centrifuged and the amount of undissolved material measured.

A number of factors can cause poor solubility but typically expose to higher temperatures either as a liquid but especially as a powder during manufacture can result in reduced solubility.

Methods

- ADPI Ingredient standards book - Methods of analysis. Determination of solubility index.
- IDF Standard 129A:1988. Dried milk and dried milk products - Determination of insolubility index.

Thermostability/Coffee test/Coffee sediment test

Heat stability of reconstituted dairy powders in acid environments can be a very important property. Lack of acid stability can be due to powder composition, processing conditions or hydration issues.

The coffee test determines stability of a powder added directly to an acidic, hot liquid. The test measures the number of white particles on the surface after reconstituting the powder in hot coffee. The presence of white particles on the surface is an indication of protein instability.

A similar test with coffee measures the amount of sediment resulting from addition of a dairy powder to hot, acidic coffee.

Higher amounts of protein and calcium in the powder negatively affect the coffee test. Preheating the liquid milk to precipitate calcium, use of phosphates/citrates to chelate (tie up) the calcium and adjusting the protein level with lactose/permeate can be used to improve stability to the coffee test.

Methods

- ISO 15322:2005|IDF 203:2005. Dried milk and dried milk products - Determination of their behaviour in hot coffee (Coffee test).
- GEA Niro analytical method A 16 a. Coffee test.
- GEA Niro analytical method A 16 b. Coffee sediment test.
- NZDRI 4.10.1 Coffee sediment test. September 1990.

Sludge

Sludge is similar to the IDF test for dispersibility and is defined as the undispersed material that cannot pass through a 600 µm filter. Typically the material is lumps formed by fines that have stuck together to form a thick slurry at the bottom of a beaker.

The temperature of the water and time that the rehydrated powder is allowed to settle in the beaker depends on the whether a cold or hot application is being tested and whether the powder is agglomerated, instantized or both. Powder is placed in water of appropriate temperature, stirred, allowed to settle and then passed through a filter to determine amount of sludge.

Methods

- IDF Standard 87:1979. Determination of the dispersibility and wettability of instant dried milk. (Modified test conditions to determine sludge).

Slowly dispersible particles

A method developed by GEA Niro to determine slowly dispersible particles in agglomerated and lecithinated milk powders places the powder on the surface of water of a certain temperature. The mixture then is stirred and filtered through filter paper to measure particles that are not dispersed after mixing.

Agglomeration will improve powders that contain excessive amounts of slowly dispersible particles.

Methods

- GEA Niro analytical method A 7 a. Slowly dispersible particles in agglomerated milk powder.

Definitions

Agglomerate - Composed of two or more particles adhering to each other through moisture on their surfaces to form a structure where the original particle form is still evident.

Agglomeration - Process used to increase the size of powder particles.

Bulk density - Density or “weight” of a given volume of powder.

Chelator/chelate - A compound that can to tie up minerals like calcium to prevent them from precipitating or interacting with other components in a solution.

Denaturation - Change in the structure of a protein that often is not reversible.

Dispersibility - Ease with which a powder is distributed as single particles throughout water.

Entrained air - Air trapped within a solution.

Floc - Particles or flakes that come out of suspension.

Friable - Tendency of a solid substance to break into smaller pieces under duress.

Hydrophilic - Water loving.

Hydrophobic - Water hating.

Immersibility - Ability to sink.

Instantizing - Addition of a compound, typically a surfactant, to assist in the wetting of powder surfaces that contain fat.

Interstitial air - Air between powder particles.

Occluded air - Air within powder particles.

Particle density - Density of the individual particle.

Proteolysis - Use of enzymes (proteases) to split proteins into smaller pieces.

Reconstitution - Ability of powders to go into solution.

Rehydration - See reconstitution.

Sludge - Powder that does not disperse when placed in water and forms a thick slurry in the bottom of a beaker.

Solubility - Rate and extent to which powder constituents dissolve in water.

Thermostability - Ability of proteins to resist denaturation when heated.

Wettability - Ability of water to make contact with the particle surface.

Abbreviations

ADPI - American Dairy Products Institute
$CaCO_3$ - calcium carbonate (lime)
CaO - calcium oxide
Cu - copper
°dH - degree of hardness
Fe - iron
IDF - International Dairy Federation
MPC - milk protein concentrate
MPI - milk protein isolate
NFDM - nonfat dry milk
NZDRI - New Zealand Dairy Research Institute
ppm - parts per million
RO - reverse osmosis
SMP - skim milk powder
WMP - whole milk powder
WPC - whey protein concentrate
WPI - whey protein isolate
WPNI - whey protein nitrogen index

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