Agglomeration is the process of increasing a bulk solid material’s particle size by combining multiple smaller particles. This can benefit a manufacturing process in a number of ways, including increasing the material’s flowability, reducing the material’s tendency to generate dust, and improving the quality or performance of the final product. For example, manufacturers use agglomeration to prepare materials for tableting in the pharmaceutical industry; to create free-flowing, dustless drink mixes in the food and beverage industry; and to create easy-to-mix dairy- and soy-protein-based blends for the nutrionals industry.

Much has been written about agglomeration as an individual unit operation, but agglomeration is of little value unless it’s effectively integrated into the overall manufacturing process. In this column, I’ll examine the process for producing a dairy-based nutritional drink mix to illustrate important principles to follow and factors to consider when integrating agglomeration into an overall manufacturing process.

Example process description and materials

Our example process includes the following steps: incorporating a powder into liquid, blending multiple liquid streams, heat treatment to eliminate illness-causing microorganisms, homogenization to improve product stability, concentration by evaporation, spray drying and agglomeration, conveying, storage, and packaging the final product into individual containers. The product design is for a free-flowing, easy-to-mix powder with a bulk density that results in a consistent fill height and scoop weight in the individual product containers.

Agglomeration loosely binds individual particles or small particle clusters into larger particles that wet and disperse readily during reconstitution (when water is added to the mix). The final stage of reconstitution is the dissolution of the individual particles. The solubility of the individual powder particles is paramount to producing an easy-to-mix agglomerated powder. If these particles aren’t readily soluble, the drink will look grainy, and residue may be visible on the side of the glass, bottle, or shaker. In extreme cases, residue may be visible in the bottom of the container as well.

Nutritional drink mixes consist of varying ratios of protein, carbohydrate, fat, minerals, and vitamins. Carbohydrates, vitamins, and most minerals readily dissolve in water. The insoluble minerals can be micronized so that they’re essentially invisible to the naked eye and stay suspended when the powder is reconstituted. Homogenization breaks the fat globules into sub-micron particles that combine with some of the protein to form a creamy emulsion.

That leaves the rest of the protein. With protein that hasn’t been chemically or enzymatically modified, the key to solubility is the thermal history. For our example product, we’ll choose a low-heat, non-fat dry milk (NFDM) base. The American Dairy Products Institute defines “low-heat milk” as milk having a cumulative heat treatment of no more than 160°F for 2 minutes.

Upstream process steps

The first step in our example process is to incorporate the dry powders into water. The order of addition of the dry ingredients is important to avoid damaging the milk proteins. The most sensitive of the milk protein will begin to denature (or lose its structure) at 140°F. Carbohydrates dissolve best at higher temperatures, typically 165°F to 175°F, and should be incorporated first. The carbohydrate mixture will cool as the powder is added. The NFDM can then be added, followed by the oils. Before further processing, the blend is held for 20 to 30 minutes to allow the protein to fully hydrate and dissolve and the components to achieve a uniform dispersion. During this hydration time, the blend’s acid concentration (pH) is adjusted to near neutral (pH 7) to protect the proteins during subsequent processing.

After blending, the powder mix is emulsified, which forms an even more uniform dispersion and breaks down the fat into small droplets or globules. This step is important to ensure that the mixture receives uniform heating in
Evaporation and agglomeration.

We’ve arrived at the point in the process that makes the agglomerated powder. The reason I’ve described all these upstream process steps and the precautions taken to select and protect the protein is because they are critical to the quality of the powder we create. Denaturation of the protein can lead to poorer agglomeration and reduced solubility. Nothing that happens from this point in the process onward will improve the quality of the agglomerated powder if we haven’t taken care with the upstream steps.

Evaporation. Evaporation is the first step in the powder process and is used primarily to improve the thermal efficiency of the drying process and increase the spray dryer throughput. Using an evaporator at least 5 times more efficient at removing water than using a spray dryer alone. A multiple-effect evaporator can increase the solids content from approximately 30 percent total solids to 52 percent total solids with a steam efficiency of 3 pounds of water evaporated for each pound of steam used. In a spray dryer, on the other hand, evaporating a single pound of water requires the equivalent of 2 pounds of steam.

The percent of solids in the spray dryer feed significantly affects the spray dryer’s capacity. A spray dryer evaporates a fixed amount of water for each pound of drying air regardless of the solids concentration in the feed. A spray dryer capable of evaporating 5,000 pounds per hour of water will produce around 5,500 pounds per hour of powder at 52 percent feed solids and only around 2,400 pounds per hour of powder at 32 percent feed solids. There’s a limit to how much water you should evaporate, however. If the solids content of the feed is too high, it can lead to poor atomization in the spray dryer and result in fouling of the drying chamber and defects in the dried powder.

The evaporation process runs at low pressure to keep the evaporating liquid temperatures low. While many evaporator types are available, manufacturers typically select a falling-film type evaporator because of its low residence time. Again, the process design goal is to minimize the overall cumulative heat applied to the material.

Agglomeration. Agglomeration can take place in the spray dryer, an agglomerating fluid bed, or a combination of the two. It is done in the spray dryer alone, the process is called interspray (or once-through) agglomeration. In the spray dryer, agglomeration is controlled by the nozzle selection and atomization pressure, the nozzle angle, the fines concentration (through fines reinjection) in the agglomerating zone, and the powder moisture. The dryer operator manipulates these four variables to produce the desired agglomerate.

Fluid-bed (or rewet) agglomeration occurs after spray drying and involves wetting the powder particles with a fine mist, causing the wetted particles to collide in a well-mixed fluid bed, and then drying. The rewet agglomeration operator controls the rewetting rate, the powder fluidization, and the final powder moisture to produce the desired agglomerate. Typically, operators monitor the powder’s bulk density, mixability, and moisture level for in-process quality control.

Downstream process steps.

It’s generally easy to make an agglomerated powder that will have a good bulk density and mixing characteristics immediately after the powder leaves the dryer or fluid bed. Unfortunately, few powder processes end at the dryer or fluid bed. Our example process includes a filling line that operates two shifts per day, five days per week, while the spray dryer operates three shifts per day, seven days per week. This operating scheme requires in-process powder storage and handling systems, which will result in attrition to the agglomerated powder particles, as will the filling line. Some attrition is good, but too much attrition can negate the benefits of agglomeration. An extremely friable powder would break down during transit, resulting in an unacceptable amount of headspace in the final container that the customer would interpret as a “short fill.”

Properly selecting and operating the powder conveying systems can help minimize attrition. Gravity-flow systems that use vibrating-tube or horizontal-motion conveyors are ideal. If you must convey the powder a long distance or vertically, properly operated dense-phase vacuum or pressure pneumatic conveying systems may be effective. Avoid screw conveyors or lean- or dilute-phase pneumatic conveying systems. Similarly, you should select filling machines to minimize attrition while also delivering accurate filling.
fillers and low-speed auger fillers are two options. Avoid fillers with high-speed augers.

The agglomeration process may need to be “tuned” to your downstream process steps. This may mean driving the agglomeration further to create larger particles in anticipation of unavoidable attrition. It may also mean additional in-process tests such as particle size distribution and attrition tests to better characterize the agglomerated powder. If you plan to use a pneumatic conveying system, conduct conveying trials with several different sample particle sizes to determine how much agglomeration is necessary to offset attrition during conveying.

As the example process I’ve described shows, successful agglomeration requires the right raw materials and careful selection and design of both the upstream and downstream processing steps. This will ensure that the particles bind together effectively during agglomeration and that your product is still in its agglomerated state when it reaches the customer.

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**For further reading**

Find more information on this topic in articles listed under “Agglomeration” in *Powder and Bulk Engineering*’s article index (in the December 2017 issue and at www.powderbulk.com).