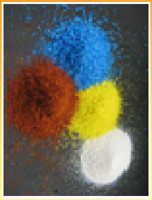

Food Facts

Spring 2014 Volume 3 No A

Brought to you by: **Material Flow Solutions, Inc.**

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In This Issue

Controlling Packaging Weight

Introduction. In the food and nutraceutical industries, it is critical that a package contain at least as much product as the advertised content displayed on the label. Package weight is related to the product density. Almost all packaging systems operate in a volumetric mode, making density control during packaging critical for proper system operation. Density control is generally a function of the bulk solids flow rate, and lack of this type of control can cause serious variations in packaging with equipment based primarily on volumetric control. As a result, most manufacturers overfill so as to avoid underweight packages due to variations in product density through a process run. To truly control variation in packaging weight, then, it is necessary to design the process to eliminate the problem.

Nutrition Facts

Serving Size 1 ounce Servings in bag 4

Amount Per Serving	
Calories 155	Calories from Fat 93
	% Daily Value*
Total Fat 11g	16%
Saturated Fat 3g	15%
Trans Fat	
Cholesterol 0mg	0%
Sodium 148mg	6%
Total Carbohydrate 14g	5%
Dietary Fiber 1g	5%
Sugars 1g	
Protein 2g	
Vitamin A 0% • Vitamin C	9%
Calcium 1% • Iron	3%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

Package label reflecting consumer expectations

DO NOT LET THIS TO HAPPEN TO YOU:
Control your package weight using key measured material properties data and sound scientific principles

Two main causes of density variation in packaging are segregation of mixture components due to different particle densities and differences in compaction caused by gas effects or compression effects. In this issue of Food Facts, we will discuss these causes and address the steps necessary to mitigate product density variation.

Density variation due to segregation. Segregation (separation) of mixtures during processing and handling frequently manifests as variation in density (or weight) of the final packaged product. Segregation occurs through several mechanisms. Identification of the primary segregation cause and the segregation pattern produced through handling is critical to prevent segregation (or de-mixing) of the final mixture during handling and packaging. Any property difference between materials can cause separation of critical material components. However, there are four common causes of segregation problems in typical handling systems: sifting, angle of repose, air entrainment, and impact fluidization.

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Influence of Gas Pressure Effects on Development of Mass Flow or Funnel Flow in Process Equipment

The ability of a given piece of process equipment to achieve flow along the walls when any material is discharged is an important behavior called mass flow. In its most simplistic form, achieving mass flow depends on the wall friction angle and the process geometry as well as the effective angle of internal friction. However, when additional body forces are added, they modify the ability of materials to flow at the walls. Gas pressure gradients can help or hurt this ability, depending on the direction in which they act. Stress gradients can induce flow along the walls where current theory suggests material will not flow. The goal is to achieve a steady, predictable movement of material through the process equipment. The best way to achieve this is by ensuring mass flow in the bin or hopper.

It should be pointed out that ratholes cannot form in bins that induce flow at the hopper walls (mass flow).

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Controlling Packaging Weight

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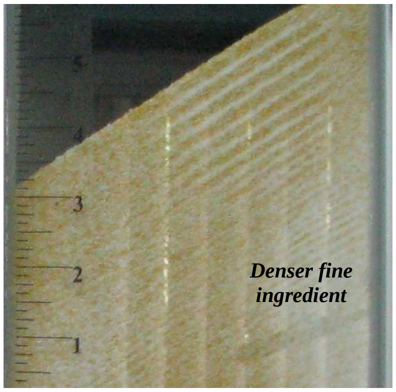

Example of sifting segregation with instant cereal packet mixture

Solving a mixture segregation problem so as to alleviate density variation during packaging requires knowledge of the root cause of that segregation. The specific flow properties of material mixtures, as well as the individual properties of the unique components in a mixture, play a significant role in product segregation. Therefore, the first step toward design-ing a mixture which will not segregate and cause weight variations during packaging is to measure the amterial flow properties and cause weight variations during packaging is to measure the material and segregation potential of that mixture.Weight variations due to a segregation problem fall into two categories. In the first case, variations occur because the different components in the mixture are segregating and have different densities. Therefore, the density variation is also tied to the component concentration segregation and, if you fix the one, you will often fix the other. In this mode, we must first measure the segregation potential of a food mixture based on the separation of components. The segregation potential test gives the magni-tude and the pattern of segregation. Often it can also give a general indication of a potential cause for the segregation. For example, air currents in process equipment can often separate the fine particle from the rest of the material. These fine particles can be carried to regions in the bin where the air currents decrease (usually near the walls). Thus, if the segregation potential test indicates that the finer components accumulate near the wall, then air entrainment segregation is an active mechanism.

Example of component segregation with bird seed mixture

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ANNOUNCEMENTS

THE UNIVERSITY OF MISSISSIPPI
School of Pharmacy

PRESENTS:
Hands-on Course in Tablet Technology

Dr. Kerry Johanson
will present the keynote instruction on

Mixing and Blending

June 1-6, 2014
September 21-26, 2014

14AIChE
Annual Meeting, Atlanta, GA

Dr. Kerry Johanson

Presents Three Papers on Particle Technology and Bulk Material Handling

and Chairs One Session

Food Facts Focus

Coming Next Quarter – Moisture pick-up and control

The glass transition effect in a typical food material is a function of both temperature and local moisture content on the surface of the particles. Many food products absorb moisture and undergo a glass transition effect. This not only causes chemical degradation of food products, but can result in increased strength and hang-up problems. It is critical to understand the moisture sorption behavior of your material along with the process operation temperatures and humidity exposures to help mitigate a flow problem caused by moisture sorption. Our next newsletter will address the relationship between the bulk strength, process geometry and operation, and the moisture sorption effects that might cause problems.

Future Topics

To put you at the cutting-edge

- Maintaining consistent flow rate
- Particle breakage: prevent size degradation of food products during processing and packaging

We welcome your suggestions for material flow and handling topics which you would like to see in future editions of *Food Facts*.

Contact: Susan at 352-379-8879

Controlling Packaging Weight

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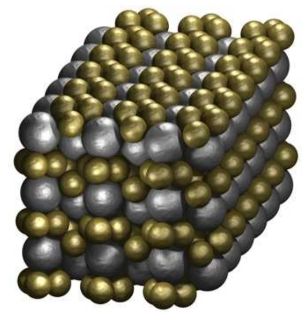
However, a more quantitative indication of what is causing segregation can be obtained by also measuring the particle size distribution, particle density, and angle of repose for the pure components. Using this information we can then provide accurate estimates of how much of the total segregation is due to sifting, angle of repose issues, or air entrainment segregation. We can then quantitatively determine how much each of the components contributes to each segregation mechanism.



Smaller particles fill the voids between larger particles

In the second case, density variations occur because the material is segregating due to difference in particle size of the components. Here the components are well mixed or there is product consists of only one component. In this case, we measure the segregation potential of the mixture based on particle size. This gives the segregation pattern based on where the fine and coarse materials end up in the system. If this is the case, then preventing the fines and coarse separation can help with weight variations. The overall procedure is the same as dealing with a component segregation weight variation, except you are dealing with a single material. The segregation potential measurement gives some indication of the segregation pattern and magnitude expected in a piece of process equipment. However, the particle size distribution, repose angles, and particle densities can also be used to quantify the segregation. Obviously, when dealing with only one material you are really only concerned with one size distribution. The key, then, is to optimize this distribution to prevent or limit segregation based on the active mechanisms. However, fines and coarse particles often have differences in angle repose values that can lead to significant repose angle segregation. Likewise, sometimes there are differences in particle density between large and fine particles that can cause air entrainment segregation. In this situation, it is all about particle size distribution (PSD) control. However, there is a relationship between particle size segregation and weight variation segregation. The fines can fit between the coarse particles increasing the density. When dealing with just two sized particles, the relationship between particle size segregation and weight variation segregation is simple and creating a mixture where all the voids between the coarse particles are filled with fines will minimize the segregation. However, the relationship becomes much more complex when there are more than just two distinct sizes of particles in the product. In this case, weight density segregation depends on the particle size and size distributions that fill the voids between the coarse particles. There may be several optimal size distributions that result in the same density material but have differences in particle sizes. However, there may only be one or two PSD within that set of constant density PSD's that also limit segregation due to the various mechanisms. Testing and analysis can help to identify these segregation free regimes.

Example of segregation by PSD difference with quinoa and dehydrated mushroom mix

Steps to control. With this information in hand, the formulator or process engineer can change the product or the process to prevent or limit segregation and bring the production facility under control. The formulator will likely recommend changes such as modifying the particle size or changing the grinding process to get a more angular component in order to combat the cause of a particular segregation mechanism. The engineer can take the same information and revamp the process to reduce pile formation if angle of repose segregation is a problem or limit inter-particle motion if sifting is a problem.

Density variation due to compaction differences. Unfortunately, a material may be completely homogenous and still result in weight variations in the packing feed systems. Generally, this occurs for one of two reasons. In the first case, the material is fine and retains air for long periods of time. Almost all packing unit operations operate on a controlled volume approach. Thus, if the density is always consistent at the package fill point then the process weight variations are not a problem. However, the compaction state of these materials at the time the package is filled determines the density. Sometimes air entrained in the material causes the material to become lighter than after the material has lost entrained air. This air loss is a rate-dependent process that

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Example of density variation due to air entrained in product during packaging which allows post-fill settling of bread mix

varies based on the air source, material permeability, compressibility of the material, and the shape and size of the package equipment.

The first step to identifying this as a potential issue is to measure the permeability and bulk density of the material as a function of the compaction pressure applied. For this to be a packaging issue there must be a significant difference in the material density between the different parts of the process. The maximum and minimum stress level in the filling equipment must be estimated so as to determine how much the density can change between these two points. If the ratio of these two densities differs by greater than 8%, then there is a potential for density variations in filling equipment to be due to the compressibility of the material. The material compresses as it flows through the process, trapping air within the void between particles. If the material is also fine and impermeable then air cannot escape fast enough and material remains in a light fluffy state during the packing process. The bulk density and permeability values can be used to compute a derived property of the material called the settlement index. This index indicates the time required for a bulk material in a particular geometry to lose its entrained air. If this settlement index is larger than the residence time in the packing machine then density variation can result during the packing process as the packing rate changes.

Steps to control. The solution to this type of weight variation is to prevent or limit the aeration in the material by limiting free fall heights in process design. The equipment should be designed to prevent hang-ups and rathole collapse that may induce air entrainment. In some cases pre-compacting the material using compaction screws or other equipment prior to passing through the packing equipment may reduce the air in the material. In some cases, the density variation is caused by a limiting flow rate raining surface from the outlet that grows across the hopper span until it becomes unstable and periodically collapses. This collapsing behavior causes surges of density through the packing process. In this case injecting the right amount of air into the packing equipment will help solve the issue. Care should be exercised with this solution. Injecting excess air or air in the wrong location will increase the magnitude of the density variations.

Example of density variation due to cohesiveness and/or strength of bulk powder with curry seasoning

In summary. Finally, some materials are cohesive and have a strength that is rate dependent. In this case, the density leaving the outlet of a hopper will depend on the bulk strength and the speed of operation. This density variation is caused by the fact that cohesive material can form loose packed structures because of adhesive forces connecting the particles together. Thus, the forces exerted during both the filling and hopper emptying can change the fill density. In this case, the cohesive flow properties of the material must be measured at various failure rates to determine the expected density during flow. An analysis should be done to relate the solid stress level and shear rate in process equipment to the strength and density in the process equipment. The density control in this case is due to stress and rate control of the filling process.

We have discussed in detail several causes of weight variations in filling equipment. Segregation of mixture components, particle size segregation, air entrainment effects, and strength and stain rate effects can all cause weigh variations. It is critical to understand the root cause of weigh variations before attempting to control them. This understanding always requires some degree of material characterization and process analysis. But, once the cause is identified, then steps can be implemented to mitigate these weight variations. Should you require additional information, please contact one of our engineers.

Non-stock pictures courtesy of: http://www.choretimehog.com/products.php?product_id=491, http://www.blippitt.com/snack-bag-fail/, http://en.wikipedia.org/wiki/sphere_packing, http://dangitbill.wordpress.com/2013/01/24/how-should-we-then-judge/

Gas Pressure Effects…

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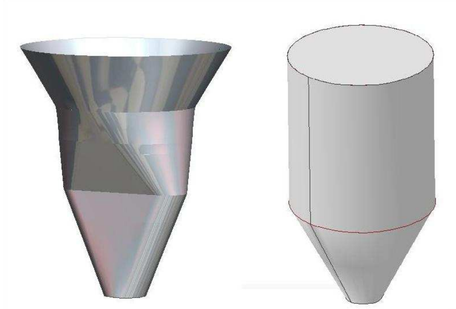
Conical hoppers, if steep enough, can induce mass flow, but plane flow hoppers can be about 11 degrees flatter and still induce mass flow. These plane flow hoppers have the added advantage that they can also prevent arching more effectively than can conical hoppers. Measurement of the key bulk material flow properties is crucial to achieving mass flow in equipment processing fibrous biomass materials. One of the significant flow properties of any material is the permeability value.



Examples: a mass flow (Diamondback®) hopper and a conical hopper

Permeability is another flow property that affects process operation with food products. It is defined as the amount of air flowing through the pores in a bulk material which causes pressure drop based on the local size of the pores, length of the void path, and the local gas velocity. In general, the resistance to flow depends on the arrangement of pores in the bulk material. It may be possible to construct a material with different air flow resistances in different directions. This gives rise to a tensorial permeability coefficient (K) which relates the gas pressure gradient to the gas velocity through the linear vector equation. Two things to bear in mind when considering flow of food mixtures:

$$U = \frac{K}{\gamma \cdot g} \cdot \nabla P \cdot \frac{\mu_o}{\mu}$$

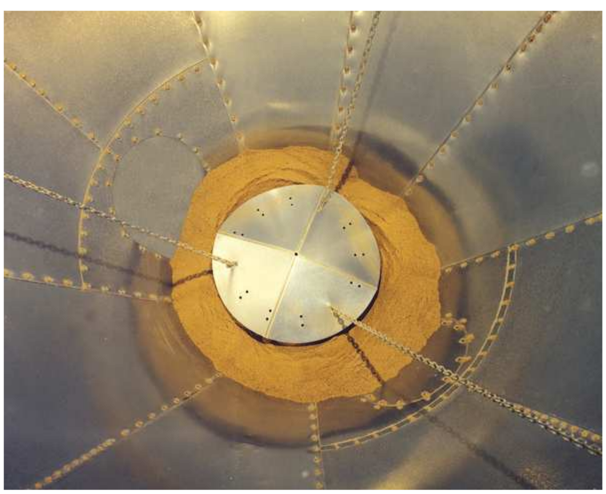
Where:
U is superficial gas velocity
K is permeability
∇p is the gas pressure gradient
γ is a reference bulk density

- Permeability decreases with finer materials and with materials that have wide size distributions.
- Permeability is a measure of the rate of the release of gas stored within the bulk material.

As a gas or fluid passes through the bulk material, it induces stresses that act in the direction of flow. These stresses can consolidate material, causing the material to increase in strength and, thereby, resulting in arch formation. Sometimes gas flow also supports the weight of the bulk material, reducing the ability of gravitational forces to break arches. In situations where gas, steam, and/or fluid interact with food products, it is critical to understand and measure the permeability of the material and calculate these additional body forces.

Learning the Trade – Recommended Mass Flow Angle

Knowing and understanding key material properties is power to characterize bulk material flow behavior. We will empower you quarterly as we discuss one of these fundamental flow properties and its industrial application.



Conical hopper with retrofit insert

Recommended mass flow angle * represents the slope angle of the conical hopper measured from the vertical that will produce flow along the walls. Conical hoppers must be steeper than this to cause flow along the walls. When designing or retrofitting the food handling process, it is important to understand that the recommended mass flow angles are a function of the shape of the bin. Plane flow hoppers converge in one direction at a time and also have a recommended mass flow angle that will produce flow along bin and hopper walls. However, plane flow mass flow angles generally require about 10 to 12 degrees flatter than corresponding conical angles to achieve mass flow. It is important to note that mass flow does not mean plug flow. Substantial velocity gradients can exist in mass flow bins. The recommended mass flow angle also depends on the solids contact stress in the bin. The stress level in a given bin depends on the position in the bin. Several measured material flow property values are required to compute the minimum hopper wall angle required to achieve mass flow in a conical hopper: unconfined yield strength, bulk density, and friction angle have been discussed in previous editions of Food Facts. A fourth property, permeability, will be discussed in our next edition. At Material Flow Solutions, Inc. we compute the range of pressure expected in a given bin configuration and then use the worse case friction angle in this stress level range to compute the recommended mass flow angle.

* Recommended mass flow angles are for flow in a conical hopper