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Particle Size Separation in Shipments of Fine Wood Flour

The Effects of Gravity and Vibration

(Wood flour particle sizes of 10 - 200 mesh or 2,000 – 75 microns)

The phenomenon by which larger coffee grains move up and smaller ones travel down when shaking a can is called *granular-size separation*. It is also referred to as the "Brazil nut" effect, because the same thing will happen when you jiggle a can of mixed nuts. This occurs for two main reasons.

First, during the shaking cycle, as the material lifts off the bottom of the can and then collides with the base again, larger particles briefly separate from smaller ones thereby leaving gaps underneath. The tinier particle sizes then slip into the gaps. When the shaking cycle finishes, the larger particles cannot return to their original positions, and therefore the bigger particles slowly "ratchet" upward.

The second action at work is called *convective mechanism*. When a can shakes, the coffee rubs against the side of the can. Friction causes a net downward motion of the material along the walls, which is balanced by a net upward flow in the center of the can. This motion establishes a convective roll pattern within the container. The downward flow along the walls of the container is confined to a very narrow region, only a few (small) particle diameters in width. Once the large coffee grains reach the top, they move towards the sidewalls. If they are too large, they cannot fit into the region of downward flow and, after a few shakes, the aggregate near the top. Typically this mechanism dominates unless friction with the sidewalls is carefully minimized.[1]

Given the effect summarized above, how does one accurately determine the particle size distribution of the material within a container?

Generally Accepted Procedures for the Sampling of Non-Solid, Non-Homogenous Materials

The process of determining the acceptability and product performance of any material with fluid-like physical properties is significantly different than those procedures used for solid-based physical samples. Wood flour is certainly no exception!

1. Wood flour has fluid-based physical properties.

    1.1. Wood flour will exhibit the same kind of material particle size separation as described above.
    1.2. This effect can occur within any package configuration (bags or bulk) but has been found to be more prevalent in loosely filled containers (bulk) where the material is able to move more freely than possible in a more compressed package.
        1.2.1. Vibration, and to a lesser extent gravity, play a role in *granular-size separation*.

2. Solid-based materials allow a point-to-point repeatability test.

    2.1. A good example is the diameter of a continuously extruded tube where the test location is marked for additional validation testing and will maintain this dimension over time.
    2.2. The same is not true when determining the particle size proportionality of a wood flour sample unless the entire sample is tested or appropriate statistical methods are employed.

3. Proportion-based statistical analysis requires that any one sample (or data point) must be used as part of a larger sampling protocol (where the sample size standard error rate is always within an acceptable limit) to determine the overall characteristics of the material being examined. In most industrial settings, this is the preferred method used to establish product performance.

    3.1. Wood flour performance validation consists (in part) of a sieve analysis where the weight on one specific sieve is reflected as a percent of the total weight of the rest of the product (the other sieves).
    3.2. Any sample of the product must be such that it is statistically significant and within an acceptable standard error rate.
        3.2.1. Single sample tests do not meet this requirement unless combined with a sufficient amount of additional or previously recorded statistical data.
        3.2.2. Multiple samples of the test material are an absolute requirement.

4. A material with fluid-like physical properties [2], especially where the fluid can further separate after manufacturing and become increasingly more non-homogenous, exasperates the need for a continuous SPC analysis as part of a comprehensive product validation protocol.

- 4.1. Wood flour is a fluid-like material where certain elements of the fluid-material (particle sizes) can separate due to gravity, vibration, etc.
- 4.2. Because wood flour can separate, individual pockets of material can develop that do not reflect the proportionate nature of the product where it was manufactured or shipped from.
  - 4.2.1. It is common to develop pockets of "finer material", or conversely, pockets of "more coarse material" in limited locations within the material's storage or shipping container whether the container is a kraft bag, bulk bag, bulk truck, or even a silo.
  - 4.2.2. It is inappropriate to take a very limited (small or single) sample size of a non-homogenous, fluid-like material to make a product acceptance determination based on the entire container's proportional-volume relationship.
    - 4.2.2.1. This is especially true when the material's lot size has been certified based on the specific characteristics of that particular manufacturing lot.

5. It is the responsibility of the manufacturer to:

- 5.1. Recognize the nature of wood flour as a fluid-based physical material with a strong tendency to become non-homogeneous over time and to manufacture a product that meets the customer's requirements.
  - 5.1.1. The manufacturer does this through their certificate of analysis certifying the particle size distribution of the material.
- 5.2. Effectively communicate this information to our customers.
  - 5.2.1. The purpose of this document is to assimilate the relevant information regarding wood flour and particle size separation methods such as *granular-size separation* and *convective mechanisms*.
- 5.3. Share test methods with the manufacturer's customer for everyone's benefit.
  - 5.3.1. Sieve analysis test methodology and test equipment will also contribute to test errors and poor test data correlation.
    - 5.3.1.1. A well-homogenized sample can significantly reduce certain test errors.
    - 5.3.1.2. Sieve material selection and routine calibration routines can also increase accuracy.
      - 5.3.1.2.1. Sieve screens made from soft metals perform poorly over time and can lead to inaccurate test results and conclusions.

6. It is the responsibility of the customer to:

   6.1. Recognize the physical nature of this material and to make certain that conforming material, shipped to the customer, is properly tested for the benefit of both parties.

   6.2. To ensure that internal manufacturing systems and process' do not contribute to any significant separation of material (particle size separations) that will cause a negative effect for their internal process'.

      6.2.1. Especially if there is a high sensitivity to specific particle sizes.

      6.2.2. Very often, the design of the customer's manufacturing process will be one of the largest determinants to introducing a well-homogenized material into the production process.

7. Introducing a well-homogenized material into a production process is in the best interest of both the manufacturer and the customer. There are many economic advantages to doing so.

   7.1. Increased machine throughputs, minimal process adjustments, consistent material dispersions, improved yields / lower scrap, and improved physical properties are just a few of the reasons for doing so.

   7.2. The resultant is a manufacturer-customer partnership that is more efficient and lower cost than those who do not understand and pursue these types of initiatives.

1 Scientific American June 2003, Heinrich M. Jaeger, Ph.D.

2 For further information see: Particle Size Measurement Volume 1, Powder Sampling and Particle Size Measurement, 5th Edition, Terence Allen, Chapman & Hall Page 3 figure 1.1 and support text.