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Powder Flow Analysis of Ground Cinnamon

Understanding ground cinnamon's flow properties is essential for efficient handling, storage, and processing.

Test Equipment:

- **Instrument**: Brookfield Powder Flow Tester (PFT)
- **Trough**: 230 cc, 6-inch diameter
- **Lid Type**: Vane Lid, 33cc, 6-inch diameter
- **Type of Test**: Flow Function Test
- **Conditions**: Room Temperature (70-72°F), Humidity: 48%

Test Method:

A PFT equipped with Powder Flow Pro software was used to evaluate the ground cinnamon. The procedure:

1. Scooping the ground cinnamon into the trough.
2. Using the scraping tool to evenly distribute the powder and form the sample.
3. Recording the sample weight and entering it into the software.
4. Running a standard flow function test.

Parameters Measured:

- **Flowability**: Easy Flowing to Cohesive
- **Bulk Density**: 446 kg/m³ (fill density) to 589 kg/m³ (final bulk density)

Analysis:

- **Hopper Shape**: Conical
- **Critical Arching Dimension**: 0.085 m (85 mm, 3.3 inches)
- **Rathole Diameter**: 0.864 m (for a bin diameter of 2 m)

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Results:

Flow Function:

The flowability of ground cinnamon at different levels of consolidating stress is illustrated in Figure 1. The results show that ground cinnamon is easy flowing at higher consolidating stresses but becomes more cohesive and difficult to flow at lower consolidating stresses.

Note: The Flow Function data is indicated by the red line in Figure 1. The other lines are references (or "Standard Flow Indices"), which distinguish the different types of flow behavior, ranging from "non-flowing" to "free-flowing." The axes are Unconfined Failure Strength (kPa) vs. Major Principle Consolidating Stress (kPa).

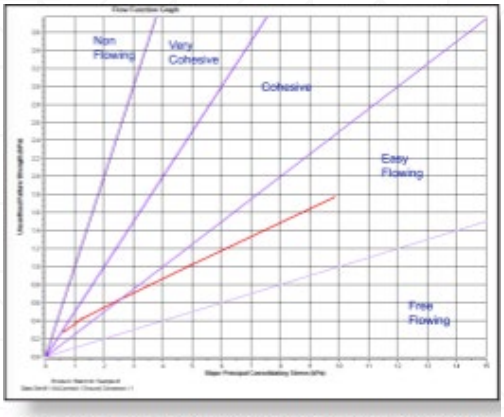

Figure 1: Ground Cinnamon Flow Function Graph

Arching and Ratholing:

Figure 2 provides the critical arching dimension and rathole diameter for a standard bin diameter of 2 meters and a bin height of 8 meters. To prevent arching, an opening greater than 0.085 meters is required. To prevent ratholing, an opening greater than 0.864 meters is necessary. These values indicate that ground cinnamon may have flow issues under certain conditions.

Data Set (#)	Arching Dimensions (m)	Rat-hole Diameter (m)
1	0.085	0.864

Figure 2: Arching Dimensions and Rat-hole Diameter

Bulk Density:

Figure 3 shows the bulk density of ground cinnamon at different levels of consolidating stress. The cinnamon has a fill density of about 446 kg/m³, which increases to approximately 589 kg/m³ at around 9.6 kPa of consolidating stress. In general, a free-flowing powder shows small changes in bulk density, while a cohesive powder exhibits significant increases. The increase in bulk density for ground cinnamon is 32%, indicating potential flowability issues.

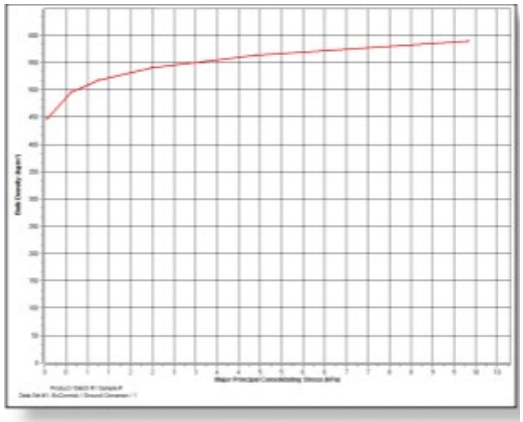

Figure 3: Ground Cinnamon Bulk Density Graph

Conclusion:

Ground cinnamon starts out as an easy-flowing powder when the feeder system is full but becomes cohesive at lower consolidating stresses as the system empties. Possible problems include:

- **Cohesive Arching**: Formation of a cohesive bridge over the outlet.
- **Ratholing**: Powder flows only from the center, leaving the rest static against the walls.

Ground cinnamon behaves like many spices, starting as an easy-flowing material and becoming more cohesive as the system empties. Due to its hygroscopic nature, high humidity levels can further complicate its flowability. The critical arching dimension of 85 mm (3.3 inches) provides a conservative estimate to prevent arching, provided the minimum outlet dimension of the hopper exceeds this value.