

Optimizing Food Packaging Size by Measuring the Tapped Density

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Abstract: A reasonable packaging size in the food industry is important not only to ensure the success of the packaging process, but also to decrease the cost of transporting products. This application note explores how the size of the food powder container is determined by measuring the bulk density and tapped density. In this research, three types of protein powders, including whey protein, soy protein and whey-soy protein mixture, were analyzed by an automatic tapped density tester - The BeDensi T1 Pro. The result demonstrates that the instrument relies entirely on providing food manufacturers with reliable information to determine the optimum packing size and choose a container that is satisfying to the customer.

Key words: Tapped Density; Protein Powders; Packaging; Food; Bulk Density; Slack Fill.

1. Introduction

A majority of food industries currently handle particulate food, involving various powders that range from ingredients, such as flours, sugars, and spices, to end products such as protein powder and instant coffee. ^[1] Great care must be taken during the handling process from production to food packaging and ultimately storage, transportation, and distribution.

Bulk properties, such as the bulk density and tapped density, play a direct and important role in food packaging ^[2]. Bulk density is the ratio of the mass to the volume of a loose powder. Tapped density is the ratio of the mass to the volume of powders tapped for a defined period. In effect the tapping process simulates the vibration that all powders endure during production, storage, transportation, and distribution. In figure 1, it is clear that the interstitial space between the particle is included. ^[3] After tapping is generated during storage and transit, the amount of interstitial air is reduced, which leads to a smaller volume.

Generally, many powdered foods are packed in a bag or bulk

container and then transported over a long distance for consumption after distribution in the shops. The density of the powders is an important parameter to know to establish the optimized size of powder packaging containers. For example, for light bulk density powders, it is an effective method for designing a more compact packaging by removing air from the product during and after filling. Therefore, the optimum packaging size can be accurately calculated by confirming the bulk density and the tapped density, and is highly significance in the economics of transporting powder. Besides, it is crucial to ensure that there is a correct fill volume in each consumer pack. ^[4] Unreasonable fill volumes such as those having too much void space in the container on opening by the customer will dissatisfy the customer and even lead to accusations of misleading the customer based on the Federal Food Drug & Cosmetic Act (FDCA). ^[5]

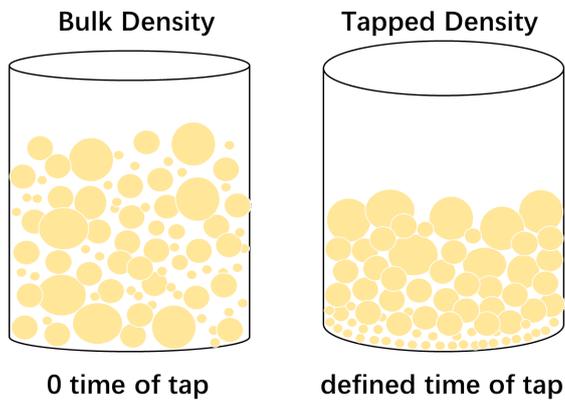


Figure 1. Comparison of bulk density and tapped density

For example, in the protein packaging industry, there is an interesting phenomenon that protein powder containers are rarely filled full which is caused by slack-fill. Slack-fill is the difference between the actual capacity of a container and the volume of product contained therein. The slack-fill covers the appropriate volume that functions for sealing and protection of the product and induced by vibration of the powder throughout shipping and storage. Ultimately when the products arrive on the shelf in a supermarket, it is possible that they may have excessive empty space inside because of tapping.

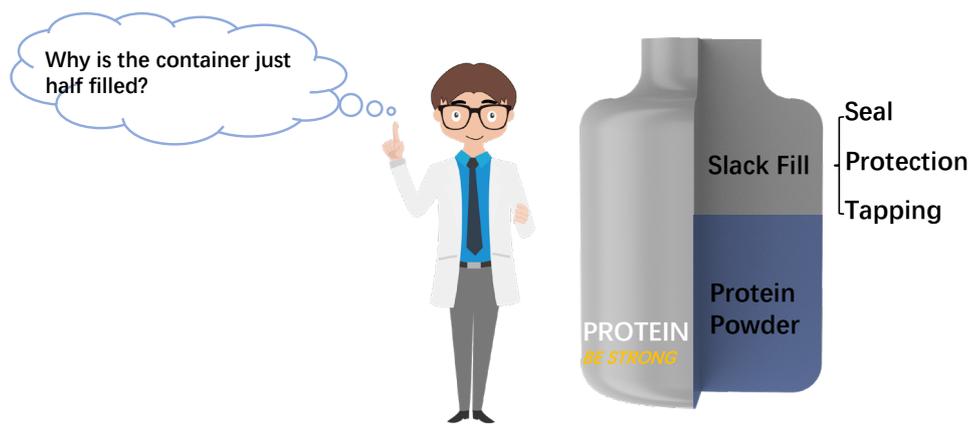


Figure 2. A protein powder container with slack-fill

Therefore, it is necessary to figure out the bulk density and tapped density of protein powders so that factories can strike a reasonable balance between the slack-fill and the actual capacity of a container. The aim of this application note is to explore the tapped densities of different protein powders to achieve reasonable and customer friendly packing sizes for the manufacturers.

2. Method

The whey protein and soy protein were bought off the shelf in a local supermarket in Shenzhen, China. The whey-soy protein was made by mixing the whey protein and soy protein powders. To make density results meaningful, the tapping conditions need to be quoted. The tapping test was performed by the BeDensi T1 Pro in accordance with the ISO standards.^[6,7] A 250 ml graduated cylinder with 50 g sample was tapped at room temperature for 625 times using the tapped density tester. The measured density was obtained by the given formula below:

$$\rho_x = m/V_x$$

where x is the number of taps, ρ is the density, m is the mass, V is the volume. ρ_0 and ρ_{625} are the measured density, in grams per milliliter, after transfer and after 625 taps, respectively.

To determine the appropriate container size with test results, 500g whey protein powder was filled in three different slack-fill containers (10, 20, and 30 vol%) before tapping. After tapping 625 times, the feedback on the different size containers from twenty Bettersize colleagues was collected.

3. Result

3.1 Pure Protein

The tapped densities of pure whey protein and soy protein powder were obtained. Table 1 denotes that both ρ_{625} and ρ_0 of soy protein are larger than whey protein, which means that a smaller container is appropriate for packing pure soy protein.

Table 1. The densities of pure protein powders

Protein	ρ_0	ρ_{625}
	(g/ml)	
Whey	0.33	0.50
Soy	0.42	0.59

3.2 Mixed Protein

The tapped density of mixed whey-soy protein powders was also measured by using the automatic tapped density tester. Table 2 presents the densities of mixed protein with 25, 50 and 75 wt.% whey proteins. The soy protein tapped density will increase with the mass fraction of whey protein. It is necessary to determine applicable containers or bags to store different protein products.

Table 2. The densities of mixed whey-soy protein with different fractions

Protein	ρ_0	ρ_{625}
	(g/ml)	
Whey-soy (3:1)	0.35	0.54
Whey-soy (1:1)	0.39	0.57
Whey-soy (1:3)	0.41	0.59

Also, the measured tapped densities are slightly larger than the calculated tapped densities based on the mass weight of the two powders, as shown in figure 3. The calculated values were obtained by the equation below:

$$\rho_{mix} = \rho_{625}^{whey} \omega_{whey} + \rho_{625}^{soy} \omega_{soy}$$

Where the ρ_{mix} is the calculated tapped density of the mixture, the ω is the mass fraction. As has been mentioned during tapping or transportation, small particles can displace

Table 3. The slack-fill volume changes in loose and tapped product

Container Volume (ml)	500 g Loose Protein Powder		500 g Tapped Protein Powder		Customer Emotion
	Volume (ml)	Slack Fill (vol%)	Volume (ml)	Slack Fill (vol%)	
1683	1515	10	1000	41	😊
1893		20		47	😐
2164		30		54	😞

Table 3 shows the slack-fill volumes of the loose and tapped products packed in different volume containers. To easily understand the change, the schematic of slack-fill changes of the simulated sample is shown in figure 4. After transit, the slack-fill percentage increased due to an increase of tapped density. For example, the 30 vol% of slack-fill percentage

the air between the larger particles thus reducing the volume and increasing the density. It is not an appropriate method to calculate the tapped density of protein powder mixture merely by using a simple model of component properties, since the density is also affected by its particle size and distribution, particle shape and surface structure.^[8] Consequently, a standard tapped density tester is required for the manufacturers to scientifically and accurately study the tapped density of the powders.

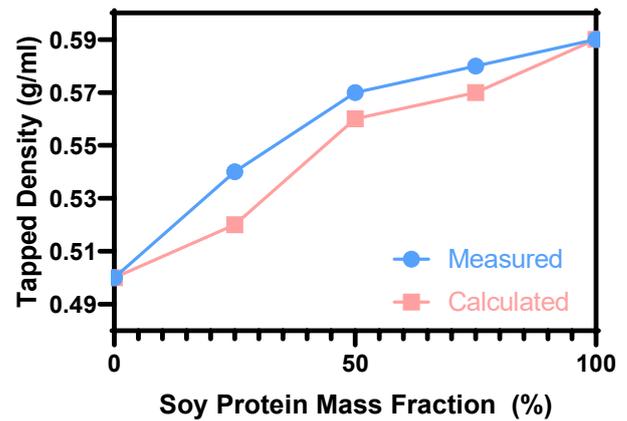


Figure 3. The measured and calculated tapped densities of the protein mixtures

4. Discussion

The bulk density and tapped density of three types of protein powders were measured successfully. The appropriate container size could be determined from these results for each of the powders. In addition, what a slack-fill percentage would elicit a positive response from customers. The packaging of 500 g whey protein powder was simulated with different container sizes and slack-fill volumes.

in the loose product increases to 54 vol% in the tapped product. The larger the packaging size, the higher the slack-fill percentage. The feedback result presents that in this case most of Betersize employees were dissatisfied with the 30 vol% initial slack fill, as presented in table 3.

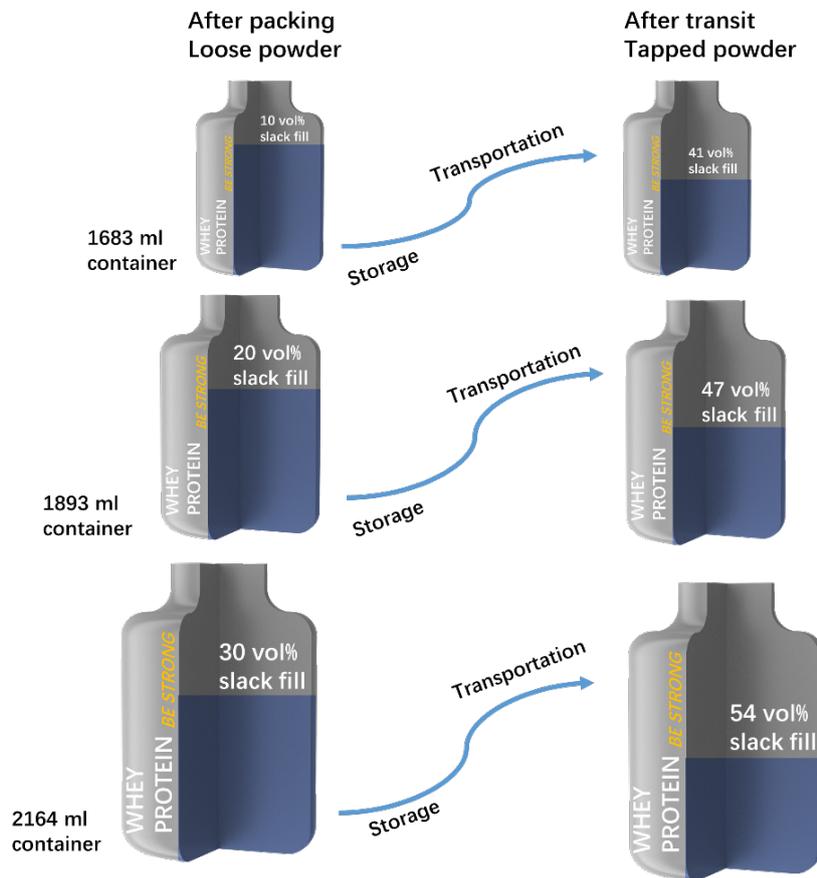


Figure 4. The slack-fill changes of the simulated sample during storage and transportation

In this case, when the protein container has a 30 vol% slack-fill initially, its tapped slack-fill will exceed 50 vol%, which would be contrary to a customer's expectations. Conversely, customers will be more satisfied if the slack-fill is less than 20 vol%. This suggests that a reasonable packing size can be achieved by controlling the initial slack-fill to less than 20 vol%.

5. Conclusion

The tapped density of the pure and mixed protein powders has been successfully measured by using BeDensi T1 Pro. For pure protein powder, different types of protein powders have different tapped densities so that the packing sizes ought to be confirmed on the premise of the density. With the change of mass ratio in the protein mixture, the tapped density is different. And the tapped density should be measured by a standard tapped density tester rather than calculated by a simple model of component properties. Based on the tapped testing results, a reasonable packing size for the whey protein product can be achieved under a 20 vol% initial slack-fill.

Thus, a standard tapped density tester is an absolute necessity for all manufacturers who wish to study the tapped

density of the powder accurately and from this information, design appropriately sized packaging. The BeDensi T Pro series can provide food powder producers with reliable information to determine an optimum packing volume which will be useful in determining a packaging which is eye-catching, fit for purpose and customer friendly.

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