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Improvement of pea protein isolate powder properties by agglomeration in a fluidized bed: comparison between binder solutions

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Abstract
This study aimed to compare the agglomeration process of pea protein isolate (PPI) using water and aqueous gum Arabic solution as binder liquids. Drying air temperature and binder flow rate were set at 75 °C and 3.1 mL/min, respectively. Moisture content, mean particle size, wetting time and flowability were analyzed. Using water as binder liquid, the responses were (4.0 ± 0.4)%, 316.13 ± 16.73 µm, 10 s and free flow, respectively. Aqueous gum Arabic solution provided (2.9 ± 0.5)%, 462.67 ± 51.23 µm, 3 s and free flow as responses. Gum Arabic solution showed to be a more promising binder.

Keywords: *Agglomeration; Pulsed fluidized bed; Pea protein isolate; Wetting time; Flowability.*

1. Introduction

The food and pharmaceutical industries use fluid bed agglomeration to improve the physicochemical properties of powders, such as wettability, density, flowability and moisture content.[1,2] The improvement of these properties depends on the operating conditions, the properties of the raw material and the binder solution.[2]

Fluid bed agglomeration consists of atomizing a binder liquid in a fluidized bed of particles and is considered as successive humidification and drying operations.[3] First, the liquid is atomized into the particles generating liquid bridges; then hot air removes water by transforming the liquid bridges into solid bridges to form agglomerates.[4] This is a complex process because it depends not only on the characteristics of the particulate solid, but also on the operational parameters and properties of the binder solution.[5]

The pea exhibits high protein content, ranging from 23 to 33% depending on the species. In addition, it has a good nutritional value, being rich in essential amino acids, vitamins and minerals.[6,7] Pea protein isolate (PPI) has great potential as a substitute for soy protein in industrial processes. However, the powder produced by spray drying is cohesive rather than instantaneous, consisting of fine particles, limiting its use in the industrial process.[8]

The main factors to be considered in the fluidized bed agglomeration process are flow and concentration of the binder solution, atomization pressure, temperature and velocity of fluidization air and bed relative humidity.[5]

Thus, the objective of this work was to analyze the influence of binder solutions on the characteristics of agglomerated PPI in pulsed fluidized bed. At the end of the process, the improvement in the wetting time, flowability and particle size distribution of the agglomerated PPI were analyzed.

2. Materials and Methods

2.1. Materials

Samples containing 0.20 kg of a commercial PPI (CA Gramkow®, Brazil) were used as raw material for all the agglomeration experiments. The PPI contains 6.4% of moisture, above 80.0% of protein, 1.12% of fibers, 7.88% of lipids, 0.28% of carbohydrates and about 4.3% of others constituents. The particle size of raw PPI, measured by laser diffraction and represented by percentiles D10, D50 and D90, were 33.30, 81.0 and 181.92 μm, respectively.

The binder solutions were water and aqueous gum Arabic solution, both at room temperature (± 27 °C). The concentration of aqueous gum Arabic solution was 15% w/w; it was prepared by submitting gum Arabic (Nexira Brasil Comercial, Brazil) and distilled water to magnetic stirring until complete dissolution of the binder, which was verified visually.

2.2. Equipment and process variables

Experiments were performed in a rotating pulsed fluidized bed (RPFB). Details of this equipment are described by Andreola et al.[9]

The following operational conditions were kept fixed: sample mass at 0.2 kg, nozzle height at 300 mm, pulsation frequency at 4 Hz, atomizing air pressure at 7.0 Psi and binder amount at 76 mL. The fluidizing air velocity, fluidizing air temperature and binder flow rate were set at 0,39 m/s, 75 °C and 3.1 mL/min, respectively. The operating conditions were selected based on preliminary experiments (data not shown) that were performed to obtain an agglomerated product in stable fluidization conditions. Experimental responses express the average of three replicates.

2.3. Moisture content, mean particle size and particle size distribution

The moisture content in the samples was determined by an infrared moisture analyzer (MB200, Ohaus Corporation, USA), that was previously calibrated according to the AOAC standard methodology.[10]

The mean particle diameters and particle size distributions of raw and agglomerated PPI were measured by Mastersize S (Malvern Instruments, Malvern, UK).

2.5. Wetting time and flowability

Wetting time was measured as the time required for 3 g of powder to disappear from the surface of water (80 mL at 27 °C) when the slider that separates the powder and liquid sections were removed.[11] The Hausner index (*HR*) was calculated from the bulk (ρ_b) and tapped (ρ_t) densities of the raw and agglomerated powder, as shown in Eq. (1).

$$HR = \frac{\rho_t}{\rho_b} \qquad (1)$$

Classification of powder flowability based on the *HR* value is given in Table 1.[12]

Table 1. Classification of powder flowability based on the Hausner index (HR)

HR	Flowability
<1.2	Free
1.2-1.4	Intermediate
>1.4	Non-free

3. Results and discussion

3.1. Raw material and binders properties

Commercial PPI shows density and mean diameter of 1.2659 ± 0.0035 g/cm^3 and 81.00 ± 0.61 μm, respectively, and its fluidization behavior could be classified as pertaining to Geldart group A. Wetting time was over 300 s and *HR* was 1.3, classifying the flowability as intermediate. The large particle distribution is the main factor responsible for high wetting time and low flowability, because it provides more compacted bed, decreasing the porosity.[2,9,12]

Density, superficial tension and rheology of both liquid binders must be considered. Water presents density of 1.00 g/cm^3, superficial tension of 7.2 x 10^6 mN/m and Newtonian behavior; while gum Arabic solution presents 1.0522 ± 0.0002; 47.35 ± 0.69 and pseudoplastic behavior, respectively.

3.2. Process responses

3.2.1. Moisture content

In agglomeration using water as liquid binder, moisture content reaches (4.0 ± 0.4)%, while with the use of gum Arabic solution, moisture content was (2.9 ± 0.5)%, after 24.5 min of atomization and 10 min of drying. For both cases, this parameter was at least 2% lower, getting at 3.5%, compared to the raw material.

Low moisture contents are important mainly for material storage. Temperature at 75 °C is enough to promote water evaporation of the system, making the product drier. Binder flow rate at 3.1 mL/min also provide this type of product, whereas the binder wets the particles less and, when associated with temperature, its evaporation is more effective.[2,9]

Fig. 1. shows the relative humidity at bed exit. Although the same temperatures and flow rates were used for both conditions presented, the environment inside the bed remained moister, at least 20% higher, when the water was used as a binder. The fact that the gum Arabic solution has 15% solids, can produce this effect, since there is less water available.

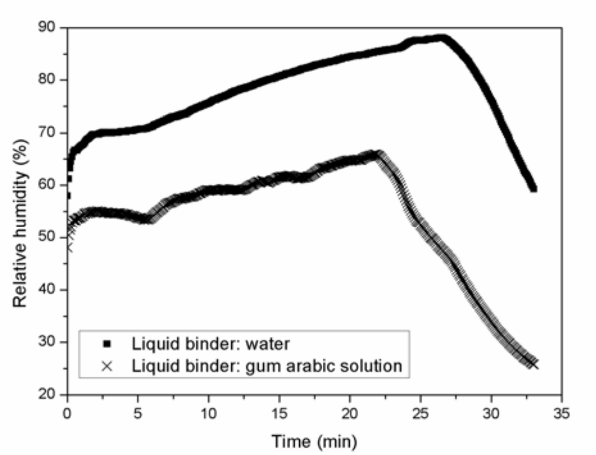

Fig. 1. Relative humidity at bed exit in relation to time.

3.2.2. Mean particle size and particle size distribution

Both liquid binders afforded agglomerated PPI with diameter larger than the initial size of raw PPI. To water as binder, particles increased 3.8 times, reaching 316.1 ± 16.7 µm, and when gum Arabic solution was used, the particle size reached 462.7 ± 51.3 µm, corresponding to a growth of 5.7 times. We also detected several particles with diameter higher than 600 µm. The particle size distribution to raw and agglomerated PPI is presented in Fig. 2.

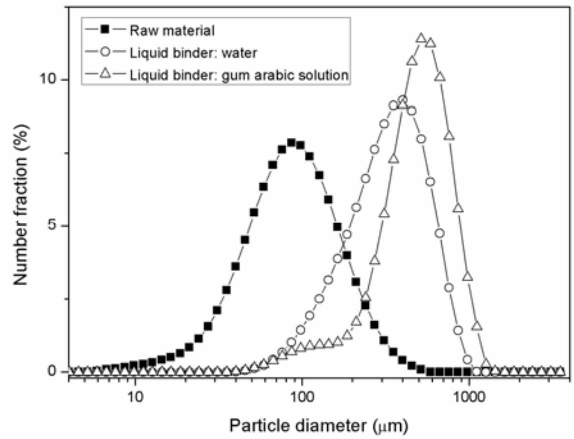

Fig. 2. Particle size distribution of raw and agglomerated PPI.

Agglomerated product also presented fines with diameter of less than 50 µm, which represented approximately 19% and 24% to agglomeration process with water and gum

Arabic solution, respectively. These fines correspond to non-agglomerated particles and may originate from breaking of the agglomerates by friction within the moving bed.

3.3. Wetting time

Compared with raw PPI, agglomerated PPI underwent faster wetting, even though the powders were not completely immersed into water. Agglomerated PPI achieved complete wetting in less than 10 s, to agglomeration with water, and 3 s, to gum Arabic solution which attests to its greater capacity to absorb moisture. It represents a decrease of 97% and 99% in wetting time, respectively.

The presence of fine particles allows for a more compact powder during storage, i. e., the smaller particles can penetrate into the spaces between the larger particles, so the product occupies less space.[11,13]

3.4. Flowability

Agglomeration process with water furnished bed density (ρ_b) of 0.2579 ± 0.0058 g/cm^3, and compact bed density (ρ_t) of 0.2970 ± 0.0070 g/cm^3. Already for agglomeration for gum Arabic solution, ρ_b = 0.1640 ± 0.0284 g/cm^3 and ρ_t = 0.1939 ± 0.0284 g/cm^3. The *HR* values obtained for agglomerated PPI were 1.15 and 1.18, classifying the product as free. Raw PPI consists of fine particles, which may confer the material a strong cohesive behavior, whereas agglomeration improves PPI flowability. Although the flowability of agglomerated PPI is not yet ideal, this product exhibited significantly better handling properties than raw PPI.

4. Conclusions

The particle agglomeration of PPI occurs due to the pulverization of liquid binder on the surfaces of the particles, resulting in a wetted sticky surface and subsequent particle coalescence. On particle drying, the agglomerated structure consolidates, leading to particle enlargement.

Agglomeration of PPI using gum Arabic solution produced larger granules with high flowability and lower cohesiveness when compared to agglomeration with water and spray dried raw material. Additionally, size enlargement also resulted in an improvement of instant properties that was characterized by the higher wettability of the granules.

5. Nomenclature

Greek letters

ρ	density	gcm^{-3}

Subscripts

b	bulk
t	tapped

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