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# Fluid dynamics and morphological characterization of soy protein isolate particles obtained by agglomeration in pulsed-fluid bed

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ABSTRACT

The aim of this work was to study the fluid dynamics profiles of cohesive soy protein isolate powders at several air pulsation frequencies in a pulsed-fluid bed. Additionally, the physical property modifications of soy protein isolate powder produced by a wet-agglomeration process were also evaluated. During agglomeration, the raw particles coalesce, resulting in the formation of granules with increasing size, but morphological changes were also verified. The shape of the raw powder particles were circular and compact, while the agglomerated particles were wrinkled and showed lower circularity and tight solid bridges. The fluidization of spray-dried particles was enhanced with the pulsation system, resulting in higher fluid bed homogeneity and agglomerated products with narrow particle size distribution.



## 1. Introduction

The agglomeration of food powders is commonly used to produce porous granules with higher wettability and dispersability in water or milk, called as instant products [16]. Particle agglomeration is obtained by spraying liquid over solid particles fluidized by hot air. The growth mechanism depends on operation condition, initial material properties, drying condition and fluid dynamics of bed [3,7]. The raw material is generally produced by spray drying and its fluidization behavior could be classified as pertaining to Geldart's group C or A, and presents cracks and channeling. In view of that, vibration or pulsation systems can be attached in the fluid bed equipments in order to improve the bed homogeneity and to allow the particle fluidization using lower fluidizing air flow [12,15]. The pulsed fluidized bed dryer is a modified conventional fluidized bed in which gas pulses cause vibration of the particle bed. The pulsed fluidized bed has the following advantages [13]: (i) Easy fluidization for irregularly shaped particles or with wide size distribution; (ii) Fluidization with 30–50% less air; (iii) Improved fluidization uniformity (reduced channeling); (iv) Fluidization of fragile particles; and (v) Lower pressure drop.

The lower air velocity required to achieve the fluidized state in a pulsed fluidized bed compared to a conventional fluidized bed makes it possible to reduce air consumption [5,9,11].

This work aims to study the fluid dynamics profiles of raw material and the physical property modifications of soy protein isolate powder produced by a top-spray agglomeration process in a pulse-fluid bed as a function of fluidizing air pulsation frequency. The performance of the process was evaluated by the granulated powder yield.

Most experimental works in the literature consider relatively large particles, which fluidize easily, and inert particles agglomerated with model binders. This study presents more realistic data for the agglomeration of spray-dried cohesive particles (Geldart type A) in a fluid bed, which was enhanced by air pulsation. In a previous work Dacanal and Menegalli [4] have achieved the optimal process conditions to agglomeration of soy protein isolate, but the pulsation frequency effects and fluid dynamic profiles were not evaluated, which is the aim of this research. There are similar works in the literature that used fluid bed systems to process cohesive powder. Jinapong et al. [8] produced instant soy milk by fluid bed agglomeration but the details of fluid dynamics profiles were not reported. Chen et al. [1] used a fluid bed to coating cornstarch particles by atomization of hydroxypropyl cellulose aqueous solution, and, additionally, Chen et al. [2] studied the granulation of that coated particles in that same equipment, but the fluid dynamics profiles of those system weren't achieved. In general, there are few reports in the literature of agglomeration of cohesive foodstuff powders in fluid bed systems, and this work intends to give a better visualization of the fluid dynamics profile changes of the raw material when air pulsation frequencies are used.

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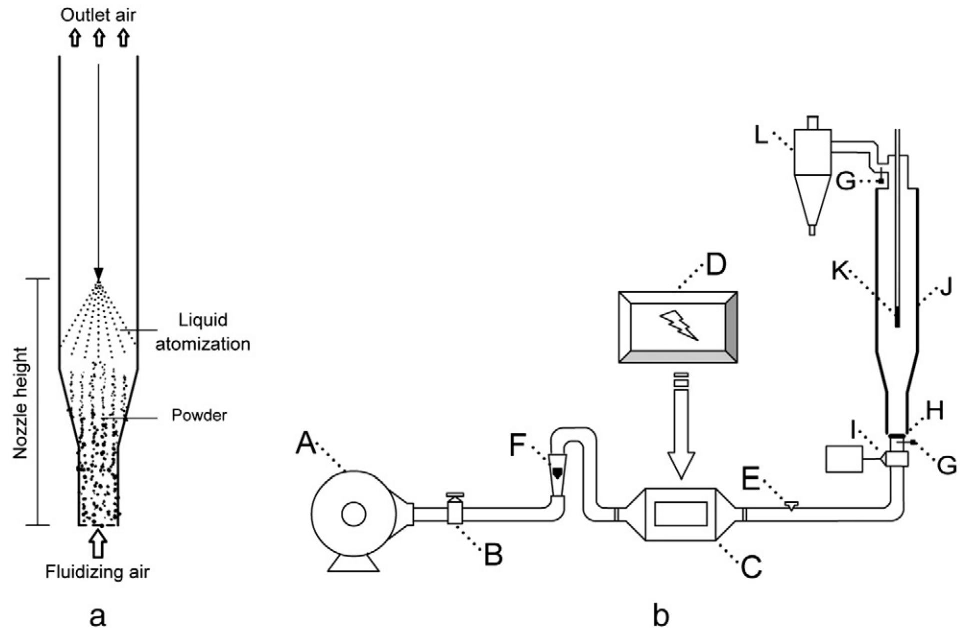


**Fig. 1.** Schemes of the fluidized bed agglomeration process (a) and equipment used (b): A—Blower; B—Valve; C—Heater; D—PID controller; E—Air deflector; F—Rotameter; G—Temperature sensor; H—Air distributor; I—Rotating spherical valve; J—Bed chamber; K—Nozzle; L—Cyclone [4].

## 2. Materials and methods

### *2.1. Materials used*

Samples containing 0.15 kg of a commercial soy protein isolate (Supro® 780, The Solae Company, Brazil) were used as raw material for the agglomeration experiments. The chemical composition of the soy protein isolate consists of 91.3% of protein, 2.2% of fibers, 0.5% of lipids, 4.1% of moisture and 1.9% of other constituents.

An aqueous solution containing maltodextrin (20% DE, MOR-REX® 1920, Corn Products, Brazil) at 27 °C was used as a liquid binder.

### *2.2. Equipment and process variables*

The equipment used was a batch-fluidized bed [4] equipped with a rotating spherical valve installed below the air distribution plate that promotes the fluidizing air pulsation at frequencies of 0, 300, 600 and 900 rpm. The fluid bed chamber has a cylindrical base (75-mm diameter and 150-mm height), above which there is a conical expansion of 150-mm height and a cylindrical body (150-mm diameter and 600-mm height), as shown in Fig. 1.

The fluid bed chamber was constructed from a transparent acrylic material. An on/off electrical heater controlled the fluidizing air temperature. The fluidizing airflow was monitored by a rotameter. The fluidizing air temperature and velocity were fixed at 75 °C and 0.57 m/s, respectively. The elutriated particles were collected by a cyclone. The liquid binder and the pressured air were pumped into the bi-fluid nozzle (model 1/8JN-SS + SU12-SS, Spraying Systems), resulting in the atomization of the liquid. Atomization was performed countercurrent to the fluidizing airflow, consisting of a jet sprayed with a conical geometry and a circular projection area. The nozzle height was fixed at 300 mm inside the fluid bed. The maximum process time or period of liquid atomization was fixed at 40 min. However, before starting to inject the liquid, the process variables were fixed at the selected operational conditions. Subsequently, the raw product was introduced into the fluid bed, starting the process. Atomizing air pressure and the concentration of the binder and feed flow rate were fixed at 55 kPa, 49% w/w and 2.7 g/min, respectively.

The bed aerodynamic behavior was determined by measuring the bed pressure drop as a function of air velocity and pulsation frequency for the raw material without atomization of binder. The physical properties of the agglomerated products and raw soy protein isolate were evaluated by analysis of the particle size distribution, moisture content and image analysis.

### *2.3. Moisture content*

The raw and agglomerated product moisture contents were determined by drying at 70 °C under vacuum, according the AOAC Official Method 920.151.

### *2.4. Particle size and shape parameters*

The soy protein isolate particles were deposited and dispersed on a glass slide and observed under a stereomicroscope (Citoval 2, Zeiss, Germany) equipped with a digital camera (Kodak EasyShare DX4530). The colored images (RGB color) of 2580 × 1932 square pixels were captured. Several slides can be used to image the required number of particles. The images are manually focused to give good definition of the particle silhouettes. These images were then treated and analyzed and the 2D shape parameters describing the silhouette of the particles extracted using the software IMAGEJ v1.37 (National Institutes of Health, USA). Before performing the 2D measurements, the colored images were converted into gray levels (8-bit) and then transformed by a set of operations. The first step was to adjust the brightness and contrast of the image, if necessary. After that, the particle silhouettes were enhanced using the following image filters:

i. Threshold: the gray level images were transformed into a binary mode using the threshold filter;
ii. Elimination of the objects that contacted the board of the image;
iii. Dilate: the particle surface contour was expanded in 1 pixel;
iv. Close: the open holes or surface imperfections that came with the threshold filter were closed;
v. Hole filling;
vi. Erode: the particle surface contour expanded in 1 pixel was eroded back to its original size;
vii. Manual exclusion of the imperfect particles, if necessary.