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Agglomeration of turmeric powder and its effect on physico-chemical and microstructural characteristics

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ABSTRACT

Agglomerated foods have gained attention in recent years due to their convenience in use. Turmeric powder has been subjected to agglomeration process at different moisture contents (10–28%) and steaming times (0–60 min). Experimental cumulative particle size distribution data of agglomerated samples can be predicted well ($0.951 \leqslant r \leqslant 0.999$, $p \leqslant 0.01$) with Rosin–Rammler–Bennett model. The functional properties related to hydration characteristics like wetting time (10–35 s) and sinking time (15–115 s) of agglomerated samples decrease with an increase in moisture content and/or steaming time. Microstructural observation shows that the non-agglomerated sample possesses spheroids and ellipsoids of different sizes. The size of agglomerates ranges between 50 and 160 μm; their shape varies from spheroid to elongated ellipsoids. Image analysis infers that the size related parameters increase with an increase in moisture content/steaming time. A four-layered artificial neural network having a structure of 2–10-8–4 has been developed to predict the agglomeration process of turmeric powder.

1. Introduction

Powdery food materials are frequently used for convenience in applications during transportation, handling, processing and for product formulations (Ghosal et al., 2010). A variety of food powders from different sources are used to serve specific purposes including improving sensory appeal and nutritional status of finished products. Occasionally, there is a need to modify the structure of food to achieve certain specific characteristics and convenience in use. Agglomeration is a physical phenomenon and can be described as the sticking of particulate solids, which is caused by short-range physical or chemical forces among the particles (Barbosa-Canovas et al., 2005). This phenomenon is triggered by specific processing conditions, or binders and substances those adhering chemically or physically to form bridges between particles (Pietsch, 2003). The main purpose of particle size enlargement by agglomeration is to regulate certain physical properties of food powders such as density, flowability, to improve dispersion and dissolution characteristics, and reduce the tendency of caking and dust formation (Mukherjee and Bhattacharya, 2006).

Spices are widely used in food products to create the distinctive flavor and character that are representative of different cuisines. The delightful flavor and pungency of spices make them indispensable in the preparation of palatable dishes. In addition, they are used in the preparation of a number of pharmaceutical formulations (Peter, 2004). Turmeric, a commercially important spice, is mainly consumed as dry powder primarily for coloring because of its attractive yellow color and its associated therapeutic properties. It also imparts the characteristic flavor and preserves the freshness of the product prepared (Govindarajan and Stahl, 1980). The main biological activities of turmeric rhizome reported are anti-inflammatory, anti-microbial, anti-tumor and wound healing (Jayaprakasha et al., 2005). Turmeric powder is usually stored in bulk in opaque containers in which moisture absorption and light exposure are avoided. The aroma of turmeric is contributed by its volatile oil (e.g., terpeniods and aromatic compounds), while the color is attributed to the presence of diaryl heptanoids viz., curcuminoids (Govindarajan and Stahl, 1980). However, turmeric powder is not a free flowing sample. It also sticks to utensils when used for transferring during food preparations and forms lumps when added in large quantity in institutional cooking.

The microencapsulated turmeric oleoresin powder can be obtained by spray drying of oleoresin using edible gum as a matrix (Kshirsagar et al., 2009). One of the demerits of spray-dried powders is their small particle size, typically in the range 10–100 μm in diameter. This small particle size may result in poor reconstitution properties, product separation during shipping and handling (when mixed with other ingredients), poor handling properties (e.g., flow and quantification), and dusting problems during manufacturing (Buffo et al., 2002). To overcome these problems, turmeric powder can be agglomerated directly. This will be an alternate process compared to the existing process of extraction of oleoresin, encapsulation followed by agglomeration. The agglomeration process

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Nomenclature

a_0, a_1, a_2, a_{11}, a_{22}, a_{12} model coefficients for the variables
a^* redness (–)
b^* yellowness (–)
dp_i mass mean mesh size (m)
$f(p)$ threshold (sigmoid) function of the independent input variable p (–)
F_{max}, F_{min} Feret diameters (m)
$F(x)$ cumulative under size mass fraction (–)
k consistency index (Pa s^n)
L^* lightness (–)
n flow behavior index (–)
N number of data sets
n_R uniformity index of the particle size distribution (–)
P perimeter (m)
R correlation coefficient (–)
S surface area (m^2)
x mesh size (m)
x_i mass fraction (–)
x_R size parameter (m)
X_1, X_2 independent variables
Y response function
W_{Expt}, W_{Pred} experimental and predicted values of target parameters

Greek letters
$\dot{\gamma}$ shear-rate (s^{-1})
$\triangle E$ total color difference (–)
ε random error of the regression model
σ shear-stress (Pa)
χ^2 variance

involves the use of binders (e.g., moisture), applying pressure and increasing temperature (Palzer, 2011). Therefore, scope exists to monitor the physical and physico-chemical properties for which scientific data on agglomeration of turmeric powder are scarce.

Earlier studies have been conducted on the characterization of turmeric powder with respect to its prime components like starch, volatile and nonvolatile components (Dhanalakshmi et al., 2011; Dhanalakshmi and Jaganmohan Rao, 2012). The results indicate that cured-dried turmeric powder exhibits a high yield of volatile and nonvolatile components (Dhanalakshmi and Jaganmohan Rao, 2012), which are the principal components of importance. Therefore, the objectives of the present study are to (a) conduct agglomeration of turmeric powder using water as a binder at different moisture contents and steaming times, (b) determine the physical, physico-chemical and functional characteristics, and morphological changes, and (c) development of an artificial neural network to predict the agglomeration process.

2. Materials and methods

2.1. Materials

Fresh turmeric (*Curcuma longa*) rhizomes were procured from a local cultivator near Mysore, Karnataka, India. The rhizomes were manually cleaned with water to remove the adhering soil and extraneous matter (Dhanalakshmi et al., 2011). The fresh rhizomes were cured by employing the conventional method of cooking in excess of boiling water for 1 h; excess water was discarded and the rhizomes were dried in the shade for a week. These dried rhizomes were powdered in a pulverizer to obtain fine powder; temperature during grinding was less than 40 °C. This powder sample is referred as 'cured-dried' sample; the process was repeated twice.

2.2. Methods

2.2.1. Agglomeration of turmeric powder and experimental design

Turmeric powder (6% moisture content) was mixed in a Hobart mixer (Model #1/BSP-BM7, Bakery Mixer, Malaysia) at room temperature (about 25 °C); water was sprayed from a spray gun onto turmeric powder to obtain samples with moisture contents of about 10%, 15%, 18%, 22%, 25% and 28%. The volume of powder sample was about 2.5 L and spray time was between 3 and 5 min. The materials were mixed at the lowest speed of rotation for 30 min to ensure homogeneous product; moisture content was rechecked after this mixing step. Latter, the samples with different moisture contents were divided into seven batches. The first batch sample, after addition of moisture (without steaming), was subjected to granulation in a laboratory model granulator (Model # CMJ-8, Cadmach Machinery, Ahmedabad, India) and dried in a tray dryer at 50 °C for 8 h. The other batches were steamed in a pressure cooker at the ambient pressure for different time intervals (10–60 min). After steaming, these samples were granulated in the laboratory model granulator as mentioned earlier. These granules were also dried in the same tray dryer at 50 °C for 8 h. These samples were stored in double walled polyethylene bags at room temperature for further analysis within 24 h of sample preparation. The agglomeration process was repeated twice.

2.2.2. Physico-chemical characterization

The non-agglomerated and agglomerated samples were used for the determination of mass mean particle size and particle size distribution employing the method of sieve analysis (McCabe et al., 2005). A set of standard sieves with apertures of 800, 710, 500, 355, 250, 150, 105 and 53 μm were stacked one upon the other in an ascending order of the aperture size. The sample to be tested was placed on the top sieve with aperture of 800 μm, and the sieving was performed for 20 min. The particles retained on each sieve were removed and weighed to calculate the mass fractions of particles. Particles that passed through the entire sieve sets were collected in the bottom pan of the stack. The mass mean mesh size (dp_i) was calculated as the mass mean of two consecutive sieves used for analysis. Mass fraction (x_i) was determined as the ratio of mass of sample retained on each sieve divided by the total mass. The mass mean particle/granule diameter was calculated based on the mass fraction using Eq. (1) (McCabe et al., 2005).

$$\text{Mass mean diameter} = \sum_{i=1}^{n} x_i dp_i \quad (1)$$

Here, n was the number of sieves including a receiver (sieve $i = 1$ with an aperture of 0 μm).

The particle size distribution of non-agglomerated turmeric powder sample (control) was determined. No sample was retained on sieves with apertures of 800, 710, 500, 355 and 250 μm. The maximum amount of particle was retained on the sieve with apertures of 105 μm. The mass of particles passing through the sieve with aperture 150 μm (particles with size less than the mass mean