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Drying of yellow pea starch on inert carriers: Drying kinetics, moisture diffusivity, and product quality

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ABSTRACT

This study aimed at investigating the drying of yellow pea starch dispersions on inert solid carriers and determining the drying kinetics, moisture diffusivity and the product quality, quantified through damage index and final moisture content. Drying kinetics accomplished in a convective drying tunnel show that the overall mass transfer is controlled by internal migration of moisture within the starch particles. For a given inlet air temperature from 100 to 180 °C, the apparent diffusion coefficient derived from the drying curves increases exponentially with the instantaneous moisture content, with values ranging from 4×10^{-11} to 3×10^{-8} m^2/s. Due to low diffusivity and the thin coat formed on the surface of solid carriers, the resistance to internal diffusion is negligible as compared to the overall mass transfer resistance when drying of starch dispersions takes place on inert solid carriers. Drying of yellow pea starch dispersion on Teflon particles as inert carriers was studied in laboratory and pilot fast spouted bed dryer for inlet air temperatures from 140 to 240 °C, and initial solid content of 38%, mass (d.b.). The starch damage index for targeted product moisture content was below 2.5% in the inlet air temperature range from 120 to 210 °C, when atomizing from the bottom of dryer.

1. Introduction

Cereals (e.g., corn, wheat), potatoes and peas are the most popular sources of starch for many applications, including the production of emerging biopolymers and animal diets. Several researchers have also reported the possibility for the use of pea starch as an encapsulating agent (Yilmaz et al., 2001; Öngen et al., 2002; Korus et al., 2003). Drying of pea starch dispersions is usually performed in a spray dryer, a spin-flash dryer, or a pneumatic-flash dryer. For required production rate, ranging typically from 5 to 150 kg of dry starch per hour, the size of such dryers is so big that the related capital and operating costs reduce greatly the profit margins. Smaller equipment of similar performance is therefore needed. Drying on inert solid carriers is one of the most efficient methods of drying for this throughput range that offers low capital cost and compact equipment, which facilitates its integration in the existing industrial production site. It should be noted that the solid carriers can be either active where the drying material is adsorbed by the carrier to form a composite product (contact-sorption drying), or inert where the drying material is only deposited on the carrier surface and removed from it by attrition once it is sufficiently dry (Kudra and Mujumdar, 2009). Drying on inert carriers has been laboratory and pilot tested in various hydrodynamic configurations such as turbulent fluidized bed, swirling bed, mechanically spouted bed, fast spouted bed (Spitzner-Neto et al., 1982; Barrett and Fane, 1989; Markowski, 1992; Ochoa-Martinez et al., 1993; Benali and Amazouz, 2002; Kutsakova, 2004; Benali, 2004; Passos et al., 2004; Wachiraphansakul and Devahastin, 2005; Benali and Amazouz, 2006a; Barcelos and Freire, 2006; Rocha et al., 2009; Pereira et al., 2010; Tatemoto and Miyazawa, 2011). A novel configuration of the fast spouted bed has been developed (Benali and Amazouz, 2006b), which allows better control of the final moisture content and size distribution of a dry product. This novel configuration of the dryer consists mainly of a conical drying chamber in conjunction with a reverse cone serving as a conical disengaging chamber. The lower cone has a supporting grid for inert particles. A conical screen is attached to the dryer exit to avoid the entrainment of the inert carrier when discharging the powdery product with the exhaust gas but also to enhance removal of a dry coat from the inert carriers. The experiments performed on both laboratory and pilot units, revealed that heat transfer coefficients in this novel design are sufficiently high (from 21.5 to 35.8 W/m^2 K) to attain rapidly the thermal equilibrium between the three phases involved in the drying process: inert solid carriers, drying air, and aqueous starch dispersion. The ideal drying cycle in a fast spouted bed is based on four successive steps: (a) heating of the inert carrier, (b) coating of the inert carrier with fine droplets of starch dispersions, (c) drying of the wet coat, and (d) attrition of the dry coat due to multiple collisions within the dryer and entrainment of

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