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Operating air velocities for fiber separation from corn flour using the Elusieve process

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ABSTRACT

Fiber separation from corn flour could increase ethanol productivity and increase energy value as feed for non-ruminants (swine and poultry). Elusieve process, a combination of sieving and air classification, has been found to be effective in separating fiber. The objectives of this study were to determine the operating air velocities for corn particles and to compare physical properties of corn particles with that of DDGS particles from an earlier study. The operating air velocities for large, medium and small corn size fractions were 2.9–3.8, 2.8–3.0 and 2.5–2.6 m/s, respectively. Densities of nonfiber particles for corn flour were higher than for DDGS (earlier study). Compared to DDGS, the difference between fiber and nonfiber particle terminal velocities was higher for corn, which signifies relative ease of operability for fiber separation from corn flour.

1. Introduction

Corn is widely used as animal feed and for fuel ethanol production. The fiber present in corn does not convert to ethanol. Also, this fiber is not digested well by non-ruminants (swine and poultry). Fiber separation from corn flour could increase ethanol productivity and increase energy value as feed for non-ruminants. Fiber can also be used as combustion fuel, cattle feed, and as a feedstock for producing valuable products such as cellulosic ethanol, corn fiber gum, oligosaccharides, phytosterols, and polyols (Dien et al., 1997; Crittenden and Playne, 1996; Moreau et al., 1996; Buhner and Agblevor, 2004).

Elusieve process, a combination of sieving and air classification, was found to be effective in separating fiber from corn flour (Srinivasan and Singh, 2008a; Pandya and Srinivasan, 2011). Hammer millled corn flour is sieved into different size fractions: large, medium, small, fines and the pan, pan being the smallest size fraction. The large, medium, small and fines fractions are air classified to separate fiber. The process of air classification takes advantage of the difference in physical properties of fiber and nonfiber particles such as shape, weight and density of particles.

Air classification is carried out at air velocity higher than fiber terminal velocity and lower than nonfiber terminal velocity. Terminal velocity is the constant velocity attained by a falling particle when the upward drag on the particle and the buoyancy force balance the downward force of gravity (DRI, 2005). The gravitational force on the particle is higher than the buoyancy force, hence the downward acceleration of the particle. For a sphere shaped particle, the upward drag force on the particle is proportional to the square of the velocity of the particle in laminar flow. As the downward falling particle is accelerating, the upward drag force increases. At some velocity, the gravitational force acting downward due to weight of the particle balances the upward drag force and the buoyancy force. This velocity is the terminal velocity of the particle, at which the acceleration of the particle becomes zero and there is no further change in velocity. Air velocity higher than terminal velocity of fiber particles and lower than terminal velocity of nonfiber particles results in effective fiber separation. If air velocity is higher than the terminal velocity of nonfiber particles, nonfiber particles would get carried along with the fiber particles, resulting in poor quality separation.

Srinivasan and Singh (2008b) experimentally determined the terminal velocity of DDGS particles. No work has determined the terminal velocities for corn flour particles, till now. Presently, the air velocities are adjusted by trial and error for separation of fiber from corn flour. Experimental determination of terminal velocities for fiber and nonfiber particles will enable precise adjustment of operating air velocities in aspirators for effective fiber separation. In this study, terminal velocities of fiber and nonfiber particles in corn flour were obtained experimentally using a 152 mm (6-inch)

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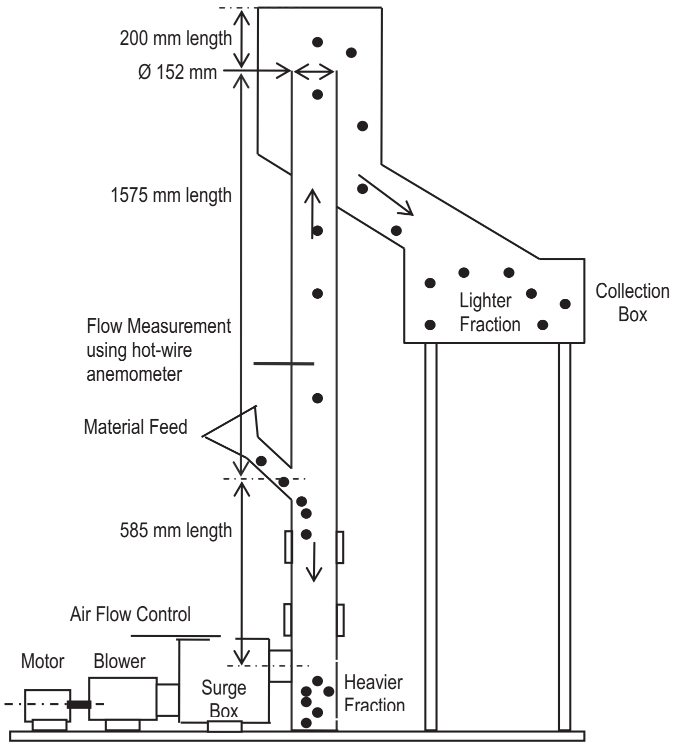

Fig. 1. Schematic of elutriation column set up.

Fig. 2. Photograph of elutriation column set-up for measuring particle terminal velocities.

elutriation column. Measurement of particle size and densities helps us understand the relative differences in physical properties that govern separation. The objectives of this study were to determine air velocities that can be used to operate pilot and commercial elusieve set-ups for effective fiber separation from corn flour and to compare size, weight and densities of corn fiber and nonfiber particles with that of DDGS particles from previous study.

2. Materials and methods

2.1. Elutriation column

To measure the terminal velocities of fiber and nonfiber particles, an elutriation column was constructed at the Pace Seed lab, Mississippi State University, similar to the one used by Srinivasan and Singh (2008b) (Figs. 1 and 2). It mainly consists of a 6-inch pipe, a blower and motor assembly to generate air flow, a surge box for controlling the air flow and a fiber collection box. To attain a fully developed flow in the pipe, the distance of the top of the elutriation column from the material inlet (1575 mm) was maintained more than six times the column internal diameter (155 mm) (ASHRAE Standard 41.8-1989). A 2440 mm (8 feet) long, 152 mm (6 inch) diameter clear rigid Schedule 40 PVC pipe was used. The transparent pipe provided good visibility of the fiber separation taking place in the elutriation column. The blower (Dayton blower 8 15/16″, model 2C820, Lake Forest, IL, USA) was powered by a 0.4 kW (0.5 hp) motor (Dayton motor model# 6K482, Lake Forest, IL, USA). The surge box was built out of plywood sheet and was provided with a vent and a sliding cover to control the air flow through the column. An inlet was provided in the column through which the sieved corn flour was fed at a rate of 50 g/min. To facilitate the collection and to reduce loss of lighter fraction material, a collection box made of transparent acrylic sheet was used. To arrest fine particles that might escape with the exiting air, the top of the collection box was fitted with a very fine mesh screen.

2.2. Elusieving for separation of fiber and nonfiber

Yellow dent corn (75 kg) was procured from the local feed store (Oktibbeha County Cooperative, Starkville, MS). The initial moisture content of the corn was 11.5%. The corn kernels were milled using a hammer mill (Bliss Industries, Ponca, OK). The 3.2 mm (8/64-inch) retainer screen opening was chosen in the hammer mill as it results in best fiber separation (Pandya and Srinivasan, 2011). Studies were conducted using three replicates by dividing each sample into three batches of 25 kg each (Fig. 3). Each batch of corn flour was sieved into five size categories using SWECO sifter

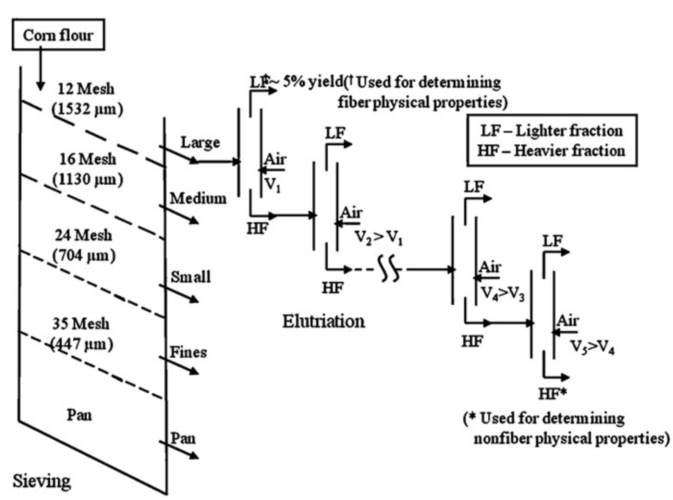

Fig. 3. Schematic of sieving and sequential air classification of large size fraction (based on Srinivasan and Singh, 2008b). The medium, small and fines size fractions were also air classified in similar way. Pan size fraction was not subjected to air classification.