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Grain classification using aerodynamic principles

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Abstract: Winnowing is the general age long method of separating chaff from grains. Classification processes such as cleaning and grading are done with machines such as aspirator, specific gravity separator, size grader/ sieve and destoner which result in increased unit cost, and space, energy and machine requirements. The feasibility of simultaneously utilizing air flow for both winnowing and classification of legume grains was investigated using a cross flow classifier. Data showed the possibility of using cross flow system for cleaning and classifying legume grains into density grades, especially when the blow angle is inclined at 22.5^{o} to the horizontal. The performance of the cross flow classifying system compared favorably with an industrial specific gravity separator.

Introduction

Grains on handling after harvest contain various proportions of material other than grains (MOG) such as stone, pod, stem and dirt. Separation of the MOG is essential to upgrade the quality of food material. Some of the methods employed for separating MOG include winnowing (traditional method), aspiration, sieving and use of vertical air stream Ademosun, 1993, Ogunlowo and Adesuyi, 1999; Kulkarni, 1989). The common and conventional method of classifying grains to size grades has always been the use of screen. Air steam is commonly used for separating lighter impurities such as chaff and pod from grains. It is rarely used for grain grading (Fernando and Hanna, 2005). Farran and Macmillan (1979), and Gorial and O' Callaghan (1991a) concluded that it is impossible to separate grains into size grades using vertical air stream.

There are basically two types of pneumatic separators utilizing aerodynamic principles namely the vertical air stream and horizontal air stream separators (Gorial and O'Callaghan, 1991a & b). In the vertical air stream separator, air stream flows vertically against the injected mixed product such that heavy particles (grains) drop through the air (counter current flow) while the light materials (chaff) move upward and are carried along by the air (concurrent flow). In the horizontal air stream separator, air is blown horizontally or at an inclined angle to the horizontal against mixed product injected along the vertical plane. The heterogeneous materials are displaced along the horizontal plane at various distances based on their aerodynamic properties (Gorial and O'Callaghan, 1991b; Adewumi *et al.*, 2006a, b).

Gorial and O'Callaghan (1991b) and Adewumi *et al* (2005, 2006a, b, c, d and 2007) suggested the possibility of classifying grains into size grades using horizontal air stream. Cross flow classifiers have the advantage of producing more than two fractions from particulate or granular admixtures within a short time (Wang *et al.*, 2001; Adewumi, 2007; Adewumi *et al.*, 2006a, b, 2007; Gorial and O'Callaghan, 1991b). Cross flow system could reduce the overall unit cost of machinery and production cost; save space and increase the rate of production (Adewumi, 2006, 2007). Considering its numerous seeming potentials and advantages, and noting that limited researches are conducted/ reported so far in this field of study, it is essential to conduct some more studies on cross flow system. The objective of the research therefore was to further study the feasibility of simultaneously utilizing air flow for both winnowing and classification of legume grains, using a cross flow classifier.

Materials and Methods

A cross flow classifier test rig developed at the Department of grain Science and Technology, Central Food Technological Research Institute, Mysore, India was used for the study (Adewumi, 2006). It is made up of a blower, blower frame, and feed hopper/ vibratory feeder, classifying chamber, and tilting mechanism. The classifying chamber is made up of a frame, collector trays and grain deflectors or guiding plates. One of the longitudinal sides is covered with sheet metal (18-gauge) and its inner wall is colored with black paint while the other side is covered with plain perspex sheet to enable visibility. The deflectors/ guide plates guide the grains and ensure they fall into appropriate trays and regulate the fall/ drop height of grains. The sheet metal and perspex sheet were bolted to the frame of the classifying chamber. The deflectors also provide sufficient height to prevent the grains from bouncing into another tray. The classifying chamber has a total dimension of 0.50 x 2.5 x 2.62 m and provided with four wheels for easy shifting. The construction of the cross flow classifier system is made flexible such that many parameters such as grain inlet velocity, feed rate, air speed, feed height, drop height, angle of inclination of blower and angle of inclination of deflector/ guide plates can be varied. Fig. 1 shows the picture of the classifier.

Experiments were conducted using the cross flow classifier system to study the effects of air speed and blower angle of inclination on the classification of the soybean at average feed height of 0.15 m, feed rates $\geq$300 kgh^{-1} (high range) and ≤170 kgh^{-1} (medium range), and moisture content below 12%. Air speed of 12, 15 and 18 ms^{-1} and blower angle of inclination of 0, 22.5 and 45^{o} to the horizontal were used for the experiments with the classifier. Each experiment was conducted in triplicate for 2 mins per run. The angle of inclination of the guide plates was fixed at about 5^{0} at a spacing of 0.5 m. The bulk density of the materials collected in each of the trays was determined in triplicates using the mass-volume method (Carman, 1996).

Fig. 1: The assembly of the cross flow test rig with the feed hopper (without the collection trays)

A specific gravity separator manufactured by Forsberg Agric Tech, India in the 1 ton/day CFTRI pilot maize mill (RESC, 1998) was also evaluated for performance and compared with the classifier (See Fig. 2). The separator mostly performs a cleaning operation and separates based on the specific gravity of materials. It is made up of a feeding hopper, blower which provides a fluidized bed and powered by an electric motor, adjustable grain deck, pitch and deck inclination controls and exhaust ports (4 No.). While the densest materials in the mixture are collected in tray 1, the lightest materials are collected in tray 4. The result of the performance of the specific gravity separator was taken at optimum condition of 58.4 ± 1.73 kgh^{-1}. The density distribution of the grains in the classifier chamber and the specific gravity separator was plotted and studied.

Fig. 2: Specific gravity separator at CFTRI 1 ton/day pilot maize mill

Results and Discussions

Table 1 shows the respective feed rates of the cross flow classifier system at higher feed rate (≥300 kgh^{-1}) and lower feed rate (≤170 kgh^{-1}) for soybean for the various operating conditions. Figs. 3 and 4 show the density distribution of materials in the classifier at the specified operating conditions for feed rate of 300 kgh^{-1} and ≤170 kgh^{-1} respectively, while Fig. 5 shows same for specific the gravity separator.

Figs.3 and 4 shows that the cleaning and separation based on bulk density of the grains is highly feasible using the cross flow system. The test rig was able to classify materials based on density, particularly with adequate selection of the angle of inclination of the fan, fan speed and feed rate. The spatial distribution of the grains in the trays along the horizontal distance was adequate. Close observations during experimentation showed that grading of the grains was reasonably achieved with the cross flow system especially at blower inclination of 22.5 ^{o} and air speed of 12 m/s. The largest proportion of the big, medium and small seeds were collected in tray 1 ($x \leq 0.5$ m), tray 2 ($0.5 \leq x \leq 1.0$ m) and tray 3 ($1.0 \leq x \leq 1.5$ m), respectively, while the largest percentage of the halved, broken, shattered, immature, infested seeds and chaff were collected beyond tray 3 ($x > 1.5$ m). The same trend was observed for the specific gravity separator (Fig. 5). It is evident that the gradient of the curves produced for medium feed rate (Fig. 4) is sharper than that at high feed rate (Fig. 3), indicating that classification was better at medium feed rate.

Table 1: Cross flow classifier system feed rate for the soybean

Operating parameters	Higher feed rate, kgh^{-1}	Lower feed rate, kgh^{-1}
0^{o}, 12m/s	325.6 ± 0.23	146.4 ± 3.81
0 ^{o}, 15m/s	307.2± 0.86	166.0 ± 0.03
0 ^{o}, 18m/s	307.7 ± 0.09	157.5 ± 9.5
22.5 ^{o}, 12m/s	301.3 ± 0.48	154.9 ± 1.82
22.5 ^{o}, 15m/s	310.2 ± 0.80	152.0 ± 4.49
22.5, 18m/s	311.1 ± 3.92	159.6 ± 10.63
45 ^{o}, 12m/s	311.7 ± 2.22	NA[b]
45 ^{o}, 15m/s	312.1± 4.49	160.2 ± 12.87
45 ^{o}, 18m/s	302.4 ± 1.16	167.4 ± 0.01

[a]angle of inclination of blower, air speed)
[b]NA implies not available

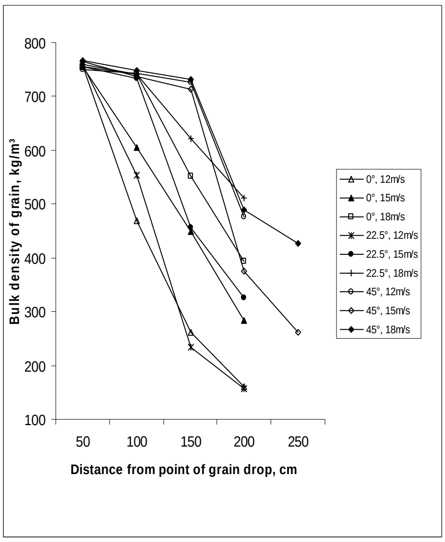

Fig. 3: Density distribution of soybean in the classified chamber at feed rate ≥300 kgh^{-1}

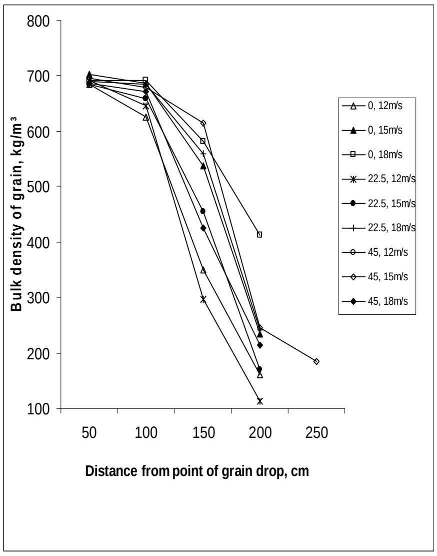

Fig. 4: Density distribution of soybean in the classified chamber at feed rate ≤170 kgh^{-1}

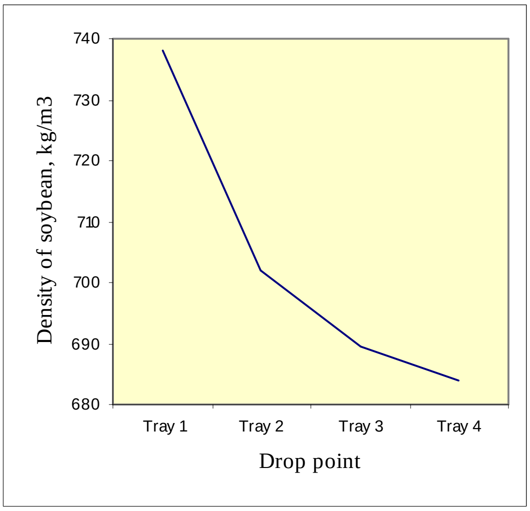

Fig. 5: Density distribution of the soybean in the specific gravity separator

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