MOISTURE DEPENDENCE OF SOME AERODYNAMICS PROPERTIES OF BENISEED

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Abstract
Some aerodynamics properties of two beniseed accessions (Yandev 55 and E8) were determined at moisture content levels of 5.3, 10.6, 16.1 22.4, 28.3 per cent (wet basis). The determined properties were particle diameter, frontal area, terminal velocity and drag coefficients. A - 2 x 5 factorial experiment in Completely Randomized Design with a total of 30 observations was used for each of the parameters. The particle diameter and frontal area increased from 1.52 to 1.78 mm and 1.77 to 2.49 mm^2 for Yandev 55; 1.74 to 2.18 mm and 2.38 to 3.73 mm^2 for E8, respectively as the moisture content increased from 5.3 to 28.3%. The respective terminal velocities decreased from 3.05 to 2.74 m/s and 2.80 to 2.48 m/s for Yandev 55 and E8 within the studied moisture content levels. Increasing the moisture content from 5.3 to 16.10% increased the drag coefficient from 2.67 to 2.70 and 2.74 to 2.78 for the two accessions, respectively. A further increase to 22.4% deccreased the respective values to 2.64 and 2.61. The effect of moisture content on beniseed was highly significant on the terminal velocity.

Keywords: Aerodynamics, Properties, Beniseed, Accessions, Moisture content

Introduction

The economic relevance of beniseed becomes apparent when one considers that it is put to various forms of usage with almost all parts of the plant being utilized. These includes edible seeds, leaves used in soups, stems used as domestic fuel and the extracted oil for numerous purposes such as cooking, lubrication, solvents for drugs and perfumes, soap manufacture, margarine and spirit. High demand for the seed exists on the global cash crop market (Oyeku et al., 2006; Akinoso et al., 2006).

The major characteristics used in separation are size, shape, density, surface texture, terminal velocity, electrical conductivity, colour and resilience (Koya and Adekoya, 1994; Lucas and Olayanju, 2003). These determine what methods of cleaning can be used and their level of efficiency. Most cleaning operations used physical and aerodynamics properties of grain either singly or in some combination. This depends primarily on the grain being cleaned, the quantity of weeds and other contaminants in the mixture and the purity requirements that must be met.

Cleaning methods are classified as either "wet" or "dry" type. Wet methods leave the product surface moist, thus posing a number of problems such as making material susceptible to attack by micro organisms, causing pollution with waste water effluent (Olayanju et al., 2003). Hence, there is preference for dry-type processes. The economics of drying after separation of crop products and convenience of pneumatic conveyance has, therefore, influenced the desirability of exploiting crops in air streams (Babatunde and Olowonibi, 2000).

Therefore, the objective of this work was to determine some aerodynamics properties of two beniseed accessions (Yandev 55 and E8) at various moisture content levels. The properties determined were particle diameter, frontal area, terminal velocity and drag coefficients.

Materials and Methods

Description of Test Equipment

Terminal velocity of beniseed, the velocity at which the seed remains in suspension, was measured by using a vertical air tunnel (Figure 1). It consists of the following components: a frame, wind tunnel, plenum chamber, flow straightener, centrifugal blower, electric motor, pitot tubes and inclined manometer filled with coloured water.

The centrifugal fan was mounted on a frame and it provides air current for the equipment. A vertical tunnel which was coupled to the fan is 1200 mm long with 100 mm x 100 mm cross section. Air current was monitored in the tunnel with a pitot-static tube mounted inside the tunnel below the product-holding screen. These were two in numbers; the total pressure pitot tube and the static pressure pitot tube. The former is a right-angled bent tube with long arm being 290 mm and short arm being 95 mm. The static tube is straight with 200 mm^2. The diameter of the glass tube is about 10 mm.The out ports of the pilot static tube were connected to the two arms of a - coloured water filled manometer.

Principle of Operation

From Bernoulli's equation (Douglas et al., 1985), at two points 1 and 2 in a flowing fluid (Figure 2):

$$\frac{P_1}{D} + \frac{V_1^2}{2g} + m = \frac{P_2}{D} + \frac{V_2^2}{2g} + h_2$$

where $\frac{P}{D}$ is the pressure head

$\frac{V^2}{2g}$ is the velocity head and h is the elevation head.

D is the density based on gravity.

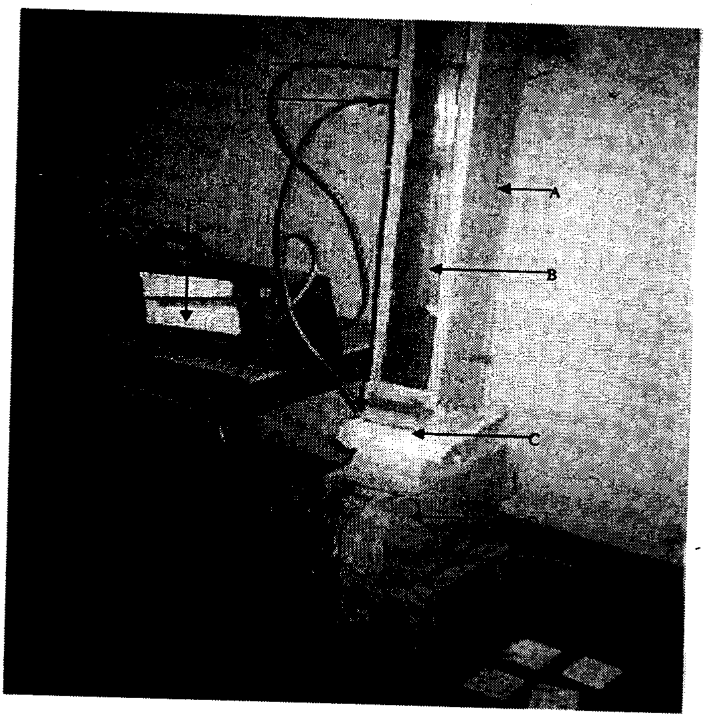

Figure 1: Terminal Velocity Test Equipment

A – Vertical Tunnel; B – Perspex Glass; C – Seed Inlet; D – Centrifugal Blower; E – Manometer; F – Total Pressure Tube; G – Static Pressure Tube

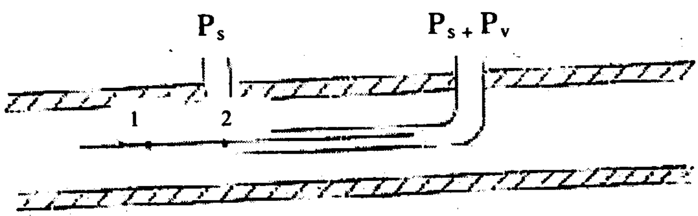

Figure 2: Static and Total Pressure Pitot Tubes

Bernoulli's principle states that in a pipe where fluid flows under steady state conditions without friction, total head is constant; if pressure head is lost, it would appear as an angle of inclination, $\acute{\O} = 12^0$ gain in velocity head.

In a flow of fluid through a level pipe as shown above, applying Bernoullis equation to points 1 and 2 gives:

$$\frac{P_1}{D} + \frac{V^2}{2g} = \frac{P_2}{D} + 0$$

The velocity at point 2 is zero as this is a stagnation point where only static pressure is considered to be acting. Therefore,

$$\frac{P_2 - P_1}{D} = \frac{V^2}{2g}$$

The pressure heads measured by the manometer is h. Therefore,

$$V = \sqrt{2gh}$$

where, h is the head measured by the manometer after it has been converted into head of working fluid. In this, the range of different air velocities was obtained by adjustable speed motor attached with blower.

Measurements of Terminal Velocity

The test equipment was initially run without any seed while response of the measuring instrument: Pitot – static tube and manometer were observed. The beniseed sample was placed on a mosquito wire netting within the duct and was blown upwards using a centrifugal blower whose speed was controlled by a variable speed motor. The air velocity at which the seed was suspended in the air was determined. Five readings were taken for each observation.

Computation of Terminal Velocity using Sphericity Method

The terminal velocity of beniseed was also computed based on its sphericity. According to the equation proposed by Torobin and Gauvin (1960) as reported by Gorial and O'callaghan 1991; the drag coefficient, $C_D = 5.31 - 4.884\,\psi$ for low Reynold's number (with $\pm$ 4% accuracy) where ψ is sphencity of grain with $2000 < Re < 200{,}000$.

The value of C_D was then used in an equation proposed by Kashayap and Pandya (1986) for calculation of terminal velocity as:

$$V_t = \sqrt{\frac{2Mg}{A_p S_f C_D}}$$

where:

M = Weight of particle (kg)

A_P = Projected area of seed, LW (m^2)

C_D = Drag Coefficient

δ_f = Density of fluid (air), (kg/m^3) = 1.150

g = Acceleration due to gravity, m/s^2 = 9.81

Note that density and viscosity of air were assumed constant at the temperature and pressure when the experiment was carried out

Results and Discussion

A summary of the result obtained for terminal velocity of beniseed using the vertical wind tunnel and manometric displacements for the pitot – static – tube is as shown in Table 1. The result of computed terminal velocities using equation based on the sphericity of the seed at different moisture content levels is shown in Table 2. The difference between the mean terminal velocity of 2.0 m/s obtained based on the manometric measurements and 2.6 m/s obtained from computation based on sphericity may be due to human error and turbulence in the air stream. However, the two results compared favourably well with those obtained for other crops by Perry et al. (1985); Koya and Adekoya (1994) as well as Babatunde and Olowonibi (2000).

The analysis of variance tables are summarized in Table 3. The result indicates that only moisture content levels have highly significant effects on the terminal velocity of beniseed at the 0.05 level. Consequently dry separation using air stream will considerably reduce cost of processing.

Table 1: Measured Terminal Velocity of Beniseed Using Vertical Tunnel

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Table 2: Computed Terminal Velocity of Beniseed based on Sphericity

Variety	M.C %wb	Mass, M (10^{-6}kg)	Projected Area, Ap ($10^{-6}m^2$)	Sphencity ψ	Drag coeff $C_d = 5.31 - 4.8844\psi$ (± 4% accuracy)	Terminal Velocity, m/s $V_t = \sqrt{\frac{2Mg}{A_p S_f C_D}}$
Y-55	5.3	2.63	1.803	0.541	2.668	3.054
	10.6	2.72	1.938	0.540	2.673	2.993
	16.10	2.88	2.120	0.535	2.697	2.931
	22.40	2.93	2.307	0.544	2.653	2.858
	28.30	2.96	2.556	0.547	2.638	2.736
E8	5.3	2.98	2.375	0.527	2.736	2.797
	10.6	3.02	2.559	0.528	2.731	2.715
	16.10	3.08	2.820	0.518	2.780	2.589
	22.40	3.46	3.129	0.519	2.775	2.459
	28.30	3.50	3.712	0.553	2.609	2.483

Table3: Analysis of Variance for the Mechanical Characteristics of Beniseed at 5% Significance Level*

Source of variation	Degree of freedom	Sphericity, %	Drag Coefficient,	Terminal Velocity m/s
Treatment	9			
Main effects: Accession (A)	1	0.0434^{NS}	0.0341^{NS}	0.0571^{NS}
Conditioning (C)	1	4.141^{NS}	18.13**	4.350^{NS}
Moisture content (M)	2	2.281^{NS}	7.000^{NS}	193.00**
2 – way interactions (A X C)	1	122.25**	1.05^{NS}	11.00^{NS}
(A X M)	2	1.091^{NS}	18.00**	0.434^{NS}
(M X C)	2	0.464^{NS}	0.060^{NS}	1.00^{NS}
3 – way interactions (A X C X M)	2	0.0078^{NS}	0.0031^{NS}	0.0006^{NS}
Total	11			

values represent F – calculated; **highly significant difference; NS - non significant difference

Conclusion

Vital values of some aerodynamics properties of beniseed had been established. The following conclusions are drawn:

- The particle diameter and frontal area of beniseed increased from 1.52 to 1.78 mm and 1.77 to 2.49 mm^2 for Yandev 55; 1.74 to 2.18 mm and 2.38 to 3.73 mm^2 for E8 respectively as the moisture content increased from 5.3 to 28.3%.
- The respective terminal velocities decreased from 3.05 to 2.74 m/s and 2.80 to 2.48 m/s for Yandev 55 and E8 within the studied moisture content levels.
- The measured and computed average values of terminal velocity for beniseed are between 2.0 to 2.7 m/s.
- Increasing the moisture content from 5.3 to 16.10% increased the drag coefficient from 2.67 to 2.70 and 2.74 to 2.78 for the two accessions respectively.
- The effect of moisture content on beniseed was highly significant on the terminal velocity.

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