View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Federal University of Agriculture, Abeokuta: FUNAAB Journal

ISSN - 2277 - 0593
© UNAAB 2009

Journal of Natural Sciences, Engineering and Technology

MOISTURE DEPENDENCE OF SOME AERODYNAMIC PROPERTIES OF BENISEED

***[1]T.M.A, OLAYANJU [2]R. AKINOSO, [1]A.A. ADERINLEWO,**
[1]O.U. DAIRO AND [1]I.A OLA

[1]Department of Agricultural Engineering, College of Engineering,
University of Agriculture Abeokuta, P.M.B. 2240, Ogun State, Nigeria.
[2]Department of Food Technology, Faculty of Technology,
University of Ibadan, Oyo State, Nigeria.
***Corresponding author:** tiyanju@yahoo.com

ABSTRACT

Some aerodynamic properties of two varieties of beniseed (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 1.78mm 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 2.74m/s and 2.80 to 2.48m/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% decreased the respective values to 2.64 and 2.61. The effect of moisture content on beniseed was highly significant on the terminal velocity.

Keywords: Aerodynamic, 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 include 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).

One approach at meeting increasing demands for food supplies is reducing heavy losses of food grain at the post harvest stage (Classen, 2002). UNIFEM (1998) gave post harvest losses estimate in Nigeria to be up to 25%. Harvesting and post harvest handling methods encourage the presence of contaminants such as stones, sticks, chaff and dust (Wang *et al.,* 2004), which need to be cleaned. Adegbulugbe (1983) reported that the total cost of losses, which occur during post harvest phase, is substantially greater than that incurred during the production phase. He pointed out that grain threshed manually using simple appliances require considerable additional cleaning before it can be used as food, whole or ground and even as seed. The cleaning process, he postulated, presents more difficulties than the actual threshing process.

Before the introduction of the first set of machines, contaminants were removed from seeds by hand. A mixture of grain and straw was spread in a thin layer on the threshing floor and the large contaminant particles mostly pieces of straw, were removed with a rake. The remaining contaminants larger than the grains were removed with broom or goose wing. Light contaminants were removed by throwing the grain against the wind which lifted the contaminants and ensured partial separation.

This manual process is usually time and energy consuming and the efficiency of separation is low. This led to the invention of cleaning machines. The operation of those machines as reported by Adegbulugbe (1983) consists almost solely of separating non-edible impurities such as rubble, lumps, stick, straw, stringe and trapped irons which are obvious. 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 combinations. 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 is to determine some aerodynamics properties of two varieties of beniseed (Yandev 55 and E8) at various moisture content levels. The properties include particle diameter, frontal area, terminal velocity and drag coefficients.

MATERIALS AND METHODS

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 1200mm long with 100mm x 100mm cross section. An adjustable flap at the top of the fan allows variation of admission of air from the fan into the tunnel. The tunnel was built with mild steel sheet but the front was covered with 2mm thick transparent plastic material for observation. A window was cut at the front of the test section, and below it is a small screen braced to cover the inside of the section. This was to break small eddies behind the vanes and to keep the seed from falling into the chamber (Figure 2).

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 290mm and short arm being 95mm. The static tube is straight with 200mm^2. The diameter of the glass tube is about 10mm.

The out ports of the pilot static tube were connected to the two arms of a - coloured water filled manometer. It is made with a 10mm diameter glass tube inclined at 12^0 to the horizontal. It has a length of 440mm; longer limb 320mm and shorter limb 320mm. The manometer was installed on a – 700mm long, 400mm wide and 12mm thick plywood. Two-holes were drilled at the top of the frame to hold the rubber corks through which manometer limbs passed out. The manometer was connected to the pilot tubes by Ǿ 10mm rubber tubes. A ruler was screwed to the frame below the manometer. This is to aid the reading of the rise of the liquid.

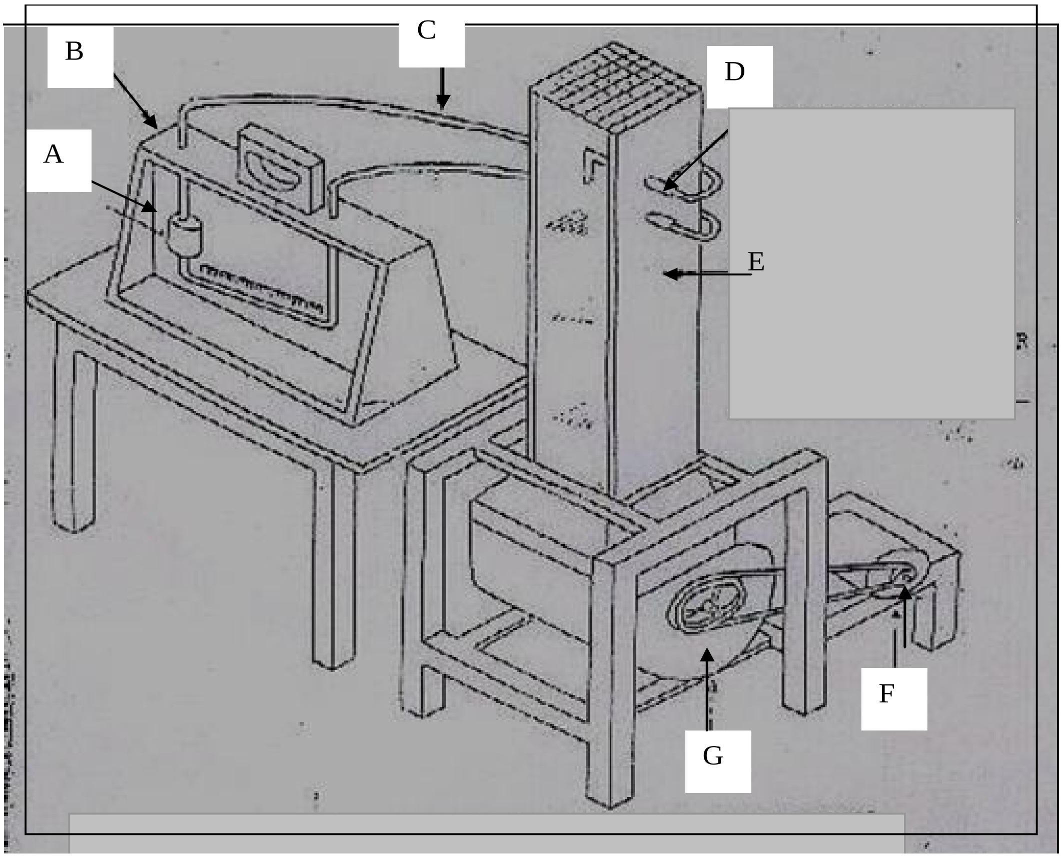

Figure 1: Isometric View of the Terminal Velocity Test Equipment
A – Manometer; B – Manometer Box; C – Rubber Hose; D – Pitot Tube; E – Wind Duct; F – Electric Motor; G – Blower

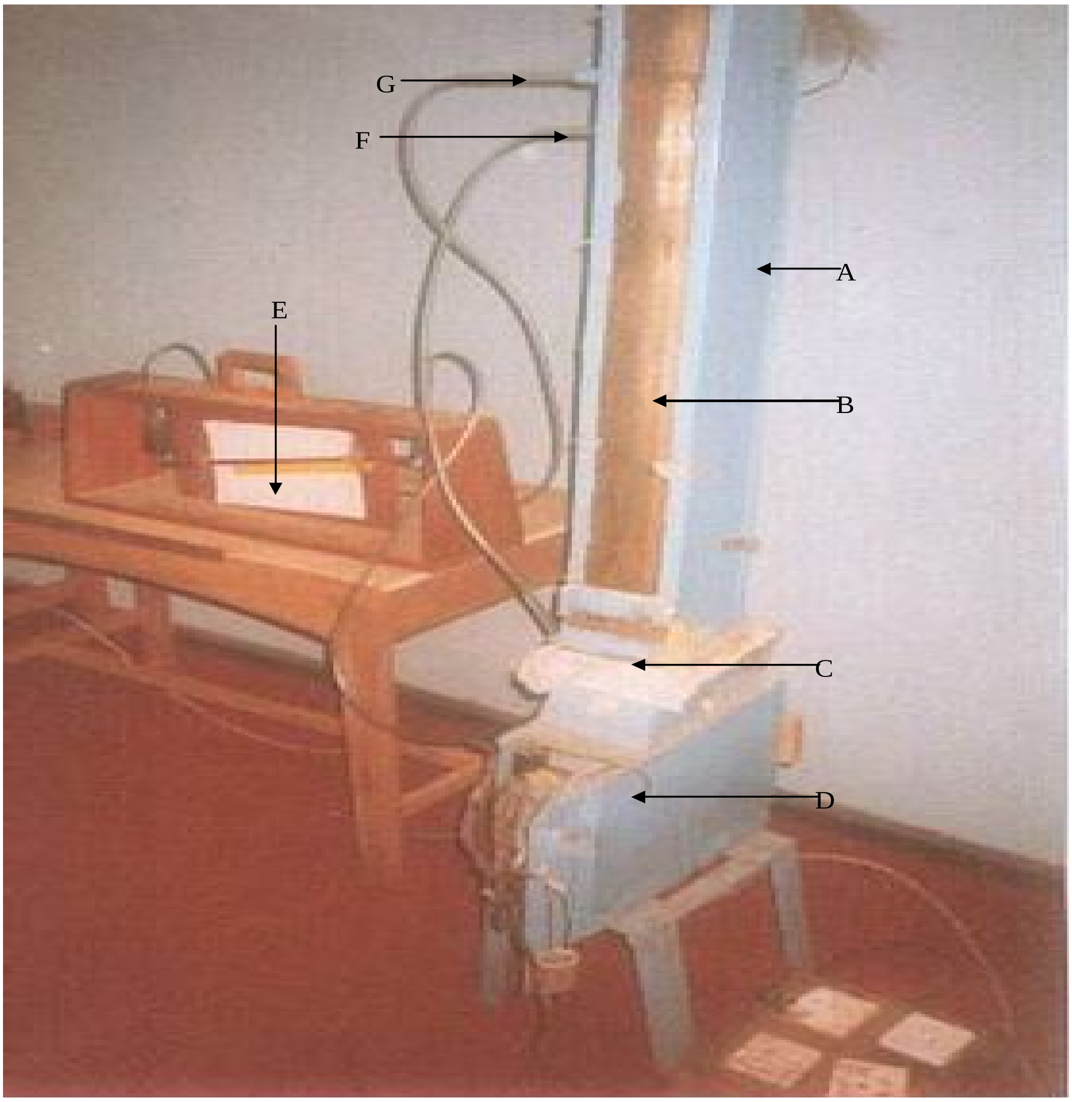

Figure 2: Terminal Velocity Test Equipment
A – Vertical Tunnel; B – Perspex Glass; C – Seed Inlet; D – Centrifugal Blower; E – Manometer; F – Total Pressure Tube; G – Static Pressure Tube

Principle of Operation

From Bernoulli's equation (Douglas *et al.*), at two points 1 and 2 in a flowing fluid (Figure 3):

$$\frac{P_1}{\rho} + \frac{V_1^2}{2g} + m = \frac{P_2}{\rho} + \frac{V_2^2}{2g} + h_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where, $\frac{P}{\rho}$ is the pressure head

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

ρ is the density based on gravity.

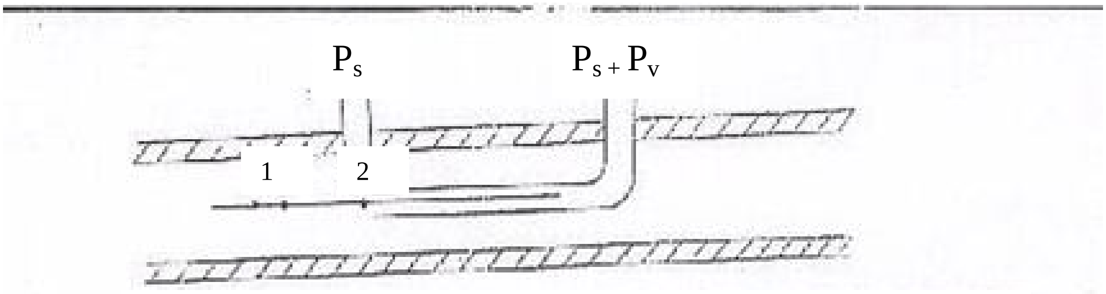

Figure 3: Static and Total Pressure Pitot Tubes

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 appears as a $\acute{\varnothing} = 12^0$ 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:

$$\frac{P_1}{\varrho} + \frac{V^2}{2g} = \frac{P_2}{\varrho} + 0 \quad \text{……………..(2)}$$

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

$$\frac{P_{-2} - P_1}{\varrho} = \frac{V^2}{2g}$$

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

$$V = \sqrt{2gh} \quad \text{………………(3)}$$

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 lifted off the contacting surface 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 Ganvin (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 sphericity 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:

$$V_t = \sqrt{\frac{2Mg}{A_p \varrho_f C_D}} \quad \text{………………...(4)}$$

where:

M = Weight of particle (kg)

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

C_D = Drag Coefficient

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

Note that- Density and Viscosity of air were assumed constant at the temp and pressure when the experiment was carried out.

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

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 2.0m/s obtained based on the manometric measurements and 2.6m/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.

CONCLUSION

Vital values of some aerodynamics properties of beniseed had been established. This would assist engineers, food scientists and processors to improve the mechanisation of production and utilisation processes of Nigerian grown beniseed. The following conclusions are drawn:

- The particle diameter and frontal area of beniseed increased from 1.52 to 1.78mm 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 2.74m/s and 2.80 to 2.48m/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 2.7m/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.

ACKNOWLEDGEMENTS

Part of this work was conducted at the Department of Agricultural Engineering, Federal College of Agriculture, IART, Ibadan with the assistance of Dr O Adejuyigbe. Prof. V.I.O. Olowe of the Research and Development Centre (IFSERAR) UNAAB provided the beniseed accessions used for the study.

Table 1: Measured Terminal Velocity of Beniseed at the Storage Moisture Content of 5.3%

Serial No	Inclined length L, 10-3(m)	Actual length hw = Ls inθ, 10-3 (m)	Height of air a=hwdw/da, 10-3 (m)	Terminal velocity Vt = 2/gha, (m/s)
1	1.1	0.23	0.19	1.95
2	1.2	0.25	0.21	2.02
3	1.1	0.23	0.19	1.95
4	1.1	0.23	0.19	1.95
5	1	0.21	0.17	1.84
6	1	0.21	0.17	1.84
7	1.2	0.25	0.21	2.02
8	1.1	0.23	0.19	1.95
9	1.2	0.25	0.21	2.02
10	1	0.21	0.17	1.84
11	1.1	0.23	0.19	1.95
12	1.1	0.23	0.19	1.95
13	1.2	0.25	0.21	2.02
14	1.4	0.29	0.24	2.18
15	1.1	0.23	0.19	1.95
16	1.1	0.23	0.19	1.95
17	1.2	0.25	0.21	2.02
18	1.2	0.25	0.21	2.02
19	1.2	0.25	0.21	2.02
20	1.1	0.23	0.19	1.95
21	1.2	0.25	0.21	2.02
22	1.1	0.23	0.19	1.95
23	1.1	0.23	0.19	1.95
24	1.6	0.33	0.28	2.33
25	1	0.21	0.17	1.84
26	1.1	0.23	0.19	1.95
27	1.2	0.25	0.21	2.02
28	1.2	0.25	0.21	2.02
29	1.4	0.29	0.24	2.18
30	1.2	0.25	0.21	2.02
31	1.4	0.29	0.24	2.18
32	1.1	0.23	0.19	1.95
33	1.5	0.31	0.26	2.26
34	1	0.21	0.17	1.84
35	1.5	0.23	0.19	1.95
36	1.6	0.33	0.28	2.33
37	1.1	0.23	0.19	1.95
38	1.1	0.23	0.19	1.95
39	1.2	0.25	0.21	2.02
40	1.1	0.23	0.19	1.95
41	1	0.21	0.17	1.84
42	1.1	0.23	0.19	1.95
43	1.5	0.31	0.26	2.26
44	1.1	0.23	0.19	1.95
45	1.2	0.25	0.21	2.02
46	1	0.21	0.17	1.84
47	1.1	0.23	0.19	1.95
48	1.6	0.23	0.19	1.95
49	1.6	0.33	0.28	2.33
50	1.1	0.23	0.19	1.95
Mean	**1.176**	**0.2452**	**0.2036**	**2.0018**
Max.	**1.6**	**0.33**	**0.28**	**2.33**
Min.	**1**	**0.21**	**0.17**	**1.84**
SD	**0.16**	**0.032**	**0.029**	**0.13**

θ = Manometer's angle of inclination = 12deg;

δw = Density of manometer's fluid (water) = 1000kg/m;

δa = Density of air at room temperature = 1.2kg/m; g = Acceleration due to gravity = 9.81m/s

Table 2: Computed Terminal Velocities of Beniseed based on Sphericity

Variety	M.C % wb	Mass, M (10^{-6}kg)	Projected Area, Ap (10^{-6}m^2)	Sphen-city ψ	Drag coeff $C_d = 5.31 - 4.8844\,\psi$ ($\pm$ 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

Table 3: 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

REFERENCES

Adegbulugbe, T. A. 1983. An Investigation into the Pneumatic Separation of Rice and Stone. Unpublished M.Sc. Thesis in Agricultural Engineering Dept., University of Ibadan.

Akinoso, R., Igbeka, J.C., Olayanju, T.M.A. 2006. Process Optimisation of Oil Expression from Sesame Seed (Sesamum indicum Linn.). *Agricultural Engineering International – the CIGR Ejournal,* Manuscript FP06 011. VIII: December, 7pp. International Commission of Agricultural Engineering, U.S.A. (online @ http://www.cigr-ejournal.tamu.edu)

Babatunde, O.O., Olowonibi, M.M. 2000. Experimental Study of Cleaning Dry Crop products Using Forced Air Stream in a Vertical Tunnel. Proceedings of the Nigerian Institution of Agricultural Engineers, 22: 103– 107.

Classen, S.L. 2002. Seed Management on Agricultural Research Farms. IITA Res. Guide 12.

Douglas, J.F, Gascorek, J.M., Swafield, J.A. 1985. Fluid Mechanics. 2nd Ed. ELBS. London 730 P.

Gorial, B.Y., O'callaghan, J.R. 1991. Separation of Particles in a Horizontal Air Stream. Journal of Agricultural Engineering Research (JAER) 49: 273 – 284.

Kashayap, M.M., Pandya, A.C. 1986. Air Velocity Requirement for Winnowing Operations. *Journal of Agricultural Engineering Research* (JAER) 11(1): 24 - 32.

Koya, O.A., Adekoya, L.O. 1994. Some Physical and Aerodynamics Properties Prevalent in Destoning Some Grain Crops. *Ife Journal of technology,* 4 (2): 35 – 40.

Lucas, E.B., Olayanju, T.M.A., 2003. Effect of Moisture Content on Some Physical Properties of Two Beniseed (Sesamum indicum L.) Accessions. *Journal of Applied Science and Technology,* 3(1): 7–12.

Olayanju, T.M.A., Hassan, L.O., Oresanya, M.O. 2003. Mechanical Dehulling of Beniseed – Process and Equipment. *Tropical Oilseeds Journal,* 8: 72–82.

Oyeku, O.M., Kupoliyi, C.F., Adeyemo, F.S., Oyedoyin, B.O., Oresanya, M.O., Akinoso, R., Olayanju, T.M.A. 2006. Economic Evaluation of Beniseed Oil Production. *Journal of Industrial Research and Technology,* 1(1): 41–48.

Perry, R.H., Green, D.W., Maloney, J.O. 1985. 6th Ed. Perry,s Chemical Engineer's Handbook. McGraw-Hill Book Co. New York, 5: 9–12.

UNIFEM, 1988. Cereal Processing Food Cycle and Technology Source Book 3. The United Nations Development Fund for Women.

Wang, Y.S., Chung, D.S., Spillman, C.K., Eckhoff, S.R., Rhee, C., Converse, H.H. 2004. Evaluation of Laboratory Grain Cleaning and Separating Equipment – Part 1. *Trans. ASAE,* 37(2): 507–513.

(Manuscript received: 7th October, 2008; accepted: 14th May, 2009).