International Journal of Food Engineering

Volume 4, *Issue* 8 | 2008 | *Article* 7

The Effects of Varieties and Moisture Content on Some Physical and Aerodynamic Properties of Sesame Seeds (*Sesamum indicum L*) as Related to Cleaning

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Recommended Citation:
Akinoso, Rahman; Olayanju, Tajudeen Adeniyi; Idehai, John Ohioma; and Igbeka, Joe (2008) "The Effects of Varieties and Moisture Content on Some Physical and Aerodynamic Properties of Sesame Seeds (*Sesamum indicum L*) as Related to Cleaning," *International Journal of Food Engineering*: Vol. 4: Iss. 8, Article 7.
DOI: 10.2202/1556-3758.1303

The Effects of Varieties and Moisture Content on Some Physical and Aerodynamic Properties of Sesame Seeds (*Sesamum indicum L*) as Related to Cleaning

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Abstract

Some physical and aerodynamic properties of two varieties of sesame seeds (Yandev -55 and E8) were determined at varied moisture content levels. These properties are factors in the design and selection of sesame seed-cleaning machines. For the Yandev-55 and E8 varieties, major diameters ranged from 2.8 mm to 3.3 mm and 3.4 mm to 3.8 mm, intermediate diameters ranged from 1.8 mm to 2.1 mm and 2.2 mm to 2.5 mm, and minor diameters ranged from 0.7 mm to 0.9 mm and 0.6 to 0.9 mm, respectively. Their geometric means ranged from 1.5 to 1.8 mm and 1.7 to 2.0 mm, their spheroids ranged from 0.5 to 0.6 and 0.5 to 0.6, and their frontal areas ranged from 1.8 to 2.6 and 2.2 to 3.2, respectively. The terminal velocities of Yandev-55 were 2.9, 3.6, 4.7 and 5.4, while the terminal velocities of E8 were 3.4, 4.12, 5.1 and 6.3 at a moisture content level of 8.0, 10.3, 15.9 and 21.2 % (w.b.), respectively. The drag coefficients were in the range of 0.4 to 2.7 while Reynolds number varied from 2775.0 to 7840.7. The terminal velocities of the associated materials within the seeds were 1.5, 2.3, 3.1, and 3.6 at a moisture content level of 8.0, 10.3, 15.9 and 21.2%, respectively. The studied properties significantly varied with the varieties of sesame seeds. Also, the effects of moisture content are non negligible.

KEYWORDS: sesame seed, variety, moisture content, physical properties, aerodynamic properties

INTRODUCTION

Sesame seed are pear-shaped, ovate, small, slightly flattened, and thinner at the hilium. The colour varies; it is either white, yellow, reddish brown or black. Light-coloured seeds yield better quality oil than dark but lower oil content (Weiss 2000). The oil content varies with genetic and environmental factors (Sudhi *et al* 1996). Sesame is adapted to equatorial and subtropical regions of the world. It is fairly drought resistant, thrives best in hot dry area, and has a well-developed tap root system that can reach underground water layers (Voh 1998). An average daily temperature of 23 – 30 ^{o}C and annual rainfall of 625 – 2,250 mm is required for effective growth of sesame (Busari and Ajewole 1993). It matures within 4 months of cultivation. The major sesame seed producing countries are India, Mexico, Sudan, China, Burma and Nigeria.

The seed is a staple food of many ethnic groups in Nigeria and it is cultivated in most of the local government areas of north central Nigeria. Sesame seed is a priced oilseed in the world because of the products that are derived from it. It is a rich source of edible oil, protein, phosphorous and calcium. The oil reacts rapidly on exposure to air, but forms a soft film after long exposure. This unique characteristic makes it one of the major edible oils in the semi-drying oil (Yen and Shyu 1989). The seed contains about 50 – 55 % oil; 20 – 25 % protein; 20 – 25 % carbohydrate; 5 – 6 % ash while the hull accounts for about 20 % of the seed (Sahay 1998). The oil is widely employed as cooking oil and raw materials in the manufacture of margarine and pharmaceuticals.

Harvested sesame after threshing contains foreign materials and impurities which affect the quality and market value of the end products. Hence, separation processes are carried out to ensure clean seeds. The knowledge of physical and aerodynamic properties of the oilseed is required in the design of cleaning machine. Yandev -55 and E8 are the two main varieties that are commercially cultivated in Nigeria (NCRI 2003), thus the scope of this report is limited to the two varieties. The information on the interaction between sesame varieties and moisture content is necessary in knowing whether a screen specified for Yandev -55 at a given moisture content can be used for E8 at the same or different moisture content.

MATERIALS AND METHODS

The two varieties of sesame (Yandev- 55 and E8) used for this experiment were sourced from National Cereal Research Institute (NCRI) Badegi Nigeria. Both Yandev- 55 and E8 are commercially grown in Nigeria. The moisture content of the seeds was determined using ASAE 1998 standard. The desired moisture contents were obtained by adding distilled water calculated from equation 1(Akinoso et al 2006).

$$Q = A(b-a) / (100-b) \quad (1)$$

where
A - Initial mass of the sample
a - Initial moisture content of the sample, % wet basis (w.b.)
b - Final (desired) moisture content of sample % w.b.
Q - Mass of water to be added kg.

Each sample was sealed in a separate polyethylene bag. These samples were kept at 5 ^{o}C in a refrigerator for a week to enable the water to distribute uniformly. Four moisture content levels were prepared for each variety and they were 8.0, 10.3, 15.9 and 21.2 % all on wet basis. In determining the size of the seed, 1000 kernels were randomly selected from each variety. From the sample of 1000 kernels, 100 seeds were randomly selected and their three principal dimensions namely major, intermediate and minor diameter were measured with a digital micrometer screw gauge (China) with accuracy of 0.01mm. Mean values were recorded as geometric dimension. The geometric mean diameter, spheroid and frontal area of the seeds were determined using the following equations (Mohseni 1986).

$$\mathrm{d_p} = (LBT)^{1/3} \quad (2)$$

$$\psi = (LBT)^{1/3} / L \quad (3)$$

$$A_p = \pi d_p^{\,2} / 4 \quad (4)$$

where
d_p - geometric mean diameter, m
A_p - frontal area, m^2
ψ - spheroid
L - major diameter, mm
B - intermediate diameter, mm
T - minor diameter, mm

The true density defined as the ratio of a given mass of sample to volume was determined by displacement method. Accordingly, a known weight (50 g) of samples was poured into a 100 cm^3 graduated cylinder containing 50 cm^3 toluene. The volume of toluene displaced by the sample was observed. For small seeds like sesame, 1000 kernels were weighed and a parameter known as the thousand kernel weight (TKW) was determined. Tecator 6110 electronic weigh balance having a sensitivity of 0.01g was used. Mean values of 10 replications were obtained.

Terminal velocity of sesame seed, the air velocity at which the seed remains in suspension was measured by using a vertical wind tunnel (Sensor UK Ltd). This test equipment was complemented by a manometer and pitot static tubes. A duct 1 m long with a rectangular section of 0.1 m x 0.1 m was used to suspend the seed in an air stream. Air was supplied by a centrifugal fan driven by an electric motor. The seeds were placed on a mosquito wire netting within the duct and were blown upwards using a centrifugal blower whose speed was controlled by a variable speed motor. The air velocity at which the grains were lifted off the contacting surface was determined. Ten readings were taking for each observation. Appropriate equations (5 & 6) were applied to calculate Reynolds number and drag coefficient.

$$R_e = {V_t d_p \rho}/{\mu} \qquad (5)$$

$$C_d = {2F_d}/{A_p} \rho V_t^2 \qquad (6)$$

where

R_e - Reynolds number, dimensionless

V_t - terminal velocity ms^{-1}

d_p - geometric mean diameter m

ρ - density of air kg m^{-3}

μ - kinematics viscosity of air kg s m^{-1}

C_d - drag coefficient

F_d - drag force

A_p - frontal area

Analysis of variance in factorial experiment with 2 factors at various levels was used. The first factor is the variety, V_1 and V_2 Yandev-55 and E8 while the second is moisture content MC_1, MC_2, MC_3 and MC_4 which are 8.0, 10.3, 15.9 and 21.2 %. Regression equations were developed using SPSS software package to relate interaction between moisture content and the investigated physical and aerodynamic properties of sesame.

RESULTS AND DISCUSSION

The geometric dimensions and the geometric mean increased with increase in moisture content of the two varieties of sesame seed (Table 1). The same applies to the frontal area and thousand kernel weight. From the results obtained, the size indices exhibit linear increase with the moisture content. Similar results have been presented by other investigators such as Gowda *et al* (1990) for linseed in the moisture range of 4.5 to 15 %; Hsu *et al* (1991) for pistachios; Arora (1991) for 3 varieties of rough rice at 5 moisture content levels. True density decreased with increase in moisture content . This is due to the fact that as the moisture content increase, the particle volume increases, thus the same weight of the material occupies more volume of the cylinder and hence leading to a decrease in density. Effect on sphericity of the oil seed exhibits a polynomial function. Obtained results in the investigated varieties may be attributed to the large increase in major diameter relative to intermediate and minor diameters. Sesame seed can be said to have a mean sphericity of 0.5 and ovate in the analysis of rate process (Table 1). Subjecting the results in to ANOVA, it was clearly shown that moisture content has highly significant effect on all the parameters but non significant on major diameter and spheroid at 0.05 level of significance (Table 2).

Sesame seed can be cleaned based on properties of the desirable seed and contaminates. According to Sahay (1998) vibration screens separate products on the basis of differences in sizes of various constitute whereas air screen cleaners separate material on the basis of difference in size and weight. If any of these principles is to be applied in design, one of the important factors that must be considered is variety and moisture content of sesame seed. Handling losses during cleaning are affected by size and shape of sesame seed. If the hole is too big, this may result in un-cleaned seeds while too small a hole may lead to lesser efficiency. For optimum performance of the cleaner, the sizes of perforations have to be carefully selected. The regression analysis of interaction between the physical properties and moisture content are shown in Table 3.

A significant effect of moisture content was noticed on terminal velocity, drag coefficient and Reynolds number. The terminal velocity increased with increase in moisture content of the varieties of sesame seed. The same apply to Reynolds number. But reverse was the case for the drag coefficient as increase in moisture content lead to decrease in drag coefficient (Table 4). Addition of moisture to the investigated oilseed increases it weight, thus more force is required to lift the material. This could necessitate the observed increase in terminal velocity with increase in moisture content. Obtained values for Reynolds number and drag coefficient corroborate equations 5 & 6. From equation 5, Reynolds number is directly proportional to terminal velocity and size while these parameters are inversely proportional to drag coefficient (equation 6). As it shown, both terminal velocity and size of sesame seed increase with increase in moisture content. Therefore, behaviour of Reynolds number and drag coefficients of studied varieties of sesame to treatments is rational.

Table 1. Mean physical properties at four different moisture content levels

Materials	Moisture Content (%w.b.)	Majo r Diam. (mm)	Interm. Diam. (mm)	Minor Diam. (mm)	Geom. Mean (mm)	Spheroid	Frontal Area (mm^2)	True Density kg m^{-3}	Thous. Kern. Wt. (g)
Yan 55	8.0	2.8	1.8	0.7	1.5	0.5	1.8	1035.2	2.5
	10.3	2.8	1.8	0.7	1.5	0.5	1.9	1027.0	2.6
	15.9	3.1	1.9	0.8	1.7	0.5	2.2	1010.1	2.8
	21.3	3.3	2.1	0.9	1.8	0.6	2.6	1001.3	2.9
E8	8.0	3.4	2.4	0.6	1.7	0.5	2.2	1030.5	3.0
	10.3	3.5	2.3	0.7	1.8	0.5	2.4	1023.6	3.0
	15.9	3.8	2.4	0.8	1.9	0.5	2.9	1008.1	3.2
	21.2	3.8	2.5	0.9	2.0	0.5	3.2	1000.9	3.3

Major, intermediate and minor diameter, geometric mean, spheroid, frontal area (n=100)
Density and TKW (n=10)

Table 2. Summary of analysis of variance for the physical properties

Source Of Variation	Degree of Freedom	Major Diam. (mm)	Interm. Diam. (mm)	Minor Diam (mm	Geom. Mean (mm)	Spheroid	Frontal Area (mm^2)	True Density kg m^{-3}	Thousand Kernel Wt. (g)
Treatment	7								
Variety	1	7.7**	9.0**	1.2 NS	3.5 NS	0.3**	10.3**	12.0**	964.7**
M. Cont.	3	2.6 NS	63.0**	59.0**	19.5**	0.8 NS	60.4**	72.5**	1301.6**
Interaction	3	0.0 NS	0.1 NS	0.3 NS	0.0 NS	0.3 NS	1.0 NS	1.0 NS	0.7 NS
Error	250								

** Significant difference
NS Non significant difference

Table 3. Regression equations for some physical properties of sesame

Properties	Yandev –55		E8	
Length (mm)	L=0.0364M+2.496	R^2 =0.98	L=0.0315M+3.191	R^2 =0.93
Breath (mm)	B=0.0226M+1.606	R^2 =0.92	B=0.0254M+1.986	R^2 =0.99
Thkns. (mm)	T=0.0131M+0.583	R^2 =0.98	T=0.0161M+0.515	R^2 =0.99
G. Mean (mm)	G=0.0225M+1.326	R^2 =0.97	G=0.0256M+1.488	R^2 =0.99
Sphericity	S=0.0052M+0.567	R^2 =0.83	S=0.0005M+0.723	R^2 =099
F.Area (mm^2)	A=0.075M+1.653	R^2 =0.99	A=0.0587M+1.301	R^2 =0.96
Den. kg m^{-3}	ρ =5.708M+1074.1	R^2 =0.99	ρ =4.9921M+1064	R^2 =0.99
T.K.Wgt (g)	TKW=0.03M+2.74	R^2 =0.98	TKW=0.03M+2.28	R^2 =0.97

M-moisture content, %w.b.
R- Coefficient of determination

Table 4. Mean aerodynamic properties of sesame at four moisture content levels.

Variety	Moisture Cont.(%w.b.)	Terminal Vel. (ms^{-1})	Drag Coeff.	Reynolds Number
Yandev-55	8.0	2.9	2.7	2775.0
	10.3	3.6	1.9	3401.2
	15.9	4.7	1.0	4835.0
	21.2	5.4	0.7	6037.5
E8	8.0	3.4	1.9	3570.2
	10.3	4.2	1.2	4549.3
	15.9	5.0	0.8	5947.1
	21.2	6.3	0.4	7840.7

(n=10)

These results were subjected to analysis of variance and summary of the results are shown in Table 5. As revealed, application of pneumatic separation method for sesame seed cleaning require information on moisture content and variety of the seed as these factors significantly influenced aerodynamic properties of sesame seed. The regression equations in the moisture range for aerodynamic properties are shown in Table 6. As shown from the analysis of variance, there were significance differences in properties of the two investigated varieties of sesame.

Table 5. Summary of analysis of variance for the aerodynamic properties.

Source of Variation	Degree of Freedom	Terminal Vel. (ms^{-1})	Drag Coeff.	Reynolds Number
Treatment	7			
Variety	1	452.6**	163.2**	1861.2**
M. Cont.	3	1743.9**	436.1**	3462.6**
Interaction	3	19.7**	15.8**	56.4**
Error	79			

** Significant difference

Table 6. Regression equation for the aerodynamic properties of sesame

Properties	Yandev –55		E8	
Terminal velocity	V_t=0.183M+1.60	R^2=0.98	V_t=0.204M+1.890	R^2=0.99
Drag coefficient	C_d=55.60$M^{-1.457}$	R^2=0.99	C_d=36.31$M^{-1.4328}$	R^2=0.99
Reynolds Num.	Re=247.3M+836	R^2=0.99	Re=312.1M+1154	R^2=0.99

The mean terminal velocities of chaff/dry leaves at four different moisture contents are shown on table 7. Terminal velocity increased from 1.5 ms^{-1} to 3.6 ms^{-1} in the moisture range of 8.0 % to 21.2 %w.b. Regression equation illustrating the relationship between the terminal velocity of chaff/leaves and moisture content is V_t = 0.1563M + 0.4731. The coefficient of determination R^2 is 0.93 and correlation coefficient r is + 0.97. The chaff was positively correlated with the moisture content. Separation of mixture of each variety of sesame seed with associated material using a vertical air tunnel (Sensor UK Ltd) revealed that for all moisture content levels there was good separation of chaff from the sesame seed with E8 having the best separation. As shown in Fig. 1, wider margin was recorded between terminal velocity of E8 and chaff/dry leaves. Since pneumatic separator operates on the principle of difference in terminal velocities, this might account for better separation recorded from un-cleaned E8 variety than Yandev-55.

Table 7. Mean terminal velocity of the associated materials (chaff/dry leaves)

Moisture content (%w.b.)	Terminal velocity (ms^{-1})
8.0	1.5
10.3	2.3
15.6	3.1
21.2	3.6

(n=10)

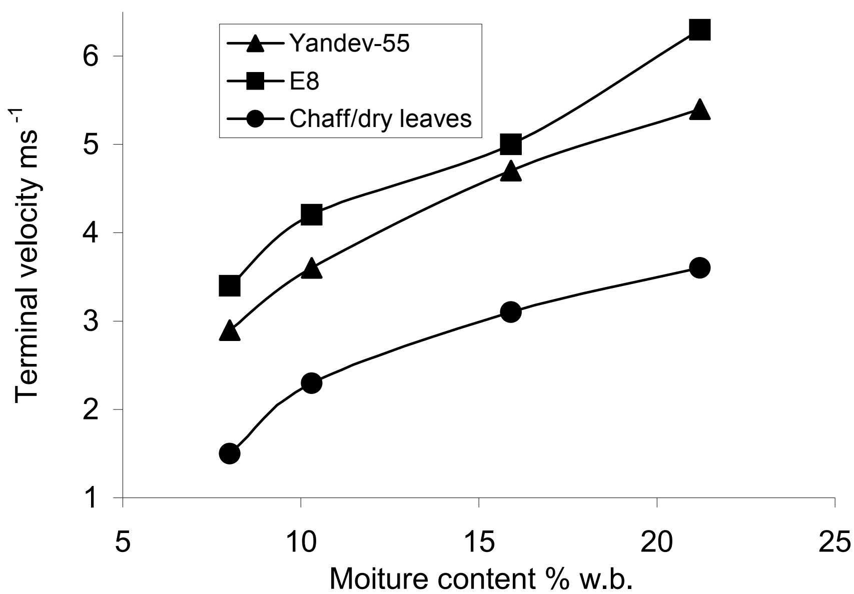

Fig. 1.Plot of terminal velocity against moisture content

DOI: 10.2202/1556-3758.1303

CONCLUSION

The studied properties significantly varied with varieties of sesame seed. Also effects of moisture content are non negligible. It is evidence that variety of sesame seed and moisture content are important factors that must be considered in conceptual design on sesame seed cleaning machines.

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DOI: 10.2202/1556-3758.1303