EFFECT OF MOISTURE CONTENT ON AERODYNAMIC PROPERTIES OF CORN SEED (ZEA MAYS)

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ABSTRACT

Knowledge of the aerodynamic properties of agricultural materials is needed in equipment design for operations such as cleaning, separation and pneumatic conveying in loading/unloading operations of corn seeds into/from silos. While considerable information is available on seed grains, little is known about the aerodynamic behavior of corn seed (*Zea mays* L.). In this research, aerodynamic properties of corn seed at different moisture level were determined. It was observed that moisture content has great effect on seeds aerodynamic properties. The results showed that the terminal velocity of the corn seeds increased linearly from 10.65 to 12.15m/s as the moisture rose from 4 to 40% (d.b) at four levels of moisture content. The results also showed initial decrease in drag coefficient from 0.61 to 0.52 at 4 and 12% moisture content respectively, and thereafter increases from 0.53 to 0.63 at 16 to 40% moisture content respectively, due to the variation in the shape of the seeds as observed on the process. The experiment showed that seed drag coefficient is independent of seed weight, but depends mainly on the shapes of the seed. It was also observed that the seed drag force increased linearly from 1.57 to 2.85 N as the moisture increased from 4 to 40% (d.b). Linear regression model equations for aerodynamic properties and moisture content of seeds were determined from the graph of moisture against aerodynamic properties using excel. The analysis of variance (ANOVA) performed showed a great significant difference in aerodynamic properties at different level of moisture content of the seeds.

KEYWORDS: Maize, Corn, Moisture content, Aerodynamic properties, Terminal velocity, Drag force, Drag coefficient

1. INTRODUCTION

The word *corn* has many different meanings depending on what country you are in. Corn in the United States is also called maize or Indian corn. In some countries, corn means the leading crop grown in a certain district. Corn in England means wheat; in Scotland and Ireland, it refers to oats. Corn mentioned in the Bible probably refers to wheat or barley. It has been established that Mesoamerican region, now Mexico and Central America is the center of origin for Zea mays (Ozkan et al. 2005). According to Bar Yosef (1998), the domestication of maize began at least 6000 years ago, occurring independently in regions of the south-western United States, Mexico, and Central America. The Portuguese introduced maize to Southeast-Asia from the America in the 16th century. The maize was introduced into Spain after the return of Columbus from America and from Spain it went to France, Italy and Turkey. In India, Portuguese introduced maize during the seventeenth century. From India it went to China and later it was introduced in Philippines and the East Indies. Corn is now a major staple food grown in virtually every parts of the world including USA, China, Brazil, Argentina, Mexico, South Africa, Rumania, Yugoslavia, India and West Africa as well as Nigeria (Borojevic and Borojevic, 2005).

Corn has huge economic, nutritional and medicinal importance. Several millions of households, communities and industries rely on corn for their daily diet, survival and raw materials. Maize could be processed into bread, noodles, poultry feeds and other value added products as well as feedstock for biodiesel production. Corn is a storehouse of nutrients essential for human diet. Corn provides nearly 55% of carbohydrate and 20% of the food calories. It contains carbohydrate 78.10%, protein 14.70%, fat 2.10%, minerals 2.10%, indigestible cellulose material called dietary flour and considerable proportions of vitamins (thiamine and vitamin-B) and minerals (zinc, iron). Corn is also a good source of traces minerals like selenium and magnesium, nutrients essential to good health. By nature, con has several medicinal virtues. Starch and gluten in corn provide heat and energy. The outer bran provides the much-needed roughage which cures widespread prevalence of constipation and other digestive disturbances and nutritional disorders, indigestion and aids easy movement of the bowel. Corn can also help to build and repair muscular tissues and can be used for cure of some heart diseases. It has proven effective in handling diseases such as coeliac disease, schizophrenia, gluten ataxia, migraines, acute psychoses, and a range of neurological illnesses. corn also provide protection against ischaemic, disease of the colon, called diverticulum, appendicitis, obesity, diabetes as well as autoimmune diseases such as rheumatoid arthritis which may be more prevalent in coeliac patients and relatives.

Knowledge of aerodynamic properties of grain such as terminal velocity, drag force and drag coefficient are important design criteria for modern harvesters, grain cleaners, pneumatic conveyors and other equipment. It also helps in agro based industries where proper separation of grains from their foreign materials with less or no grain loss is vital. Such design criteria are be based on the aerodynamic characteristics of the grain (Mohsenin, 1970). Nigeria imports large quantity of high quality/ high grade grains annually to meet the growing demand both for consumption and industrial purposes, despite the fact that it is a major producer of maize. The reason for the massive importation as observed is likely due the inferior quality of the locally produced maize occasioned by improper cleaning and poor post harvest operation. In addition, there is lack of local machines for cleaning and separation of contaminants from the products. Importation of these machines is not a viable option as they quit expensive and often times in adaptable to the local maize varieties. The possibility of aerodynamically separating seed from chaff was studied by Uhl and Lamp (1966). Hawk et al (1966) determined the aerodynamic properties of several different kinds of grain in a horizontal wind tunnel. The terminal velocity of alfalfa seed as a function of size has also been reported. Aerodynamic properties has also been used in separating the whole kernel of beans from the broken ones.

The moisture content of agricultural materials greatly affects aerodynamic properties of grains. Despite the huge medicinal, economic importance and the high consumption rate of corn seed and its potential as a good source of foreign earnings for Nigeria if properly winnowed, the traditional method of post harvest processing, provides a poor-quality product. This limits it utilization both locally and internationally. In Nigeria, there is scarcely any large-scale cleaning, winnowing and processing machine. Many small-scale producers carry out these operations manually. Many researchers have worked on the effect of moisture content on aerodynamic properties of various grains, very little information is available for corn seeds.

The broad objective of this work is to determine the effect of moisture content on the aerodynamic properties of corn seed. The specific objectives are to determine the aerodynamic properties of corn seed, to determine the moisture content of corn seeds at various levels and to analyze the results using statistical tools such as SPSS and excel packages.

2. MATERIALS AND METHODS

2.1 Sample Collection and Preparation

The corn seeds samples (Figure 1) used were selected from Corn, Zea Mays L. varieties hybrid single cross (SC 10) planted in the Department of Agricultural Extension Farm, University of Nigeria, Nsukka. The seeds were cleaned manually to remove all foreign materials and immature seeds.

Figure 1. Samples of corn seeds

The initial moisture content of the samples was measured as 9.8% (d.b.). The density of the corn seed samples was also determined by the fluid (Toluene) displacement method (Mohsenin, 1970) as 1267.02 kg/m^3 with three replications. The volume of the seed was calculated from its mass and density. The dimensions (Figure 2) were measured and were used in computing the projected area of the corn seed samples.

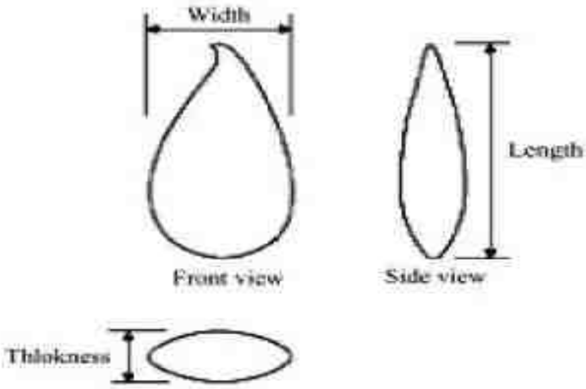

Figure 2. Dimensions of corn seeds

2.2 Determination of Moisture Content of Corn Seeds

The initial moisture contents of the seeds were determined using ASAE 1998 standard. The 500g of the sample was divided into 5 parts. The desired moisture contents were obtained by adding distilled water calculated using equation (1). The samples were quickly transferred to separate high density polyethylene bags and sealed tightly and labeled. The samples were kept at 5°C in a refrigerator for a week to enable the moisture to be distributed uniformly throughout each sample. This rewetting technique to attain the desired moisture content in seeds and grains has frequently been used (Coskun *et al*., 2005; Garnayak *et al*., 2008; Sacilink *et al*., 2002). Before use, the samples were kept in a dessicator (Glaswerk Wertheim, Model 471, Size 1172, Germany) Every weighing and recording was done using electronic balance (Yamato, model HB 3000, Japan) reading to 0.01g.

$$Q = \frac{A(b-a)}{(100-b)} \qquad (1)$$

Where, A is initial mass of the sample (g); a is the initial moisture content of the sample (% dry basis); b is the final (desired) moisture content of sample (% dry basis) and Q is the mass of distilled water to be added (g).

2.3 Determination of Aerodynamic Properties of Corn Seeds

2.3.1 Determination of Terminal Velocity of the Corn Seeds

The terminal velocity of corn seed was determined by the slight modification of that developed by Adejumo et al. (2009) and Babatunde and Olowinbi (2000). The terminal velocity was determined using cylindrical air column with fluid (Glycerol) in a glass measuring cylinder as shown in Figure 3.

Figure 3. Set up for the measurement of terminal velocity

The terminal velocity of the seeds at different moisture content (4-40%) was determined by placing the seeds in the outlet of the cylindrical air column and forced air into the cylindrical air column through air tube connected to the cylindrical air column which then dropped the seed into a glass measuring cylinder filled with glycerol oil. As the seeds was accelerating in the fluid, it was observed at a certain point that the seeds initial velocity ceased and at that point the seed assumed uniform velocity. The initial high velocity of the seed in the viscous fluid was opposed by viscous fluid force of the fluid which equals the viscous drag force and downward force of the seed. On the other hand, as the seed accelerate, the speed increases and so does the viscous force of the fluid until a point is reached were the viscous drag force equals to the downward force. At this stage, the terminal velocity is reached and time is taken for the displacement (i.e. from the initial high velocity to where the velocity ceased and move with uniform velocity) of the fluid. The measured time and displacement is used to calculate the terminal velocity of the seeds at different moisture content using equation (2)

$$V_t = \frac{Displacement(m)}{Time(\sec)} \qquad (2)$$

2.3.2 Determination of the Drag Force of the Corn Seeds

The drag force is a resistive force, opposing the motion of the corn. The most familiar form of drag force is made up of friction forces, which act parallel to the object's surface, plus pressure forces, which act in a direction perpendicular to the object's surface. For a solid object moving through a fluid, the drag is the component of the net aerodynamic or hydrodynamic force acting in the direction of the movement. The component perpendicular to this direction is considered lift. Therefore drag acts to oppose the motion of the object. The drag force can be computed using equation (3)

$$F_d = \frac{C_d \ell_a A_p V_t^2}{2} = C_r V_t^2 \quad (3)$$

The projected area of the corn seed can be calculated using equation (4)

$$A_p = \frac{\pi L W}{4} \quad (4)$$

Where, F_d is the drag force (N); C_d is drag coefficient (dimensionless); ℓ_a is air density (1.25, kg/m^3); A_p particle area projected to air (m^2); V_t is terminal velocity (m/s); C_r is resistance coefficient (kg/m); L is length of the corn seed and W is width of the corn seed.

2.3.3 Determination of the Drag Coefficient of the Corn Seeds

Among aerodynamic properties, the drag coefficient (commonly denoted is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment such as air or water. It is used in the drag equation, where a lower drag coefficient indicates the object will have less aerodynamic or hydrodynamic drag. The drag coefficient is always associated with a particular surface area. It is computed with equation (5)

$$C_d = \frac{2F_d}{V_t^2 \ell_a A_p} \quad (5)$$

Where, all the parameters and units are as defined earlier.

2.4 Statistical Analyses

Data was analyzed statistically using SPSS and simple Excel packages. Analysis of Variance (ANOVA) was performed to determine the significance of the treatment and interaction effects. When analysis of variance was significant at the *5%* probability level, treatments were separated by Duncan's New Multiple Range Tests at the 5% level of probability. Simple Excel was used to plot the graph of Moisture Content (%db) of the corn seeds at various level against the aerodynamic properties of seeds to obtain graphical and linear representation of moisture effect on aerodynamic properties of the seeds.

3. RESULTS AND DISCUSSIONS

Table 1 presents the mean values of the terminal velocity, drag coefficient and drag force of corn seeds at various moisture content (% db).

Table 1. Mean values of aerodynamic properties of corn seeds

Moisture Content (%) d.b	Mean Terminal Velocity(m/s)	Mean Drag Coefficient (C_d)	Mean Drag Force (N)
4	10.65	0.61	1.57
8	10.77	0.55	1.68
12	11.14	0.52	1.77
16	11.36	0.53	1.88
20	11.46	0.57	1.98
24	11.65	0.54	2.08
28	11.69	0.57	2.25
32	11.77	0.58	2.45
36	12.04	0.64	2.71
40	12.15	0.63	2.85

3.1 Aerodynamic Properties of Corn Seeds

3.1.1 Terminal Velocity

It was observed that moisture content significantly affected terminal velocity. By increasing moisture content from 4 to 40%, the terminal velocity increased linearly from 10.65 to 12.15m/s. This result was the same as found by other researchers for some other agricultural materials (Tabak and Wolf, 1998; Gupta and Das, 1997; Suthar and Das, 1996 and Carman, 1996). Figure 4 shows the effect of corn moisture content on terminal velocity. The reason for the increase in terminal velocity with moisture content could be because of the increase in the mass of an individual seed per unit frontal area presented to the airflow. The relationship between moisture content and terminal velocity produced a linear equation with a very high coefficient of determination, R^2 of 0.966.

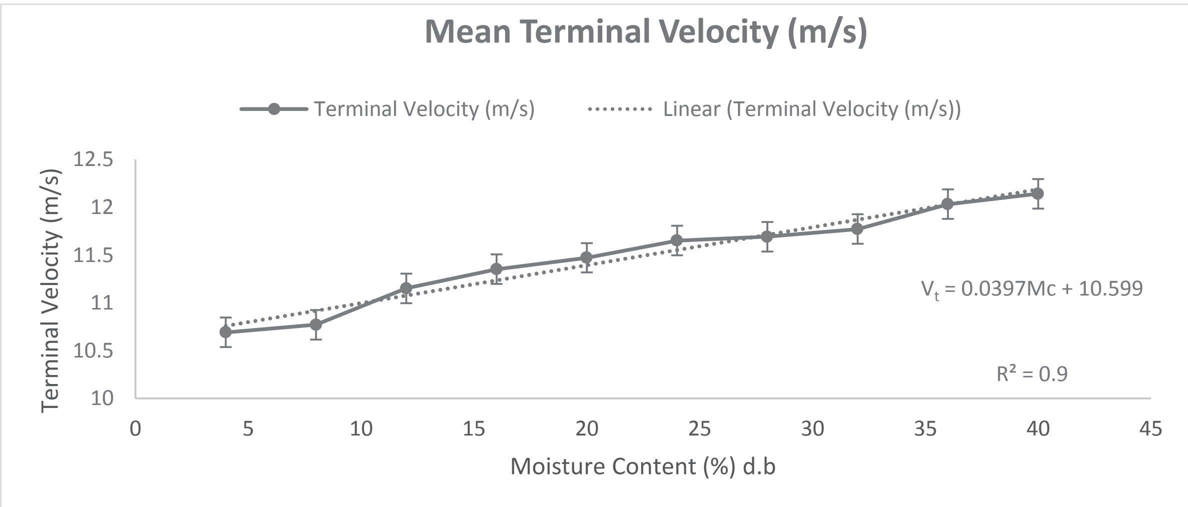

Figure 4. Terminal velocity (m/s) as affected by moisture content (%db)

3.1.2 Drag Force

Drag force is the force acting opposite to the relative motion of the seed moving with respect to a surrounding fluid. Drag force increased linearly from 1.57 to 2.85N as moisture content vary from 4 to 40%db at an intervals of 4. From Table 5, it is clear that moisture has great effect on seeds drag force. Increase in the acceleration of seeds in the fluid leads to increase in the drag force of the fluid. And this increase in acceleration of seeds in the fluid is caused by increase in the moisture content of the seeds. The relationship is a linear curve with a very high coefficient of determination, R^2 (0.9743).

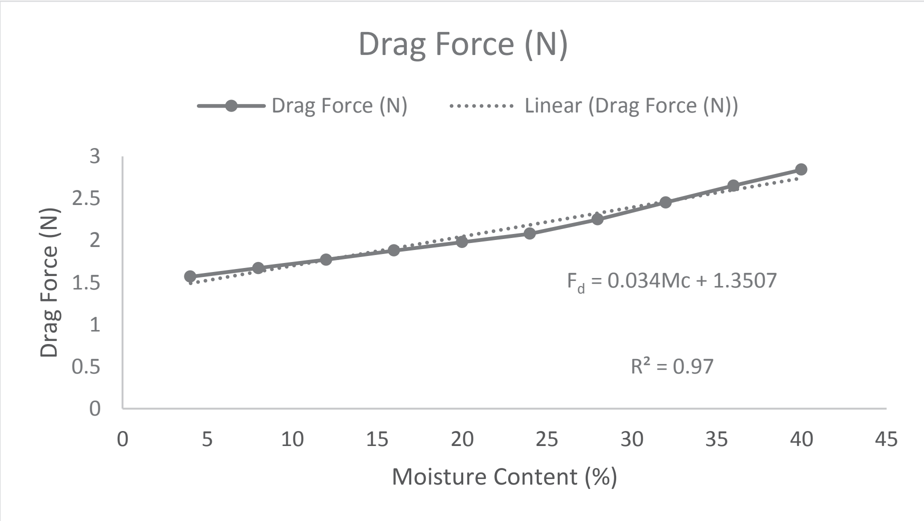

Figure 5. Effect of moisture content on drag force

3.1.3 Drag Coefficient

Drag coefficient for the seeds initially decreased from 0.61 to 0.52 as the moisture increases from 4 to 12% (Figure 6), and thereafter rose from 0.53 to 0.57 as the moisture increased from 16 to 20% (d.b). Drag coefficient value increased from 0.57 to 0.64 between moisture content of 28 and 36. It was 0.63 at 40 %db. This increase and decrease of drag coefficient of the grain at different moisture level is mainly due to the changes in the shape of the seeds, it was also observed that seed drag coefficient is independent of seed mass. Drag coefficient against moisture content also gave a linear curve.

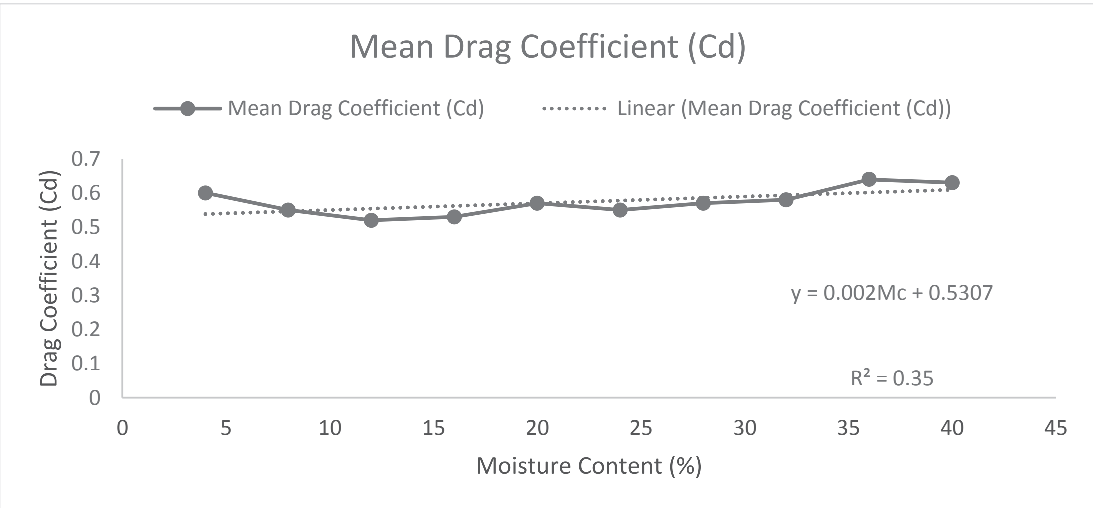

Figure 6. Drag coefficient as affected by moisture content (%db)

3.2 Statistical Analysis Results

The analysis of variance (ANOVA) performed showed a great significant difference (at 5% probability levels) in the terminal velocity, drag force and drag coefficient at different level of moisture content of the seeds. All these are shown in Tables 2 – 4.

Table 2. Difference among means of terminal velocity of the corn seed at ten moisture levels

Terminal Velocity (m/s)

Duncan

Moisture content (d.b)	N	Subset for alpha = 0.05				
		1	2	3	4	5
4.0	3	10.6500				
8.0	3	10.7667				
12.0	3		11.1400			
16.0	3			11.3633		
20.0	3			11.4633		
24.0	3				11.6500	
28.0	3				11.6933	
32.0	3				11.7700	
36.0	3					12.0467
40.0	3					12.1467
Sig.		.060	1.000	.103	.065	.103

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Table 3. Difference among the means of drag force of the corn seeds at ten moisture levels

Drag Force (N)

Duncan

Moisture content db	N	Subset for alpha = 0.05									
		1	2	3	4	5	6	7	8	9	10
4.0	3	1.5733									
8.0	3		1.6800								
12.0	3			1.7733							
16.0	3				1.8767						
20.0	3					1.9800					
24.0	3						2.0800				
28.0	3							2.2533			
32.0	3								2.4533		
36.0	3									2.7167	
40.0	3										2.8500
Sig.		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Table 4. Difference among the means of drag coefficient of corn seed at ten moisture levels

Drag Coefficient Cd

Duncan

Moisture contentdb	N	Subset for alpha = 0.05				
		1	2	3	4	5
12.0	3	.5200				
16.0	3	.5200				
24.0	3	.5433	.5433			
8.0	3		.5500			
28.0	3		.5667	.5667		
20.0	3		.5667	.5667		
32.0	3			.5800		
4.0	3				.6100	
40.0	3				.6333	.6333

36.0	3					.6467
Sig.		.099	.109	.338	.084	.311

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

4. CONCLUSIONS AND RECOMMENDATIONS

A preliminary study to characterize the aerodynamic properties of corn seed at varying moisture content was investigated. Terminal velocity and drag force increased with increase in moisture content. It was also observed that drag coefficient decreased to some point and increased there after as the seeds moisture content increased. The terminal velocity, drag force and drag coefficient all gave linear curve with moisture content.

It has been observed that the reason why most Nigerians prefer imported grains such as maize to the locally produced ones is due to improper cleaning and separation of impurities from the grains. And this problem can only be solved by applying the knowledge of aerodynamic properties of grains at varying moisture content in cleaning, winnowing, separating operations in our local agro-base industries.

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