



Effect of Moisture Content on the Physiochemical Mechanical and Aerodynamic Properties of Beniseeds

¹**Rimamnuskep Stephen.,** ²**A.B. Istifanus.,** ³**Ishaya Genesis**

¹Department of Agricultural and Bio Resources Engineering, Faculty of Engineering,
Taraba State University, Jalingo P.M.B 1167, Taraba State-Nigeria

^{2&3}Department of Agricultural Engineering, Faculty of Engineering, Federal
University Wukari, P.M.B 1020 Wukari, Taraba State-Nigeria

Corresponding Author Email: stephenrimamnuskep@gmail.com,

+2348134064522

Abstract

The physical, mechanical and aerodynamic properties of black and white beniseeds were determined at Moisture Content (MC%) range of 9.70, 13.50, 15.60, – 21.70% (d.b). The major, minor, intermediate, arithmetic mean, geometric mean diameters and sphericity, projected area of the two varieties were 6.64mm, 27.55 mm, 49.57 mm, 90.69 mm, and 8.92mm², 28.21mm, 43.15mm, 116.22mm respectively. The increase in MC resulted decrease in true density from 1328.77, 1297.23, 1284.19, 1271.03kg/mm² and 1319.07, 1294.47, 1271.9, 1269.33kg/mm² for white and black beniseeds seed respectively. The terminal velocity of white beniseeds seed ranged from 3.43, 3.83, 4.66, 5.57m/s while black beniseeds seed ranged from 3.16, 4.84, 5.68-6.71m/s at MC range of 9.70, 13.50, 15.60-21.70% (d.b). The drag coefficient were 22.86 and 22.9 for white and black beniseeds seed respectively as MC ranged from 60.5-60.5%(d.b) while Reynold number varied from 2096, 4766, 7779-12577 and 2237, 6095, 8895 -17151 for white and black beniseeds seed respectively at MC range of 9.70- 21.70% (d.b). The properties of beniseeds seed determined varied significantly with variety and MC. These findings are the prerequisite in the design and selection of beniseeds seed separating machine. A pneumatic separator can be designed with provision for effective separation of undesired light material with average terminal velocity below 5.51m/s and 6.71m/s for white and black beniseeds seeds respectively.

Keywords: Aerodynamic, Physical, Mechanical Properties, Moisture Content, Beniseed seeds

Introduction

The proper air speed required of any agricultural material for their proper separations can be determined from some physical and aerodynamic properties such like, projected area, sphericity, true density, major, minor, intermediate, arithmetic mean, geometric mean diameters, moisture content and terminal velocity, drag coefficient, drag force of that agricultural material respectively. This property has been noticed to be affected mostly by moisture content and variety of the agricultural products (Aglave, 2017).

Effects of moisture content and variety on some physical and aerodynamic properties of beniseeds seed are vital in order to develop a machine that can process this underutilized biomaterial to exploits its numerous health benefits and commercial values

(Akinoso, *et.al.*, 2008; Akpata & Miachi, 2001; Bukya & Vijayakumar, 2013; AOAC, 2002; Aviara, Onuh, & Ehiabhi, 2012; Aviara, Power & Abbas, 2013; Bart- Plange & Mohammed, 2012; Baryeh, 2002; Chavoshgoli, *et.al.*, 2014). Benniseed that belongs to the family of Pedaliaceae and it is one of the oldest oil seed widely grown in the world (Eze & Oluksa, 2014). It plays important role in human nutrition as most of the seeds are used for oil extraction and the rest are used for edible purposes (Eze & Eze, 2017). It is known as Queen of oil seeds because of its marvelous qualities of the seed, oil and meal (Fariku, Ndongya, & Bitrus, 2007). Beniseeds is grown primarily for its soil - rich seed sand prior to its ability to add nutty-like flavor or garnish foods, they were initially used for oil and wine production (Gandhi, 2009). The cake left after expression of oil from beniseeds seeds are mostly for livestock feeds and of tenas manure. These same colour varies from cream-white to charcoal-black but it is mainly referred to as white or black beniseeds seeds while other colours such like yellow, red and brown are very scarce (Ide, Eze, & Offor, 2019).

In Nigeria, the species of beniseeds widely grown are mainly white and black (Khier, Ishag, & Yagoub, 2008). Beniseeds has very high commercial, nutritional and health benefits and it known to contain about 42-54% quality oil, 22-25% protein, 20-25% carbohydrates and 4-6% ash. Its hull contains large quantities of oxalic acid, crude fiber, calcium and other minerals (Khoshtaghaza & Mehdizadeh, 2006). When the seed is properly dehulled, the oxalic acid content is reduced from about 3% to less than 0.25% of the seed weight (Kingsly, *et.al.*, 2006). Beniseeds seed contains antioxidants which inhibit the development of rancidity in the oil. For these reasons, therefore there need to bulk process this under-utilized biomaterial in order to exploit its wonderful benefits which cleaning, sorting, grading, separation of chaffs and non-viable seed from viable become paramount important. Therefore, this research is limited to some physical, mechanical and aerodynamic properties of beniseeds seed varieties at varying moisture content.

Materials and Methods

Sources and preparation of sample

10kg bag, each of the two common beniseed white and brown were obtained from a local market in Garba-chede, Bali local Government Area of Taraba State, Nigeria at as table moisture content. The sourced sample were manually cleaned to remove all foreign materials such as dust, dirt, stones, broken and cracked materials. The initial moisture content of the sample was determined by the equation described by Koocheki, *et.al.* (2007). The desired moisture contents were obtained by adding distilled water calculated from equation reported by Marathe, Jaybhaye, & More (2017).

$$Wm = \frac{Mi(Mf - Mci)}{(100 - Mf)} \quad (1)$$

Where;

Wm=mass of water to be added (g),

Mi=initial mass of the sample (g),

Mf=final (desired) moisture content sample % db,

Mci= initial moisture of the sample, % wet basis (w. b).

Each sample was sealed in a separate polyethylene bag. These samples were kept at 5°C in a refrigerator for a week to enable the water to distribute uniformly. The physical properties of the samples were determined at five moisture content levels of 9.7, 13.5, 15.6 and 21.7% (db).

For Dimension and mass of beniseeds were measured by a digital caliper with an accuracy of 0.01 mm and a digital scale with 0.01 g respectively (Mohsenin, 1986a). The sphericity of seeds was calculated using Equation reported by Mohsenin (1986b). Projected area was obtained according to method of Mohsenin (1986b) in Equation (2). True density is defined as the ratio of mass of the sample to its true volume (Mohsenin, 1986b), it was calculated using equation (3). Arithmetic and geometric mean diameters were calculated using the equation (4&5) reported by Aviara, Power, & Abbas (2013).

Bulk density

The bulk density of beniseed at different moisture content was determined by filling a container of known self-weight and volume to the brim with beniseeds and weighing to determine the net weight of the seeds. Uniform density was achieved by tapping the container 10 times in the same manner in all measurements. The bulk density was calculated as reported by (Tajudeen M.A.O. 2002)

$$\text{Bulk Density (g/cm}^3\text{)} = \frac{\text{Weight of sample (g)}}{\text{Volume occupied (cm}^3\text{)}} \quad (3)$$

True Density

The true or solid density defined as the ratio of a given mass of sample to its volume was determined by the water displacement method. Accordingly, a known weight (50g) of sample was poured into a 100cm³ fractionally graduated cylinder containing 50cm³ distilled water. The volume of water displaced by the seeds was observed. The true density was calculated as reported by (Tajudeen M.A.O. 2002).

$$\text{True Density (g/cm}^3\text{)} = \frac{\text{Weight of the sample (g)}}{\text{Volume of distilled water displaced (cm}^3\text{)}} \quad (4)$$

Porosity

The porosity of an unconsolidated agricultural material can either be determined experimentally using the porosity tank method or theoretically from bulk and true densities of the material. Results from both methods have been found to be in close agreement (Waziri and Mittal, 1983). The porosity of beniseed in this work was determined using the relationship presented by Mohsenin (1986a) & Tajudeen M.A.O. (2002) as follows;

$$\text{Porosity} = (1 - (\text{Bulk Density} / \text{True Density})) / 1 \quad (5)$$

Thousand Kernel Weight

For small seeds like beniseed, 1000 kernels were weighed and a parameter known as the thousand-kernel weight (TKW) was determined. An electronic weighing balance

having a sensitivity of 0.10g was used as reported by Tajudeen M.A.O. (2002).

Coefficient of Friction

The static coefficient of friction was obtained on three structural surfaces namely mild steel, plywood and glass. A tilting table constructed by the Department of Agricultural & Bio-Resources Engineering, Taraba State University Jalingo was used. The surface to be tested was fixed on the tilting table and the beniseed were poured into a cardboard paper ring of diameter 10cm by 2cm deep until the ring was full. Care was taken to raise the ring slightly so that it did not touch the surface. The table was then slowly tilted by a gentle screwing device until movement of the seeds down mounted against the edge of the tilting table. The tangent of the angle of friction is the coefficient of friction (Tajudeen, M.A.O. 2002).

Mechanical Behaviour of Beniseed under Compression Loaded

Compression tests were performed on beniseed kernels using the Monsanto Universal Testing Machine of the National Centre for Agricultural Mechanization, (NCAM) Ilorin, Kwara State. Testing Conditions for the Instron Machine were loading range: 0 - 500N; chart speed – 50rpm/mm; Crosshead speed – 1.5mm/min. The procedure used by Braga *et. al.* (1999) was followed. Ten samples, each of the two beniseed at four moisture content levels were used for the test. Each seed was placed between the compression plates of the tens onometer. The beniseed was compressed at a constant deformation rate of 1.25mm/min. The applied forces at bio yield and oil points and their corresponding deformations for each seed sample was read directly from the force-deformation curve. The mechanical behavior of beniseed was expressed in terms of force required for maximum strength of the seed, energy required to deform the seed to initial rupture and seed specific deformation. The rupture force was determined as the force on the digital display when the seed under compression makes a clicking sound. Each process was often completed whenever the break point of the positioned seed is reached. The results of the different experiments carried out in the present work are presented.

Determination of the Aerodynamic Properties of Beniseeds

Terminal velocity of beniseed, the air velocity at which the seed remains in suspension was measured by using a vertical wind tunnel (air velocity rig) as was reported by Mohsenin (1987). This test equipment was complemented by a manometer and pivot static tubes. A duct 100cm long with rectangular section of 10cmx10cmw as 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 wire net within the duct and were blown upwards using a centrifugal blower whose speed was controlled by a variable speed motor (Agu & Oluka, 2012). The air velocity at which the grains were lifted off the contacting surface was determined as terminal velocity (V_t) (Marathe, Jaybhaye, & More, 2017; Mohsenin, 1987).

Drag Force of the Beniseeds

A drag force is the resistance force caused by the motion of a body through a fluid, such as water or air. A drag force acts opposite to the direction of the oncoming flow velocity (Marathe, Jaybhaye, & More, 2017). This is the relative velocity between the body and the air. Dragforce, F_D , depends on the density of the sample, the upward velocity, and the size, shape, and orientation of the sample. (Khoshtaghaza and Mehdizadeh, 2006).

Drag Coefficient of the Seed

It is used to quantify drag or resistance of an object in a fluid environment such as air or water, it was calculated using the equation reported by Marathe, Jaybhaye, & More (2017) and Mohsenin (1987) given as

$$C_d = \frac{2F_d}{\rho A_p V_t} \quad (7)$$

Where;

C_d = drag coefficient,

$2F_d$ = drag force

A_p = surface area of the sample

V_t = terminal velocity

δ = density of air kgm^{-3}

Reynolds Number of the Seeds

Reynolds number is generally used to determine the flow regime. The Reynolds number (NR_e) is a dimensionless value that represents the ratio of inertial forces to viscous force in the fluid, it is used to categorize the fluid systems in which the effect of viscosity is important in controlling the velocities or the flow pattern of a sample in a fluid or in air (Marathe, Jaybhaye, & More, 2017).

It is calculated using the equation reported by Marathe, Jaybhaye, & More (2017) and Mohsenin (1987).

$$NR_e = \frac{\rho V_t d_p}{\mu}$$

Where;

R_e = Reynolds number,

V_t = terminal velocity m/s,

D_p = Geometrical Mean Diameter (mm),

μ = Kinematic Viscosity (kgm^{-3})

δ = Density of air, given as (1.164 kg/m^3)

Results and Discussion

Properties	White sample				Brown sample			
Moisture content (%)	9.70	13.50	15.60	21.70	9.70	13.50	15.60	21.70
Major Diameter (mm)	2.96	3.12	3.21	3.33	2.98	3.11	3.23	3.34
Minor Diameter (mm)	1.51	1.8	1.9	2.1	1.56	1.99	2	2.2
Intermediate diameter (mm)	0.55	0.89	1.1	1.3	0.61	0.82	0.97	1.4
Porosity (%)	99.34	33.35	34.32	34.86	32.04	31.33	31.8	32.69
AM (mm)	1.67	1.94	2.07	2.24	1.72	1.97	2.07	2.31
GMD (mm)	0.82	1.67	2.24	3.03	0.95	1.69	2.09	3.43
Sphericity	0.28	0.54	0.7	0.91	0.32	0.54	0.65	1.03
Projected area(mm ²)	6.64	27.55	49.57	90.69	8.92	28.21	43.15	116.22
Mass (g)	1.86	2.31	2.67	3.52	1.89	2.33	2.82	3.51
True density(kg/m ³)	1328.77	1297.23	1284.19	1271.03	1319.07	1294.47	1271.9	1269.33
Bulk density(kg/m ³)	876.02	864.65	843.46	828	896.38	888.86	867.43	854.34

Table 1: Some physical Properties of beniseeds Varieties at Varying Moisture Content

The variation of 1000 seed mass with moisture content is presented in Table 1. It was observed that 1000 seed mass of beniseeds seed sample increased from 1.86, 2.31, 2.67 -3.52g and 1.89, 2.33, 2.82 -3.51g for white and black beniseeds seed samples respectively as moisture content increased from 9.70 -21.70%, it was observed that as the moisture content increased from 5.51 to 6.71%, the Sphericity ranged from 0.28, 0.54, 0.7- 0.91 and 0.32, 0.54, 0.65 -1.03 for white and black beniseeds seed sample respectively, this finding is in agreement with what Oluka & Nwuba (2001), Rahman, *et.al.* (2007); Tunde-Akintunde & Akintunde (2007) reported on watermelon, millet and Beniseed respectively.

The variation in sphericity may be attributed to the large increase in major diameter relative to intermediate and minor diameters. It was observed that the projected area of beniseeds seeds increased from 6.64, 27.55, 49.57 -90.69 mm² and 8.92, 28.21, 43.15 -116.22 mm² for white and black samples respectively when moisture Content of the sample increased from 5.51 to 6.71% (d.b). The finding was in line with what Tunde- Akintunde & Akintunde (2004) and Oluka & Nwuba (2001) reported on dried pomegranate seeds and Benniseed. It was observed that the true density of the beniseeds seed decrease from 1328.77, 1297.23, 1284.19 -1271.03kg/m³ and 1319.07, 1294.47, 1271.9 -1269.33 kg/m³ for white and black beniseeds seed sample respectively.

Reynolds Number

The result obtained from the experiment carried out for Reynolds number of beniseeds were presented in the Figure 1: relationship between terminal velocity and drag co-efficient, the values of Reynolds number of white samples were found increased from 2096, 4766, 7779 -12577 while black sample 2237, 6095, 8895 -17151 with corresponding increase in moisture content from 5.51 to 6.71% (w.b.), respectively. Addition of moisture to the investigated seed increased its weight, thus more force required to lift the material. This could necessitate the observed increase in terminal velocity with increase in moisture content. Thus, Reynolds number is directly proportional to terminal velocity and size while these parameters are inversely proportional to drag co-efficient. As is shown, both terminal velocity and size of beniseeds seed increase with increase in moisture contents. The Reynolds number varied significantly with changes in moisture content of seeds.

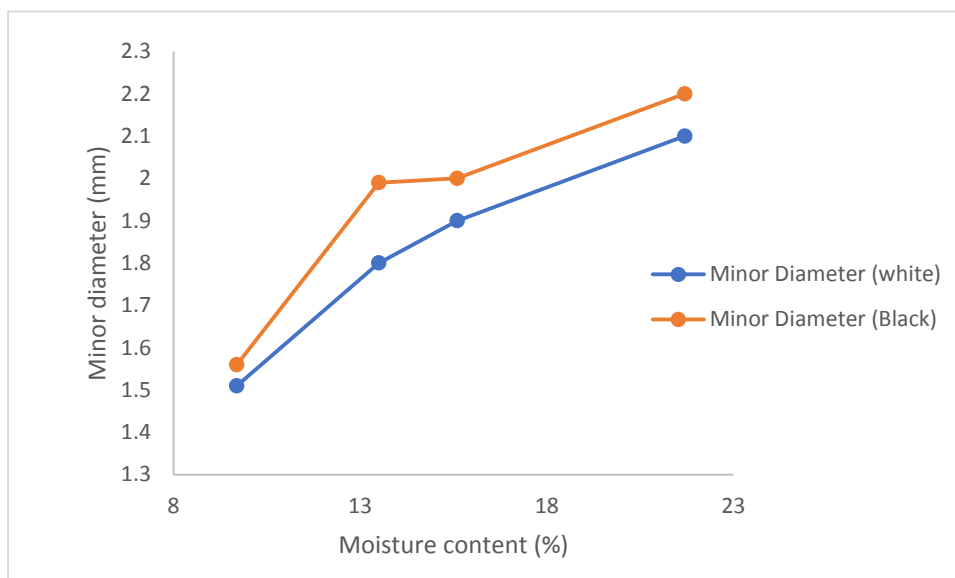


Figure 2: The Relationship Between Terminal Velocity and Drag Co-efficient

Conclusion

Some physical properties of beniseeds seed varied with moisture content levels. The major, minor, intermediate diameters, sphericity, projected area and 1000 weight increased with increased in moisture content, this is because the samples swell as moisture content increases but true density was inversely proportion to moisture content increment, this can be attributed to the fact that, as moisture content increase, the weight of the sample occupies more volume in the cylinder which caused decrease in true density. The terminal velocity and Reynolds number increased with increase in moisture content but drag co- efficient was inversely proportional to the moisture content and terminal velocity.

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