AERODYNAMIC AND THERMAL PROPERTIES OF MELON (CITRULLUS LANATUS) SEEDS UNDER VARYING DRYING TEMPERATURE FOR SEPARATION FROM SHELLS AND PROCESSING

F. U. Asoiro¹1, M. I. Simeon² and I. C. Ezugwu³

¹,³Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka  
² Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna

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ABSTRACT

The effect of temperature on aerodynamic and thermal properties of melon seed is very important in the design of drying, processing and storage equipment. To this end, some thermal and aerodynamic properties of melon seed were investigated as a function of temperature. The thermal conductivity, specific heat capacity and thermal diffusivity were the thermal properties that were determined. Terminal velocity, seed drag force and drag coefficient were the aerodynamic properties investigated. The results obtained for the terminal velocity of the seed at temperatures of 30°C, 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C, 70°C, and 75°C were 7.415, 7.135, 6.32, 9.95, 5.885, 5.62, 5.32, 5.205, 4.88m/s respectively. The values continued to reduce until 100°C with a value of 3.37m/s. The drag force of the melon seed attained its maximum value at temperature of 50°C (1.777N). A minimum value was attained at the temperature of 100°C (0.343N). At various temperature levels of 35°C, 40°C, 45°C, 55°C, 60°C, 65°C, and 70°C, values for drag force were 1.472N, 1.349N, 1.275N, 1.079N, 0.981N, 0.883N, and 0.884N respectively. The drag coefficient was at its maximum at temperature of 80°C with a value of 1.179, and minimum at 30°C with a value of 0.743. For the thermal properties, the specific heat capacity attained a maximum value of 2.995KJ/Kg/K at a temperature of 30°C, while it attained a minimum value of 1.596KJ/Kg/K at temperature of 100°C. The thermal conductivity was maximum at 30°C with a value of 3.62W/m/K, and minimum at 100°C with a value of 0.46W/m/K. In the same vein thermal conductivity reduces with an increase in temperature. At the temperatures of 30°C, 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C, 70°C, 75°C, and 80°C, the thermal conductivity values were 3.26W/m/K, 1.545W/m/K, 1.1W/m/K, 1.83W/m/K, 1.725W/m/K, 0.64W/m/K, 0.605W/m/K, 0.555W/m/K, 0.53W/m/K, 0.52W/m/K, and 0.505W/m/K respectively. The thermal diffusivity attained a maximum value at 30°C (6.19×10⁻⁵m²/s) and a minimum value of 1.16×10⁻⁶m²/s at 100°C. Therefore, it can be clearly observed that temperature has a very great effect in the aerodynamic and thermal properties of egusi melon and these values are vital to engineers and food processors in the design of storage and processing equipment for melon seeds.

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*Corresponding author Email address: felix.asoiro@unn.edu.ng
1.0 INTRODUCTION

One of the important food and cash crops that is grown in most African countries is melon (Egusi) (*Citrullus colocynthis lanatus*) and used as food source, in medicine, engineering and cosmetics (Jeffrey, 1980). Melon (Egusi) is a tendril climbing herbaceous crop. It belongs to the family of *Cucurbitaceae*, with excellent genetic diversity, vegetative and reproductive characteristics. *Citrullus lanatus* is classified into three sub-species; *lanatus, mucospermus fursa* and *vulgaris fursa*. Some of the species are edible and grown in most parts of the world (Enoch et al., 2008). Egusi is grown and utilized as food source in most parts of Africa. Melon seed is also an important component of the traditional cropping system usually inter-planted with such staple crops as cassava, maize, sorghum, etc and by nature, a creepy growing plant which covers large area when properly grown, and as such control weeds, thereby improving soil fertility. Its leaves are deeply lobed and blue-gray, and are alternately arranged (Jeffrey, 1980; Enoch et al., 2008). The yellow-green fruit at maturity, which is identified by the drying of its leaves, is about the size of edible watermelon, but its flesh is white and the back is often shiny. The melon pod has an almost spheroidal external shape and ellipsoidal seed cavity (Oloko and Agbetoye, 2006).

Melon (Egusi) originated from Africa and Asia and over the years, it is widely cultivated in the Caribbean, Indonesia and Africa. In Nigeria, the existence of melon dates back to the 17th century. Melon (popularly known as *Egusi* in the Igbo speaking parts of Nigeria) is a popular crop because of the edible seeds which are commonly used in the preparation of local soup or stew and snacks such as fried melon seed ball known as *Robo* in South Western Nigeria, and grinded melon mixed with bitter leave known as *ofeegusi* in eastern part of Nigeria. Recent statistics shows that 100,000 and 488,000 metric tons of melon were produced in Nigeria in 1992 and 1997. The melon (Egusi) seed, *C. lanatus* had been reported to contain an average about 22g of protein, 30g of fat and 11g of carbohydrate and as well as good quantities micronutrients per 100g sample. It is a good source of amino acids such as arginine, vitamins B1, vitamins B2, niacin, tryptophan and methionone, and minerals such as zinc, iron, potassium, phosphorus, sulphur, manganese, calcium, lead, chloride and magnesium (Eugene and Gloria, 2002). Melon seeds contain between 30-50% by weight of oil which is comparable to other oil plants and the oil contains a high level of saturated fatty acids. According to Oloko and Agbetoye (2006), melon seeds offer valuable sources of vegetable oil for local and export trade. Recently, it has been proved to be a fed-stock for bio-fuel (Gusmini et al., 2004; Solomon et al., 2010). Melon has about 60% protein content that enriches the diet of the consumer. Melon such as (*Citrulluslanatus*), Bara (*Colocynthiscitrullus*) and Serewear are most common in Nigeria. The *Colocynthis citrullus* has the widest distribution. The geographical distribution was attributed to consumers’ preference rather than physiological adaptation of the crop.

Despite the huge economic, nutritional, medicinal and cultural potential of these product, very little is known of the aerodynamic and thermal properties. As a result, there is scarcity of machines, systems and gadgets for wide scale post harvest operation such as processing, distribution and value addition accessioned by dearth of design data. In most African countries in general and Nigeria in particular, postharvest operations are carried out manually with its attendant drudgery, poor quality product and low productivity and economic value. To transform this product into internationally acceptable and marketable products, their aerodynamic, thermal properties are expedient as well as high quality maintained. Since only a few agricultural crops such as fresh fruits
and vegetables go from field to the table without any thermal processing, therefore thermal processing becomes unavoidable. Thermal processing (include treatments such as pasteurization, concentration, drying, cooling, etc.) is frequently used in food processing, transportation, storing and cooking to improve the shelf life and good quality of the material. To achieve these, there is therefore need to determine the thermal properties of these product.

Knowledge of the aerodynamic and thermal properties of melon seeds are vital in equipment design for operations such as pneumatic conveying in loading/unloading operations of melon seeds. It is also useful to both engineers and food scientists; plant and animal breeders and also for data collection in the design of machines, structures, processes and controls; and in determining the efficiency of a machine or an operation. On the other hand, the knowledge of temperature requirements plays a very vital role on the storability of the seed. Pneumatic conveying may offer important functional and economic advantages in handling materials. The utilization of forced-air streams for the transport and drying of agricultural materials is becoming increasingly important in Nigeria. It is, therefore, necessary that the aerodynamic characteristics of this material at varying temperature be investigated so that their behaviour in an air stream can be estimated with a degree of certainty, and so a fair basis on which to establish blower design can be provided.

Thermal properties of food and agricultural materials are important engineering parameters in the mathematical modeling and design of systems and equipment needed for drying, storing, aeration, and refrigeration. These properties are also essential for the prediction of drying and refrigeration processes. A number of researchers have determined three moisture-dependent thermal properties (such as specific heat capacity, bulk thermal heat conductivity, and thermal heat diffusivity) for several grains, seeds, and kernels such as minor millet (Sestaria italıa, Panicum miliare, Panicum miliaceum, Paspalum sorobiculatum, Eleusine coracana, Echinochola colona) (Subramanian and Viswanathan, 2003), guna seed (Citrus coloynthis) (Aviara et al., 2008), coriander (Coriandrum sativum) and anise (Pimpinella anisum) seeds (Hacikuru and Kocabiyik, 2008), chickpea (Cicer arietinum) (Singh et al., 2008), pumpkin seeds (Cucurbita pepo) (Kocabiyik et al., 2009), peanut (Arachis hypogaea) pods, kernels and shells (Bitra et al., 2010), pigeonpea (Singh and Kotwaliwale, 2010), prairie carnation (Saponaria vaccaria) (Shrestha and Baik, 2010), roselle seeds (Hibiscus sabdariffa) (Bangoye and Adejumo, 2010), and black pepper (Panniyur-1) (Meghwal and Goswami, 2011). Alagusundaram et al. (1991) determined only the thermal conductivity of lentil (Laird) as a function of moisture content.

Also, the effect of temperature on thermal properties of melon seeds is very important in the design of drying, processing and storage equipment. Therefore, this work seeks to determine the aerodynamic (terminal velocity, drag force and drag coefficient) and thermal properties (thermal conductivity, thermal diffusivity and specific heat capacity) of melon seeds (Citrus L.) under varying drying temperature.

2.0 Materials and Methods
2.1 Sample Collection and Preparation
The study was carried out using local but common variety of melon (Egusi) seeds, Colocynthiscitirus, which also has the widest distribution. Samples of the melon seeds were
purchased from a local market known as Ogige Market inNsukka, Enugu State, Nigeria. The seeds were shelled and cleaned. Contaminants, immaturesd and other foreign materials were removed manually before the experiment was conducted. Samples of the seeds were oven dried and conditioned to the required temperature (30 to 100°C) which spans the temperature range of harvest to the post harvest processing operations.

2.2 Determination of Aerodynamic Properties of Melon Seeds
2.2.1 Determination of terminal velocity of melon seeds
The terminal velocity, \( V_t \) of melon seeds measured in metre per second (m/s) was determined according to the method by Shahbazi (2013). A vertical wind tunnel as shown in Figure 2 was developed and used. A centrifugal fan powered by an HP motor was used in the inlet of the wind tunnel to supply airflow. The airflow rate of the fan was controlled by changing the velocity of the electric motor through an inverter set and a diaphragm. The final section of the wind tunnel consisted of a Plexiglas region where the terminal velocity of the seed was measured. To determine the terminal velocity, each seed was placed in the centre of the cross-section of the wind tunnel on the screen. The airflow was then increased until the seed flotation point. At this moment, when the rotational movement of the seed was lowest, the air velocity was measured using a hot-wire anemometer with an accuracy of 0.1 m \( \text{s}^{-1} \).
2.2.2 Determination of drag force
The drag force is a resistive force, opposing the motion of the melon seeds. 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 (1)

\[ F_d = \frac{C_d \rho_a A_p V_t^2}{2} = C_r V_t^2 \]  

(1)

The projected area of the melon seed can be calculated using equation (2)

\[ A_p = \frac{\pi L W}{4} \]  

(2)

Where, \( F_d \) is the drag force (N); \( C_d \) is drag coefficient (dimensionless); \( \rho_a \) 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 melon seed and \( W \) is width of the melon seed.

2.2.3 Determination of the drag coefficient of the corn seeds
Among aerodynamic properties, the drag coefficient (commonly denoted as 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 (3)

\[ C_d = \frac{2F_d}{\rho_a V_t^2 A_p} \]  

(3)

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

2.3 Determination of Thermal Properties of Melon Seeds
2.3.1 Determination of thermal conductivity of melon seeds
Steady state technique was used in the determination of thermal conductivity of melon seeds. The instrument used in this work is guarded hot plate. In this process, some melon (egusi) samples were placed between the plates. One plate is heated to a required temperature and the other is cooled or heated to a lesser extent. The temperature of the plate is monitored until they are constant. The steady state temperature, the thickness of the sample, and the heat input to the hot plate are used to calculate thermal conductivity using equation (4) given according to Isaj et al. (2014).

\[ \lambda = \frac{Q \times d}{T_1 - T_2} \]  

(4)

Where \( \lambda \) is thermal heat conductivity (W/m/K), \( Q \) is the quantity of heat passing through a unit area of the melon samples in unit time (W/m\(^2\)), \( d \) is the distance between the sides of the sample in metre (m), \( T_1 \) is the temperature on the hotter side of the sample (k) and \( T_2 \) is the temperature on the colder side of the sample (k). Figure 3 shows the schematic diagram of Guided Hot Plate used for the determination of thermal heat conductivity.
2.3.2 Determination of thermal diffusivity of melon seeds

The thermal diffusivity of melon seeds was determined according to Indian standard (IS: 10698 - 1983). The apparatus consist of a thermal diffusivity tool and an insulated water bath of 25 liters capacity. The cylinder was filled with milled melons and the entire assembly was placed with end caps and thermocouples in a water bath. Heat at constant rate is applied to the water bath with the help of 1000 Watt immersion heater. The water in the bath was stirred with the help of a stirrer at suitable speed, driven by a motor of 40 Watt, 4000rpm and coupled to a speed regulator. The thermal diffusivity was computed by using the expression by Kachru et al. (2002) and Alam et al. (2002) as shown in equation (5)

\[
\alpha = \frac{R^2 A}{4(T_R - T_C)}
\]

Where, \(\alpha\) is thermal diffusivity \((m^2/s)\) of the melon seeds, \(R\) is radius of the thermal diffusivity tube \((m)\), \(T_R - T_C\) is constant temperature difference at any time between temperature at the surface \(T_R\) and temperature at the centre \(T_C\) of thermal diffusivity tube in \(^\circC\) and \(A\) is constant slope of temperature versus time curve \((^\circC/s)\).
2.3.3 Determination of specific heat capacity of melon seeds

The method of mixtures has been the most common widely reported technique in literature for measuring the specific heat capacity of biomaterials (Razavi and Taghizadeh, 2008). For the determination of specific heat capacity of melon seeds, the method of mixture was used. Molded melon samples of known mass and temperature were dropped into a cupper calorimeter containing water of known mass and temperature. The calorimeter was insulated so as to prevent heat loss to the room in which the experiment was performed. The mixture was stirred continuously using a glass stirrer. A digital thermometer was used to monitor the temperature of the mixture. The equilibrium temperature was noted. The specific heat capacity was determined using equation (6) according to Aviara and Haque (2001).

\[
C_1 = \frac{M_2C_2(\theta_3 - \theta_1) + (M_3 - M_2)C_w(\theta_3 - \theta_1)}{M_1(\theta_2 - \theta_3)}
\]

Where, \(M_1\) is mass of the melon sample (kg), \(M_2\) is mass of the calorimeter (kg), \(M_3\) is mass of calorimeter + water (kg), \(\theta_1\) is the initial temperature of water (K), \(\theta_2\) is the temperature of the melon sample (K), \(\theta_3\) is the final temperature of the mixture (K), \(C_1\) is the specific heat capacity of the melon sample (J/kg/K), \(C_2\) is the specific heat capacity of calorimeter, which was 400J/kg/K and \(C_w\) is the specific heat capacity of water, which was (4200J/kg/K).

2.4 Methods of Statistical Analyses

Data for both aerodynamic and thermal properties 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 5% probability level, treatments were separated and presented by Duncan’s New Multiple Range Tests (DNMRT) at the 5% level of probability. Simple Excel was used to plot the graph of the aerodynamic and thermal properties of the melon seeds against drying temperature (30-100°C) of the melon seeds, to obtain graphical and linear representation of temperature effect on aerodynamic and thermal properties of the seeds.

3.0 Results and Discussions

3.1 Aerodynamic Properties

Table 1 shows the summary result of the mean values of the aerodynamic properties of melon seeds at varying drying temperature.

3.1.1 Terminal velocity

Terminal velocity of melon seeds vary with drying temperature. As the temperature increased from 30°C to 100°C, terminal velocity decreased from 7.45 to 3.37m/s. At 30°C, 35 and 40°C terminal velocities were 7.415, 7.135 and 6.32m/s respectively. The terminal velocity was 5.95m/s at 45°C and decreased by 1.1, 5.5, 10.6 and 12.5% as temperature increased to 50, 55, 60 and 65°C respectively. Terminal velocities of melon seeds were 4.88, 4.57, 4.1, 3.635 and 3.6m/s at temperature of 70, 75, 80, 85, and 90 respectively. At temperature of 100°C, the terminal velocity was 3.37m/s while at 95°C; the terminal velocity was 3.4m/s.
Table 1. Mean values of aerodynamic properties of melon seeds at varying drying temperature.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Terminal Velocity (m s⁻¹)</th>
<th>Drag Force (N)</th>
<th>Drag Coefficient (dimensionless)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>7.415j</td>
<td>1.567j</td>
<td>0.734h</td>
</tr>
<tr>
<td>35</td>
<td>7.135j</td>
<td>1.472j</td>
<td>0.801h</td>
</tr>
<tr>
<td>40</td>
<td>6.32j</td>
<td>1.349j</td>
<td>0.869h</td>
</tr>
<tr>
<td>45</td>
<td>5.95ij</td>
<td>1.275ij</td>
<td>0.925gh</td>
</tr>
<tr>
<td>50</td>
<td>5.885i</td>
<td>1.777i</td>
<td>0.99g</td>
</tr>
<tr>
<td>55</td>
<td>5.62i_h</td>
<td>1.079i_h</td>
<td>0.852f</td>
</tr>
<tr>
<td>60</td>
<td>5.32i_h</td>
<td>0.981i_h</td>
<td>0.832e</td>
</tr>
<tr>
<td>65</td>
<td>5.205i_gh</td>
<td>0.883i_gh</td>
<td>0.736d</td>
</tr>
<tr>
<td>70</td>
<td>4.88f_g</td>
<td>0.884f</td>
<td>0.91dh</td>
</tr>
<tr>
<td>75</td>
<td>4.57f</td>
<td>0.785e</td>
<td>0.993cd</td>
</tr>
<tr>
<td>80</td>
<td>4.1f</td>
<td>0.736d</td>
<td>1.179c</td>
</tr>
<tr>
<td>85</td>
<td>3.635ef</td>
<td>0.589c</td>
<td>1.084b</td>
</tr>
<tr>
<td>90</td>
<td>3.6d</td>
<td>0.54b</td>
<td>1.165b</td>
</tr>
<tr>
<td>95</td>
<td>3.4b</td>
<td>0.441a</td>
<td>0.939ab</td>
</tr>
<tr>
<td>100</td>
<td>3.37a</td>
<td>0.343ab</td>
<td>0.869a</td>
</tr>
</tbody>
</table>

3.1.2 Drag force

The drag force of melon seeds was 1.567N at 30°C and 0.343N at 100°C. At 35, 40, 45, 50, 55 and 60°C, the drag force of melon were 1.472, 1.349, 1.275, 1.777, 1.079 and 0.981N respectively. Drag force decreased from 60°C drying temperature to 65°C by 10% and slightly increase by 0.1% from 65 to 70°C thereafter fell to 0.785N at 75°C; 0.736N at 80°C; 0.389N at 85°C and 0.54N at 90°C. The drag force of melon seed at 95 and 100°C were 0.441 and 0.343N respectively.

3.1.3 Drag coefficient

As melon drying temperature increased from 30 to 50°C, the drag coefficient rose from 0.734 to 0.79. At 55°C, 60, 65, and 70°C, the drag coefficients were 0.852, 0.832, 0.736 and 0.91 respectively. Mean drag coefficient was maximum at 90°C (1.165) and minimum at 30°C (0.734). Drag coefficient values were 0.993, 1.084, 1.165, 0.939 and 0.869 at drying temperature of 75, 85, 90, 95, and 100°C respectively.

3.2 Thermal Properties

Table 2 shows the summary result of the mean values of the thermal properties of melon seeds at varying drying temperature.

3.2.1 Specific heat capacity

The mean specific heat capacity of melon seed was maximum at 30°C (2.995KJ/Kg/K) and minimum at 100°C (1.596KJ/Kg/K). Specific heat capacity decreased (2.8, 2.376, 1.906, 1.848, 1.811 and 1.785 KJ/Kg/K) with increasing temperature (35, 40, 45, 50, 55 and 60KJ/Kg/K). The value of specific heat capacity at 65°C (1.766KJ/Kg/K) decreased by 0.9%, 1.6, 2.2 and 2.6% at 70, 75, 80 and 85°C.
respectively. At 90, 95 and 100°C, the specific heat capacity values of melon seeds were 1.655, 1.611 and 1.596 KJ/Kg/K respectively.

**Table 2. Mean values of the thermal properties of melon seeds at varying temperature**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Specific Heat Capacity (KJ Kg⁻¹ K⁻¹)</th>
<th>Thermal Heat Conductivity (W m⁻¹ K⁻¹)</th>
<th>Thermal Heat Diffusivity (m² s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>2.995&lt;sub&gt;k&lt;/sub&gt;</td>
<td>3.62&lt;sub&gt;l&lt;/sub&gt;</td>
<td>6.19E-05&lt;sub&gt;o&lt;/sub&gt;</td>
</tr>
<tr>
<td>35</td>
<td>2.8&lt;sub&gt;k&lt;/sub&gt;</td>
<td>1.545&lt;sub&gt;l&lt;/sub&gt;</td>
<td>2.17E-05&lt;sub&gt;n&lt;/sub&gt;</td>
</tr>
<tr>
<td>40</td>
<td>2.376&lt;sub&gt;k&lt;/sub&gt;</td>
<td>1.1&lt;sub&gt;kl&lt;/sub&gt;</td>
<td>1.21E-05&lt;sub&gt;m&lt;/sub&gt;</td>
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<td>45</td>
<td>1.906&lt;sub&gt;cj&lt;/sub&gt;</td>
<td>1.83&lt;sub&gt;k&lt;/sub&gt;</td>
<td>7.97E-06&lt;sub&gt;l&lt;/sub&gt;</td>
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<tr>
<td>50</td>
<td>1.848&lt;sub&gt;j&lt;/sub&gt;</td>
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</tr>
<tr>
<td>55</td>
<td>1.811&lt;sub&gt;i&lt;/sub&gt;</td>
<td>0.64&lt;sub&gt;j&lt;/sub&gt;</td>
<td>4.71E-06&lt;sub&gt;lj&lt;/sub&gt;</td>
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<tr>
<td>60</td>
<td>1.785&lt;sub&gt;h&lt;/sub&gt;</td>
<td>0.605&lt;sub&gt;i&lt;/sub&gt;</td>
<td>3.55E-06&lt;sub&gt;lh&lt;/sub&gt;</td>
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<tr>
<td>65</td>
<td>1.766&lt;sub&gt;g&lt;/sub&gt;</td>
<td>0.555&lt;sub&gt;h&lt;/sub&gt;</td>
<td>3.06E-06&lt;sub&gt;lj&lt;/sub&gt;</td>
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<tr>
<td>70</td>
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<td>2.68E-06&lt;sub&gt;gl&lt;/sub&gt;</td>
</tr>
<tr>
<td>75</td>
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<td>0.52&lt;sub&gt;f&lt;/sub&gt;</td>
<td>2.19E-06&lt;sub&gt;gf&lt;/sub&gt;</td>
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<td>80</td>
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<td>0.505&lt;sub&gt;e&lt;/sub&gt;</td>
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<td>0.5&lt;sub&gt;d&lt;/sub&gt;</td>
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<td>90</td>
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<td>0.49&lt;sub&gt;c&lt;/sub&gt;</td>
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</tr>
<tr>
<td>95</td>
<td>1.611&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.49&lt;sub&gt;b&lt;/sub&gt;</td>
<td>1.26E-06&lt;sub&gt;be&lt;/sub&gt;</td>
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<tr>
<td>100</td>
<td>1.596&lt;sub&gt;a&lt;/sub&gt;</td>
<td>0.46&lt;sub&gt;a&lt;/sub&gt;</td>
<td>1.16E-06&lt;sub&gt;ae&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

**3.2.2 Thermal heat conductivity**

Thermal heat conductivity of melon seeds decreased between 30°C (3.62W/m/K) and 40°C (1.1W/m/K) and thereafter increased to 1.83W/m/K at 45°C. It later decreased again from 50°C (1.725W/m/K) to 100°C (0.46W/m/K) by 73.3%. It has maximum value at drying temperature of 30°C (3.62W/m/K) and a minimum value at 100°C (0.46W/m/K).

**3.2.3 Thermal heat diffusivity**

The thermal heat diffusivity of melon seeds was maximum at 30°C (6.19 × 10⁻⁵ m²/s), minimum at 100°C (1.16 × 10⁻⁶ m²/s); 2.17 × 10⁻⁵ m²/s; 1.21 × 10⁻⁵ m²/s; 7.97 × 10⁻⁶ m²/s; 5.89 × 10⁻⁶ m²/s and 4.71 × 10⁻⁶ m²/s at 35, 40, 45, 50 and 55°C respectively. The thermal conductivity of melon seeds decreased with increased temperature. It was 3.55 × 10⁻⁶ m²/s, 3.06 × 10⁻⁶ m²/s, 2.68 × 10⁻⁶ m²/s, 2.19 × 10⁻⁶ m²/s, 1.79 × 10⁻⁶ m²/s, 1.62 × 10⁻⁶ m²/s and 1.26 × 10⁻⁶ m²/s at drying temperature of 55, 60, 65, 70, 75, 80, 85, 90, and 95°C.

**3.3 Statistical Analyses of Results**

**3.3.1 Aerodynamic properties**

At 5% probability level, the mean values of terminal velocity of melon seeds at 30, 35, 40 and 45°C are statistically non-sig. These values are significantly different from the mean terminal velocity value at 45°C (5.95 m/s). The mean value of terminal velocity of the seeds at 45°C is non-significant from the value at 50°C (5.885 m/s). The mean terminal velocity value of melon seed at
55°C (5.62m/s), 60°C (5.32m/s) and 65°C (5.205m/s) are all non significant from each other but the terminal velocity value at 65°C is significant from the values at 55°C and 60°C. It is non significant from the value at 70°C (4.88m/s). The values of terminal velocity of melon seeds at 75°C (4.57m/s), 80°C (4.1m/s) and 85°C (3.635m/s) are all the same statistically. The value of terminal velocity at 85°C is different statistically from those at 75°C and 80°C. The terminal velocity values of melon seeds at 90°C (3.6m/s), 95°C (3.4m/s) and 100°C (3.37m/s) are all statistically significant from one another at 5% probability level.

The mean drag force values of melon seeds at 30°C, 35°C, 40°C and 45°C are all statistically non significant. The drag force value at 45°C (1.275N) is significant from values at 30, 35 and 40°C but statistically the same with the drag force value at 50°C (1.777N). Mean drag force values at 55°C (1.079N), 60°C (0.981N) and 65°C (0.883N) are all statistically the same at 5% probability level, but for the value drag force at 65°C which is significantly different from those at 55°C and 60°C respectively. The drag force values at 70°C (0.884N), 75°C (0.785N), 80°C (0.736N), 85°C (0.589N), 90°C (0.54N) and 95°C (0.441N) are all significantly different from one another at 5% probability levels. However the drag force value of melon seed at 100°C (0.343N) is non significant with value at 90°C and 95°C respectively.

The mean values of drag coefficient of melon seeds at 30°C (0.75), 35°C (0.801), 40°C (0.869) and 45°C (0.925) are statistically the same, but the mean drag coefficient value at 45°C is different statistically fro 30, 35 and 40°C respectively. However, the same with the drag coefficient value at 50°C (0.99). The mean drag coefficient value at 55°C (0.852), 60°C (0.832) and 65°C (0.736) are all statistically significant, but the drag coefficient value of melon seed at 65°C, 70°C and 75°C are all non significant at 5% probability level. Mean drag coefficient value of melon seeds at 75°C (0.993) and 80 (1.179) are non significant. Drag coefficient values at 85°C (1.084), 90°C (1.165) and 95°C (0.939) are all non significant. The values of drag coefficient of melon seeds at 95°C are significant from values at 85°C and 90°C respectively.

### 3.3.2 Thermal properties

Specific heat capacity of melon seeds decreased with temperature, The mean values of the specific heat capacity of melon seeds was maximum at 30°C (2.995 KJ/Kg/K). and minimum at 100°C (1.596KJ/Kg/K). The values were all significantly different at the different temperature levels. However, the specific heat capacity at 85°C (1.72KJ/Kg/K) and 90°C (1.655KJ/Kg/K) were not significant (p ≤ 0.05)

The mean values of thermal heat conductivity of melon seeds at 30°C (3.62W/m/K), 35°C (1.545W/m/K) and 40°C (1.1W/m/K) are non significant. The thermal heat conductivity of melon seeds at 45°C (1.83W/m/K) and 50°C are non significant at 5% level of probability. However, the thermal heat conductivity value of 1.1W/m/K at 40°C is significant from the values at 30°C, 35°C, and 45°C, 50°C respectively. The thermal heat conductivity value of melon seed at 55°C (0.64W/m/K), 60°C (0.605W/m/K), 65°C (0.555W/m/K) and 70°C (0.53W/m/K) are all significant. The thermal heat conductivity value of melon seeds at 75°C (0.499W/m/K), 95°C (0.49W/m/K) and 100 (0.46W/m/K) are all significantly different from one another at 5% level of probability.
All the thermal heat diffusivity values of melon seeds (m²/s) are significantly different from one another at the different drying temperature levels (30 to 100°C)

4.0 Conclusions
Increase in temperature reduced the values of terminal velocity and drag force of (egusi) melon seeds while it increased the values of the drag coefficient. The terminal velocity attained its maximum value which was found to be 7.414 m/s at the temperature of 30°C, and attained its minimum value which was 3.37m/s at 100°C. The drag force of the melon seed attained its maximum value of 1.777N at temperature of 50°C and minimum value of 0.343N at temperature of 100°C. At 35°C, 40°C and 45°C, the drag force values were 1.472N, 1.349N, and 1.275N respectively. Drag coefficient has a maximum value of 1.179 at temperature of 80°C and minimum value of 0.743 at temperature of 30°C.

For thermal properties, as temperature increased, the values of specific heat capacity and the thermal conductivity of the melon seed decreased. The specific heat capacity attained its maximum value at temperature of 30°C with a value of 2.995KJ/Kg/K, while it attained its minimum value 1.596KJ/Kg/K at temperature of 100°C. The thermal conductivity was maximum at 30°C with a value of 3.62W/m²K and minimum at 100°C at a value of 0.46W/m²K. The thermal diffusivity attained maximum value of 7.97×10⁻⁶m²/s at a temperature of 45°C, and minimum at 100°C with a value of 1.1×10⁻⁶m²/s.

Reference
Asoiro, et al.: Aerodynamic and thermal properties of melon (Citrullus lanatus) seeds under varying drying temperature for separation from shells and processing. AZOJETE, 14(sp.i4):149-160. ISSN 1596-2490; e-ISSN 2545-5818, www.azojete.com.ng


