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ORIGINAL RESEARCH ARTICLE

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

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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 ($6.19\times10^{-5}m^2/s$) and a minimum value of $1.16\times10^{-6}m^2/s$ 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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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, mucosospermus 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 fron 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 Sereweare 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 italia* , *Panicum miliare*, *Panicum miliaceum*, *Paspalum sorobiculatum*, *Eleusine coracana* , *Echinochola colona*) (Subramanian and Viswanathan, 2003), guna seed (*Citrullus colocynthis)* (Aviara *et al.,* 2008), coriander (*Coriandrum sativum* L) and anise (*Pimpinella anisum* L) seeds (Hacikuru and Kocabiyik, 2008), chickpea (*Cicer arietinum* L) (Singh *et al*., 2008), pumpkin seeds (*Cucurbita pepo* L) (Kocabiyik *et al.,* 2009), peanut (*Arachis hypogaea* Linnaeus) 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* L) (Bamgboye 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 *(citrullus 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, *Colocynthiscitrullus,* which also has the widest distribution. Samples of the melon seeds were purchased from a local market known as Ogige Market in Nsukka, Enugu State, Nigeria. The seeds were shelled and cleaned. Contaminants, immatured 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 100ºC) which spans the temperature range of harvest to the post harvest processing operations.

Figure 1. Shelled melon samples

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 s^{-1}.

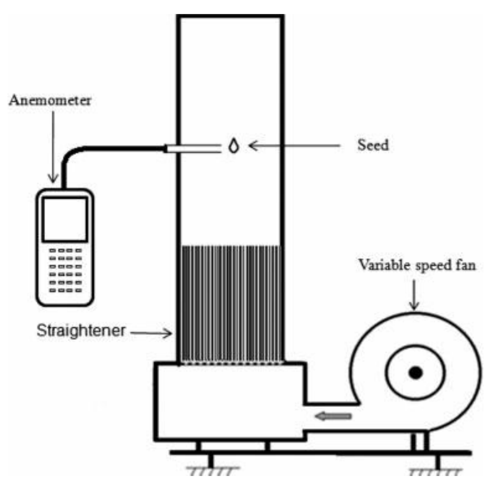

Figure 2. Set up for the measurement of terminal velocity of melon seeds

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)

$$F_d = \frac{C_d \ell_a A_p V_t^2}{2} = C_r V_t^2 \quad (1)$$

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

$$A_p = \frac{\pi LW}{4} \quad (2)$$

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 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 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 (3)

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

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).

$$\lambda = \frac{Q \times d}{T_1 - T_2} \quad (4)$$

Where λ 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.

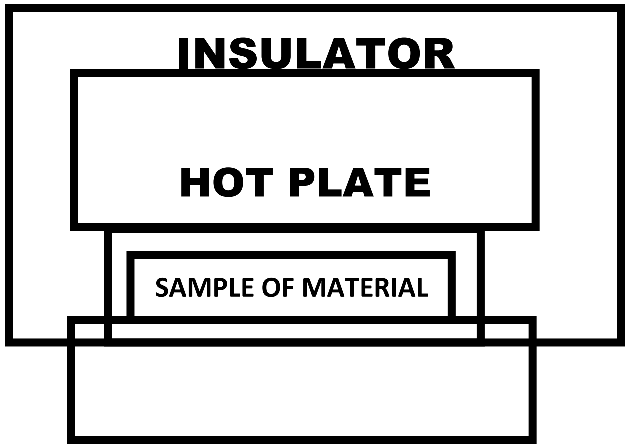

Figure 3. Schematic diagram of Guided Hot Plate for the determination of thermal conductivity.

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)

$$\alpha = \frac{R^2 A}{4(T_R - T_C)} \tag{5}$$

Where, α is thermal diffusivity (m^2/s) of the melon seeds, R is radius of the thermal diffussivity 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 (°C) and A is constant slope of temperature versus time curve (°C/s).

Figure 4. Set up for determination of thermal diffussivity of melon seeds

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).

$$C_1 = \frac{M_2 C_2(\theta_3 - \theta_1) + (M_3 - M_2)C_W(\theta_3 - \theta_1)}{M_1(\theta_2 - \theta_3)} \qquad (6)$$

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), Θ_1 is the initial temperature of water (K), Θ_2 is the temperature of the melon sample (K), Θ_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^oC) 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^oC to 100^oC, terminal velocity decreased from 7.45 to 3.37m/s. At 30^oC, 35 and 40^oC terminal velocities were 7.415, 7.135 and 6.32m/s respectively. The terminal velocity was 5.95m/s at 45^oC and decreased by 1.1, 5.5, 10.6 and 12.5% as temperature increased to 50, 55, 60 and 65^oC 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^oC, the terminal velocity was 3.37m/s while at 95^oC; the terminal velocity was 3.4m/s.

Table 1. Mean values of aerodynamic properties of melon seeds at varying drying temperature.

Temperature (°C)	Terminal Velocity (m s^{-1})	Drag Force (N)	Drag Coefficient (dimensionless)
30	7.415_j	1.567_j	0.734_h
35	7.135_j	1.472_j	0.801_h
40	6.32_j	1.349_j	0.869_h
45	5.95_{ij}	1.275_{ij}	0.925_{gh}
50	5.885_i	1.777_i	0.99_g
55	5.62_h	1.079_h	0.852_f
60	5.32_h	0.981_h	0.832_e
65	5.205_{gh}	0.883_{gh}	0.736_d
70	4.88_g	0.884_f	0.91_{dh}
75	4.57_f	0.785_e	0.993_{cd}
80	4.1_f	0.736_d	1.179_c
85	3.635_{ef}	0.589_c	1.084_b
90	3.6_d	0.54_b	1.165_b
95	3.4_b	0.441_a	0.939_{ab}
100	3.37_a	0.343_{ab}	0.869_a

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 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 100ºC, the specific heat capacity values of melon seeds were 1.655, 1.611 and 1.596KJ/Kg/K respectively.

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

Temperature (ºC)	Specific Heat Capacity (KJ Kg^{-1} K^{-1})	Thermal Heat Conductivity (W m^{-1} K^{-1})	Thermal Heat Diffussivity. (m^2 s^{-1})
30	2.995_{k}	3.62_{l}	$6.19E\text{-}05_{o}$
35	2.8_{k}	1.545_{l}	$2.17E\text{-}05_{n}$
40	2.376_{k}	1.1_{kl}	$1.21E\text{-}05_{m}$
45	1.906_{cj}	1.83_{k}	$7.97E\text{-}06_{l}$
50	1.848_{j}	1.725_{k}	$5.89E\text{-}06_{k}$
55	1.811_{i}	0.64_{j}	$4.71E\text{-}06_{j}$
60	1.785_{h}	0.605_{i}	$3.55E\text{-}06_{i}$
65	1.766_{g}	0.555_{h}	$3.06E\text{-}06_{h}$
70	1.75_{fb}	0.53_{g}	$2.68E\text{-}06_{g}$
75	1.738_{e}	0.52_{f}	$2.19E\text{-}06_{f}$
80	1.728_{d}	0.505_{e}	$1.79E\text{-}06_{e}$
85	1.72_{c}	0.5_{d}	$1.62E\text{-}06_{d}$
90	1.655_{c}	0.499_{c}	$1.41E\text{-}06_{c}$
95	1.611_{b}	0.49_{b}	$1.26E\text{-}06_{b}$
100	1.596_{a}	0.46_{a}	$1.16E\text{-}06_{a}$

3.2.2 Thermal heat conductivity

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

3.2.3 Thermal heat diffusivity

The thermal heat diffusivity of melon seeds was maximum at 30ºC ($6.19 \times 10^{-5} m^2/s$), minimum at 100ºC ($1.16 \times 10^{-6} m^2/s$); $2.17 \times 10^{-5} m^2/s$; $1.21 \times 10^{-5} m^2/s$; $7.97 \times 10^{-6} m^2/s$; $5.89 \times 10^{-6} m^2/s$ and $4.71 \times 10^{-6} m^2/s$ at 35, 40, 45, 50 and 55ºC respectively. The thermal conductivity of melon seeds decreased with increased temperature. It was $3.55 \times 10^{-6} m^2/s$, $3.06 \times 10^{-6} m^2/s$, $2.68 \times 10^{-6} m^2/s$, $2.19 \times 10^{-6} m^2/s$, $1.79 \times 10^{-6} m^2/s$, $1.62 \times 10^{-6} m^2/s$, $1.49 \times 10^{-6} m^2/s$ and $1.26 \times 10^{-6} m^2/s$ at drying temperature of 55, 60, 65, 70, 75, 80, 85, 90, and 95ºC.

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 45ºC are statistically non significant. These values are significantly different from the mean terminal velocity value at 45ºC (5.95 m/s). The mean value of terminal velocity of the seeds at 45ºC is non-significant from the value at 50ºC (5.885m/s). The mean terminal velocity value of melon seed at

55ºC (5.62m/s), 60ºC (5.32m/s) and 65ºC (5.205m/s) are all non significant from each other but the terminal velocity value at 65ºC is significant from the values at 55ºC and 60ºC. It is non significant from the value at 70ºC (4.88m/s). The values of terminal velocity of melon seeds at 75ºC (4.57m/s), 80ºC (4.1m/s) and 85ºC (3.635m/s) are all the same statistically. The value of terminal velocity at 85ºC is different statistically from those at 75ºC and 80ºC. The terminal velocity values of melon seeds at 90ºC (3.6m/s), 95ºC (3.4m/s) and 100ºC (3.37m/s) are all statistically significant from one another at 5% probability level.

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

The mean values of drag coefficient of melon seeds at 30ºC (0.75), 35ºC (0.801), 40ºC (0.869) and 45ºC (0.925) are statistically the same, but the mean drag coefficient value at 45ºC is different is different statistically fro 30, 35 and 40ºC respectively. However, the same with the drag coefficient value at 50ºC (0.99). The mean drag coefficient value at 55ºC (0.852), 60ºC (0.832) and 65ºC (0.736) are all statistically significant, but the drag coefficient value of melon seed at 65ºC, 70ºC and 75ºC are all non significant at 5% probability level. Mean drag coefficient value of melon seeds at 75ºC (0.993) and 80 (1.179) are non significant. Drag coefficient values at 85ºC (1.084), 90ºC (1.165) and 95ºC (0.939) are all non significant. The values of drag coefficient of melon seeds at 95ºC are significant from values at 85ºC and 90ºC 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 30ºC (2.995 KJ/Kg/K). and minimum at 100ºC (1.596KJ/Kg/K). The values were all significantly different at the different temperature levels. However, the specific heat capacity at 85ºC (1.72KJ/Kg/K) and 90ºC (1.655KJ/Kg/K) were not significant ($p \leq 0.05$)

The mean values of thermal heat conductivity of melon seeds at 30ºC (3.62W/m/K), 35ºC (1.545W/m/K) and 40ºC (1.1W/m/K) are non significant. The thermal heat conductivity of melon seeds at 45ºC (1.83W/m/K) and 50ºC are non significant at 5% level of probability. However, the thermal heat conductivity value of 1.1W/m/K at 40ºC is significant from the values at 30ºC, 35ºC, and 45ºC, 50ºC respectively. The thermal heat conductivity value of melon seed at 55ºC (0.64W/m/K), 60ºC (0.605W/m/K), 65ºC (0.555W/m/K) and 70ºC (0.53W/m/K) are all significant. The thermal heat conductivity value of melon seeds at 75ºC (0.499W/m/K), 95ºC (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 (m^2/s) are significantly different from one another at the different drying temperature levels (30 to 100ºC)

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 30ºC, and attained its minimum value which was 3.37m/s at 100ºC. The drag force of the melon seed attained its maximum value of 1.777N at temperature of 50ºC and minimum value of 0.343N at temperature of 100ºC. At 35ºC, 40ºC and 45ºC, 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 80ºC and minimum value of 0.743 at temperature of 30ºC.

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 30ºC with a value of 2.995KJ/Kg/K, while it attained its minimum value 1.596KJ/Kg/K at temperature of 100ºC. The thermal conductivity was maximum at 30ºC with a value of 3.62W/mºK and minimum at 100ºC at a value of 0.46W/mºK. The thermal diffusivity attained maximum value of $7.97\times10^{-6}m^2/s$ at a temperature of 45ºC, and minimum at 100ºC with a value of $1.1\times10^{-6}m^2/s$.

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