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Evaluation of Some Engineering Properties of Bambara Beans for Effective Post-Harvest Machinery Design

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Abstract

Evaluation of some engineering properties of bambara groundnut for effective post-harvest machinery design was carried out at Michael Okpara University of Agriculture Umudike. The aerodynamic experiment was conducted at the Agricultural and Bio- resource engineering laboratory while antioxidant test was conducted at chemistry laboratory all at Michael Okpara University of Agriculture Umudike. The result showed brown Bambara specie had maximum length, width and mass of 14.067cm, 11.812cm and 1.202g respectively, while the black Bambara specie had the maximum thickness of 10.974 cm. The cream Bambara specie has the maximum height of 72.645cm. The cream Bambara species had the highest terminal velocity of 19.18m/s while the terminal velocity of the black Bambara species was 18.24m/s. The brown colored Bambara species had terminal velocity of 18.99 m/s while the mixed Bambara species had terminal velocity of 18.31 m/s. The mixed colored Bambara species had highest percentage absorbance of 12 mgAAEq/g while the black Bambara specie had the lowest percentage absorbance of 6 mgAAEq/g. The maximum drag coefficient value was obtained from the cream Bambara specie with value of 0.000324. The results indicate that the cream colored species had better aerodynamic properties as compared to other Bambara species. These properties are essential in post-harvest machinery design of equipment for Bambara beans processing.

Keywords: Aerodynamics; Bambara bean; Engineering properties; Machinery design; Postharvest

Introduction

Bambara bean (*Vigna subterranean L. Verdc*) is known also as Hog peanut. Bambara bean or ground bean is an indigenously grown grain legume cultivated largely by subsistence farmers in mostly dried aerial of sub-Saharan zones in Africa [1]. This bean is rated among most important legume in the orders of groundnut and also cowpea [2, 3]. Bambara bean holds numerous advantages in the class of other legumes as a result of its nutritional value and high natural flavored content. Its tolerance to adverse environmental conditions gives it an edge over other crops. Bambara ground bean represents a cheap protein-rich source cultivated annually that can improve the food and nutrition security status of rural households. From nutritional point of view, it is seen as an adequate food. Bambara bean is most useful in its powdered form, from where it can be processed to other useful different food forms. According to [4], the nutritional contents one which is desired by nutritionist due to its protein contents of 18.0-24.0%, iron 4.9-48mg/100g, amino acids contents of fat 5.0-7.0%, fiber 5.0-12%, calcium 95.8-99mg/100g, sodium 2.9-12.0 mg/100g, potassium 1144-1935mg/100g, and carbohydrate 57.43-63.09%. Due to the diverse nutritional composition [5, 6] bambara nut can meet dietary needs globally. Therefore, it is of uttermost importance to determine the useful properties necessary for the design of equipment for processing the bean into powdered form.

Biomaterial and aerodynamics properties are seen as the most essential properties to be considered for design purposes. The conscious production of biomaterials presents a viable and sustainable alternative for replacing packaging and textile materials, as well as applications in the areas of biomedicine and dentistry [7, 8, 9]. To evaluate the biomaterials of seeds, nuts and fruits, the determination of the aerodynamic properties becomes essential [10]. The aerodynamic properties of seed, nut and fruits at harvest are important for developing new approaches and methods for handling, de-hulling, and sorting, drying, milling and sieving in order to reduce energy use, increase process efficiency, and enhance product quality. The aerodynamic properties include; rupture/cracking force, coefficient of friction, drag coefficient and terminal velocity. These properties are essential for designing and developing postharvest handling and processing equipment and operations [11]. The cracking force is an important parameter in designing the decorticating machine because force applied along the axes can cause the nut breakage and decrease in the nut quality. All the parameters mentioned above are also of uttermost important in the development of bambara nut processing machine hence its determination. According to [12], Bambara nut is rated as an underutilized nut which is as a result of lack of equipment for its handling which involves decorticating, milling and sieving. This lack of material/equipment for its processing is traceable to lack of information/data on its aerodynamic and biomaterial properties which is of uttermost importance to the design of this equipment, and this is a relief to both small and medium scale bambara flour processors across the nation. This technology improve hygiene through elimination of human contact involved during sieving loading/discharging of intermediate processed flour among the unit operations and reduce excessive drudgery and food loss in this sector aiding mass production of quality bambara flour at low cost providing, food security, creating employment and alleviating poverty.. Hence, this study provides a detailed methodology and extensive data collection across multiple properties, such as physical dimensions, mass, terminal velocity, and antioxidant levels of this very useful bean to enable the design of materials for its processing. The objective is to evaluate some engineering properties of bambara ground bean for effective post -harvest machinery design.

Materials and Methods

Materials

Four different species of Bambara beans were discovered from investigation and interaction with farmers to be the most widely cultivated and generally accepted they include: cream, black, brown and mixed colored species which can be obtained from various local markets within Nigeria, such as Abia, Imo, Bauchi, Adamawa, Kano, Gombe, Ebonyi, Enugu and Anambra State. The freshly variety of Bambara beans were used for the study, the apparatus used include; transparent pipe, blower, measuring tape,

anemometer, venire-caliper, stop watch, weighing balance

Limitation

For the purpose of designing materials for processing the Bambara ground bean, the limited available spices which were sourced, was used for this study.

Methodology

The aerodynamic experiment was carried out at the Agricultural and Bio- resource laboratory of Michael Okpara University of Agriculture Umudike. The antioxidant test was carried out in Chemistry Department Laboratory of the College of Pure and Applied Sciences, Michael Okpara University of Agriculture, Umudike and the steps adopted explained below.

Preparation of the Bambara nut

In preparation of the sample 50grams of freshly harvested Bambara bean species which include: cream, black, brown and mixed colored were measured out and properly sift to get rid of debris, stones and unwanted elements from the bean. The bambara bean were dried by exposing it to open air under sun light and also with the help of an oven at a temperature of 103°C ± 2°C until a constant weight were reached.

Determination of the Aerodynamic Properties of Bambara bean

The terminal velocity of Bambara bean fractions was determined using equipment that consists of a vertical cylindrical wind tunnel made of Plexiglas, connected to a 1hp motor-powered centrifugal fan to supply air flow into the wind tunnel. A wire screen was positioned in the top section of the vertical wind tunnel to prevent the nut from falling down to the bottom. The air flow rate of the fan was controlled at the bottom section of the wind tunnel using an adjustable diaphragm. An opening was made on the Plexiglas just above the wire screen where a hot-wire probe of a digital anemometer was inserted to measure the terminal velocity of the nuts. To measure the terminal velocity for each of the nut fractions, the nut was placed on the wire screen within the cylindrical wind tunnel. The air flow from the centrifugal fan was then increased until the nut was suspended in the air stream within the wind tunnel. At the point when the rotational movement of the nut was lowest, the air velocity was measured [13] using the digital anemometer measuring to an accuracy of 0.1 ms^{-1}. To probe the hot wire used, anemometer was inserted into the air stream through the perforation on the wind tunnel to measure the air velocity near the location of the suspended nut.

For an object in a free fall, the object will attain a constant terminal velocity (Vt) at which the net gravitational accelerating force (Fg) will equal the resisting upward drag force (Fr).

To derive a general expression for the terminal velocity of the bean, the gravitational force (Fg) is set to be equal to the resisting drag force (Fr), and the velocity V, equaled to the terminal velocity V_t. The expression for the terminal velocity is given in equation *(1)* to equation (3).

$$V_t = \sqrt{\frac{2mg\left(\rho_s - \rho_a\right)}{\rho_s \rho_a A_p C_d}} \quad (1)$$

The drag coefficient C_d can be derived as follows;

$$C_d = \frac{2mg\left(\rho_s - \rho_a\right)}{\rho_s \rho_a A_p V_t^2} \quad (2)$$

And the projected area, Ap

$$A_p = \frac{\pi}{4} LW \quad (3)$$

where, Ap is the projected area of the nut (m^2),C_d is the drag coefficient (dimensionless), g is acceleration due to gravity (9.81 m s^{-2}), L is the nut length (m), m is the mass of nut (kg), V_t is terminal velocity (m s^{-1}), W is the nut width (m), ρ_a is the density of air (1.206 kg m^{-3} at room temperature), ρ_s is the density of the nut seed (kg m^{-3}).

Reynolds number is an important aerodynamic attribute that represents the ratio of inertial effects (i.e., the product of the particle's velocity and length scale) to viscous effects (i.e., viscosity of the medium/fluid in which the particle is moving—in this case, air) [14]. The Reynolds number (Re) will be calculated using the terminal velocity of each nut sample from the following relationship [15];

$$Re = \frac{\rho_a V_t D_g}{\mu} \quad (4)$$

Dg is the geometric mean diameter of the nut (m);

μ is air viscosity (1.816×10^{-5} Ns m^2 at room temperature)

Antioxidant Test

The free radical scavenging activity or antioxidant activity was evaluated according to the method by [16]. A 100microliters of the extract was added to 1ml of the DPPH solution. After 30 minutes of incubation in a dark room at room temperature, the decrease in absorbance was determined at 517nm. Ascorbic acid was used as a standard, and the antioxidant activity was expressed as milligrams ascorbic acid equivalents per gram Bambara bean dry weight (mg AAE/g DW).

Results and Discussion

Physical Properties of Bambara bean

The physical properties of four Bambara bean species were examined and analyzed. The length, width, thickness, mass, and height of the brown, black, brown and mixed colored Bambara beans were measured and analyzed. The result in table 1 shows the lengths of the creamed colored Bambara bean as 11.866cm, width value of 10.73 cm mean thickness value of 10.948 cm. The cream Bambara specie also had the highest mean height of 72.645 cm. and mass value of 0.985g.

Table 1: Physical and aerodynamic properties of cream Bambara bean specie

S/N	Length	Width	Thickness	Mass	TerminalVelocity	Height
1	11.3	10.2	11.1	0.87	21.9	22.86
2	11.7	10.2	10.7	0.87	21.1	33.02
3	11.5	11.4	11.6	1.07	0	0
4	12.3	10.7	12.8	1.18	18	55.88
5	11.6	10.8	11.8	0.87	18.9	53.34
6	12.2	10.4	11.5	0.96	18.9	38.1
7	11.7	11.1	11.7	1.07	22.3	40.64
8	10.8	9.6	10.7	0.78	23.1	40.64

9	12.2	10.6	10.7	0.95	19.1	6.04
10	11.8	10.8	10.5	0.81	17.1	5.08
11	12.9	10.2	11.1	0.91	22.1	25.04
12	11.5	10.4	11.9	0.99	17.9	35.56
13	10.8	10.1	10.1	0.73	22.2	38.1
14	11.8	12.1	11.6	1.13	17	43.18
15	11.5	11.1	11.5	1.04	17.9	22.86
16	12.1	8.9	11.8	0.91	19.1	73.66
17	11.1	10.2	11.1	0.73	20.9	25.4
18	11.4	9.5	10.3	1.73	17.9	33.02
19	12.5	12.8	12.1	1.21	22.2	25.4
20	12.9	11.1	11.1	1.01	15.6	58.42
21	12.2	12.7	10.2	1.23	18.1	27.94
22	12.7	12.2	15.6	1.35	16.6	17.78
23	11.2	11.4	11.2	1.35	19.9	30.48
24	12.6	4.1	10.2	0.94	20.5	42.18
25	12.1	9.1	11.1	0.95	19.5	33.02
26	12.1	11.8	9.2	0.78	23.3	33.02
27	11.4	10.1	11.2	1.04	14.5	55.88
28	12.6	11.8	11.2	0.85	23.1	12.7
29	12.2	9.4	10.4	1.08	21.5	55.88
30	12.2	11.3	11.7	0.9	22.1	15.24
31	12.7	10.2	11.1	1.2	22.2	17.78
32	10.5	11.6	10.2	0.8	18.9	20.32
33	12.6	11.1	11.5	1.92	21.4	38.1
34	13.7	13.2	11.4	1.1	16.6	22.56
35	11.2	10.5	10.1	1.28	20.1	25.4
26	12.6	10.2	11.4	0.11	16.7	20.5
37	11.3	10.2	10.4	0.79	23	22.86
38	10.7	10.5	11.7	0.86	16.5	27.94
39	13.7	11.4	11.2	1.19	19.5	20.4
40	11.2	11.1	10.3	0.93	19.5	27.94
41	12.2	11.5	10.2	0.91	18.5	12.7
42	11.2	10.5	9.4	0.83	18.4	20.9
43	12.9	11.4	10.2	0.99	16.5	16.5
44	11.2	10.1	10.5	0.83	20.1	20.32

45	11.1	11.1	9.4	0.85	21.1	40.64
46	12.2	11.6	10.7	0.94	21.9	20.32

Table 2 shows the aerodynamic properties of black colored bambara beans where 50 seeds were sampled, from the table the average lengths, width, thickness, mass, terminal velocity and height of the black colored Bambara bean were determined as 11.7cm, 9.5cm 9.6cm,0.72cm, 18.6cm and 53.34cm respectively. The black Bambara specie had the highest thickness of 9.6 cm and is also seen to be next to cream colored specie with mean height value of 40.234 cm. the black Bambara specie also had the lowest mass of 0.729g when compared to other bambara bean species

Table 2: Physical and aerodynamic properties of Black Bambara bean specie

S/N	Length	Width	Thickness	Mass	Terminal Velocity	Height
1	11.2	91	10.6	0.69	20.1	25.4
2	12.3	11.3	10.3	1.12	18.1	25.4
3	11.6	10.5	9.2	0.9	16.1	43.18
4	11.4	9.2	10.5	0.79	21.1	33.02
5	12.5	10.7	9.6	0.8	19.8	30.48
6	10.4	10.7	10.4	0.77	13.1	40.64
7	11.3	10.4	8.2	0.76	20	30.48
8	11.6	8.1	7.7	0.53	19.4	33.02
9	11.2	10.5	10.7	0.93	19.2	25.4
10	11.7	9.6	9.6	0.6	16.5	50.8
11	13.7	10.1	10.6	0.98	16.9	43.18
12	11.7	9.2	9.3	0.69	17.6	33.02
13	11.1	9.6	8.7	0.67	17.6	76.2
14	11.2	10.5	10.8	0.076	16.1	43.18
15	12.6	8.1	9.2	0.57	20.1	68.58
16	10.6	10.7	8.3	0.7	17	33.02
17	11.3	9.1	9.1	0.7	19.2	33.02
18	11.4	11.6	9.4	0.91	17.1	25.4
19	12.2	10.5	10.6	0.91	20	25.4
20	13.6	11.2	10.6	1.09	19.5	40.64
21	12.6	10.4	10.4	0.8	15.5	53.34
22	10.7	8.3	9.3	0.7	16.5	38.1
23	13.3	10.1	9.4	0.93	20.2	35.56
24	10.3	10.2	10.2	0.89	20.4	25.4
25	12.2	11.2	10.3	1.05	18.8	50.8
26	11.2	9.2	10.6	0.73	17.2	27.94
27	12.9	7.6	8.9	0.63	19.5	63.5

28	11.2	9.3	9.2	0.71	17.1	38.1
29	12.3	10.2	9.3	0.95	18.2	43.18
30	12.7	9.5	9.1	0.62	17.4	38.1
31	12.2	9.3	8.2	0.73	19.3	30.48
32	11.4	8.4	8.3	0.68	17.4	48.26
33	11.6	10.7	9.2	0.79	20.4	50.8
34	12.9	9.3	9.3	0.84	19.5	48.26
35	10.7	9.1	8.4	0.57	18.5	50.8
36	10.7	9.1	8.4	0.57	18.5	48.26
37	10.3	9.3	8.8	0.49	17.1	38.1
38	11.6	10.6	9.7	0.63	20	25.4
39	11.2	9.2	10.2	0.72	16.6	55.88
40	11.4	9.6	8.9	0.55	14.6	35.56
41	11.2	10.6	10.4	0.88	19.5	50.8
42	11.8	9.6	8.6	0.64	18.4	43.18
43	9.2	8.3	7.2	0.5	19.5	35.56
44	10.2	8.7	8.5	0.45	19	27.94
45	11.3	9.4	9.5	0.67	16.6	35.56
46	12.8	10.77	10.2	0.89	20.2	30.48
47	10.1	9.1	9.8	0.61	18.2	40.64
48	11.3	9.3	9.4	0.79	17.1	35.56
49	10.4	9.6	86	0.57	17.8	53.34
50	11.7	9.5	9.6	0.72	18.6	53.34

Table 3below shows the aerodynamic properties of brown colored bambara beans, where 50 seeds were sampled, from the table the average lengths, width, thickness, mass, terminal velocity and height of the brown colored Bambara bean were determined as 14.6cm,12.3cm,10.2cm, 1.4cm,18.8cm and 27.94cm respectively. The result also showed that the brown colored Bambara bean had the highest length, width and mass of 14.67cm, 12.3cm and 1.4g respectively when compared to other species but had the lowest height of 27.94 cm.

Table 3: Physical and aerodynamic properties of Brown colored Bambara bean specie

S/N	Length	Width	Thickness	Mass	Terminal Velocity	Height
1	14.4	12.6	11.2	1.31	17.5	30.48
2	15.2	13.7	11.6	1.37	16.7	27.94
3	15.7	12.7	10.3	1.45	20.9	25.4
4	15.6	13.3	11.2	1.32	20.2	35.5
5	14.7	11.2	11.6	1.42	24.1	73.66
6	15.6	12.7	10.6	1.29	22.2	22.86

7	14.8	10.5	11.2	1.31	20.9	27.94
8	16.7	12.9	10.5	1.01	19	60.96
9	14.5	12.6	11.2	1.34	17.9	22.86
10	16.7	12.9	11.2	1.49	16.5	40.64
11	11.7	10.2	10.5	1.47	17.1	68.58
12	14.4	12.7	11.3	1.49	24.2	22.86
13	13.4	11.5	10.2	0.94	14.9	76.2
14	14.4	14.7	11.2	1.7	20.4	17.78
15	12.2	10.4	10.3	1.06	22.5	40.64
16	15.8	12.4	12.4	1.64	18.9	45.72
17	14.5	11.3	11.4	1.25	19.5	25.4
19	15.9	11.2	11.2	1.29	16.5	20.32
20	14.4	17.8	11.2	1.49	20.1	27.94
21	13.4	11.3	11.5	1.26	20.9	33.02
22	13.2	11.3	10.3	0.98	14.5	76.2
23	16.8	12.2	11.9	1.5	19.2	43.18
24	12.3	11.6	10.2	0.84	19.6	17.78
25	15.3	12.78	11.4	1.44	19.3	27.94
26	13.7	11.7	11.5	1.07	16.6	38.1
27	14.3	11.6	11.3	1.44	19.9	33.02
28	13.4	12.6	11.3	1.29	18.1	25.4
29	13.2	11.1	10.1	1.15	17.1	40.64
30	13.4	11.7	10.2	1.23	19.2	53.34
31	13.1	12.4	10.4	1.06	19.1	22.86
32	14.8	12.2	10.2	1.08	18.4	35.56
33	12.2	10.3	10.5	0.97	16.6	35.56
34	13.3	10.4	10.1	0.98	17.7	35.56
35	12.9	10.4	10.7	0.77	17	40.64
36	14.7	10.2	10.2	0.99	18.6	55.88
37	13.6	11.3	11.5	0.97	18.9	35.56
38	13.3	11.7	10.2	1.03	24.1	43.18
39	14.2	11.4	11.6	1.28	24.1	43.18
40	13.6	11.5	9.2	1.09	20.4	35.56
41	15.4	10.7	9.3	0.71	17.1	25.4
42	11.4	11.3	11.6	1.18	16.1	50.8
43	13.8	11.3	11.6	1.82	16.1	50.8

44	12.9	10.8	10.6	0.82	19.9	76.2
45	11.4	10.3	9.6	0.63	16.5	53.34
46	12.7	10.3	9.4	0.79	20.67	50.6
47	14.7	11.9	10.5	1.22	17.9	53.34
48	13.3	13.7	10.4	1.31	18.9	73.6
49	13.8	9.2	10.2	0.97	19.5	22.86
50	14.6	12.3	10.2	1.4	18.8	27.94

Table 4 shows the aerodynamic properties of mixed colored bambara bean specie. From the table you can deduce that the mixed Bambara bean had mean width value of 10.27cm, length value of 12.612cm and had the lowest mean thickness of 9.67 cm. The mixed colored Bambara specie had mean height value of 40.386 cm and mean mass value of 0.863g.

Table 4: Physical and aerodynamic properties of mixed colored Bambara bean specie

S/N	Length	Width	Thickness	Mass	Terminal Velocity	Height
1	11.4	10.5	9.5	0.69	18.9	43.18
2	11.3	9.2	9.5	0.64	19.6	38.1
3	13.4	10.4	8.5	0.8	19	30.48
4	11.7	9.2	9.5	0.64	17.4	43.18
5	11.4	9.2	9.5	0.64	20.7	68.58
6	11.4	10.2	9.2	0.95	18.1	30.48
7	11.1	11.6	10.2	0.88	19.9	27.94
8	11.4	10.1	10.5	0.88	18.4	35.56
9	11.1	10.2	10.7	0.84	17.6	30.48
10	12.7	10.3	10.2	0.96	21.1	27.94
11	11.2	10.3	10.4	0.91	20.1	27.94
12	12.2	11.1	10.3	1.00	17.9	50.8
13	14.2	11.1	10.2	1.21	19.5	40.64
14	13.3	12.4	10.1	1.12	18.1	25.4
15	11.4	11.5	9.6	1.03	17.6	38.1
16	12.5	10.2	10.6	0.95	18.6	30.48
17	12.1	10.2	10.1	0.88	19.9	43.18
19	12.5	11.1	10.5	1.03	20.1	27.94
20	14.5	11.1	10.8	1	19.7	27.94
21	12.2	10.5	9.2	0.81	19.1	38.1
22	10.3	9.2	8.3	0.51	18.1	53.34
23	11.3	10.5	8.3	0.72	16.5	40.64
24	11.6	10.2	9.1	0.77	17.2	38.1

25	12.3	10.2	10.4	0.9	18.6	35.56
26	12.3	9.2	9.3	0.73	19.6	63.5
27	10.5	10.4	9.4	0.82	19.4	43.18
28	12.3	11.2	9.2	0.9	20.6	35.56
29	12.1	10.2	8.4	0.83	19.3	30.48
30	11.1	9.1	8.3	0.64	19.3	50.8
31	12.2	9.3	9.4	0.77	19.3	33.02
32	13.6	10.5	10.6	0.87	19.1	40.64
33	10.6	8.3	8.6	0.51	14.1	73.66
34	13.3	10.4	10.1	1.21	17.6	22.86
35	12.7	9.2	9.1	0.84	15.6	66.04
36	12.4	10.5	9.6	0.79	18.4	48.26
37	12.2	10.3	9.2	0.78	16.6	22.86
38	12.4	10.1	9.2	0.87	19.8	30.48
39	12.2	10.1	9.2	0.83	19.4	60.96
40	12.3	10.2	10.1	0.94	16.9	27.94
41	12.4	10.2	10.1	0.92	15.1	55.88
42	12.4	11.3	10.2	1.05	20	20.32
43	12.3	10.3	10.7	0.96	16.6	33.02
44	12.4	11.3	10.5	1.04	17.6	38.1
45	11.3	10.5	9.1	0.78	18.8	60.96
46	13.4	10.2	10.3	1.01	18.6	66.04
47	14.5	10.2	9.4	1.01	9.8	40.64
48	11.4	10.5	9.2	0.79	16.6	40.64
49	13.3	10.3	9.3	0.98	18.8	33.02
50	12.6	10.2	10.5	0.85	20.1	30.48
Average	11.4	9.2	9.3	0.68	16.9	55.88

Antioxidant Properties of Various Bambara Species

The free radical scavenging activity/antioxidant activity was carried out and the result presented in Table 5. The result showed that the percentage absorbance of the Bambara bean biomaterial increased with increase in concentration of the Bambara bean. The maximum absorbance of 0.2% was obtained at 10 mg/L. At 8 mg/L and 6 mg/L, percentage absorbance of 0.17 and 0.12 were obtained.

Table 5: Percentage absorbance of the cream colored Bambara species

Concentration mg/L	*% absorbance*
0	0
2	0.048
4	0.078
6	0.118
8	0.158
10	0.201

Aerodynamic Properties of Various Bambara Species

In the consideration of the Aerodynamic Properties of Various Bambara Species, the environmental condition of the bambara grand bean were considered. According to [17, 18] the growth of the bean is about 30-3 cm in height, and they went further to describe the bambara nut which aided in determining terminal velocity, effect of mass on the terminal velocity of the Bambara nut species, drag coefficient which are its Aerodynamic Properties considered in this study. Also the equipment description such as the calibration, and other conditions is as reported [19].

Terminal Velocity

The terminal velocity of the Bambara bean species were measured and presented in figure 1. The result indicated that the cream Bambara species had the highest terminal velocity of 19.18 m/s which can be attributed to their mass. The terminal velocity of the black Bambara species was obtained as 18.24m/s while the brown colored Bambara species had terminal velocity of 18.99 m/s. The mixed Bambara species had terminal velocity of 18.31 m/s. the value of the terminal velocities recorded were higher than the wheat and barley studied by [20]. [21] also reported terminal velocity of 18.10 m/s for shea nut.

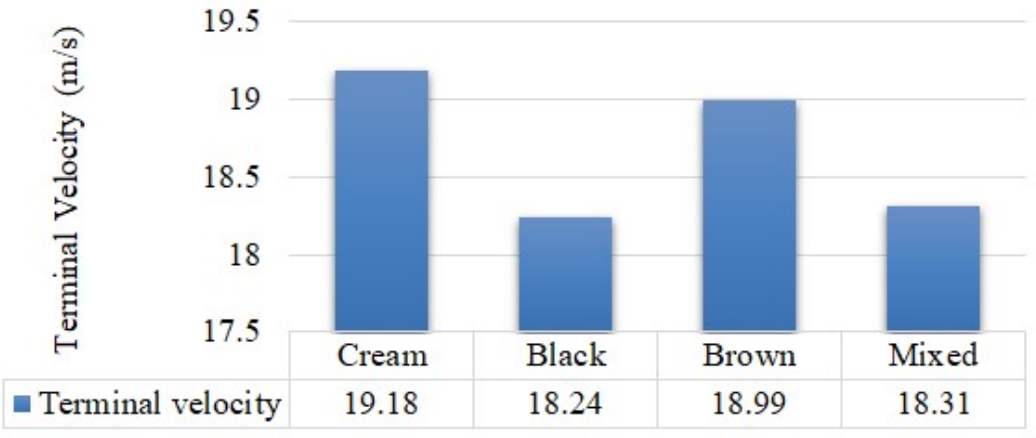

Figure 1: Terminal velocity of the Bambara bean species

Effect of mass on the Terminal Velocity of the Bambara Nut Species

The relationship between the mass of the Bambara nut species and the terminal velocity is depicted in figure 2. The result showed that the terminal velocity increased with the increase in the mass of the Bambara nuts. As the grain mass of the nuts increases, it needs more air velocity for carrying it and a corresponding increase in its terminal velocity was observed. To relate

the changes in grain mass with the terminal velocity, a regression analysis was employed. The correlation coefficient (R^2) indicated the significant relationship between the mass and terminal velocity. The R^2 value of 0.6354 is fairly favorable and significant

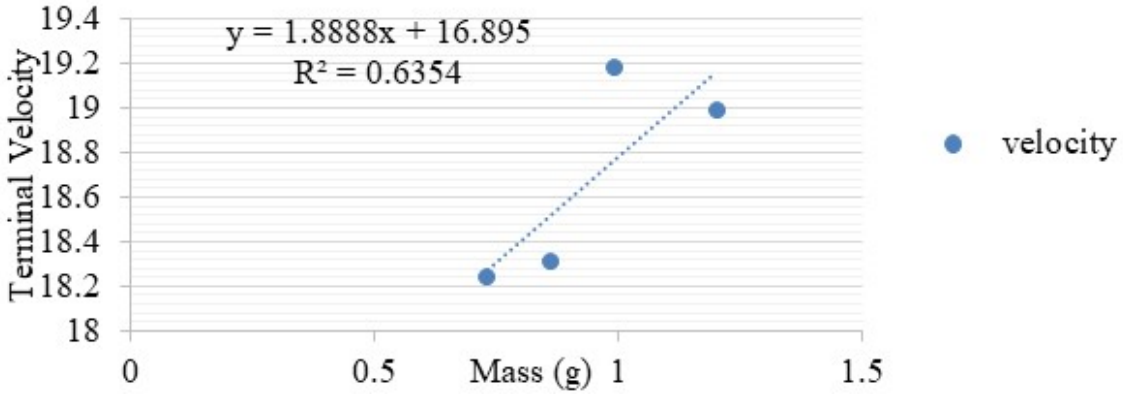

Figure 2: Effect of mass on the terminal velocity

Drag Coefficient

The drag coefficient values of the Bambara bean species were depicted in figure 3. The result showed that drag coefficients of the species were within 0.0003 and 0.0002. The maximum drag coefficient value was obtained from the cream Bambara specie with value of 0.000324. The brown and mixed Bambara species had drag coefficient values of 0.000307 and 0.000315 respectively. The minimum drag coefficient of 0.000256 was obtained from the black Bambara specie. The low drag coefficient values of the bean can be attributed to the fact that the shapes of the beans are spherical. It can be inferred that the beans can be efficiently transported with the application of pneumatic force since the area of the beans in contact with the layer of the fluid does not offer appreciable opposition to the air pressure

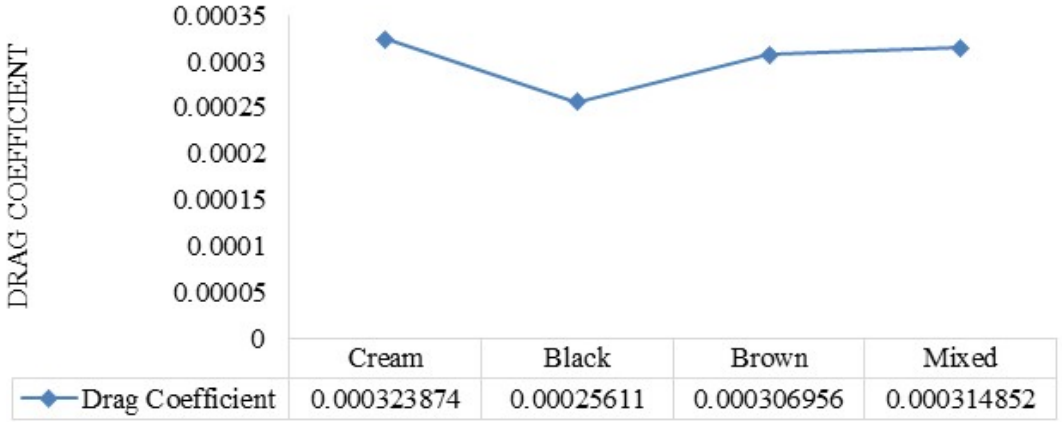

Figure 3: Drag coefficients of the Bambara bean species

Conclusion

The results obtained above showed that brown Bambara specie had the maximum length (14.067cm), width (11.812cm) and mass of (1.202g) while the black Bambara specie had the maximum thickness (10.974 cm). The cream Bambara specie has the maximum height of 72.645cm. The cream Bambara species had the highest terminal velocity of 19.18m/s while the terminal velocity of the black Bambara species was 18.24m/s. The brown colored Bambara species had terminal velocity of 18.99 m/s while

the mixed Bambara species had terminal velocity of 18.31 m/s. The percentage absorbance of the biomaterials in the Bambara species showed that the maximum absorbance of 0.2% was obtained at 10 mg/L. At 8 mg/L and 6 mg/L, percentage absorbance of 0.17 and 0.12 were obtained. The correlation coefficient (R^2) of 0.6354 indicated the significant relationship between the mass and terminal velocity. The maximum drag coefficient value was obtained from the cream Bambara specie with value of 0.000324. The brown and mixed Bambara species had drag coefficient values of 0.000307 and 0.000315 respectively while the black Bambara specie had drag coefficient of 0.000256.

The results indicated that the aerodynamic properties of cream Bambara species were better than other Bambara species. Its highest thickness value aids in decreasing the coefficient of static friction which is important in the design and construction of hopper for gravity flow. These engineering properties obtained in this research will serve as useful data for design purposes in bambara sector. This data bank undoubtedly will help in mass production of equipment for its processing thus making bambara farming appealing and adequately positioned for food security and job creation.

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