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Some Physical and Mechanical Properties of Black Cumin Seeds Preparatory to Primary Processing

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Abstract

The study was carried out to determine the physical, mechanical and frictional characteristics of black seeds, namely, principal axes, arithmetic mean diameter, geometric mean diameter, surface area, volume, 1000 unit mass, sphericity, aspect ratio, porosity and angle of repose bio-yield force, rupture force, compressive force and strength, modulus of elasticity of black seeds. Results showed that seeds have length, width and thickness values varied from 2.94 to 3.65 mm, 1.31 to 2.11 mm and 0.62 to 1.32 mm respectively. The mean sphericity, aspect area, surface area, volume and 1000 unit mass of black seeds were 55%, 47%, 17.26 mm^2, 7.83 mm^3 and 3.18 g. Stainless steel surface had the lowest value of static and dynamic coefficient of friction. The positive interaction was observed between density, rupture force, yield force, yield compressive strength and significantly different at ($P<0.001$). Stainless steel is more appropriate for the construction of hopper and chute of the machine.

Keywords

Density, compressive force, principal axes, volume, friction, angle of repose

1. Introduction

The black seeds *Nigella sativa* are rich in nutritive substances and have high medicinal value. The seeds have been used in traditional medicine by many countries for instance Asia, Middle East and Egypt to treat different types of ailment such as headache, coughs, abdominal pain, diarrhea, asthma, rheumatism and other diseases [1, 2]. Many researchers have engaged in comprehensive studies of phytochemically and pharmacologically of this plant due to its medicinal and economic values [3]. The oil extracted from black seeds is rich in thymoquinone and also possess antioxidant, anti-inflammatory, anticancer, analgesic, immune booster and antimicrobial activities. Furthermore, phytochemical analyses of black cumin seeds contain more than hundreds of phytoconstituents which include majorly alkaloids, saponins, sterols and essential oil [1, 2, 4]. The (*Nigella sativa* L.) commonly called black seeds in English is an annual herbaceous plant and a member of Ranuculacea family [5].

The different nations of the world called the *Nigella sativa* seeds as: schwarzkummel (German), Hak Jung Chou (China), coriander (Romans), kalonji (Hindi/Urdu), kezah (Hebrew), chernushka (Russian), corek-out (Turkish), siyahdaneh (Persian), Kalijeera (Bangladesh), Kalonji (Indian) and carvi (French) [6]. According to Gharib-Zahed et al. [7], it described black seed as having angular shape with weight ranged between 1 and 5 mg, and also bitter tastes and peppery with a crunchy texture. The composition of the matured seeds involves moisture content ranged from 5.52% to 7.43%, crude protein from 20% to 27%, ash from 3.77% to 4.92%, ether-extractable lipid from 34.49% to 38.72% and carbohydrates from 23.5% to 33.2% [8].

According to Yimer et al. [9], the nutritional composition of black seeds reported from different sources revealed 20%-85% of protein, 38.20% of fat, 7%-94% of fiber, and 31.94% of total carbohydrates. Takruri and Dameh [10] and Ramadan [11], observed that black cumin seed is enriched in iron, copper, zinc, phosphorus, calcium, thiamin, niacin, pyridoxine, and folic acid. Furthermore, phytochemical analyses of black seeds contain more than hundreds of phyto-

constituents which include majorly alkaloids, saponins, sterols and essential oil. The black seed contain fixed oil (26%-34%), linoleic acid (64.6%) and palmitic acid (20.4%) [12, 13].

The information on the geometrical properties of agricultural materials is fundamental in designing machines for cleaning, sorting, grading and separation. Gravimetric characteristics are essential for the design and manufacture of machines associated with aeration, drying, storage, packaging systems and transport. The knowledge of porosity, bulk and true densities is critical in designing and manufacturing of storage capacity, air flow, drying, separating, transporting, grading and cleaning systems packaging systems, heat exchanger, transport systems and separation. The frictional characteristics for instance the angle of repose, the coefficient of static and dynamic friction are essential parameters associated with the design of grains and fruits bins and other storage structures together with the compressibility and flow behavior of biological materials.

The physical and mechanical properties have been studied for different biomaterials products by different scientists in order to develop database essential for the designing and construction of equipments for harvesting, material handling, processing, storage and packaging, such as soybean, [14] groundnut grains [15], pistachio nut and kernel, [16] cowpea [17], watermelon seed [18], shea kernel [19], cucurbit seeds [20] castor seed [21). Paucity of information on some physical and mechanical properties of black seeds which are imperative to understand the behavior of the product during processing, transporting, packaging and storage processes operations. The aim of this study was therefore to determine some the engineering characteristics of black seeds.

2. Materials and Method

2.1 Sample preparation

The black seeds (Figure 1) used for this research were purchased Ibadan, Oyo State, Nigeria. Samples were cautiously selected to avoid premature, seeds. Thus, only mature amd healthy seeds were chosen for the conduct of this experiment. This study was carried out at the moisture range of 7.6% dry basis. The moisture content of the black seeds was investigated according to ASAE [22] standard S 352.2.

Figure 1. Black seeds.

2.2 Geometric properties

To determine mean of black seeds dimension, 50 seeds were randomly and carefully selected and their three linear dimensions namely, length (*L*), width (*W*) and thickness (*T*) were measured using digital Vernier Caliper with an accuracy of 0.01 mm. The mean length, width and thickness of black seeds cumin were determined using the three axial dimensions. The arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (Φ), surface area S, aspect ratio R_a of black seeds were calculated by using the following relationships [16, 18, 20, 21, 23].

$$\mathrm{Da} = \frac{\mathrm{L} + \mathrm{W} + \mathrm{T}}{3} \tag{1}$$

$$\mathrm{Dg} = (\mathrm{LWT})^{0.333} \tag{2}$$

$$\mathrm{Dsm} = \left(\frac{lW + WT + LT}{3}\right)^{0.5} \tag{3}$$

$$\mathrm{De} = \frac{\mathrm{Da} + \mathrm{Dg} + \mathrm{Dsm}}{3} \tag{4}$$

$$\Phi = \frac{\sqrt[3]{(LWT)}}{L} \tag{5}$$

$$Ra = \frac{W}{L}100 \quad (6)$$

$$As = \frac{\pi B L^2}{(2L-B)} \quad (7)$$

$$V = \frac{\pi B^2 L^2}{6(2L-3)} \quad (8)$$

$$B = (LW)^{0.5} \quad (9)$$

The volume (V) of black seeds was estimated using Davies [24]. The 1000 unit mass of black seeds determined using precision electronic balance to an accuracy of 0.01 g. To evaluate the 1000 unit mass for fruits and nut, 50 randomly selected samples were weighed and multiplied by 20 to give the mass of 1000 seeds. The experiment was replicated ten times.

2.3 Mechanical Properties

The Universal Testing Machine with precision was 0.01 N. was used for the test. Individual sample was placed on desired section and preferred speed of loading and force was applied force until it ruptured at a deformation speed of 10 mm min-^{1}. The mechanical properties were determined according to Davies [24]

3. Result and Discussion

Some physical properties of black seeds were represented in Table 1. The length, width and thickness of black seeds varied from 2.94 to 3.65 mm, 1.31 to 2.11 mm and 0.62 to 1.32 mm respectively. The minimum, maximum and mean arithmetic mean diameter values of black seeds were 1.62 mm, 2.36 mm and 1.96 mm respectively. The geometric mean diameter and square mean diameter were 1.77 mm and 1.85 mm. The sphericity and aspect ratio of black seeds ranged between 45.37% and 55.05% and 57.81 and 44.56%. Davies [25] reported the sphericity of three species of melon seeds; *C. lunatus*, 53%, *C. edulis*, 47% and *C. vulgaris*, 45%. It was observed that black seeds will rather slide than roll based on the recommendation by Garnyak 2008 [25], that sphericity value higher than 70% is taken as spherical for grain, fruit and seed. Thus, black seed is not spherical. The mean values of sphericity as reported by Jayan and Kuman [27] for maize, red gram and cotton were 62.1%, 75.0% and 67.7%. This property is essential in the design of hoppers and chute of a machine.

The surface area of black seeds ranged between 5.62 and 14.74 mm^2. According to Davies and Mohammed [28], mentioned surface area of soursop seeds varied from 195.10±7.73 mm² to 385.05±4.75 mm². This is an indication that surface area of black seeds is much lower than surface area of soupsop seeds. The usefulness of this property is found in the determination of spray coverage, residues removal, rate of respiration, light reflectance and the rate of reaction during biochemical processes. The volume of black seeds varied from 7.83 to 12.50 mm^3. The 1000 unit mass black seeds ranged between 2.15 and 4.02g.

The static coefficient of friction of black seeds against five different structural surfaces was experimented. The angle of repose was 23.6^o as presented in Table 2. The mean angle of repose for maize, red gram and cotton were 22.1˚, 28.48˚ and 21.48˚ as reported by Jayan and Kuman [27]. The results of plywood structural surface had the highest value of static and dynamic coefficient of friction. Fiberglass surface had the lowest static coefficient friction. According to Tabatabaeefar [29], the static coefficient of friction of wheat follow similar trend. The static coefficient of friction of black seeds against five different structural surfaces was experimented. The angle of repose was 23.6^o. The mean angle of repose for maize, red gram and cotton were 22.1˚, 28.48˚and 21.48˚was reported by Jayan and Kuman [28].

Table 1. Some physical properties of black seeds

Properties	No. of Samples	Maximum	Minimum	Mean
Length (cm)	100	3.65	2.94	3.24
Width (cm)	100	2.11	1.31	1.53
Thickness (cm)	100	1.32	0.62	1.12
Arithmetic mean Diameter (mm)	100	2.36	1.62	1.96
Geometric mean Diameter (mm)	100	2.17	1.34	1.77
Square Mean diameter	100	2.26	1.47	1.85
Equilvalent Diameter	100.00	2.26	1.48	1.86
Sphericity (%)	1.00	59.05	45.37	55.28
Aspect ratio (%)	100	57.81	44.56	47.22
Surface area (mm^2)	100	14.74	5.61	9.85
Volume (mm^3)	100	12.50	6.05	7.83
1000-Unit mass (g)	50	4.02	2.41	3.18

The results presented in Table 2 showed that plywood structural surface had the highest value of static and dynamic coefficient of friction. Stainless steel surface had the lowest static coefficient friction. The positive interaction were observed between density, rupture force, yield force, yield compressive strength and significantly different at (P<0.001) as shown in Table 3. However, density had strong negative correlation with porosity (P<0.001). This is an indication that all the investigated mechanical properties have strong positive interactions with each other except porosity that had negative relationship with the other properties.

Table 2. Frictional properties of black seeds

Properties	Seeds	
	Average	Coefficient Variation (%)
Angle of repose (^{o})	23.6	10.76
	Static coefficient	
Stainless steel	0.256	5.43
Galvanised iron sheet	0.342	9.89
Plastic sheet	0.323	10.6
Plywood sheet	0.387	11.4
	Dynamic coefficient	
Stainless steel	0.219	9.75
Galvanised iron sheet	0.295	6.08
Plastic sheet	0.331	7.31
Plywood sheet	0.352	9.61

Table 3. Relationship among mechanical properties variables

Property	DT	PO	RP	YF	BY	CF	MOE
DT	1.00						
PO	-0.96***	1.00					
RF	0.93***	-0.88***	1.00				
YF	0.88***	-0.89***	0.76**	1.00			
BY	0.87***	-0.91***	0.83**	0.79***	1.00		
CF	0.92***	-0.94***	0.80**	0.83***	0.87***	1.00	
CS	0.95***	-0.90***	0.85**	0.78***	0.75***	0.81*	
MOE	0.90**	-0.82**	0.93**	0.86*	0.84*	0.83**	1.00

*=significant at P<0.05, **=significant at P<0.01, ***=significant at P<0.001, density (DT), Porosity (PO), bioyield (BY), rupture force (RF), yield force (YF), yield compressive strength (CS), Modulus of Elasticity (MOE).

4. Conclusion

The physical and mechanical properties of black seeds such as length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area, 1000 unit mass, spherity, aspect ratio, rupture force, compressive force and strength were determined:

1. The length, width and the thickness of black seeds varied from 2.94 to 3.65 mm, 1.31 to 2.11 mm and 0.62 to 1.32 mm respectively.
2. The arithmetic and geometric mean diameter and square mean diameter black seeds were 1.96, 1.77 and 1.85 mm.
3. The mean sphericity, aspect area, surface area, volume and 1000 unit mass of black seeds were 55%, 47%, 17.26 mm^2, 7.83 mm^3 and 3.18 g respectively.
4. Plywood surface had the highest value of static and dynamic coefficient of friction.
5. The positive interaction was observed between density, rupture force, yield force, yield compressive strength and significantly different at (P<0.001).

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