RESEARCH ARTICLE

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Modeling of Measured Physical Properties and Determination of Chemical Composition of Black Tamarind (Dialium Guineense) Seed

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Abstract

Modeling of physical properties and determination of the chemical composition of BTS were studied at 12.25% wet basis. Mass correlation with principal dimensions was modeled and evaluated using statistical parameters including chi-square (χ^2), coefficient of determination (R^2), root mean square error (RMSE), and standard error (SE). Chemical properties were analyzed using standard techniques. Results showed mean values of seed mass, major, intermediate, and minor diameters of 0.18±0.02 g, 0.85±0.007 mm, 0.73±0.074 mm, and 0.38±0.046 mm, respectively. The seed was spherical (72.64%) with mean aspect ratio (1.17±0.124), ellipsoid ratio (2.27±0.31), and eccentricity (0.4768±0.16). The correlation of mass with intermediate diameter, and with the interaction of intermediate and minor diameters, produced the best non-linear regression models. The intermediate diameter model yielded the highest R^2 (98%) and lowest χ^2 (2.4×10^{-5}). The interaction model achieved R^2 of 99% with the lowest RMSE (0.0032), χ^2 (0.0029), and SE (1.04×10^{-5}) for predicting seed mass. Proximate and phytochemical compositions were not significantly different ($p > 0.05$) from recommended levels by WHO and NAFDAC. This study provides a basis for developing standardized, cost-effective processing methods to enhance market value and ensure compliance with international quality standards.

Keywords: modelling, seed, physical properties, measurement, composition.

Nomenclatures:

w_1 = crucible weight
w_2 = sample and crucible weight
w_3 = final weight of sample and crucible.
m = mass
d = diameter of the seed
a = major diameter
b = intermediate diameter
c = minor diameter

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A_a, A_b and A_c = projected areas based on principal dimensions
A_{GMD} = areas based on GMD
S_s = specific surface area
x = mole of HCl
w = weight of sample
M = mass
V_s = titrate volume of sample
V_b = titrate volume of blank
N = nitrogen
ρ_p = solid density
V_e = volume of ellipsoid
V_p = volume of prolate spheroid
V_o = volume of oblate spheroid
GMD = geometric mean diameter
A.R. = aspect ratio
RR = roundness ratio
Ecc = eccentricity
ER = ellipsoid ratio
DES = diameter of equivalent sphere

1 Introduction

Black tamarind (*Dialium guineense*) is a multipurpose tropical tree crop that belongs to the third largest family of dicotyledonous flowering plants (Leguminosae) [1]. It is widely grown in different regions of Africa (Nigeria, Ghana, Ivory Coast, Cameroon, and the Democratic Republic of Congo) of which Nigeria is the major producer. The tree produces edible fruit that comprises 11-30% shell and fiber, 30-50% pulp and 25-40% seed [2, 3].

The fruit is consumed for its high nutrition and rich health potential. The pulp contains water (17.8-35.8g), protein (2-3g), fat (0.7g), carbohydrate (41.1-61.4g), fibre (2.9g), ash (2.6-3.9g) and carbohydrate (34-94g) [4]. The mineral contents include potassium (62-570 mg/100g), phosphorus (86-190 mg/100 g), calcium (81-466 mg/100g), magnesium (25.6-30.2 mg/100g) and sodium (23.8-28.9 mg/100g) and low values of copper (0.8- 1.2 mg/100g) and zinc (0.8-0.9 mg/100g) [5]. The fruit is used as an additive or sweetener, in producing beverages and jams and, for preparing traditional medicine.

The seed is the by-product of processed black tamarind fruit and is made up of 20-30% seed coat and 70-75% kernel and is used to produce powder (black tamarind kernel powder), tannin, adhesive and polysaccharide [3]. It is a good source of protein and oil.

The processing stages for extracting the seed from the fruit include cracking (manually or mechanically) the dark-surfaced soft shell that covers the mesocarp, de-pulping and extracting the seed by washing it in water and dry it.

The design and development of systems for postharvest processing, handling, and configuring of optimum packaging condition and storage earnestly require the understanding of the physical characteristics of seed to easily meet the mechanization demand [6–8]. The physical parameters of the seed that are mostly needed to create standards and design metrics for fabricating systems include principal dimensions, mass, volume, projected and surface areas, specific surface area, density, porosity, texture, color, shape and size. These parameters may be obtained by direct measurement using appropriate instruments and by applying the right mathematical models [8, 9]. The model reflects the relationship between parameters and aids in predicting the best condition for quality determination and achieving an effective system.

The mass-base classification technique for determining the quality of produce through sorting and grading more accurate, acceptable, cost-effective, time-saving and effective [10] than the size (dimensions) and shape-base. It is then essential to set up a relationship between the mass of the seed and other physical parameters which will enhance the automation of the equipment mechanization for processing, handling, packing, and transportation of the seed [11].

Several reports exist on the modeling of mass relationship with the physical properties of fruits and seeds as well as their chemical properties: kinnow mandarin fruit [12], chebula fruit [13], date [14], plum [11], persimmon [8], pepper berries [15], onion [16], saffron crocus corm [17], sweet lemon [18], wood apple [19], melon seed and kernel [20] and sunflower seed [21]. However, there is no previous study or report on predicting the relationship between the physical properties and the mass of black tamarind seed. Besides, there is a paucity of scientific research regarding the specific nutritive and bioactive compounds (which can provide insights into their potential therapeutic applications). Hence, this study aimed to model the correlation of mass with measured physical properties and to determine the bioactive compounds and chemical composition of black tamarind (*Dialium guineense*) seed (BTS).

(a)

(b)

Figure 1. The Matured Black Tamarine Fruits (a) and (b) Seeds.

2 Materials and methods

Matured fruit of black tamarind (*Dialium guineense*) (Figure 1(a)) was sourced from Umuchima Ideato South LGA, Imo State Nigeria. The samples were cleaned, sorted and cracked manually to extract the dark-brown thick seed (Figure 1(b)) used for the study. The seeds were stored in an airtight container for 24 hours to achieve uniform moisture content. The initial moisture content of the seeds was determined using a laboratory oven set at 105 °C for 4 hours.

The mass and principal dimensions (major, intermediate and minor diameters) of 100 seeds were measured using a digital balance of 0.01 g accuracy (scout Pro SPU 405, made in China) and a vernier caliper of 0.01 mm accuracy (Mitutoyo China). Other physical parameters were calculated [22, 23]:

$$GMD = \sqrt[3]{abc} \quad (1)$$

$$AMD = \frac{(a+b+c)}{3} \quad (2)$$

$$Sphericity = \frac{\sqrt[3]{abc}}{a} \quad (3)$$

$$A.R = \frac{a}{b} \quad (4)$$

$$DES = \left(\frac{M}{\rho_s} \times \frac{6}{\pi}\right)^{\frac{1}{3}} \quad (5)$$

$$RR = \frac{a}{\sqrt{bc}} \quad (6)$$

$$Ecc = \left[1 - \left(\frac{b}{a}\right)^2\right]^{1/2} \quad (7)$$

$$ER = \frac{a}{c} \quad (8)$$

where a = major diameter, b = intermediate diameter, c = minor diameter, GMD = geometric mean diameter, A.R. = aspect ratio, RR = roundness ratio, Ecc = eccentricity, ER = ellipsoid ratio, DES = diameter of equivalent sphere, ρ_s = sample density, M = mass of sample.

2.1 The volume and solid density of the seeds were calculated as:

$$V_e = \frac{\pi abc}{6} \quad (9)$$

$$V_p = \frac{\pi ab^2}{6} \quad (10)$$

$$V_o = \frac{\pi ca^2}{6} \quad (11)$$

$$\rho_p = \frac{m}{v} \quad (12)$$

where ρ_p = solid density (gcm^{-3}), $m = mass\ of\ the\ fruit\ in\ air\ (g)$, V_e = volume of ellipsoid (cm^3), V_p = volume of prolate spheroid (cm^3), V_o = volume of oblate spheroid (cm^3)

Bulk density was calculated as the ratio of the weight of the material to the volume of the container it occupies [24].

2.2 Area of the seed

This measures the total area that the surface of a given object occupies. It affects heat processing, packaging and spray coverage of agricultural products. The surface areas of BTS determined include areas based on GMD (A_{GMD}), projected areas based on principal dimensions (A_a, A_b and A_c) and specific surface area, S_s, (mm^2/cm^3) [25, 26]:

$$A_{GMD} = \frac{\pi d^2}{4} \quad (13)$$

$$A_a = \frac{\pi ac}{4} \quad (14)$$

$$A_b = \frac{\pi b^2}{4} \quad (15)$$

$$A_a = \frac{(\pi bc)}{4} \quad (16)$$

where d = diameter of the seed

$$S_s = \frac{(A_{GMD} \times \rho_b)}{(m)} \quad (17)$$

where m = mass (g) of unit seed.

2.3 Chemical properties

The kernel of the seeds was milled to powder using the burr mill after removing the dark brown seed coat and was used to determine the proximate, minerals and phytochemical compositions of the seeds.

2.4 Proximate composition

The soxhlet extraction method described by Waksmundzka-Hajnos et al. [27] was used to determine the fat content of the seed and was calculated as:

$$\%\ Fat = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100 \quad (18)$$

where W_1 = weight of filter paper, W_2 = sample and filter paper weight, W_3 = final weight of sample and filter paper.

Ash content was determined according to the description of Baraem [28]. 5 g of the sample was placed in a muffle furnace set at 600 C for four hours until a grayish-white substance was obtained. Percentage ash was calculated as:

$$\%\ Ash = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100 \quad (19)$$

where W_1 = crucible weight, W_1 = sample and crucible weight, W_3 = final weight of sample and crucible.

Table 1. The mean values of physical properties of black tamarind (*Dialium guineense*) seed.

Parameters	max	Min	mean	SD	CV	SE	kurtosis	Skewdness
A	0.99	0.7	0.85	0.007	0.0792	0.0121	-0.04	-0.37
B	0.85	0.51	0.7323	0.0744	0.01016	0.0134	1.11	-0.9196
C	0.48	0.3	0.3771	0.0462	0.1225	0.0083	-0.2277	0.2376
Mass	0.23	0.13	0.18	0.02	0.1261	0.0042	0.67	-0.64
GMD	0.7142	0.5252	0.6145	0.041	0.0668	0.0074	0.3349	0.0112
AMD	0.75	0.54	0.6524	0.0428	0.0656	0.0076	0.9024	-0.4051
DE	0.3224	0.1947	0.2521	0.0291	0.1155	0.0052	0.1867	0.1498
Sph	0.8095	0.6599	0.7264	0.0415	0.0571	0.0075	-0.7983	0.0815
AR	1.43	1	1.17	0.1248	0.1069	0.0224	-0.7691	0.6273
ER	2.9	1.75	2.27	0.3100	0.1361	0.0557	-0.8107	0.2024
Ecc	0.7141	0.1576	0.4768	0.1552	0.3254	0.0278	-0.9694	-0.1798
A (a)	0.3577	0.1851	0.2516	0.0408	0.1621	0.0073	0.6476	0.8174
A (b)	0.5675	0.2043	0.4254	0.0821	0.1929	0.0147	0.1969	-0.5976
A (c)	0.2891	0.1558	0.2166	0.0329	0.1520	0.0059	-0.1321	0.1566
SA	0.4007	0.2166	0.2979	0.0397	0.1331	0.0071	0.4807	0.2297
SSA	2.86	2.1	2.45	0.1658	0.0676	0.0298	0.3975	0.413
V_e	0.1908	0.0758	0.1231	0.0246	0.1996	0.0044	0.7546	0.4524
V_o	0.2361	0.75	0.143	0.0323	0.2256	0.0058	0.9591	0.8784
V_p	0.3405	0.0967	0.2419	0.0549	0.2271	0.0099	0.2749	-0.4492
ρ_e	2.03	0.9959	1.53	0.2425	0.1585	0.0436	0.0825	-0.0559
ρ_p	0.9823	0.4116	0.6799	0.1243	0.1828	0.02232	0.8687	0.3707
ρ_o	1.83	0.8047	1.32	0.2540	0.1916	0.0456	-0.127	0.1788
B/density	-	-	0.71	0.01	0.012	0.0083	-	1.62

The crude fibre content of the seed was determined using the Weenden gravimetric method Calculation was made [29, 30]:

$$\%\, Crude\ fibre = \frac{(W_2 - W_3)}{(W_1)} \times 100 \quad (20)$$

The protein content of the seed was determined using the Kjelhahl method and was calculated as [31–33]:

$$\%\, N = \frac{x \times (V_s - V_b)\, cm^3}{(1000\ \times\ \frac{14}{mole})} \quad (21)$$

% protein = % N × 6.25

where x = mole of HCl, w = mass of sample, mole of nitrogen = 14, V_s = titrate volume of sample, V_b = titrate volume of blank, N = nitrogen.

Carbohydrate (CHO) content determination was done by subtracting the sum of all other nutrient contents determined from the total weight.

$$CHO = 100 - (\%protein + \%fat + \%ash + \%moisture + \%fibre) \quad (22)$$

2.5 Mineral composition of the seed

The atomic absorption spectrophotometer (AAS Model; 2000) was used to analyze the seed mineral contents like calcium, magnesium, sodium and potassium.

2.6 Phytochemical composition of the seed

The proportion of phytochemicals (tannins, flavonoids, alkaloids, phenols) of the seed was determined using the Analytical method as described by Ejikeme et al. [34].

2.7 Modeling of the physical properties of BTS

Non-linear empirical equations were studied for predicting the mass of BTS. The data obtained were fitted to equations 24 - 26 with the goodness of fit tested using statistical parameters.

1. Quadratic equation 1: $M_{BTS} = Zx^2 + Zx + C$
2. Quadratic equation 2: $M_{BTS} = Zx + Zxy + Zy + C$
3. Power equation: $M_{BTS} = \left(Zx^2 + Zx + C\right)^{-1}$

Microsoft Excel 2010, Math LAB 2015b and OrijinPro

2023b software were used to analyze the data and to determine regression models in either linear or nonlinear forms. Chi-square (χ^2), Coefficient of determination (R^2), Root mean square error (RMSE) and standard error (SE) were used to evaluate the regression models. The model with the highest value of R^2, and lowest RMSE, χ^2 and SE values gave a better estimation.

3 Results and discussions

3.1 The measured physical properties of black tamarind (*Dialium Guineense*) seed.

The result of measured physical properties of black tamarind (*Dialium guineense*) seed (see Table 1) showed that the mass, major, intermediate and minor diameters ranged from 0.13 to 0.23 g, 0.70 to 0.99 mm, 0.51 to 0.85 mm and 0.30 to 0.48 mm respectively. The average values are 0.18±0.02 g, 0.85±0.007 mm, 0.73±0.074 mm and 0.38±0.046 mm respectively. The major diameter was insignificantly ($p < 0.05$) higher (14.14%) than the intermediate diameter and significantly higher (51.52%) than the minor. The minor was also less than the intermediate diameter by 43.53% indicating that the seed is relatively sphere in shape.

The mass, major, intermediate and minor diameters of the BTS deviated from the values observed by Mansouri et al. [20] and Lorestani et al. [26] for melon and castor seeds respectively. This could be attributed to the differences in cultivar of the seeds and the environmental factors that affect the compositional and morphological formation of agricultural produce. The low values of statistical indices measured showed that the deviation of the values from the mean is tolerable. The values of kurtosis and skewness are low indicating platykurtic distribution and approximately no outliers were observed. Mass, major and intermediate diameters skewed to the left while minor diameters skewed to the right.

3.2 The calculated diameters and the areas of BTS

The GMD, AMD and DE of BTS ranged from 0.5252 to 0.7142 mm, 0.54 to 0.75 mm and 0.1947 to 0.3224 mm with mean values of 0.6145±0.04 mm, 0.6524±0.04 mm and 0.2521±0.03 mm respectively. The GMD and AMD are the same but differ statistically by 60.20% from the DE value. These aids in choosing the size of opening (aperture) in equipment needed to grade and shell the seed. Werby et al. [35] observed similar behavior for jatropha seeds.

The mean values of the projected areas for major, intermediate, minor and equivalent diameters, and specific surface area of BTS are 0.2516±0.04 mm^2, 0.4254±0.08 mm^2, 0.2166±0.03 mm^2, 0.2979±0.03 mm^2 and 2.45±0.17 mm^2 respectively. The projected area of intermediate diameter is higher than the other projected areas by a relatively 39.96% indicating that the seed is not round and during handling, drag would be more effective on the intermediate axis than the others axis. Surface areas encourage the determination of the optimum heat and mass transfer, packaging, storing and handling conditions for agricultural produce.

3.3 The shape indices of BTS

The mean values of sph, AR, ER and E_{cc} were observed as 72.62±4.15%, 1.17±0.124, 2.27±0.31 and 0.4768±0.16 respectively. These values indicate that BTS is spherical as the sphericity value is above the critical point (50%), AR and E_r are greater than one and E_{cc} is between zero and one. This means that BTS can only slide on a given surface rather roll. Mansouri et al. [20] observed a relatively similar value (2.23) of Er and a lower value of sph (0.3485) for two varieties of melon seeds (Somsori and Varamin). This could be attributed to the higher values of the major axis of the melon seeds. The shape indices had platykurtic distribution and skewed positively except ER indicating zero outliers and negligible deviation from the means. This knowledge is essential for sizing, grading and packaging of the seeds.

The V_o, V_p and V_e of BTS ranged from 0.2361 to 0.7500 mm^3, 0.3405 to 0.0967 mm^3 and 0.108 to 0.0758 mm^3 respectively. Their mean values are 0.1430±0.035 mm^3, 0.2419±0.055 mm^3 and 0.1231±0.025 mm^3 respectively.

The bulk density, densities of oblate, prolate and ellipsoid shapes of BTS had mean values of 710±0.01 gcm^{-3}, 679.9±0.12 gcm^{-3}, 1320±0.25 gcm^{-3} and 1530±0.24 gcm^{-3} respectively. The density values of ellipsoid and prolate shapes are statistically similar but differ by 52.29% from that of oblate density affirming the spherical shape of BTS. This could be due to the differences in the axis of calculation. Volume and density values aid in developing systems for handling, packaging and storing and optimum heat and mass transfer conditions during heat treatment.

Table 2. Mass correlation with principal dimensions of Black Tarmaind (*Dialium guineense*) seed.

Models	R^2	Adj. R^2	RMSE	SE	χ^2
$M_a = 0.4492a^2 - 0.3780a + 0.175$	0.7777	0.6369	0.0130	0.0038	3.12E-4
$M_b = 0.8377 - 2.23b + 1.82b^2$	0.9825	0.9475	0.0831	0.0046	2.45E-5
$M_c = \left(400.85 - 2142.05c + 285.74c^2\right)^{-1}$	0.9203	0.7608	0.0106	0.0028	1.57E-4
$M_{ab} = 0.19 + 0.000625a - 0.02059b$	0.9615	0.8855	0.0073	5.3e-5	0.0273
$M_{ac} = 0.18 + 0.03139a - 0.00402c$	0.786	0.3959	0.0168	2.8e-4	0.0531
$M_{bc} = 0.18 + 0.0045b - 0.003031c$	0.9926	0.9777	0.0032	1.04e-5	0.0029

Table 3. ANOVA of the Models for Mass correlation with principal dimensions of Black Tarmaind (*Dialium guineense*) seed.

Regression Equations	DF	Sum of Squares	Mean Square	F Value	Prob>F	Significant
M_a	1	0.001031	0.001031	5.59	0.1418	✓
M_b	1	0.001376	0.001376	112.34	0.0087	✓
M_c	1	0.001237	0.001237	15.15	0.0601	✓
M_{ab}	2	0.001357	0.000679	15.94	0.1744	✓
M_{ac}	2	0.001116	0.000558	1.96	0.4508	✓
M_{bc}	2	0.001388	0.000694	56.65	0.0935	✓

3.4 Modeling of mass relationship with measured principal dimensions of BTS

The models for predicting the mass of BTS from measured principal dimensions are presented in (see Table 2). The tested statistical parameters revealed a good fit for the major, intermediate and minor axis. The result revealed that the quadratic model for the intermediate axis had the best fit for predicting the mass of BTS with the highest value of coefficient of determination (R^2) and adjusted R^2, and lowest values of χ^2 and RMSE.

For the interaction of the principal axis, minor and intermediated axis interaction with mass had higher R^2, adj R^2 and lowest values of χ^2, RMSE and SE, hence mass modeling of BTS based on the intermediate axis and interaction of the intermediate and minor axis is recommended. This is contrary to the report about castor seed.

The non-linear regression models are significant ($p < 0.05$) as indicated in Table 3. The mass relationship with the intermediate axis and interaction with the intermediate and minor axis had the best probability outcome with a very low p-value (see Table 3). This means that the models are fit for predicting the mass of BTS.

3.5 The proximate composition of black tamarind seeds

The result of the proximate analysis presented in Table 4 showed that the mean moisture content (7.87±0.12) of BTS is statistically ($p < 0.05$) the same as the findings of Achoba et al. [36] and Ogbuewu et al. [37], but greatly differs from the recordings of Okudu et al. [38]. The difference could be due to the varying levels of maturity and ripening of the studied seeds. The ash content value was low (3.73%), though higher than the findings of Achoba et al. [36] and Okudu et al. [38] by 52.61% and 45.12%, respectively, and lower than that of Ogbuewu et al. [37] by 62.58%.

Table 4. The Proximate composition of black tamarind seeds.

S/N	Parameters	mean	SD	WHO
1	M.C %	7.87	0.12	5.00
2	ASH %	3.76	0.06	3.00
3	FAT %	9.64	0.06	10.00
4	FIBRE%	3.40	0.06	4.80
5	PROTEIN %	17.15	0.06	22.00
6	CHO %	59.35	1.49	72-90

The mean values of fat, fibre, and protein contents of BTS observed were higher than the values recorded by Achoba et al. [36], Ogbuewu et al. [37], and Okudu et al. [38], while the carbohydrate content was lower by 31.47% and 69.88%, respectively, and higher by 3.54% compared to the findings of Okudu et al. [38]. These differences could be attributed to the variations in the concentration of minerals and organic matter in the soil, which characterized different locations. The proximate composition of BTS is statistically similar to the recommendations of the World Health Organization (WHO); hence, it can be used as an additive to enhance the quality of food and beverages.

3.6 The Mineral and phytochemical compositions of black tamarind seeds.

The mean values of mineral composition (Ca, Mg, K and Na) of BTS as observed (see Table 5) were higher than the values recorded by Osanaiye et al. [39] and Ogbuewu et al. [37] except for sodium which was lower.

Table 5. The Mineral and phytochemical compositions of black tamarind seeds.

Parameters	A	B	C	MEAN	SD
Mineral composition					
Ca mg/g	9.30	9.00	8.907	9.07	0.205
Mg mg/g	8.50	8.55	8.447	8.49	0.052
K mg/g	0.92	0.90	0.848	0.8893	0.037
Na mg/g	0.58	0.61	0.520	0.5700	0.046
Phytochemical composition					
Tannin %	0.03	0.02	0.025	0.025	0.005
Flav %	3.38	3.4	3.27	3.35	0.07
Alka %	3.42	3.38	3.29	3.36	0.067
Phenol mg/g	0.77	0.75	0.69	0.7367	0.042

The mean values of tannin, flavonoid, alkaloid and phenol are 0.025±0.005, 3.35±0.07, 3.36±0.067 and 0.7367±0.042 respectively. These are lower than the values observed by Okudu et al. [38] and could be attributed to differences in growing conditions. Though the values are lower than the standard limit (Tannin = 5.00, flavonoid = 10.00 and phenol = 4.80; World Health Organization (WHO)), they can be of other health benefit when consumed like enhancing clotting of blood, minimizing blood pressure, reduce cholesterol level and produce liver necrosis.

4 Conclusion

It can be concluded that the mass, major, intermediate and minor diameters of dried BTS ranged from 0.13 to 0.23 g, 0.70 to 0.99 mm, 0.51 to 0.85 mm and 0.30 to 0.48 mm respectively. The seed is spherical with a mean value of 72.64%.

Mass correlation with the intermediate diameter and interaction of intermediate and minor diameters had the best non-linear regression models for predicting the mass of BTS. The seeds had low values of phytochemical compositions, rich in energy (59.35% carbohydrate) and desirable quantities of protein (17.15%) and fat (9.64%).

The consistent physical properties of BTS seeds would enable efficient and cost-effective mechanized processing and, supporting large-scale production. Their chemical composition aligns with safety standards, indicating fit for use in food, feed, and pharmaceutical industries. these features suggest that BTS seeds have promising economic potential across various commercial sectors.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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