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Physical properties of an underutilized crop: Browntop millet (*Urochloa ramose*)

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Abstract

Browntop millet (*Urochloa ramose* L.) known as 'korale' in Karnataka is an annual warm-season grass often used as a forage crop gaining importance because of its nutritional qualities. Very fewer researches have been done so far on the millet. The research was conducted to determine the physical properties of the browntop millet. The physical properties were determined at moisture content 11.2 ± 0.16 (w.b). The mean values of length, width and thickness of the browntop millet were found to be 3.00 ± 0.21, 1.79 ± 0.10 and 1.15 ± 0.09 mm, respectively. The geometric mean diameter and arithmetic mean diameter were 1.82 ± 0.09 and 1.99 ± 0.1 mm, respectively. The mean weight of 1000 browntop millet seeds was 3.42 ± 0.14 g. The bulk density and true density were 601.17 ± 4.08 and 1305.47±95.5 kg/m^3, respectively. The mean porosity, aspect ratio and sphericity were found to be 53.74 ± 3.23, 58.58 ± 3.84 and 59.82 ± 2.60%, respectively. The shape of the browntop millet was oval. The angle of repose was 27°47' ± 0.21 and the coefficient of friction for the three surfaces namely, Glass, Aluminum and Wooden Sheets were 0.62 ± 0.0009, 0.59 ± 0.0051 and 0.6 ± 0.0063, respectively. The terminal velocity was 7.2 m/sec. The tristimulous colour values (L*, a* and b*) were found to be 60.45 ± 0.44, 3.78 ± 0.06 and 14.71 ± 0.33, respectively. Hence this study helps agricultural and food engineers, designers, scientists and processors towards design of equipment and efficient process for browntop millet grain processing.

Keywords: Browntop millet, dimensional properties, angle of repose, terminal velocity, tristimulous colour value

1. Introduction

Millets are small-grained grasses which are cultivated around the world as cereal crops or grains for fodder and human consumption. In the world small millets are popularly grown with an area of 31.24 million hectare with an annual production of 28.46 million tons. India's contribution is much in millet production among other countries; the year 2017 witnessed a record millet production of 11.56 million tons with an area of 9.1 million hectare. In the present drought threat situation and climate change scenario leading to water scarcity, millets are suitable crops for dry land rain fed regions where most of our farmers are striving hard to sustain.

Browntop millet (*Urochloa ramose* L.) (Fig 1, Fig 2, Fig 3) is also known as 'korale' or 'karlakki' in Karnataka, 'andakorra' in Andhra Pradesh is the underutilized millet, which is neglected by the mono-crop based agriculture system. It originated from Southeast Asia and is presently grown in Africa, Western Asia, Arabia, China and Australia (Clayton, Vorontsova, Harman & Williamson, 2006) [7]. It was introduced to the United States from India in 1915 (Oelke, Oplinger, Putnam, Durgan, Doll & Undersander, 1990) [17]. In the US, it is mainly grown in the Southeast for hay, pasture and game bird feed. Browntop typically grows only to 0.6 to 1.5 m tall. In India, the browntop millet is growing in the states of Karnataka, Tamil Nadu, Andhra Pradesh and parts of north central India referred as Bundelkhand region. In spite of having high micronutrient potentiality, storage stability and fodder quality browntop millet is grown in negligible parts of these states. The browntop millet is mainly grown in the districts of Tumakur, Chitradurga, Chikkaballapur and Mandya in Karnataka state and Ananthapur district in Andhra Pradesh state for the traditional food preparations (Roopa, Jamuna, Brunda & Darshan, 2016; Sujata, Prabhu, Nandini, Prabhakar & Thippeswamy, 2018) [21, 27].

Knowledge of the physical parameters i.e. length, width, thickness, geometric mean diameter, is important, useful and necessary in the design of processes, machines, structures and controls. The basic information on these physical properties helps engineers towards efficient process and equipment development. And also in selecting the proper separating and cleaning equipment these parameters play an important role whereas the main dimensions are considered in selecting and designing the suitable size of the screen perforations, for their handling, storing and processing (Balasubramanian & Vishwanathan, 2010; Ojediran, Adamu & Jim, 2010; Swami and Swami, 2010; Singh, Mishra & Saha, 2011; Ramappa, Batagurki, Karegoudar & Shanrnakumar, 2011; Sunil, Venkatachalapathy, Shanmugasundaram, Akash & Loganathan, 2016; Dayakar, Sukreeti, Kiranmai & Tonapi, 2019) [4, 18, 29, 24, 19, 28, 8]. However, data on physical properties of browntop millet is still insufficient. Hence the study was conducted with an objective of determine the physical properties of the browntop millet.

Fig 1: Browntop plant

Fig 2: Tender browntop

Fig 3: Browntop millet

2. Materials and Methods

2.1 Processing of browntop millet for experiments

The browntop millet used for the studies was procured from Mr. Dharanendra, a progressive farmer from Bengaluru District, Karnataka State. The millet used is a local variety commonly grown in Tumakur district of Karnataka State. The grains were cleaned by removing all foreign matters, brokens and immature grains in a Cleaner-cum-Grader manufactured by Bhavani Industries, Mandya, India.

The cleaned and sound grains were randomly selected for the experiments. The determination of dimensional properties (length, width and thickness), the frictional properties (coefficient of friction and angle of repose), 1000 grain weight, bulk density, true density, porosity, aspect ratio, sample volume and sample surface area were performed in 10 replicates.

Other physical properties such as moisture content, aerodynamic property (terminal velocity) and Colour attributes were performed in 5 replicates.

2.2 Moisture content on wet basis

The moisture content (%) was determined by taking 4 g of browntop millet in dry and clean crucible and dried in a hot air oven drier at 101 to 105 °C for 24 h. The dried samples were removed and cooled until a constant weight was obtained [44 to 15.02 (AACC, 2000)] [1]. The following Eq. (1) was used for the moisture content (%) calculations.

$$\text{Moisture content}(\%) = \frac{W2-W3}{W2-W1} \times 100 \qquad (1)$$

Where;

W1 = Weight of empty crucible, g
W2 = Weight of crucible + flour before drying, g
W3 = Weight of crucible + flour after drying, g

2.3 Dimensional properties

A total of ten seeds were randomly selected for determining the three different dimensional properties of the grains. The length (L), width (W) and thickness (T) values were recorded using a digital vernier caliper having a least count of 0.01 mm (Mohsenin, 1986) [15].

2.3.1 Geometric mean diameter

The geometric mean diameter was determined by using the measured dimensions (L, W & T) of browntop millet samples. The following Eq. (2) was used for calculating geometric mean diameter (Dg).

$$Geomtric\ Mean\ Diameter = [LWT]^{\frac{1}{3}} \qquad (2)$$

Where,

L= longest intercept (Length), mm
W= longest intercept normal to L (Width), mm
T= longest intercept normal to L and B (Thickness), mm

2.3.2 Arithmetic mean diameter

The arithmetic mean diameter (Da) of the browntop millet sample was determined by the methods of Mpotokwane *et al.* (2008) [16]. The following Eq. (3) was used for calculating arithmetic mean diameter (Dg).

$$Da = \frac{L+W+T}{3} \qquad (3)$$

Where,
L = Length, mm
W = Width, mm
T = Thickness, mm

2.3.3 Length-breadth (width) ratio
The length-breadth ratio of the browntop millet was determined by the following Eq. (4):

$$\text{Length} - \text{bredth ratio} = \frac{L}{W} \quad (4)$$

Where,

L= Length, mm
W= Breadth/Width, mm

2.3.4 Shape of the Browntop millet
The shape of the browntop millet was determined by comparing the images (shapes) of browntop millets with the standard shapes presented in the chart by Mohsenin (1986) [15].

2.4 One thousand (1000) grain weight
Ten samples, each containing thousand unbroken, sound seeds were selected manually. Samples were weighed using the digital electronic balance with 0.001 accuracy and the values were recorded.

2.5 Bulk density
A wooden box of volume 1000 ml was used for the determination of bulk density. The browntop millets were poured into the box and the top was leveled off. These millets were weighed using a precision electronic balance. The bulk density was calculated using the Eq. (5) (Chandan Kumar *et al.*, 2018) [6]:

$$\text{Bulk density } (\text{kg/m}^3) = \frac{\text{Weight of millets (kg)}}{\text{Volume of millets including void space } (\text{m}^3)} \quad (5)$$

2.6 True density
The apparatus used for measuring the true density of browntop millet consists of a 100 ml measuring jar and a weighing balance. Fifty ml of toluene was taken in a measuring jar and ten grams of millets were poured into the measuring jar. The rise in the toluene level was measured. The true density of the grains was calculated by using the following Eq. (6) (Mohsenin, 1986) [15]:

$$\text{True density } \left(\frac{\text{kg}}{\text{m}^3}\right) = \frac{\text{Weight of millets (kg)}}{\text{True volume of millets excluding void space } (\text{m}^3)} \quad (6)$$

2.7. Porosity
Porosity (%) of the millets was calculated by using the following Eq. (7):

$$\text{Porasity } (\%) = \left(1 - \frac{\text{Bulk density}}{\text{True density}} \times 100\right) \quad (7)$$

2.8. Sphericity
The sphericity is used to describe the shape of the grain. The sphericity was calculated using the Eq. (8) (Mohesenin, 1986).

$$\text{Sphericity } (\Phi) = \frac{D_m}{L} \quad (8)$$

Where,
D_m= Geometric mean diameter and
L= longest intercept (Length), mm

2.9 Aspect ratio
The aspect ratio (%) of browntop millet was calculated using Eq. (9), method of Vanrnamkhasti *et al.* (2008) [30] as follows:

$$Aspect\ ratio = \frac{Width}{Length} \times 100 \quad (9)$$

2.10 Surface area
The surface area (mm^2) of browntop millet was calculated using Eq. (10), method suggested by Karababa & Coşkuner, 2013 [13].

$$Surface\ area = \frac{2BL^2}{(2L-B)} \quad (10)$$

Where;

B = *(WT)* $^{1/2}$
W = Width, mm
T = Thickness, mm
L = Length, mm

2.11 Sample volume
The sample volume (mm^3) of the millets was calculated using Eq. (11), method suggested by Karababa & Coşkuner, 2013 [13].

$$Sample\ volume = \frac{\pi B^2 - L^2}{6(2L-B)} \quad (11)$$

Where;

B = *(WT)* $^{1/2}$
W = Width, mm
T = Thickness, mm
L = Length, mm

2.12 Frictional properties
2.12.1 Angle of repose
The method described by Sahay and Singh (1994) [22] was followed for determining the angle of repose of browntop millet. The height and diameter of grains heaped in natural piles were recorded. The angle of repose was calculated by using the following Eq. (12):

$$\text{Angle of repose}, \theta = \tan^{-1}\left(\frac{2H}{D}\right) \quad (12)$$

Where,

θ = Angle of repose, degrees
H = Height of the heap, m
D = Diameter of the heap, m

2.12.2 Coefficient of friction
The coefficient of friction of grains was determined against three surfaces namely, glass, aluminum and wooden sheet (Mohsenin, 1986) [15]. The grains were placed in each test surfaces separately The static angle of friction was determined by measuring the angle of inclination at which the grain placed on it just began to slide of inclined test surface was measured. The following Eq. (13) was used for calculation.
Coefficient of static friction (µ) = tanθ (13)

Where,
θ = Angle of friction, degrees

2.13 Aerodynamic property
The aerodynamic properties are important and required for design of air conveying systems and the separation equipment for agricultural products (Sahay and Singh, 1994) [22].

2.13.1 Terminal velocity
Terminal velocity is the air velocity at which the particle remains in a suspended state in a vertical pipe. Air is blown through a column and the millets will be dropped from the top.

The velocity of the air is measured by a digital anemometer having least count 0.1 m/s. The velocity of air at which the millets are suspended in the column will be recorded (Gharibzahedi *et al.*, 2010b) [10].

2.14 Colour
The colour of browntop millets was determined using a Minolta chromameter (Make: Minolta Instrument Co., Japan; Model-CRB 200). It is a light weight tristimulus colour analyzer measures reflected-light of the sample. The advanced electronics and optical technology of the device provides accurate and complete portability of data.

The chromameter takes accurate colour measurements by using an 8 mm diffused illumination and a 0° viewing angle. The readings are instantaneously displayed. Initially the chromometer is calibrated with a white colour standard, then the sample colour was measured in terms of Yxy, L*a*b* and ΔE by placing sample on the measuring head of the device (Chandan Kumar *et al.*, 2018) [6].

3. Results and Discussion
3.1 Moisture content
The moisture content of the browntop millet was found to be 11.2 ± 0.16% on wet basis. Grains moisture content is one of the important factors which will aid in grains physical properties (Goswami, Manikantan, Gupta, & Vishwakarma, 2015).

Moisture content indicates as whether the grains can be stored for a long or short period (S.E. Ramashia *et al.*, 2019). At higher moisture content, the growth of the molds is rapid and the shorter storage life of the grain (Abdullah, Ch'ng, & Yunus, 2012) [2]. All the physical properties were determined at 11.2% MC (w.b.).

3.2 Dimensional properties
The mean values of length, width and thickness of the browntop millet were found to be 3.00 ± 0.21, 1.79 ± 0.10 and 1.15 ± 0.09 mm, respectively (Table 1). Similar results were reported for length 3.32 ±0.07, width 1.73 ±0.09 and thickness 1.15 ±0.01 of the browntop millet at 9% moisture content (Srinivas, 2019), for kodo and little millets (Balasubramanian, 2016) [5] and for foxtail millet (Sunil *et al.* 2016) [28].

The mean results of the geometric mean diameter and arithmetic mean diameter were found to be 1.82 ± 0.09 and 1.99 ± 0.1 mm, respectively. The result for geometric mean diameter was similar to the result obtained by Srinivas *et al.* (2019) for the browntop millet. Dayakar *et al.* (2019) [8] also reported the similar results for geometric and arithmetic mean diameter.

The length to breadth/width ratio was found to be 1.71± 0.10 and the shape of the browntop millet was oval (Mohsenin, 1986) [15]. The shape of the kodo millet (M.I. Gomez, 2003) [11] is also same as browntop millet.

Table 1: Dimensional properties of browntop millet

Properties	***Dimensional Value (mm)***
Length	3.06 ± 0.21
Width	1.79 ± 0.1
Thickness	1.15 ± 0.09
Geometric mean diameter	1.82 ± 0.09
Arithmetic mean diameter	1.99 ± 0.1

Note: The mean ± standard deviation, n =10.

3.3 Physical properties of browntop millet
The mean weight of 1000 browntop millet seeds was found to be 3.42 ± 0.14 g. The result was on far with the findings of Srinivas (2019).

The results for bulk density, true density and porasity were 601.17 ± 4.08 kg/m^3, 1305.47 ± 95.5 kg/m^3 and 53.74 ± 3.23%, respectively (Table 2).

The results were in line with the findings of Srinivas *et al.* (2019), Balasubramanian, (2016) [5] and Sunil *et al.* (2016) [28] obtained for the browntop, kodo and little millets, respectively at moisture content 8.9 to 11.1% on wet basis having bulk density (520 to 709 kg/m^3), true density (1000 to 1852 kg/m^3) and porosity (34.16% to 64.1%). Balasubramanian and Viswanathan (2010) [4] also reported similar findings for the porosity.

The mean results for the aspect ratio and sphericity were found to be 58.58 ± 3.84 and 59.82 ± 2.60%, respectively. Adebowale *et al.* (2012) [3] reported that millet grains were found to have 59.62% aspect ratio at a moisture content of 10%. Dayakar *et al.* (2019) [8] also reported the same results of 66% aspect ratio.

The sphericity result (60 ± 0.30%) was in line with the findings of the S.E. Ramashia *et al.* (2019) reported for pearl millet having spherity 64.17 ± 0.16. The mean result of the surface area was found to be 8.98 ± 0.92 mm^2 is comparable with the findings of the Dayakar *et al.* (2019) [8]. The mean volume of the result was found to be 2.15±0.33 mm^3.

Table 2: Physical properties of browntop millet

Properties	**Values**
1000 grain weight g	3.42±0.14
Bulk density (kg/m^3)	601.17±4.08
True density (kg/m^3)	1305.47±95.5
Porosity (%)	53.74±3.23
Aspect ratio (%)	58.58 ± 3.84
Sphericity (%)	0.60±0.30
Surface area (mm^2)	8.98 ± 0.92
Volume (mm^3)	2.15±0.33

Note: The mean ± standard deviation, n =10.

3.4 Frictional properties
The frictional properties like angle of repose and coefficient of friction helps the engineers in designing of storage bins, godowns etc.

The mean result for the angle of repose was 27°47'± 0.21 is comparable with the angle of repose (27-32°8') reported for the finger millet, kodo millet and little millet (Shivabasappa *et al.*, 2012; Balasubramanian, 2016; Dewendra Kumar *et al.*, 2016) [23, 5, 9].

The coefficient of friction for the three surfaces namely, Glass, Aluminum and Wooden Sheets were 0.62 ± 0.0009, 0.59 ± 0.0051 and 0.6 ± 0.0063, respectively (Table 3). Balasubramanian and Viswanadan (2010) [4] were reported similar results for minor millets.

Table 3: Frictional properties of browntop millet

Properties	Values
Angle of repose(θ)	27°.47'± 0.21
Static coefficient of friction	
Glass sheet	0.62± 0.0009
Aluminum Sheet	0.59± 0.0051
Wooden Sheet	0.6±0.0063

Note: The mean ± standard deviation, n =10.

3.5 Aerodynamic property
The mean terminal velocity of browntop millet was 7.2 m/sec. The results were comparable with the findings of the Srinivas *et al.*, (2019) reported for browntop millet and Chandan kumar *et al.*, (2018) [6] reported for kodo millet were found to be 5.95 and 5.66 m/s, respectively. The terminal property will helps agricultural and food engineers for developing air conveying system.

3.6 Colour
The tristimulous colour values (L*, a*and b*) for the browntop millet were found to be 60.45 ± 0.44, 3.78 ± 0.06 and 14.71 ± 0.33, respectively (Table 4). The L* value is similar to that by Siwela *et al.* (2007) [25] which ranged from 45.9 ± 0.9 to 68.4 ± 0.6 for finger millet. Goswamy *et al.*, (2015) [11] also reported the similar L* values of muffin sample containing 10 g/100 g barnyard millet flour in flour blend 71.98 and the a* values were also in line with his findings that ranged from 2.11 to 4.72 in 100 g/100 g barnyard millet flour blend muffins. The L*, a* and b* values help to find out the colour of the millet.

Table 4: Color value (L*, a*, b*) of browntop millet

Colour L*	a*	b*
60.45 ±0.44	3.78±0.06	14.71±0.33

Note: The mean ± standard deviation, n =5.

4. Conclusion
In the present study, the physical properties of browntop millets were studied by using standard procedures at moisture content 11.2 ± 0.16 (wet basis). The coefficient of friction on aluminum sheet was least as compare to glass and wooden sheets.

The shape of the browntop millet was oval having sphericity of 59.82 ± 2.60%. The tristimulous colour values (L*, a*and b*) were found to be 60.45 ± 0.44, 3.78 ± 0.06 and 14.71 ± 0.33, respectively. The information from this study would therefore be useful for agricultural engineers, food engineers, food processors and food scientists in the design of equipment which is suitable for planting, harvesting, handling, cleaning and grading, storage, processing and packaging of browntop millet grain.

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