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Studies on engineering properties of grain amranthus

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Abstract
The current study was carried out to look into the engineering properties of Grain amranthus. Engineering properties of Grain amranthus were determined at moisture content of 9%. The average value for size, true density, bulk density, porosity and weight of 1000 grains were 1 mm, 1389.06 kg/m^3, 834.66 kg/m^3, and 39.90% respectively. Average value for angle of repose was found to be 24.7º. The coefficient of friction on three types of structural material was found to be 0.386 (plywood surface), 0.35606 (glass), and 0.363 (mildsteel) respectively. The study is important for designers and processors for developing processing equipment.

Keywords: Grain amranthus, physical properties, aerodynamic properties, frictional properties

Introduction
Grain amranthus is commonly known as "Rajgira" or "Ramadana". When compared to true cereals, Grain amranthus is a highly nutritious pseudo cereal with higher protein content. It has long been grown as a minor crop in Central and South America, as well as several parts of Asia and Africa. China is the world's leading producer of Grain amranthus. A single plant is capable of producing more than 500 g of grains. The average yield in India's northwest hills is 2250 kg/ha. The Grains of amranthus are very small. The colour of the seed coat varies from black to brown to yellow to white. The embryo of a seed is round. In India, grain amranthus is grown and consumed as a grain or as a leafy vegetable. There are around 60 species of amranthus known globally. This pseudo-cereal is lentil-shaped and 1 mm in diameter. It is abundant in lysine, an amino acid that is lacking in other grains. According to the Educational Concerns for Hunger Organization (ECHO), the protein is of extremely high quality. It is a reasonably balanced diet with functional qualities that have been demonstrated to have medicinal benefits. The health advantages include lowering plasma cholesterol levels, immune system stimulation, anticancer activity, reducing blood glucose levels, and improved hypertension and anemia conditions. It has also been found to have anti-allergic and antioxidant properties. Many countries make traditional food from Grain amranthus, such as "alegria" and "atole" in Mexico, "alboroto" in Guatemala, "bollos" in Peru, "Chapati" in the Himalayas, "laddoos" in India, and "sattoo" in Nepal. Modern food applications of grain amranthus include breakfast foods, infant/weaning food formulations, breads, pastas, flakes, drinks and beverages, etc. Grain amaranth can be used as grains or flour to make products such as cookies, cakes, pancakes, bread muffins, crackers, pasta and other bakery products Kudos and Solanki (2018) [11]. The physical properties of grain amranthus, like those of other grains, play a significant role when designing processing equipment for further handling and post-harvest processing. The physical properties of grains are used to construct various types of cleaning, grading, and separating equipment Sahay and Singh (1994) [15].

For the purpose of designing processing equipment effectively, knowledge of a crop's physical characteristics is essential. The grain's size distribution and unique dimensions are vital for the design of cleaning, sorting, and separating equipment Kachru *et al*. (1994) [10]. While true density is important for designing suitable separation equipment, the bulk density can be utilised to estimate storage and transport capacities. Additionally, the porosity of the grain mass affects the airflow resistance during aeration and drying operations [Brooker *et al.* (1992) Kachru *et al.* 1994)] [3, 10]. For the design of grain bins and other storage structures, frictional characteristics like angle of repose and coefficient of friction are essential Vilche *et al.* (2003) [17]. These characteristics are influenced by the grain's size, shape, and moisture content, among other things. An examination of the literature found absence of data on the physical characteristics of amaranth grains across a range of moisture contents.

Therefore, understanding these physical characteristics is essential when constructing post-harvest processing equipment like cleaners, graders, and dehuskers. However there is currently a lack of information about the Grain amranthus engineering characteristics. The purpose of the study, this point, was to find out engineering properties of Grain amranthus.

Fig 1: Grain amranthus Crop

Fig 2: Grain amranthus

Materials and Methods

The raw materials were procured from Mr. Narayanaswamy G.M., a progressive farmer from kolar District, Karnataka state. The proposed study was carried out at Department of Food Process Engineering, Agricultural Engineering College and Research Institute, TNAU, Coimbatore.

Moisture Content

The moisture content (%) was estimated by taking 5 g of Grain amranthus in dry and clean crucible and dried in a hot air oven at 105±2 °C for 24 h. The dried samples were removed and cooled until a consistent weight was obtained. The following Eq. was used for the moisture content (%) calculations. Horwitz and Latimer (2000) [9].

$$\text{Moisture content (\%)} \frac{W_2-W_3}{W_2-W_1} \times 100$$

Where;
W1 = weight of empty crucible
W2 = weight of crucible + sample before drying
W3 = weight of crucible + sample after drying

Physical properties

Various physical parameters were measured, including size, 1000 grain weight, porosity, bulk density, true density.

Size

The size was determined using particle size analyser (MICROTRAC MRO). Measurement was diameter (mm).

Thousand grain weight

Thousand grains were counted using digital seed counter and weighed using an electronic balance with an accuracy of 0.1 g Ghadge and Prasad (2012) [6]. Five replications were weighed and the mean weight of thousand grains was calculated.

Porosity

Porosity of grain amranthus was calculated from the bulk density and true density values by using the following formula Mohsenin (1986) [13].

$$\text{Porosity \%} = 1\text{-}\frac{\text{Bulk Density}}{\text{True Density}} \times 100$$

True Density

In a measuring jar, 50ml of toluene was placed. The measuring jar was filled with a known weight of grain sample, and the rise in the toluene level was recorded. The true density of the grain was estimated using the formula given by Mohsenin (1986) [13].

$$\text{True Density, kg/m}^3 = \frac{\text{Weight of the Grains (kg)}}{\text{volume of Grains Excluding void space (m}^3\text{)}}$$

Bulk Density

The bulk density was calculated using a known volume container. The sample was placed in a container of known capacity and weighed. The formula was used to calculate the bulk density Mohsenin (1986) [13].

$$\text{Bulk Density, kg/m3} = \frac{\text{weight of the Grains (kg)}}{\text{volume of grains including pore spaace (m}^3\text{)}}$$

Frictional Properties

The frictional properties such as angle of repose and coefficient of friction are key considerations for building storage bins, hoppers, chutes, pneumatic conveying systems, screw conveyors, forage harvesters, and other similar structures. The angle of repose and coefficient of friction, which are crucial frictional parameters, were determined as indicated below.

Angle of Repose

The angle of repose indicates the nature of the pile generated by the material. When material is piled, it forms an angle with regard to the horizontal. The apparatus is made out of a hollow cylinder and a plywood plate. The cylinder was filled with grains and gently inclined, allowing the grains to fall until it was empty. The scale was used to determine the height and radius of the estimated slope. For accuracy, the average of three readings was taken Firouzi and Alizadeh (2012) [5].

$$\theta = tan - 1(2h/d)$$

h= height of slope
d= diameter

Coefficient of friction

Coefficient of friction was determined in comparison to four different material surfaces by inclined surface method. Plywood, glass and mildsteel sheet were used. When the grain first began to slide on the test surface, the static angle of friction was measured Mohsenin (1986) [5]. The following Eq. was used for calculation.

$$\text{Coefficient of static friction } (\mu) = \tan\theta$$

Where, θ = Angle of friction, degrees

Aerodynamic Properties

The aerodynamic properties are essential and required for the design of air conveying systems and agricultural product separation equipment Sahay and Singh (1994) [15].

Terminal velocity

Terminal velocity is the air velocity at which a particle in a vertical pipe remains suspended. The millets are dropped from the top of a column while air is blasted through it. A digital anemometer with a minimum count of 0.1 m/s is used to measure the velocity of the air. The air velocity at which the millets are suspended in the column will be measured Gharibzahedi *et al.* (2010) [7].

Result and Discussion

Moisture content

The moisture content of the grain amranthus was found to be 9% on wet basis. A key factor that affects the physical properties of grains is their moisture level Goswami *et al.* (2015) [8]. The amount of moisture in the grains determines whether they can be kept for a long or short time Ramashia *et al.* (2018) [14]. The grain's storage life is shortened and mould growth is more accelerated at increased moisture contents Abdullah *et al.* (2012) [1]. All the physical properties were determined at 9% MC (W.b.).

Physical properties of Grain amranthus

The mean size and weight of 1000 grain weight was found to be 1mm and 7.6g. The results for bulk density, true density and porosity were 834.66 kg/m^3, 1389.06 kg/m^3 and 39.90%, respectively (Table 1). The results were in line with the findings of Sunil *et al.* (2016) [16], obtained for the 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 *et al.* (2016) [2].

Table 1: Physical properties of Grain amranthus

Physical parameters	Observation
Size(mm)	1±0.01
Thousand grain weight (gm)	7.6±0.205
True density kg/m^3	1389.06±15.75
Bulk density kg/m^3	834.66±2.05
Porosity %	39.90±0.82

*Each number is the average of three conclusions.

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 24.7° is comparable with the angle of repose (27-32 °C) reported for the little millet. The coefficient of friction for the three surfaces namely, Plywood surface, Mildsteel, and Glass were 0.38, 0.36, and 0.35, respectively (Table 2). Kumar *et al.* (2016) [12], were reported similar results for minor millets.

Table 2: Frictional properties of *Grain amranthus*

Parameters	Observation
Angle of Repose	24.7° ±1.70
Coefficient of friction	
Plywood surface	0.38±0.003
Mildsteel	0.36±0.004
Glass	0.35±0.005

Aerodynamic Properties

The mean terminal velocity of Grain amranthus was 2.3 m/s. The results were comparable with the findings of the Chandan Kumar *et al.* (2018) [4], reported for kodo millet were found to be 5.1 m/s, respectively. The terminal property will help agricultural and food engineers in developing air conveying system.

Table 3: Aerodynamic properties of *Grain amranthus*

Parameter	Observation
Terminal velocity m/s	2.3 ±0.152

*Each number is the average of three conclusions

Conclusion

Understanding physical properties is essential when designing equipment and devices used for harvesting and for activities such as storage that take place subsequently. These factors are significant in selecting machine size, particularly for equipment used for material sorting, transporting, and separation. Agricultural engineers, food engineers, food processors, and food scientists can use the knowledge from this study. In order to develop machinery for the processing of grains and other foods, designers must also be aware of the size, shape, and sphericity features of the grain. As a result, it is possible to evaluate the quality of grains using information about their physical features.

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