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Determining the physical properties of Barnyard millet (*Echinochloa esculenta*) and figuring out the appropriate time for soaking

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Abstract
This research examined the physical features of Barnyard Millet (BM) (*Echinochloa esculenta*) grains as well as the appropriate soaking conditios of the Barnyard Millet. Physical parameters of grain such as sample weight, bulk density, true density, porosity, sphericity, dimensional qualities, and moisture content were determined. Microsoft Excel was utilised for simple statistical applications such as mean, standard deviation (SD), standard error (S.Em), and percentages. The true density and bulk density of the Barnyard Millet was found out to be 1.25 g/cm^3 and 0.769 g/cm^3 respectively. The sphericity, aspect ratio and porosity were found to be 39%, 26.6% and 39.2% respectively. The proper soaking duration was determined to be 2 to 2 hours and 30 minutes. Such characteristics are particularly important for developing post-harvest machines and equipment such as graders, de-hullers, millet threshers, de-stoners, and storage structures.

Keywords: Barnyard millet, dimensional properties, physical properties, soaking time

Introduction

Barnyard millet (*Echinochloa esculenta*), also known as Japanese millet, is a grass species in the Poaceae family that is grown on a modest scale in India, Japan, China, and Korea for both food and animal fodder. Barnyard millet is known by several names in India, including shyama in Bengali, moraiyo in Gujarati, sanwa rice in Hindi, oodalu in Kannada, Kuthiraivaali in Tamil, and udalu in Telugu. The grain would possibly mature within 45 days after seeding if moisture and temperature conditions are favourable. The crop will be harvested in October-November with a moisture content of 0.24-0.26 kg^{-1} dry matter and dried in the sun until the moisture content drops to 0.12-0.14 kg^{-1}dry matter. The inflorescence contains one viable and one sterile floret, which is supported by two uneven glumes. The glumes completely round the kernel. Two epidermal layers make to the adult pericarp. The epidermal cells of the inner epidermis are tightly packed against the cells of the outer portion. The aleuronic layer of barnyard millet is expected to include heavily cutinized cell walls. It has a carbohydrate content of 57-66%, protein content of 5-8.5%, a fat content of 3.5-4.6, an ash content of 2.5-4.0%, and a fibre content of 6.4-12.2 at a moisture content of 0.25-0.05 kg^{-1} dry matter. According to the MoFPI the annual yield of barnyard millet variety more than 2500 kg/ha. Compared to main cereals like rice, wheat, and maize, grains are favoured for their great nutritional content and reduced cost. It is a rich source of fibre, protein, carbs, and, most significantly, micronutrients including iron (Fe) and zinc (Zn), which have been linked to a number of health advantages (Saleh *et al.*, 2013) [27]. Millet has all of the needed nutrients, making it excellent for large-scale production of infant food, energy bars, dietary food, and so on from grain, kernel, and flour. Barnyard millet is high in iron and calcium and low in phytic acid. It contains magnesium and vitamin B3 (niacin), which can aid to lessen the adverse effects of migraine problems and cholesterol levels. Phosphorus in barnyard millet aids in fat metabolism, regeneration of tissue, and the conversion of food into energy. Barnyard millet is a grain that has resulted in almost all necessary amino acids. Due to all of these advantages, barnyard millet is a perfect supplemental crop for subsistence farmers as well as an alternative crop in regions where rice and other important crops are grown when the monsoons fail. Following harvest, millet grains typically undergo two moisture treatments: Drying, which may be necessary for secure storage, and absorption of moisture, which is done in order to prepare the grains for processing.

Soaking of grains (paddy/millet) is a vital step in the processing line for parboiled, flaked and puffed rice products. Soaking induces significant quantitative (leachate loss, kernel cracking) and qualitative (colour, fragrance) modifications. Each grain has its own ideal soaking time. Freshly harvested rice takes up water at a lesser rate than stored grain. Though variances in moisture uptake are found initially in paddy with various beginning moisture content, it levels out as the soaking advances to almost the same level, regardless of initial moisture content. Soaking is carried out before to treatments such as sprouting, cooking, and the fermentation process. Soaking millets for a minimum of six to eight hours may drastically reduce their cooking time. The grains become softer, which facilitates cooking and improves digestion. Additionally, soaking millets helps break down anti-nutrients like phytic acid that can prevent the uptake of nutrients like calcium, magnesium, iron, and zinc. These nutrients are more readily absorbed by your body since soaking enhances their bioavailability. Knowledge of physical and functional features will be important in the creation of new products (Faleye, Atere, Oladipo, & Agaja, 2013) [9]. The primary physicochemical features of cereal grains describe the complex interaction amongst the structure, chemical components, composition, and physicochemical qualities of the food constituents. Physical, chemical, and/or organoleptic qualities of food are considered useful features. The objective of this study was to analyse the physical properties of BM grains, and currently there are relatively few publications that test if the grain has undergone the necessary length of soaking time. As a result, the current study attempted to investigate the physical features of barnyard millet, as well as the ideal amount of time for soaking.

2. Materials and Methods

The current research was set up in the Department of Food Engineering, National Institute of Food Technology, Entrepreneurship and Management (NIFTEM-T) Thanjavur, India. A native variety of Barnyard millet was purchased from a local market in Thanjavur, Tamil Nadu for this research.

2.1 Physical and chemical Barnyard millet Characteristics

The chemical and physical characteristics of millet, like those of other grains and seeds, influence the arrangement of equipment for handling, harvesting, processing, and conserving the grain. These factors have an impact on the properties of solid items conveyed by air or water, as well as the cooling and heating of loads of food products. As a result, these qualities must be determined (Shepherd & Bhardwaj, 1986 Oloso & Clarke, 1993; Hsu, Mannapperuma, & Singh, 1991; Singh & Goswami, 1996) [33, 34]. Other researchers have researched the physical qualities and oil content of the P. typhoides variety of pearl millet to identify the properties of different types of grains and seeds. Moisture content, weight and other physico-chemical properties, volume, size, colour, bulk density were investigated using standard procedures.

2.1.1 Weight

Using an electronic scale with a sensitivity of 0.1 mg, the weight of a randomly selected thousand grains was recorded in grams.

2.1.2 Volume

A thousand randomly chosen grains were placed into a measuring cylinder carrying a known volume of distilled water. The volume difference was measured in millilitres using the water displacement method.

2.1.3 Moisture content (Wb)

The M.C (%) was calculated using Eq. (1) employing a hot air oven drier and the procedure 44-15.02 (AACC, 2000). A dry encoded, clean crucible was placed in the oven for roughly 30 minutes, cooled, and weighed. Four grammes of BM grain varietals and flours were weighed and recorded into the crucible. The samples were then dried for 24 hours at 101 to 105 °C, removed, and cooled until a consistent weight was achieved. The percentage of moisture (%) were determined as follows.

$$\% \text{ moisture} = \frac{W3-W2}{W2-W1} * 100 \quad (1)$$

Where W1 is the weight of the empty crucible
W2 = crucible weight + flour before drying
W3 = crucible weight + flour after drying

2.1.4 Dimensional characteristics

Twenty seeds were chosen at random from each cultivator. Three distinct dimensional characteristics (mm) were obtained by measuring the length (L), width (W), and thickness (T) of the grains with a venier digital calliper on an accuracy of 0.01 mm (Mpotokwane, Gaditlhatlhelwe, Sebaka, & Jideani, 2008) [20].

2.1.5 Geometric mean diameter

Using Eq. (2), the geometric mean diameter (mm) of BM samples was calculated (Mpotokwane *et al.*, 2008) [20].

$$Dg = (L \times W \times T)^{1/3} \quad (2)$$

Dg is the geometric mean diameter,
Where L is the length.
W stands for width,
While T stands for thickness.

2.1.6 Arithmetic mean diameter (mm)

The BM's arithmetic mean diameter (mm) was calculated using Mpotokwane *et al.* (2008) [20] approach. The arithmetic mean diameter was calculated from the dimensional variables using Eq. (3).

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

Mean arithmetic diameter = Da
Where L is the length.
W stands for breadth.
T stands for thickness.

2.1.7 Porosity

Porosity (%) is the proportion of the overall grain space that is not occupied by grain (Sangamithra *et al.*, 2016) [28]. It was determined using true and bulk density readings using Eq. (4) and the method.

$$\varepsilon = \frac{P_t - P_b}{P_t} \times 100 \quad (4)$$

Where ε is the porosity
P_t is the true density
P_b is the bulk density

2.1.8 Sphericity
Sphericity (%) is defined as the ratio of the surface area of a sphere of the same volume as the grain to the surface area of the grain, and it was computed using the Hamdani *et al.* (2014) Eq. (5) approach.

$$\Phi = \frac{(L \times W \times T)^{1/3}}{L} \times 100 \quad (5)$$

Where m Φ = Sphericity

2.1.9 Grain Bulk Density
The grain was placed in a circular container with a volume of 1.482 10-3 m3 and slightly tapped. The bulk density was estimated by dividing the quantity of millets by the container's entire capacity (volume). A total of five replicas were used. To avoid grain deformation in the container and to fill the whole capacity, care should be given. The formula was used to calculate grain bulk density. The bulk density was reported in grams per millilitre.

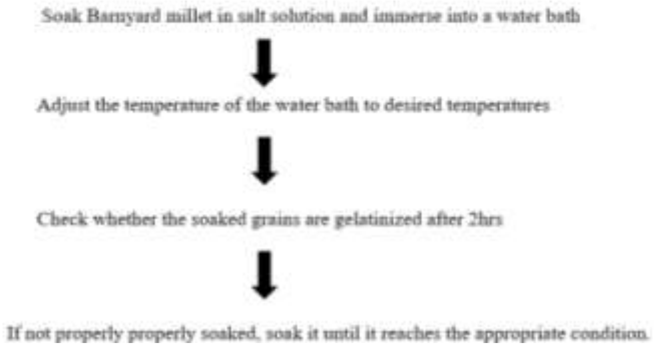
$$Bulk\ Density \left(\frac{g}{ml}\right) = \frac{weight(g)}{volume(ml)} \quad (6)$$

2.1.10 True Density
The true density (kg/m3) was measured using a top loading balance and the liquid displacement technique. In a graduated beaker, 100 g of grains were immersed in distilled water. Eq. (7) was used to calculate the quantity of water displacement.

$$P_t = \frac{sample\ weight}{V_2 - V_1} \quad (7)$$

Where Pt is the real density,
V1 is the initial volume
V2 is the final volume.

2.2 Soaking Attributes of Barnyard millet
The 50 g of barnyard millet was soaked in 100ml of saturated salt solution and it was placed in the thermostatically regulated water bath (model: REMI RWD 6). The temperature of the water in the water bath has been adjusted to meet the temperature requirements of the treatments (60°C, 70°C, and 80°C). The fluctuation in temperature in the water bath was determined to be ±2°C. The same Borosil Beaker of 500ml capacity containing 50g of millets was placed in water at ambient room temperature 34°C±3°C to execute conventional (cold water) soaking treatment. The gelatinization temperature of rice was used to calculate the water temperature for hot soaking (Igathinathane *et al.*, 2005) [32]. As a result, three degrees of hot water treatments were done and compared to typical soaking treatments (cold water soaking). Table 1 listed the treatments used in this trial.



Flowchart on Millet soaking treatments which were carried out in the experiment

2.4 Statistical evaluation
Microsoft Excel was utilised for simple statistical applications such as mean, standard deviation (SD), standard error (S.Em), and percentages.

3. Results and Discussion
3.1. Dimensional characteristics of Barnyard millet varieties
The length, width, and thickness of the BM had been measured using a Vernier digital calliper, and the mean findings were from 0.075 mm for length, 0.020 mm for width, and 0.015 mm for thickness (Table 1). The geometrical average diameter was found to be 1.36 ± 0.18, whereas the arithmetic mean diameter was 1.38 ± 0.22mm. The following are the findings of who investigated both the geometric and arithmetic mean diameters of Pear Millet cultivars: At a moisture level of 7.4%, the dimensions are 1.82 mm length, 2.12 mm breadth and 1.72 mm of thickness.

Table 1: Shows the Dimensional characteristics of barnyard millet grain varieties measured using a Vernier Digital Calliper.

Dimensions (mm)	Barnyard Millet
Length	0.075 mm
Width	0.020 mm
Thickness	0.015 mm
Geometric mean diameter	0.029 mm
Arithmetic mean diameter	0.0366 mm

3.2 Physical characteristics of barnyard millet
3.2.1 Thousand grain weight
The 1000 grain weight was found to be 3.08g. The weight of 1000 grains was determined to be 3.08g. The moisture content rose according to the Thousand grain weight. Singh and Goswami (1996) [34] discovered an exponential correlation between cumin seed moisture content and thousand seed/kernel weight. The weights of 1000 seeds and kernels with a moisture content of 6.5% db varied from 22-229 to 19-177 g.

3.2.2 Bulk Density
Barnyard millet has the highest bulk density at lower moisture levels, followed by proso, kodo, finger, little, and foxtail millet. Proso millet has the highest bulk density at increasing moisture levels, followed by barnyard, finger, kodo, foxtail and little millet and Shepherd and Bhardwaj (1986) [33] found a similar relationship between pigeon pea and gramm, on the other hand, discovered that the bulk density of karingada seeds rose linearly with grain wetness. Bulk density is an important element in determining during drying, storage, and

processing, grain quality and test weight are maintained (Adebowale *et al.*, 2012) [3]. Because the grains were similar in size and shape, the bulk density data will help with processing and storage, implying good quality and increased flour output. These variations might be attributable to grain and seed cell structure, volume, and weight development characteristics.

3.2.3 True Density
The true density of the barnyard millet was found to be 1.25g/cm^3 observations with pumpkin seeds are consistent with these findings. The true density of minor millets was discovered to be less than one gramme showed a rise in actual density from 1010 to 1134 kg/m3 for karingda kernel and 1047 to 1134 kg/m3 for moisture ranges of 5-40% db and 7-22% db, respectively (Singh and Goswami 1996) [34]. Increased seed volume and mass range result in a fall in real density, which is caused by larger seed size. Several studies have found that actual density decreases with increasing moisture content (4-32.6% db) in karingda seed and chick pea seeds (Konak *et al.* 2002).

3.2.4 M.C of BM grains and flour
The average moisture content (MC) of the BM grain was found to be 12.3% while the moisture content of BM flours ranged from 9.17 to 11.67%, respectively. As a result, these findings revealed that the MC was within the stipulated proportion of 12%, as demonstrated by Saleh *et al.* (2013) [27]. Moisture content is a significant component that influences grain physical qualities. It also tells if the grains can be stored for an extended or brief amount of time. In accordance with Abdullah, Ch'ng, and Yunus (2012), the higher the moisture level, the shorter the grain's storage life because high moisture content triggers fast the development of mould on grains.

3.2.5 Porosity
The mean porosity of the BM grain is resulted as 39.2%. Balasubramanian and Viswanathan (2010) [5] achieved comparable results of 32.5 to 63.7% at moisture contents ranging from 11.1 to 25% for minor millets with Finger Millet grain found a similar observation, varying between 45.61 to 46.66% for green wheat. Porosity varied from 38.31 to 42.32% for teff millet with a moisture level of 5.6 to 29.0% in a research by Zewdu and Solomon (2007), while porosity ranged from 45.1 to 48.8% for Pearl Millet varieties (babapuri, bajra, and GHB 30) at a moisture content of 7.4% in a study by Jain and Bal (1997).

3.2.6 Aspect Ratio
The aspect ratio of the BM grain was found to be 26.6%. Major millets were found to have 59.62% aspect ratio at a moisture level of 10% by Adebowale *et al.* (2012) [3], and 47.4% with a moisture content of 9.95% by Markowski, Zuk-Goaszewska, and Kwiatkowski (2013) [19].

3.2.7 Sphericity
The mean sphericity value obtained for Barnyard millet was 39%. The physical Properties of the Barnyard millet is listed below

Table 2: Shows some of the physical attributes of Barnyard millet grain varieties

Physical properties	Barnyard Millet
1000 grain weight (wt. g)	3.08 g
Bulk density (g/cm^3)	0.768 g/cm^3
True density (g/cm^3)	1.25 g/cm^3
Porosity (%)	39.2%
Aspect ratio (%)	26.6%
Sphericity (%)	39%

3.3 Soaking attributes of Barnyard millet
The table provides information on the soaking characteristics of barnyard millet. There will be considerable changes in proximate after processing barnyard millet such as soaking, parboiling, dehulling, milling, and cooking. Protein and carbohydrate content are higher in the soaked and cooked samples. Any of the procedures results in a considerable drop in protein, carbohydrate, and fat content, which might be due to fibre loss during dehulling and leaching of water-soluble components like as protein and minerals during dehulling and subsequent soaking and boiling. In this experiment, both traditional soaking (cold water soaking) and hot water soaking were used. The Barnyard millet was soaked in room temperature water, while the other BM samples were soaked in hot water at temperatures of 60°, 70°, and 80° degrees Celsius. In order to determine if the millet has been adequately soaked, a soaking test is carried out, which involves making a saturated salt solution and adding a little amount of the soaked millet to the salt solution. Boil for 5 minutes. After 5 minutes, remove the boiling sample from the salt solution and randomly place it on a petri dish or glass slide. Now, using another glass slide or petri dish, push the glass slide we will notice the millet spreading. The BM sample, which was held for soaking at varied temperatures and conditions, was taken out every 30 minutes to see if the millet had reached its soaking state.

(a) Hot water soaking at 60 °C (b) Hot water soaking at 70 °C (c) Hot water soaking at 80 °C (d) Traditional Soaking at room temperature

The BM that was steeped at room temperature (Cold water soaking) required 9 to 10 hours of soak duration (overnight soaking). Millets immersed in hot water at different temperatures took a range of time to achieve the optimal soaking condition. The BM that was soaked in 60 degrees took a total of three hours and 35 minutes to reach the soaking state. The BM immersed at 70°C achieved the soaking time in 2 hours and 30 minutes. Though the BM immersed in an 80°C water bath reached the soaking state in 1 hour and 30 minutes, the BM seemed to be mushy or soggy, which can frequently be triggered by two things that is the millet is overcooked, and too much liquid is absorbed into the millet. When millet overcooks and absorbs too much water, the grains might split apart and become more starchy and sticky.

4. Conclusion

Some engineering parameters of Barnyard millets were determined, such as length, breadth, thickness, geometric mean diameter, thousand grain weight, sphericity, bulk density, true density, porosity. These characteristics can be especially important for designing post-harvest machines and equipment such as graders, de-hullers, millet threshers, de-stoners, and storage structures. As a result, Barnyard millet (BM) grains/flour may be utilised by food processors to generate novel food products that may be consumed in metropolitan environments, particularly by persons suffering from chronic conditions. Agricultural technicians, food technologists, food manufacturers, and food scientists can all benefit from the findings of this study. The recommended soaking time for Barnyard millet is 2 to 2 hours and 30 minutes. This may be considered the optimal period for millet soaking. However, the soaking duration varies according on the grain. As a result, data gathered on the physical and soaking attributes of grains may be used to assess the quality of grains and can be applied for parboiling of millets.

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