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Comparative Study of Engineering and Physical Properties of Whole Grain and Milled Little Millet (*Panicum sumatrense*)

Shivbilas Maurya[1*], S.S. Shukla[1], K.C. Mahajan[2] and B.L. Sahu[1]
[1]Department of Food Science and Technology,
College of Agriculture, JNKVV, Jabalpur (Madhya Pradesh), India.
[2]Faculty of Agriculture, JNKVV, Jabalpur, Madhya Pradesh,
College of Agriculture, Ganjbasoda (Madhya Pradesh), India.

(Corresponding author: Shivbilas Maurya)*
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ABSTRACT: The present study was focused on physical properties of entire and milled little millet. The moisture content was estimated to be between 7.68 and 9.88% (dry basis), based on the physical and engineering properties. The milled kutki millet showed an important enhancement in the physical characteristics of the millet. The milled millet showed higher bulk density and true density (0.85, 1.41) as compare to kutki whole grain (0.73, 01.16), while thousand grain weight exhibited an increase in whole grains (2.67) whereas milled kutki (2.18). The angle of repose observed maximum value (28.64°) in milled kutki as compared to kutki whole grain (25.26°), while yellowness index were maximum value (76.23) in kutki whole grain followed by milled kutki (45.22). The whiteness index and aspect ratio observed maximum in milled kutki (58.96 and 0.75) followed by kutki whole grain (40.33, 0.60). The sphericity value was maximum (1.71) in whole grain followed by milled kutki (1.39). The experiment found that the (Gravimetric characteristics, frictional properties, and colour index) for both whole and hulled kutki millets were performed. The hulling improved all of the physical and engineering properties of millet. The whiteness index for hulled millet was enhanced in the colour values. Due to the preservation of their physico-engineering makeup, the design of storage structures and post-harvest processing machines allows for extended storage of dehulled kutki and kutki whole grain millet.

Keywords: Little millet, Physical properties, Engineering properties. Yellowness Index, Whiteness Index.

INTRODUCTION

A group of tiny seed grains that are referred to as "millet" could grow by itself without any particular needs, such as watering systems, like other cereal crops of both rice and wheat. Because of their health benefits, millets are often nutritionally similar to and even superior to other grains. Numerous studies on millets have demonstrated how nutritious and beneficial they are for human health. (Food & Nations 1995).

According to data from the years 2020 and 202, India produces 0.40 million metric tons of minor millet annually (DAC & FW 2020). They are considered "food for the underprivileged" since they are nutritious as well as resistant to biotic and abiotic effects, which makes them an ancient everyday food for those that live in semi-arid and tropical regions (Malleshi, 1989). Minor millets have greater quantities of proteins, minerals, vitamins, and antioxidants than non-millet grains because of their nutritional makeup (Saini *et al*., 2021).

Little millet (*Panicum sumatrense*) has an oval form, is grey to straw white in colour, and has a glossy exterior with a cellulose husk (Hegde and Chandra 2005). It contains significant amounts of cysteine and methionine, two of the amino acids that are sulphur-containing. Its nutritional components are protein (9.7 g/100 g), carbohydrate (60.9 g/100 g), crude fiber (7.6 g/100 g), and fat (5.2 g/100 g). 10 Little Millet has more zinc (3.70 mg/100 g), chromium (0.24 mg/100 g), and carotenoids (78 g/100 g), all of which increase cholesterol synthesis, enhance eyesight, and claim antioxidant effects (Girish *et al*., 2014).

Several investigators have reported that the engineering-related characteristics of different millets at various initial moisture contents (IMC). It is crucial to understand the physical and engineering properties of these small millets in order to design and manufacture post-harvest equipment. Many researchers have investigated engineering properties for distinct millets at various and initial moisture content (IMC), but no data is available for the physical and engineering properties of the minor millets (Barnyard, Kodo, and Little millet) from the standpoint of machine and equipment design (Jaybhaye *et al.,* 2010).

MATERIALS AND METHODS

Kutki millets were procured from the different blocks of Mandla and Dindori districts in Madhya Pradesh. The Kutki samples were properly cleaned, graded, hulled, and milled by perfura, hulling, and milling machines, then properly packed and stored. Experiment conducted in the cereal technology laboratory, department of food science and technology.

Kutki (Whole grain) Kutki (Milled)

Analytical method

Moisture content (%). The initial moisture content of seed was estimated using the usual hot air oven method and the formula shown below (AACC, 1995):

MC(%) = $\frac{W1-W2}{W3-W} \times 100$

Where,
MC = Moisture content on dry basis, (%)
W1 = Initial weight of the bowl, (g)
W2 = sample weight before drying +bowl weight, (g)
W3 = sample weight after drying + bowl weight, (g)

Frictional properties

Repose angle. An acrylic box with a hardwood bottom (0.30 m x 0.30 m x 0.30 m) and a detachable front panel wassed to estimate the angle of repose. When you remove the front panel, the grains fall down on a natural slope. The angle of repose was estimated by measuring the vertical depth and radius of propagation of the sample across the plywood with parallel or perpendicular streaks to the movement direction (Vilche *et al*., 2003; Mohsenin, 1986; Sologubik *et al*., 2013).

$\Theta = \tan^{-1}(2h/d)$

Where,
d = Diameter
h = Height of the cone

Gravimetric features

We calculated the grain's bulk density (ρb), true density (ρt), and porosity (ε) at various moisture contents. Since it affects the rate of heat and mass exchange of moisture during air circulation and drying methods, b and t are used to measure stockpile efficiency. The requirements for grain hoppers and storage facilities are determined by porosity.

Bulk density (ρb). A part of the grain mass for the entire volume makes up the bulk density (ρb). It was determined using a 1,000-ml container filled to a height of 15 cm and containing wheat grain, and finally measured in kg/m^3 (Mohsenin, 1970).

Pb=$\frac{Ws}{Vs}$

Where,
Ws = weight of the sample in (g)
Vs = volume of the sample in (ml), occupied by the grain in ml^3.

True density (ρt). The ratio of wheat grain weight to grain volume is known as true density (ρt). Because only a small amount of toluene (C7H8) is absorbed by grains, this calculation used the toluene (C7H8) displacement technique instead of water. A known weight of grain was added to a measuring cylinder after 50 millilitres of toluene, and the rise in toluene level was then documented (Mohsenin, 1986).

Pt=$\frac{Ms}{Vt}$

Where,
ρt = True density (g/m^3),
Ms= Mass of the grain, (g)
Vt = Volume of toluene displaced by grains (ml^3).

Porosity (ε). The volume percentage of empty space that is present in the air of grains is known as porosity (ε). The vacuum spaces that are thought to exist inside grains but are not really a part of them are estimated. The equation is used to compute it (Mohsenin, 1986). The unit of porosity is %.

(ε) = (1- $\rho b/\rho t$) ×100

Where,
ε is Porosity,
ρb is bulk density of material (g/ml)
ρt is true density of material (g/ml)

Thousand kernel weight. A grain mass of around one kg was split into 10 equal sections, and 10 random seeds were then taken from each component to calculate the thousand seed weight (W1000, kg). Their weight was measured using electronic digital scales with an accuracy of 0.0001 g, and 1000 grains' worth of weight was calculated by multiplying their weight by 100 (Shah *et al*., 2016).

Geometric mean diameter. Through the application of the geometric and arithmetic means of the three axial dimensions, it was feasible to calculate the average diameter of the grain. In order to accommodate the potential of grain geometry, it is also known as the equivalent diameter. Equations (2) and (3) were used to get the geometric mean diameter (Dg) and arithmetic mean diameter (Da) (Mohsenin, 1970). 100 minor millets were randomly chosen, and the (L, mm), (W, mm), and (T, mm) of each were measured using a digital Vernier calliper (CD-6AXS-Mitutoyo Corporation, Japan) with a minimum count of 0.01 mm. (15) Using this equation, the equivalent diameter (de, mm), viewed as the geometric average of the three primary dimensions (L, W, and T), was determined (Mohsenin, 1986):

$$de = \frac{L+W+T}{3}$$

$$R_a = \frac{W}{L}$$

Where,

L is length

W is width

T is thickness

Ra is aspect ratio

Hunter colour analysis. On the basis of L, a, and b values, the hand calorimeter (CR-400, Konica Minolta, Chroma Metre, Japan) was used to assess the impact of colour on the moisture content of the coloured wheat grain. A white, reflecting standard plate served as the calibration reference for the hand colorimeter. The top of the cone is put on the wheat grain's surface. Three locations on each replication of the wheat grain were used to measure colour, and the average values were recorded for the research (Jha *et al*., 2005).

A lab-scale colorimeter (Colour Flex EZ, Hunter Associates Laboratory Inc., Reston, VA, USA) with a 12 mm aperture was used to assess the colour values. L* stands for lightness, ranging from 0 (black) to 100 (white), a* for greenness to +a (redness), and b* for blueness to +b (yellowness). The Whiteness Index (WI), a measure of distinguishing whiteness:

$$WI = 100 - \sqrt{(100-L^*)\,2 + (a^*)^2 + (b^*)^2}$$

YI (Yellowness Index) indicates degree of yellowness can be calculated by using formula:

YI=142.86 b*/L*

Statistical Analysis. The experiment's completely randomised design was carried out in accordance with the steps outlined by Panse and Sukhatme (1967).

All experimental data, unless otherwise stated, were collected in triplicate and provided as the mean standard deviation. For statistical analysis, one factor, CRD, was used, and multiple mean comparisons within the sample set were made at a 5% significance level. For p 0.05, statistical significance was taken into account.

RESULTS AND DISCUSSION

Sphericity. In the case of various minor millet types, three orthogonal dimensions were measured, revealing statistically significant differences ($P<0.05$) in their respective sizes. Among these millets, whole little millet exhibited the smallest dimension, as indicated in Table 1. The millet grains exhibited an elongated shape, with the largest dimension, L, measuring 2.51mm, while the smallest dimension measured 1.74mm. The thickness, W, was greatest in whole grains (1.52mm) compared to milled kutki (1.32mm), and milled kutki showed a higher thickness (1.12mm) compared to whole grain (1.11mm). These measurements, particularly the Geometric Mean Diameter (GMD), are important for designing grading equipment, as depicted in Fig. 1 (Jain and Bal 1997).

Table 1: Physical and engineering properties of kutki millet (WG and KM).

Parameters	Kutki (Whole grain)	Kutki (Milled)
Moisture (%)	8.27	9.88
L (mm)	2.51	1.74
W (mm)	1.52	1.32
T(mm)	1.11	1.12
1000 grain weight (g)	2.67	2.18
Bulk Density (g/ml^3)	0.73	0.85
True Density (g/ml^3)	1.16	1.41
Porosity (%)	36.72	23.48
Angle of Repose(θ)	25.26	28.64
L	46.19	65.17
a	7.61	3.71
b	24.65	21.38
YI	76.23	45.22
WI	40.33	58.96

Note: L= length, W= Width, T= Thickness, YI= Yellowness Index, WI=Whiteness Index,

Sphericity and aspect ratio values ranged between 1.71 and 1.39, and 0.60 to 0.75, respectively. Whole grain millets exhibited the highest sphericity (1.71), followed by kutki milled (1.39), and milled kutki had the highest aspect ratio (0.75), followed by whole grain millets. Sphericity and aspect ratio data are relevant for describing the shape of the grains (Saini *et al*., 2021).

Thousand Kernel Weight. The weight of 1000 kernels of whole and hulled kutki millet ranged from 2.67 to 2.18 grams, as detailed in Table 1. Specifically, at a moisture content of 8.27% db, the 1000-seed weight was 2.67g for whole kutki grain, and at a moisture content of 9.88% db, it was 2.18g for milled kutki grain. Significant differences ($p<0.05$) were observed in the 1000 kernel weight of milled kutki grains, while no significant difference was noted for whole kutki grains (Fig. 1). As moisture content increased, the 1000 kernel weight linearly increased, as reported in previous studies (Zewdu, 2007).

Bulk Density. The bulk density of the millet grains ranged between 0.73 and 0.85g/ml. While there was no significant difference ($p<0.05$) between the bulk densities of whole kutki grain (0.73g/ml) and milled kutki (0.85g/ml), hulled kutki millet (842.73 kg/m^3)

exhibited a different bulk density. The compact arrangement of whole kutki grains contributed to its lower bulk density, and there was a linear decrease in bulk density within the moisture content range of 8.27–9.88% db (Fig. 1). Milled kutki millet displayed higher bulk density than whole kutki millet, consistent with findings for other legumes (Dutta *et al*., 1988).

True Density. The true density of the millet grains ranged from 1.16 to 1.41g/ml. Milled kutki had a higher true density (1.16g/ml) compared to whole kutki grain (1.41g/ml). True density decreased as moisture content increased, following a pattern observed in previous research (Jain and Bal 1997).

Porosity. Variations in grain porosity, which signifies the presence of air gaps within the grains, displayed notable differences ($p < 0.05$), spanning from 23.48% to 36.72%. Milled kutki grains had lower porosity (23.48%) compared to whole kutki millet (36.72%). Porosity data are crucial for understanding heat and mass transfer processes, texture characterization, and drying quality. Porosity decreased with increasing moisture content (Fig. 2), and kodo millet exhibited the highest porosity, followed by barnyard millet at all moisture contents (Sachin and Sumnu 2006).

Repose Angle. The angle of repose values ranged between 25.26° to 28.64°. Significant differences were observed ($p < 0.05$), except for whole kutki millet (25.26°) and milled kutki (28.66°). These values were within the range reported for quinoa seeds (Vilche *et al*., 2003) at varying moisture content. Angle of repose values increased with moisture content (Fig. 2).

Color Properties. Whiteness index (WI) values ranged from 40.33 to 58.96, with milled kutki millet (58.96) exhibiting the highest value among whole grains. This indicates that milled kutki had the highest perceptible whiteness, followed by whole kutki grain. Yellowness values were higher for whole kutki grain (76.23) compared to milled kutki (45.22). The redness value (a) was higher for whole grain (7.61), indicating a darker color, compared to milled kutki (3.71). Milled kutki had the highest L value (46.19), indicating a darker color, while whole kutki grain scored the lowest (46.19). The yellowness value (b) indicated a grey to straw white color with glossiness (Fig. 2). De-hulling improved the whiteness index for milled kutki (Jha *et al*., 2005).

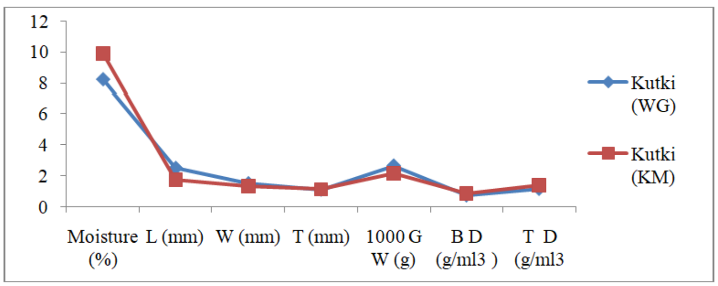

Fig. 1. Graph of physical and engineering properties of kutki millet (WG and KM).

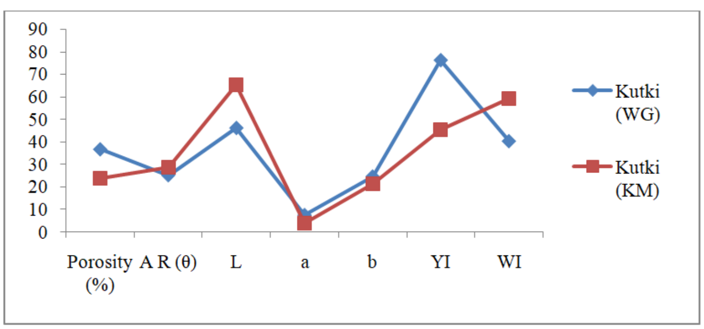

Fig. 2. Graph of physical and engineering properties of kutki millet (WG and KM).

CONCLUSIONS

The study's outcomes reveal notable enhancements in physical attributes such as hue, angle of repose, and sphericity. Milling of the millet led to an elevation in their whiteness index. In comparison to intact grains, the milling process entails more cohesive interactions, resulting in a heightened angle of repose (piling effect). While the fundamental dimensions and attributes of minor millets diminished upon de-hulling, their radius and aspect ratio demonstrated augmentation. The presence of coarse hulls preventing grain collapse accounted for the lower bulk density, implying increased inter-grain interaction. Hulled grains exhibited higher density upon tapping, attributed to their more compact alignment, along with reduced porosity. Subsequently, the identified physical and engineering characteristics hold potential for application in local manufacturing and the development of straightforwardly deployable integrated harvester-thresher systems, grading equipment, de-hullers, conveying mechanisms, silos, MVT-based grain sorters, as well as milling components, both at commercial and decentralized domestic scales.

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Conflict of Interest. None.

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