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Physicochemical, functional and nutritional properties of millet grains

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Abstract
The millets such as pearl millet, finger millet and foxtail millet were analysed for their physical properties such as thousand kernel weight, porosity, bulk density, true density and angle of repose. The functional properties of flours such water absorption and oil absorption capacity were evaluated. The proximate composition of millets was evaluated with respect to the moisture content, protein, fat, ash, crude fibre, and carbohydrates. The millets were found to be rich in ash, crude fibre, and carbohydrates. The study found that millets can be used in various products attributing to their functional and nutritional properties.

Keywords: Physicochemical, functional and nutritional properties, millet grains, weight, porosity

1. Introduction
Millets have been cultivated for around 3,000 years making them an integral part of the culture and history of India. References to millets can be seen in mythological writings, poetry, religious practices, ayurvedic recipes, and in numerous dishes. Millets are not only important for rural people's livelihoods, but also for urban population as well with their important nutritional qualities. Improved nutrition is not only contributing to economic but also it is a precondition for it. Improved nutrition breaks the chain of transmission of poverty from one generation to another. One report suggests that micronutrient deficiency alone costs India US$2.5 billion annually. Millets provide the much-needed food and nutritional security especially to the vulnerable groups. It is evident to be noted that food security at national level will only be effective when locally important crops are allowed to play their due role in attaining food and fodder needs and will restrict the undesirable dependence on other regions. (Dhan Foundation, 2012)
With an annual world production about 25 million tonnes, millets are one of the basic nutrients of humans for four thousand years in Africa and Asia and for Europe till the end of the Middle Age. The world's millet consumption has reduced at a rate of 0.9% and expected to grow positively during period of 2019-2024. "The market of millets is set to prosper from its value of more than $9 billion to over $12 billion by 2025. Favourable and positive government policies to increase the global millets market size over 2019-2025". "Millets are small-seeded cereal like grains which retain their excellent nutritional characteristics, superior to highly consumed cereals like wheat & rice. They contain high proteins and minerals such as calcium, iron, zinc etc. which may be useful in avoiding some diseases. That's why, increasing awareness about health benefits associated with millets consumption will cater this industry growth by 2025". The millets contain calcium, iron, zinc and fibres important nutrients which may help to the healthy growth in children. Their nutritional content is far better than rice and wheat such as protein, vitamins A and B, iron, calcium, phosphorus, magnesium, and manganese. Many developing countries and federal governments are making long-term initiatives & policies to roll out nutrition-based programs on millets which directed for reducing malnutrition. This will help to boost the penetration of millets in food and beverage sector and certainly the market value will grow.

2. Materials and Methods
2.1 Physical properties of raw materials
2.1.1 Dimensional properties
A total of ten seeds were randomly selected from each millet. Three different dimensional properties (mm) were determined by measuring the length (L), width (W) and thickness (T) of the grains using a vernier digital calliper at an accuracy of 0.01 mm.

2.1.2 Geometric mean diameter
The geometric mean diameter (mm) was determined based on the measured dimensions of millet samples using equation.
Geometric mean diameter (Dg) is equivalent to = (L × W × T)1/3

Where:
L0 =length.
W= width.
T= thickness.

2.1.3 Arithmetic mean diameter
The arithmetic mean diameter (mm) of the sample was obtained using the methods of Mpotokwane *et al*. (2008) [9]. Arithmetic mean diameter was calculated from the dimensional values using following equation
Arithmetic mean diameter

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

Where:
L =length.
W= width.
T= thickness.

2.1.4 One thousand (1000) sample weight
Thousand sample weight was determined by weighing, recording the weight and counting manually the number of the sample. The grain samples were weighed using digital electronic balance with 0.01 g accuracy.

2.1.5 Bulk density
Bulk density (kg/m^3) is described as the ratio of the mass of the sample to its total volume. It was determined by filling a 500 mL cylinder with grains. Bulk density (kg/m^3) was calculated as a ratio between the sample weight and the volume of the cylinder using Equation.

$$\text{Bulk density (Pb)} = \frac{\text{Sample weight}}{\text{volume}}$$

2.1.5 True density
The true density (kg/m^3) was determined by the liquid displacement method using a top loading balance. A total of 100 g of grains were immersed in graduated beaker containing distilled water. The amount of water displacement was recorded using Equation (Karababa & Coşkuner 2013) [4].

$$\text{True density (Pt)} = \frac{\text{Sample weight}}{\text{Initial volume} - \text{Final volume}}$$

2.1.6 Porosity
Porosity (%) is defined as the fraction of the space in bulk grain that is not occupied by the grain (Sangamithra *et al*., 2016) [14]. It was calculated using Equation from the true density and bulk density using method of Vanrnamkhasti *et al*. (2008).

$$\text{Porosity } (\varepsilon) = \frac{Pt - Pb}{Pt} \times 100$$

where ε =porosity, pt =true density and pb = bulk density.

2.1.7 Angle of repose
Angle of repose was determined from the height and diameter of the naturally formed heap of food grains and powdered food products (Pradhan *et al*., 2012) [13].

$$\text{Angle of repose } (\theta) = \tan^{-1} \frac{2h}{D}$$

Where θ = angle of repose in degrees;
h = height of the circular plate and
D = diameter of the circular plate
Functional properties of flours

2.1.8 Water and oil absorption capacity
One (1) gram FM flour was transferred into weighing 50 mL centrifuge tubes in triplicate to which 10 mL of distilled water/edible soybean oil was added, stirred homogeneously with a glass rod and incubated in water bath at 30 °C for 30 min. The centrifuge tubes were centrifuged at 3000 rpm for 15 min using laboratory centrifuge. The supernatants were discarded, and the residues were weighed. (Sawant *et al*., 2013) [15].

$$\text{Water/Oil absorption capacity (ml/g)} = \frac{V1 - V2}{V2} \times 100$$

Where: V1 = initial volume of the liquid.
V2 =final volume of the liquid.

2.1.9 Proximate composition of raw materials and products
Proximate composition such moisture, protein, carbohydrates, fat, ash and crude fibre were evaluated by AOAC 2000 methods.

3. Results and Discussion
3.1 Physical properties of millet grains
Physical properties are important in aspects of processing and value addition such as thousand kernel weights, porosity, bulk density, True density and angle of repose etc. Knowledge of the physical properties of grains and seeds is of paramount importance in designing handling, transportation, storing and processing equipment. Size, shape and density are important in separation processes on oscillating chafers and gravity tables. The bulk density and porosity are crucial properties in the development of aeration and drying systems as they affect the resistance to airflow through a stored mass whereas the angle of repose is very important in designing equipment or mass flow and storage structures. Data presented in table 1 showed different physical properties of finger millet, foxtail millet and pearl millet grains. The results obtained for different properties such as thousand kernel weight, thousand kernel volume, bulk densities and true densities are in average of three determinations. The finger millet, foxtail millet and pearl millet showed thousand kernel weight ranging from (2.27-9.42) g the lowest for finger millet and highest for pearl millet. The foxtail millet had 2.98 g weight for thousand kernel.
The values for length, width and thickness for finger millet, foxtail millet and pearl millet showed were 2.35, 2.62 & 2.85mm; 1.52, 1.63 & 1.85 mm and 1.23, 1.47 & 1.51mm respectively. The average arithmetic and geometric mean diameters were 1.46, 2.09 & 2.65 mm and 1.63, 1.84 & 1.99 mm respectively for finger millet, foxtail millet and pearl millet in order. The obtained results were comparable with (Badau *et al.,* 2002) [3], (Swami & Swami 2010) [18] and Arya (2008) [2] who studied physical properties of pearl millet, finger millet and foxtail millet respectively.

Table 1: Physical properties of millet grains

Properties	Finger millet	Foxtail millet	Pearl millet
Thousand kernel weight (g)	2.27	2.98	9.42
Thousand kernel volume (ml)	2.425	2.85	4.47
Bulk density (kg/m^3)	782	752	842
True density (kg/m^3)	1124.9	1250	1359
Porosity (%)	30.5	39.9	38.1
Angle of repose	20^0	27^0	28^0
Length (mm)	2.35	2.62	2.85
Width (mm)	1.52	1.63	1.85
Thickness (mm)	1.23	1.47	1.51
Geometric mean diameter (mm)	1.63	1.84	1.99
Arithmetic mean diameter (mm)	1.46	2.09	2.65

*Each value is mean of three determinations

3.2 Physical properties of flour

Physical properties of flour were determined such as bulk density, true density, % porosity and angle of repose. The physical properties are important factors for the determination of packaging materials, mixing and design of process.

Table 2: Physical properties of flour

Properties	Finger millet	Foxtail millet	Pearl millet
Bulk density (g/cm^3)	0.560	0.490	0.520
True density (g/cm^3)	1.360	1.520	1.690
Porosity (%)	50.40	55.82	67.11

*Each value is mean of three determinations

Bulk densities of finger millet, foxtail millet & pearl millet were 0.560, 0.490 & 0.520 g/cm^3 respectively. True density of finger millet was found to be 1.360 g/cm^3 which is least among all flours whereas the foxtail millet and pearl millet had 1.520 & 1690 g/cm^3 respectively. The finger millet flour 50.40 % porosity least among all millet flours whereas foxtail millet flour and pearl millet flour had 55.82 & 67.11% porosity respectively.
The values obtained were in agreement with (Mercy and Kiruba 2021) [8] who reported similar values for millet flours.

3.3 Functional properties of flour

Millet flours were analysed for different functional properties such as water absorption capacity (WAC) and oil absorption capacity (OAC) which are given in table 3.

Table 3: Functional properties of flour

Property	Finger millet flour	Foxtail millet flour	Pearl millet flour
Water absorption (ml/g) (%)	110.03	125.02	120.23
Oil absorption (ml/g) (%)	111.21	118.05	123.25

*Each value is mean of three determinations

Among the millet flours foxtail millet had highest water absorption capacity (%) and finger millet had least. The higher WAC of foxtail millet is attributed to its high fibre content. The values for water absorption capacity (%) were 110.03, 125.02 and 120.23 for finger millet, foxtail millet and pearl millet respectively. The results of WAC were similar to findings of (Olpade *et al.,* 2014). Water absorption capacity is influenced by carbohydrate composition the polysaccharides which are hydrophilic in nature greatly affects WAC. (Khatoniar & Das 2020) [6] Also observed the similar values for functional properties of millet grown in Assam region.
Oil absorption capacity (OAC) % of finger millet 111.21, foxtail millet 118.05 and 123.25 for pearl millet. The oil absorption capacity of any food material relies mainly on its capacity to physically entrap oil by a complex capillary attraction. Similar results were reported by Singh *et al.* 2005 [17].

3.4 Colour properties of millet grains

The colour of the grains has been reported in terms of three components viz., colour L*, colour a* and colour b*. L* indicates lightness and the colour intensity for L* varies from 0 (black) to 100 (white) and a* denotes redness and b* denotes yellowness. The different values for colour of millet grains are shown in table 4.

Table 4: Colour values of millet grains

Millet grains	L*	a*	b*
Finger millet	38.12	3.58	6.46
Foxtail millet	65.62	2.63	19.04
Pearl millet	64.66	3.2	8.7

*Each value is mean of three determinations

It was observed that foxtail millet was lightest in colour, followed by pearl millet and finger millet. The L* values which indicates colour were 65.66, 64.66 and 38.12 for foxtail millet, pearl millet and finger millet respectively. From a* values shown in the table it can be noted that finger millet had highest intensity towards red colour 3.58, followed by pearl millet 3.2 and foxtail millet 2.63. The amount of redness was highest in finger millet as compared to all other millets. The b* value was highest in foxtail millet 19.04 followed by pearl millet 8.7 and finger millet 6.46. The b* value denotes the yellowness which was highest in foxtail millet followed by pearl millet and finger millet. Similar results were reported by (Veena *et al.,* 2005) [19].

3.5 Colour analysis of millet flours

The colour analysis of millet flours was compared with that of refined wheat flour and the values are depicted in table 5.

Among all flours refined wheat flour had the highest value fir L* followed by foxtail millet flour, finger millet flour and pearl millet flour. The L* values for refined wheat flour and foxtail millet flour were 88.72 & 81.53 whereas for finger millet flour it was 71.65 and pearl millet showed 73.32. The a* value which indicates intensity were 3.62, 2.08, 0.34 and 0.54 respectively for finger millet flour, foxtail millet flour, pearl millet flour and refined wheat flour. The foxtail millet flour and refined wheat flour had low values for a*.

The b* values which indicates yellowness was reported highest by foxtail millet flour (22.13) followed by refined wheat flour (10.92), pearl millet flour (9.87) and finger millet flour (8.45). Similar results were given by (Gaurav *et al.*, 2021) [2] and (Mercy and Kiruba 2021) [8].

Table 5: Colour values of millet flours

Flours	L*	a*	b*
Finger millet flour	71.65	3.62	8.45
Foxtail millet flour	81.53	2.08	22.13
Pearl millet flour	73.32	0.34	9.87
Refined wheat flour	88.72	0.54	10.92

*Each value is mean of three determinations

3.6 Analysis of proximate composition of raw materials

The proximate composition of millet flours and refined wheat flour showed in table 6. The different parameters such as moisture, crude fat, crude protein, rude fibre and ash were analysed.

Table 6: Proximate composition of raw materials

Nutrient (%)	Finger millet flour	Foxtail millet flour	Pearl millet flour	Refined wheat flour
Moisture	10.55	8.65	10.18	11.27
Crude fat	1.86	4.25	4.5	0.76
Crude protein	7.18	12.29	11.48	10.37
Crude fibre	11.1	10.53	10.38	2.15
Ash	2.01	2.42	1.45	0.5
Carbohydrates	66.64	60.95	61.73	74.12

*Each value is mean of three determinations

The refined wheat flour had highest amount of carbohydrates (74.12) as compared to all millets. The carbohydrates in millets were 66.64, 61.73 and 60.95 % in finger miller, pearl millet and foxtail millet respectively. The values for fat, protein and ash for finger millet were 1.86 %, 7.18% and 2.01 % respectively.

The foxtail millet flour reported highest protein content than all others which was found to be 12.29%. The values for fat and ash were 4.25% and 2.42 % respectively for foxtail millet flour. The pearl millet had higher amount of protein than finger millet and refined wheat flour i.e., 11.48%. The fat content in pearl millet was highest among all millets which was 4.5 %. The crude fibre content of all flours was analysed, and it was found that the finger millet had highest amount of fibre as compared to foxtail millet and pearl millet flour. The values for crude fibre were 11.1%, 10.53% and 10.38% respectively for finger millet, foxtail millet and pearl millet flour.

Similar results were reported by (Maharishi *et al.*, 2021) [7] for pearl millet (Nithyashree 2019) [11] for finger millet and Kehong *et al.*, 2018 [5] for foxtail millet.

From table 18 it can be observed that all millets have had higher amount of ash, crude fibre than refined wheat flour. The amount of protein was found to be highest in foxtail millet and pearl millet had high amount of fibre and ash as compared to refined wheat flour.

3.7 Mineral composition of raw materials

Table 7: Mineral composition of raw materials

Flour	Calcium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	Phosphorus (mg/100 g)
Finger millet flour	333.57	2.44	0.84	171.46
Foxtail millet flour	31.73	2.18	0.85	181.36
Pearl millet flour	45	7.62	4.18	245.33
Refined wheat flour	20.6	1.73	0.72	75.43

*Each value is mean of three determinations

The finger millet had high amount of calcium among all the flours. Calcium content in finger millet was 333.57 mg/100 g. The phosphorous was 171.46 mg/100 g. iron and zinc in finger millet was reported to be 2.44 and 0.84 mg/100 g respectively. Pearl millet had high amount of zinc and iron as compared to all other millets. The amount of Fe and Zn in pearl millet were 7.68mg/100 g and 4.18 mg/100 g. Foxtail millet had 31.73 mg/100 g and 181.36 mg/10g of Ca and P respectively. Whereas the iron and zinc were found to be 2.18 mg/100 g and 0.85mg/100 g. From table 19 it can be observed that millet contain high amount of micronutrient as compared to wheat. The results were in accordance with (Nakarani *et al.*, 2021) [10], (Nithyashree 2019) [11], (Shonisani *et al.*, 2019) [16] & (Kehong *et al.*, 2018) [5].

4. Conclusion
From the present investigation it can be concluded that millets have good functional and nutritional properties. The finger millet had high amount of calcium among all the flours, millet contain high amount of micronutrient as compared to wheat. The foxtail millet flour reported highest protein content than all others which was found to be 12.29%. The fat content in pearl millet was highest among all millets which was 4.5 %. The crude fibre content of all flours was analysed, and it was found that the finger millet had highest amount of fibre as compared to foxtail millet and pearl millet flour.

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