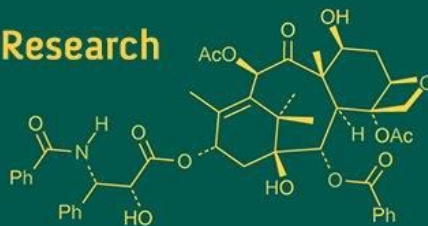


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Assessment on physico-functional properties of millet based edible cutleries

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Abstract

Millets are small seeded grains, belonging to family Poaceae, considered as crop of food security because of the sustainability in adverse agro climatic conditions. Millets are nutritionally rich and superior to cereals. This study was undertaken to evaluate millet based edible cutleries for physical and functional properties. Physical properties of raw flours indicated that control (refined wheat flour) is significantly denser (0.68) than Little Millet Flour (LMF, 0.92). Color analysis results showed that White Finger millet flour (WFMF) was lighter and Foxtail millet flour (FMF) was the most yellow color. Texture analysis of different cutleries revealed that, Hardness of control sample exhibited higher value than millet based edible cutleries. Regarding fractur ability, White Finger millet edible cutlery (WFEC) demonstrated higher values of 40.22N and least by little millet edible cutlery (LMEC, 13.54N). Adhesiveness was negative for all types of cutleries indicating lack of stickiness. Highest value of springiness exhibited by WFEC at 0.665N followed by control (0.173N), LMEC (0.054N), and FMEC (0.022), cohesiveness was highest in WFEC (0.665N) while WFEC had a negative value (-0.024N), Gumminess was highest in control (-1.65N) than WFEC (-0.56N), Chewiness was highest in control (5.59N) and WFEC showed lower chewiness (2.59N). FMEC showed higher water absorption capacity (2.93) and LMEC showed least water absorption capacity. Oil absorption capacity (OAC) recorded maximum for Foxtail millet edible cutlery (FMEC, 0.93%) and minimum for WFEC (0.05%). Highest solubility index was observed in LMEC (27.97%) and least soluble in control product (21.34%). Bulk density of control was highest 1.90g/cm³ and least was in LMEC (0.71g/cm³). Retention capacity in liquid phase is more in control (15min) and least in LMEC (9min). WFEC had higher water holding capacity than other variations, while cold water at 5° C is least absorbed through different water temperature conditions for the duration of 30 min. Millet based edible cutlery is a plant-based product with good physico functional characters. Overall, the study suggested that, millet based edible cutleries offers a nutritionally superior alternative to plastic cups and bowls. Hence cutleries can be used as an utensil to serve or taken as a meal.

Keywords: Millet, edible cutlery, water and oil absorption capacity, solubility index, textural properties

Introduction

Millets are important cereals which play a significant role in the food and nutrition security of developing countries in the semi-arid tropics of Asia and Africa, especially in India and Nigeria. They are grown on soils which typically are too poor to support any other crop. They have a higher tolerance for drought, low nutrient application, and fluctuations in temperature than other cereal crops and also unique due to their short growing season. Millets are all-season crops cultivated round the year and produces multiple securities (food, fodder, health, nutrition, livelihood and ecological) making them the crops of agricultural security available at affordable prices (FAO 2021) [3]. Millets are a major source of human food and their production has been steadily increasing in the last decades to meet the dietary requirements of the increasing world population. Important millet crops grown in India are Sorghum (Great millet), Bajra (Pearl millet), Ragi (Finger millet) and small millets viz., Korra (Foxtail millet), little millet, Kodo millet, Proso millet and Barnyard millet. These are often referred to as coarse cereals, but realizing the nutrient richness of the grains they are now considered as nutria cereals.

The study of physical parameters of the kernels, grains and seeds is essential because which are necessary for the design of equipment to handle, transport, process and storage. Physical appearance of the grain and its product were also an important characteristic which determines the consumer acceptability. Grain density is one of the important parameters which determines the dehulling and milling performance.

White finger millet [*Eleusine coracana* (L.)] is a cereal grass grown mostly for its grain. Finger millet is a robust, tufted, tillering annual grass, up to 170 cm high. The inflorescence is a panicle with 4-19 finger-like spikes that resembles a fist when mature, hence the name white finger millet. The spikes bear up to 70 alternate spikelets, carrying 4 to 7 small seeds. The seed per carp is independent from the kernel and can be easily removed from the seed coat. White finger millet is a staple food in many African and South Asian countries. It is also considered as a helpful famine crop as it is easily stored for lean years. The grain is readily digestible, highly nutritious and versatile, and can be cooked like rice, ground to make porridge or used to make cakes (Rao *et al.*, 2017) ^[5].

Foxtail millet [*Setaria italica* (L.)] is regarded as a native of China; it is one of the world's oldest cultivated crops. Foxtail millet ranks second in the total world production of millets and continues to have an important place in the world agriculture providing approximately six million tons of food to millions of people, mainly on poor or marginal soils in southern Europe and in temperate, subtropical and tropical Asia. It will grow in altitudes from sea level to 2000m. Foxtail millet is fairly tolerant of drought; it can escape some droughts because of early maturity. Due to its quick growth, it can be grown as a short-term catch crop. It is adapted to a wide range of elevations, soils and temperatures. Its grain is used for human consumption and as feed for poultry and cage birds (Rao *et al.*, 2017) ^[5].

Little millet (*Panicum sumatrense*) was domesticated in India. It grown throughout India to a limited extent up to altitudes of 2100 m, but is of little importance elsewhere. The seeds of little millet are smaller than those of common millet. This species of cereal is similar in habit to the proso millet except that it is smaller. It is an annual herbaceous plant, which grows straight or with folded blades to a height of 30 cm to 1 m. The leaves are linear, sometimes with hairy lamina and membranous hairy ligules. The panicles are from 4 to 15 cm in length with 2 to 3.5 mm long. The grain is round and smooth, 1.8 to 1.9 mm long. It can withstand both drought and water logging. It can be cultivated up to 2000 m above sea level. Little millet is another reliable catch crop in view of its earliness and resistance to adverse agro-climatic conditions. Catch crop in view of its earliness and resistance to adverse agro-climatic conditions (Rao *et al.*, 2017) ^[5].

Every year, India generates 15 Mt of plastic waste, of which only one-quarter is recycled. Every year, 350 million tonnes of plastic are manufactured throughout the world. After steel and concrete, plastic was the third most prevalent human-made substance in 2017. If current manufacturing and waste management trends continue, nearly 12,000 Mt of plastic trash will end up in landfills or the natural environment by 2050. There is a need for plastic replacement as plastic is great threat to mankind and the nature in the form of cancer, soil erosion, ocean toxicity and air pollution. So, there is need to replace plastic cutlery with better alternative like edible cutlery. Moreover, it can be cost-effective when the

production of raw materials increases, helping the ultimate product to meet up the customer's economic expectations Roy *et al.* (2022).

It is pertinent to mention that not much work has been done on the preparation of edible containers using the millet crops and other ingredients. In the proposed research paper, edible containers were made out of little millets. These edible containers could also be called as ready to eat because these do not need any further preparation and had a quality like biodegradability, eco-friendliness and edibility. Although edible cutlery that is available currently is durable to consume any type of food like hot soups to frozen desert can be served as it does not tear down easily. While edible cutlery have gained popularity, it is essential to address their limitations, such as their relatively short lifespan before becoming soggy.

Materials and Methods

Procurement of Raw Materials

White finger millet, little millet, foxtail millet, wheat flour, rice flour, sorghum flour, sugar, margarine, milk powder, salt, vanilla essence, guar gum and packaging materials such as Metalized Polyester Polyethylene (MPP) and aluminum silver foil cover were procured from local market of Bangalore.

Processing of raw materials

The procured millets such as white finger millet, little millet, foxtail millet grains were subjected to manual cleaning, washing in potable cold water to remove dust and other foreign materials. Cleaned and dried grains were ground in a commercial food processing pulverizer and passed through BS 40 mesh sieve to get a fine and uniform flour and stored in the cool and dry atmosphere for future experiments.

Formulation and Preparation of Millet based edible Cutleries

The control edible cutlery was prepared by following a method mentioned according to Rajendran *et al* (2020) with slight modifications. The ingredients like, refined wheat flour, rice flour, wheat flour, sugar, margarine, corn starch, xanthan gum, milk powder, sorghum flour, salt and vanilla essence were mixed together by adding 10ml of water. All the ingredients were mixed well and kneaded to form soft dough. The dough was allowed to rest for 10minute. Later the soft dough is spread to make a sheet of thickness 2.5mm. The prepared soft dough sheet was cut into round shape using cutlery cutter followed by moulding. The prepared soft dough moulds were baked in baking oven at temperature of 140 °C for 45 minutes. After baking the cutlery was allowed to cool naturally. The cooled cutlery was packed airtight and preserved for further study.

Table 1: Formulation of millet based edible cutleries

Ingredients (g)	Control	WFEC	LMEC	FMEC
Flour	40	40	40	40
Rice Flour	1	1	1	1
Wheat Flour	20	20	20	20
Sorghum	15	15	15	15
Other ingredients (Fat, gum, starch, sugar, Salt, essence)	24	24	24	24
Total	100	100	100	100

Physico-functional characteristics

Physical parameters such as the products and raw materials (little millet based edible cutleries) like colour and bulk density were studied using standard procedures.

Colour measurement (Mashau *et al.*, 2022) [8]

The colour of the flour was measured using a minolta chroma meter (CR- 200b) with the parameters L^* (lightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness) values were recorded.

Functional Properties of flour and cutleries

Water holding capacity (room temperature at 26 °C, cold temperature at 5 °C and hot temperature at 80 °C), oil binding capacity, bulk density (Tapped method) and solubility index was analyzed using standard procedures.

Oil absorption capacity

The oil absorption capacity of flour was measured by the centrifugation method as described by Lin *et al.* One gram sample was mixed with 10ml of oil in pre weighed centrifuge tubes. The contents were stirred for 1 min to get the complete dispersion of the sample in the oil. After holding for 30 minutes, the tubes were centrifuged for 25 minutes at 3000rpm. The separated oil then removed with a pipette and the tubes were inverted for 25 minute to drain out the oil prior to reweighing. The oil absorption capacity was expressed as ml of oil absorbed per gram of the sample.

$$\text{Oil absorption capacity (g)} = \frac{\text{Weight of oil absorbed (g)}}{\text{Weight of the sample (g)}}$$

Water absorption capacity

Water absorption capacity was determined according to the method reported by Elmonei *et al.* (2010). One gram of each flour sample was weighed into a pre weighed centrifuge tube and 10 ml of distilled water was added. Sample were vortexed for one min and allowed to stand for 30 min at 25° C before being centrifuged at 4000xg for 25 minutes. Excess water was decanted by inverting the tubes over absorbent paper and samples were allowed to drain.

$$\text{water absorption Index (g/g)} = \frac{\text{Weight of water uptake in hydrated residue (g)}}{\text{Volume of the sample (g)}}$$

Tapped bulk density (g/ml)

Tapped bulk density was measured by the method of tapped bulk density by Wang and Kinsella (1976). Ten grams of the above -mentioned flours were placed separately in a 25 ml graduated cylinder and pressed by gentle tapping of the cylinder on a bench top for ten times, until no visible decrease in volume was noticed from a height of 5 to 8 cm. The final volume of the individual flour was measured and expressed as gram per cubic centimeter (cm³).

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of sample at recored volume}}{\text{Volume of the sample (ml)}}$$

Water solubility Index (SI)

Two and half grams of each sample were suspended in 30 ml of distilled water (30 °C) in a 50 ml pre-weighed centrifuge tube by vortexing. The tubes were placed in a water bath at 30 °C and stirred intermittently for 30 min. The suspension was centrifuged for 10min at 3000 × g. The supernatant was decanted into a pre-weighed 50 ml beaker.

The supernatant was dried at 95°C and the weight of dried solids was used to calculate the SI.

$$\text{Water solubility index(\%)} = \frac{\text{Weight of dissolved solids in supernatant}}{\text{Weight of the flour}}$$

Textural Properties of developed millet based edible cutleries

Textural properties of edible cutleries (2.5x2.5x2.5 mm) from the middle section of edible cutlery were determined using a texture analyzer (Stable Micro System) with 75 mm diameter cylindrical compressed probe at test speed of 1.0./s. Parameters used: pre-test speed 2.00mm/s, post -test speed 2.0 mm/s and the load cell used was 500 Kg. The textural properties such as hardness, cohesiveness, adhesiveness, springiness, resilience, gumminess and chewiness were measured (Tasnim *et al.*, 2020) [11].

Statistical analysis

The data was tabulated and analyzed by keeping in view of the objectives and parameters of the study. All the analyses were performed in triplicate and the data was analyzed using EXCEL.

Results and Discussion

Standardization of edible cutleries

Mishra *et al* (2023) [9] developed a vegan etable cone using rice flour, bajra and whole wheat flour with nori sheets (Table-2). They incorporated rice flour (20%), bajra (5%). Whole wheat flour (5%). Refined flour (30%), multi grains (20%), corn starch (10%) and nori sheet (10%) were used completely replace refined wheat flour edible cutleries while making a cereal-based cone (Table1).

Physico-functional characteristics of developed millet based edible cutlery

Physical parameters such as the products and raw materials (little millet based edible cutleries) like colour and bulk density were studied using standard procedures (Table 3).

Table 2: Physical characteristics of samples

Treatments	Physical parameters
	Bulk Density
Control	0.68± 0.08
White finger millet flour	1.34 ± 0.04
Little millet flour	0.92±0.03
Foxtail millet flour	1.19 ± 0.05
F-value	*
SEm±	0.03
CD at 5%	0.09

Values expressed as Mean ± SD

Significantly ($P < 0.05$)

The Table 2 shows the physical parameters of different flour treatments. The density values for each treatment are as follows: The density of control that is refined wheat flour had 0.68 ± 0.08 followed by LMF, FMF and WRF with the density of 0.92 ± 0.03, 1.19 ± 0.05, 1.34 ± 0.04 respectively. The results indicate that flour control is significantly denser than LMF and FMF. WRF being the least dense among other flours. Statistically significant difference at 5% level was observed for density of different flours.

Color is an important parameter for consumer acceptance of a food product. The results of the color properties of

different millet flours and different millet based edible cutleries were analysed using minolta chroma meter (CR-200b) are presented in Table 4.

The Table 3 depicts the color analysis of different flours and millet-based edible cutleries. The values of L^* , a^* , and b^* are used to describe the color of a sample. L^* (lightness), a^* (redness/greenness) and b^* (yellowness/blueness). The higher the L^* value, the lighter the sample, while the higher the a^* and b^* values, the more red and yellow the sample. The results indicate that the millet flours have different color values with white finger millet flour being the lightest (54.37) and foxtail millet flour (9.8) being the most yellow.

Table 3: Color analysis of flours and cutleries

Flours	L^*	a^*	b^*
Millet flours			
White finger millet flour	54.37±1.25	25.06±0.95	6.13±0.35
Little millet flour	51.07±1.10	24.50±0.56	4.87±0.30
Foxtail millet flour	42.80±0.44	29.13±2.00	9.80±0.30
F-value	*	*	*
SEm ±	0.57	0.76	0.18
CD at 5%	2.03	2.68	0.65
Millet based edible cutleries			
Control	22.97±0.68	23.10±0.85	15.06±0.80
WFEC	29.90±0.20	25.90±0.10	17.00±0.10
LMEC	31.10±1.05	22.60±0.56	18.13±1.85
FMEC	30.93±1.27	30.03±1.50	21.53±1.30
F-value	*	*	*
SEm ±	0.50	0.54	0.69
CD at 5%	1.67	1.79	2.30

Note: Values are expressed as mean ±SD of triplicates determinations, L^* : Lightness, a^* : Redness, b^* : yellowness.

Control-Refined wheat flour edible cutleries, WFEC-White finger millet edible cutleries, LMEC-Little millet edible cutleries, FMEC-Foxtail millet edible cutleries

According to above Table 3, In terms of millet-based edible cutlery, WFEC exhibited higher lightness ($L^* = 29.9$) values compared to sample Control. LMEC showed the highest lightness ($L^* = 31.1$), lower red-green ($a^* = 22.6$), and moderate yellow-blue ($b^* = 18.13$) values among the millet-based cutlery samples. FMEC had L^* , a^* , and b^* values of 30.93, 30.03, and 21.53 respectively.

Present study supported by Sindhu *et al.*, (2023) [10] developed the bio-degradable spoons with natural colors. The color properties were studied using Hunter lab colorimeter. Among all the samples the chroma is higher for refined wheat flour sample (26.58) and the lowest chroma value was observed for edible spoons of beetroot extract (17.29). The highest hue angle was recorded for spinach spoons (84.08) and the lowest hue for beetroot spoons (50.75) which was higher than our present findings.

The study by (Majeed *et al.*, 2017) [6] found that the darker color of edible tablespoon was due to natural grey color of oyster mushroom as well as due to caramelization of sugar and millard reaction which promote the starch and protein degradation during the baking process at high temperature.

Texture analysis of different cutleries

Texture is one of the major quality attributes of foods and is determined from the response of tactile senses to the food product. The mean values for textural properties of developed millet based edible cutleries determined using stable micro systems texture analyzer and probe used was 75mm compression plate which is shown in Table 4. Textural characteristics namely hardness, fracturability, adhesiveness, springiness, cohesiveness, chewiness, gumminess and resilience for refined wheat flour edible cutleries, WREC, LMEC, and FMEC edible cutleries showed statistically significant results for hardness, fracturability, adhesiveness, chewiness and gumminess, springiness, cohesiveness and resilience.

Hardness refers to the force required to compress a food between the molars (Mridula *et al.*, 2009) [7]. In terms of hardness, the refined wheat flour edible cutleries exhibited a value of 28.20 N, while WREC had a slightly higher value of 31.84 N. LMEC and FMEC showed significantly lower hardness values of 16.24 N and 12.65 N respectively. Regarding fracturability, WREC cutlery demonstrated a higher value of 40.22 N followed by control (35.96 N), FMEC (25.49 N) and LMEC (13.54 N). Adhesiveness was negative for all types of cutleries, indicating a lack of stickiness. The adhesiveness values were relatively consistent across all flours with control having a value of (-0.038 N) and least stickiness observed in FMEC (-0.0667N). In terms of springiness, WREC exhibited the highest value at 0.665 N, indicating a higher ability to regain its original shape after deformation followed by control (0.173 N), FMEC (0.022 N) and LMEC (0.054 N). Cohesiveness was highest in WREC (0.665 N) indicating that it had a strong internal structure. While FMEC had a slightly negative value of (-0.024 N) suggesting a tendency to break into smaller pieces. Gumminess, which measures the energy required to disintegrate a semisolid food into a state ready for swallowing, was highest in control (-1.65 N) than WREC, LMEC and FMEC had gumminess values of -0.56 N, 4.593 N and 0.554 N respectively.

Chewiness, representing the energy needed to masticate a solid food to a state suitable for swallowing, was highest in control at 5.59 N. WREC, LMEC, and FMEC showed lower chewiness values of 2.62 N, 4.1 N, and 2.59 N. Resilience, indicating the ability of a material to absorb energy when deformed elastically and release that energy upon unloading, was highest in WREC (0.715 N) and least in FMEC (0.023 N) respectively.

When Sindhu *et al.* (2023) [10] conducted study of the textural properties of the edible spoons using texture analyser. They recorded the hardness of edible spoons by using the Brookfield Texture analyzer. Hardness for refined wheat flour edible cutlery sample was 7.95 N, T₁ (Beetroot) was 15.15 N, T₂ (Spinach) was 4.76N and T₃ (jamun) was 15.40N. T₂ Spinach sample exhibited more resistance to compression compared to C, T₁, and T₃ sample. Which is lower value than present study. Present study had Hardness of Control (28.20), WREC (31.84), LMEC (16.24) and FMEC (12.65).

Table 4: Texture profile of millet based edible cutleries

Edible cutleries	Hardness (N)	Fracturability (N)	Adhesiveness (N)	Springiness (N)	Cohesiveness (N)	Gumminess (N)	Chewiness (N)	Resilience (N)
Control	28.20±0.81	35.96±1.56	-0.03±0.02	0.17±0.06	0.16±0.00	-0.56±0.43	5.59±0.41	0.35±0.47
WFEC	31.84±2.69	40.22±3.29	-0.07±0.00	0.044±0.01	0.66±0.05	-1.65±0.55	2.62±0.45	0.71±0.23
LMEC	16.24±3.00	13.54±0.48	-0.05±0.00	0.05±0.01	0.03±0.01	4.59±0.49	4.10±0.38	0.03±0.01
FMEC	12.65±0.19	25.49±1.72	-0.06±0.00	0.02±0.01	-0.02±0.01	0.55±0.33	2.59±0.17	0.02±0.01
F-value	*	*	*	*	*	*	*	*
S.Em±	1.18	1.17	0.00	0.02	0.01	0.26	0.85	0.04
CD at 5%	3.93	3.88	0.00	0.06	0.05	0.88	1.34	0.07

Control - Refined wheat flour edible cutleries, WFEC - White finger millet edible cutleries, LMEC - Little millet edible cutleries, FMEC - Foxtail millet edible cutleries, Values expressed as Mean ±SD

Functional characteristics of refined wheat flour, white finger millet flour, little millet flour and foxtail millet flour edible cutleries

Water absorption capacity

The Table 5 represents data on functional properties of developed millet based edible cutleries. Foxtail millet based edible cutleries (FMEC) showed higher water absorption capacity of (2.93±0.05) and little millet edible cutleries showed least water absorption capacity of (2.60±0.26) than other cutleries. Higher the water absorption capacity denotes high amount of fiber and protein content in the flours.

Table 5: Functional properties of millet based edible cutleries

Edible cutleries	WAC (%)	OAC (%)	Solubility index (%)	Bulk density(g/ml)
Control	2.73±0.25	0.77±0.25	21.34±0.44	1.90 ±0.01
WFEC	2.76±0.25	0.50±0.10	22.22±0.64	0.82±0.03
LMEC	2.60±0.26	0.83±0.25	27.97±0.81	0.71±0.01
FMEC	2.93±0.05	0.93±0.15	23.61±0.06	0.94±0.01
F-value	*	*	*	*
SEm ±	0.12	0.11	0.26	0.01
CD at 5%	0.71	0.70	0.87	0.03

Control- Refined wheat flour edible cutleries, WFEC- White finger millet edible cutleries, LMEC- Little millet edible cutleries and FMEC- Foxtail millet edible cutleries.

WAC- water absorption capacity, OAC- oil absorption capacity
Values expressed as Mean ±SD *Significant ($P<0.05$)

Water absorption capacity is ability of a product to absorb water within its structural boundaries, Shrestha and Srivastava (2017). When study recorded water absorption capacity and oil absorption of (5.7% and 2.5%) for finger millet flour which was higher than present findings (2.93% and 0.93%).

Hazra and Sontakke (2023) ^[4] conducted comparative study of three different edible spoon sample S₀, S₂, S₃, S₄ at different time intervals of time i.e., 5min, 10min, 15min, 20min, 25min and 30min for water absorption capacity of spoons. Higher values for water absorption capacity were noted for sample S₄ (4g of ginseng powder and 15.5g *ragi* flour). Waterabsorption capacity of S₄ sample spoon was comparatively more than other two spoon samples that is S₀ and S₃ which is similar to the present findings (FMEC: 2.93%).

Oil absorption capacity

Oil Binding Capacity values for three blends ranged from 135.16 ± 2.31, 102.76 ± 1.078 and 101.03 ± 0.896 for blend A, blend B and blend C respectively. The results conclude that blend A shows higher values for water holding capacity and has oil binding capacity.

Oil absorption capacity attributed to the ability of food material to absorb oil. It is a manifestation of the rate at which the protein binds to fat in food constituents. OAC of edible cutleries ranged from 0.5 to 0.93% in which maximum values were recorded for foxtail millet based edible cutleries (0.93%) and minimum for white finger millet edible cutlery (0.5g/g) followed by little millet edible cutlery (0.83%) and refined wheat flour edible cutlery (0.77%).

Oil absorption index was important as oil act as a flavor retainer and increase in mouth feel of foods, palatability improvement and extension of shelf life particularly in bakery products where fat absorption is desired (Aremu *et al.*, 2007) ^[2].

Solubility index

Solubility index of different flour edible cutleries has been reported to range from 21.34 to 27.97 per cent respectively. Highest solubility index was observed in LMEC (27.97%) and least soluble in control in (21.34%).

Bulk density

Bulk density of different flours is used to determine the expansion and to know the porosity of flour. It depends on the particle size and initial moisture content of flour. Bulk density of refined wheat flour edible cutleries, white finger millet, little millet and foxtail millet flour based edible cutlery varied from 0.71 to 1.90 g/cm³. The bulk density of the refined wheat flour edible cutleries was highest 1.90 g/cm³ followed by foxtail millet flour, white finger millet flour and little millet flour flours were 0.94 g/cm³, 0.82 g/cm³ and 0.71g/cm³ respectively. Statistically significant difference was observed between the flours.

Table 6: Solid, semi-solid and liquid retention capacity of millet based edible cutleries

Phases (minutes)	Control	WFEC	LMEC	FMEC
Solid	NA	NA	NA	NA
Semi solid	30	25	24	28
Liquid	15	10	9	12

Control- Refined wheat flour edible cutleries, WFEC- White finger millet edible cutleries, LMEC- Little millet edible cutleries and FMEC- Foxtail millet edible cutleries. NA: Not applicable.

Retention capacity is the capability of things to hold or retain liquid. Table 6 provides information about the durability of millet-based edible cutleries under different phases and time intervals. In the solid phase edible cutlery retention capacity is not applicable (NA) it will stay for a longer period compared to semi-solid phase where these cutleries can maintained their integrity for up to 25 minutes

and in the liquid phase stays up to 15, 10, 09, 12 min for Control, WFEC, LMEC and FMEC.

Table 7 represents the percentages of the water absorbed by millet edible cutleries for every 5 minutes for a total of 30 minutes at three different temperature conditions. Edible cutlery which is absorbed by the hot water (80°C) samples have the overall highest amount of water absorbed at different water temperature conditions for the duration of 30 mins. White finger millet edible cutleries had higher water holding capacity than other variations. *i.e.*, 74.20, 103.23, 126.68, 151.81, 184.19 for 10 to 30 min of time interval respectively. While, cold water at 5°C which is least water absorbed through the different water temperature conditions for the duration of 30 mins.

The findings of the present study are similar to the observation reported by Rajendran *et al.* (2020) for edible spoon made of 50.12 per cent wheat flour, 26.18 per cent barnyard and 0 per cent of pearl millet flour with water absorption of 49.76 per cent, 35.93 per cent and 41.09 per cent for 10°C, 29°C, 50°C respectively. The least water absorbed means that the edible spoon can be used for a longer period of time before it disintegrates or loses its form and functionality as a spoon. These qualities portray the flour's capacity to retain water amid the blending procedure and its capacity to discharge that water amid the preparing procedure.

Table 7: Water holding capacity of millet based edible cutleries at different interval of time and temperature

Control			
Time (min)	Normal (26°C) (%)	Cold (5°C) (%)	Hot (80°C) (%)
5	29.12	17.11	39.17
10	49.30	34.81	77.20
15	70.13	45.17	113.23
20	86.33	54.22	129.68
25	102.19	67.17	156.31
30	119.93	74.12	188.29
White finger millet edible cutleries			
5	28.42	15.11	37.07
10	46.30	30.86	74.20
15	68.13	43.37	103.23
20	85.32	51.72	126.68
25	100.18	65.27	151.81
30	117.83	71.01	184.19
Little millet edible cutleries			
5	31.12	19.81	43.4
10	52.34	37.8	79.40
15	73.23	48.27	121.2
20	89.02	58.12	134.48
25	107.39	69.57	159.11
30	122.73	76.2	190.03
Foxtail millet edible cutleries			
5	25.12	13.71	34.17
10	42.36	26.81	71.21
15	64.43	41.12	100.13
20	82.3	48.12	120.68
25	97.28	62.37	147.81
30	112.82	68.11	180.39

Conclusion

Millet is considered as super food. Bulk density of refined wheat flour was highest than millet flour. Texture profile analysis of edible cutleries incorporated with millet flours showed a significant difference in all the textural parameters. White Ragi Edible Cutleries were harder than

other edible cutleries. Retention capacity in the solid phase is high compare to liquid phase of edible cutlery. Foxtail millet based edible cutlery recorded maximum oil binding capacity and minimum found in white finger millet edible cutlery. Hence Plant-based millet edible cutlery can be used to serve meals than plastic containers.

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