ECOFRIENDLY MULTIGRAIN VEGETABLE BASED EDIBLE CUTLERY- SUSTAINABLE ALTERNATIVE TO PLASTIC CUTLERY

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INTRODUCTION

1.1 Need of replacement of plastic cutlery

Globally, the two main concepts of modernization and economic growth have been focused and gaining importance in the recent days. Wide range of technologies have created the life simpler, convenient and easier with the raised the economic growth but posed several adverse effects on the environment. Plastic cutlery is one of the highly flexible utilitarian technologies turned out as part of day-to-day life in serving food. All throughout the world, efforts are being made to eradicate plastic. It was estimated that 280 million tonnes of plastic were manufactured worldwide in the year 2012 (Banerjee, 2014). The researchers indicated that by the year 2050 the percentage of plastics weight would be higher than the fishes in the rivers, oceans and seas (Boro, 2020).

Plastics are amorphous by nature and lack a specific melting temperature, which can cause food contamination. The first recorded use of the word "cutlery" was in the 14^{th} century and by the 17^{th} century, cutlery had become an essential part of the dining experience (Tomkin, 2023). Therefore, the use of edible cutlery is essential in the transition away from plastic cutlery (Krishnapriya and Jadeesh**,** 2021).

1.2. Ecofriendly edible cutlery

Edible cutlery is basically plant-based product using flours as the major ingredients which may be used for serving. The major advantage associated is that these can be consumed directly after the purpose as they are ‘ready to eat’ without any further preparation. They are made from the natural plant ingredients without any preservatives and hence considered as eco-friendly, biodegradable and organic products which can be the best alternative to plastic cutlery

(Krishnapriya and Jadeesh, 2021). Bakey's is the first Indian commercial edible cutlery firm established in 2010. Narayana Peesapaty, Hyderabad based scientist impressed during his in-flight meal by observing certain people scooping rice with a khakra instead of plastic spoon which lead to the first ever edible spoon with flour (Roy and Morya, 2022; Natarajan et al., 2019).

1.3. Importance of ingredients

Edible cutlery is made of flours and is a natural product with no preservatives, additives, emulsifiers or fats and are just flours kneaded with water. It can be eaten after using it or can be left to decompose and does not dominate the taste of the food being consumed. Since it is manufactured using flour of food grains it is low in cost and also nutritious (Narayana Peesapaty, 2017). Multigrains that are high in fibre, vitamins, minerals, and antioxidants, such as millet, quinoa, oats, and whole wheat, make the cutlery not only practical but also nourishing. Addition of pulses, nuts and seeds in making composite flour still increases the cutlery's protein and fibre content, multigrains which can promote digestive health and improve satiety. Multigrains help provide a chewable yet firm texture that makes cutlery sturdy enough to handle food or liquids without breaking down easily. The market for eco-friendly, healthful products are growing faster among consumers as they are looking for sustainable and nourishing options, where multigrain edible cutlery found to be one such alternative. Promoting the use of multigrains grains helps the local farmers and lessens reliance on monoculture by encouraging the production of a variety of crops (Subbuvel et al., 2024).

Wheat flour especially whole wheat flour is a good source of essential nutrients and serves as the base ingredient as it imparts optimal textural characters in edible cutlery preparation. Along with fiber which supports a healthy digestive system and it also contains iron and B vitamins among other vitamins and minerals. Whole wheat flour has the potential to improve heart health and control blood sugar levels. In addition to giving the dough structure and texture, it may be moulded into a variety of shapes when combined with water and other ingredients. The dough can be baked or dried to produce strong, edible utensils that provide a sustainable substitute for conventional plastic cutlery (Boita et al., 2016).

Moringa leaves have numerous health advantages and acts as a nutritional powerhouse. Along with minerals like calcium and potassium, they are full of vitamins, including

vitamins A, C and E. Rich in antioxidants, moringa can help to shield cells from the harm that free radicals do. The leaves may help decrease cholesterol and blood sugar levels and also contain anti-inflammatory chemicals. Moringa leaves can be a beneficial addition to diet to enhance general health. Because they contribute nutritional value and they have health benefits, moringa leaves can be used in edible herbal cutlery. The combination used to make edible cutlery can have its nutritional value increased by adding moringa leaf powder. Malnutrition has been treated with moringa tree leaves, especially in small children and nursing mothers. A single rounded tablespoon (8 g) of leaf powder provides nearly all of the vitamins, 40% of the calcium, 23% of the iron, and 14% of the protein that the body needs (Mishra et al., 2012). Moringa's antioxidant and anti-inflammatory characteristics may provide extra health benefits, making the cutlery both environmentally friendly and nutritious.

Beetroot is a root vegetable that contains rich source of potent nutrients and possess many health benefits. Beet root (Beta vulgaris) is an excellent source of calcium, iron, fiber, folic acid. Beetroot are rich in valuable, active compounds such as carotenoids (Dias et al., 2009), glycine, betalaine, saponins, betacyanines, folates, betanin, polyphenols and flavonoids (Vali. et al., 2007). Therefore, beetroot ingestion can be considered a factor in cancer prevention. They have antimicrobial and antiviral effects and also can inhibit the cell proliferation of human tumour cells. Beetroot is a rich source of both betaine and nitrate. Betaine is a trimethyl derivative of amino acid glycine. Betaine supplementation promotes muscular endurance, strength and power (Hoffman and Ratamess, 2009).

Milk powder plays a vital role across various industries and applications due to its versatility, nutritional value, and long shelf life. Bioactive peptides can be released during digestion by milk powder, milk protein isolates, or milk protein concentrates. Antioxidants, peptides, proteins, conjugated acids, linoleic acid, vitamins, oligosaccharides, and organic calcium are among the bioactive components that can be obtained from milk and dairy products. These elements improve haemodynamics, probiotic growth, gastrointestinal tract modulation, and immunological regulation, among other health benefits. Numerous phytochemicals and animal-based bioactive compounds have antimicrobial, metabolism-regulating, anti-obesity, satiety-regulating, hypotensive, and hypocholesterolemic properties (Gill et al., 2024).

2. MATERIALS AND METHODS

2.1 Locale of the study

The experiment of formulation and standardization of vegetable based edible cutlery in the form of cups viz., beetroot and moringa leaves edible cups was carried out in the Food Science laboratory, Department of Home Science, Sri Padmavati Mahila Visvavidyalayam University, Tirupati, Andhra Pradesh. (India). The nutrient composition analysis was done at Food Chemistry lab and microbial quality evaluation in Food microbiology laboratory of the Department.

2.2 Procurement of raw materials

The grains used for the preparation of multigrain flour such as wheat, ragi, bajra, soybean, bengal gram and rajmah were obtained from local supermarket of Tirupati, Andhra Pradesh. The other ingredients like sugar, milk powder, salt and spices were also purchased from the same supermarket. Whereas, the beetroot and moringa leaves were brought in fresh condition from the local vegetable market.

2.3 Formulation of edible cups

The main concern of this research was to replace the harmful plastic cutlery with the development of edible cutlery as a sustainable approach and also to impart nutritional and health benefits with the incorporation of functional natural plant ingredients such as multigrain, beetroot and moringa leaves extracts. Beetroot and moringa leaves edible cups were the two varieties selected in the current research and their compositions adopted for standardization were illustrated below.

2.3.1 Beetroot edible cups

Beetroot was washed thoroughly to remove surface dust and dirt, peeled, cut into small pieces and blend finely in blender with required quantity of water. Then extracted pulp was strained using muslin cloth which was utilized in the formulation of beetroot edible cups instead of water. The composition of the beetroot edible cups was represented in table 1.

Table- 1: Composition of multigrain beetroot edible cups

S.No.	Ingredients	Quantity
1.	Multigrain flour(g)	65

2.	Beetroot extract(ml)	20
3.	Sugar powder(g)	10
4.	Milk powder(g)	5

2.3.2 Moringa edible cups

The moringa leaves extract was made by separating the leaves from the bunch, washed, subjected to blanching, blending and extracting with muslin cloth. Similar to that of beetroot extract, moringa leaves extract was used in the preparation of dough instead of water in the formulation of moringa edible cups. The composition of the moringa edible cups was denoted in table 2.

Table-2 : Composition of multigrain moringa edible cups

S.No.	Ingredients	Quantity
1.	Multigrain flour(g)	73
2.	Moringa leaves extract(ml)	25
3.	Spice mix(g)	1
4.	Salt(g)	1

2.4 Edible cups making

The method was adopted from the procedure provided by Rajendran et al. (2020) with slight modifications. The ingredients were weighed accurately based on the formulations and the dough was made by mixing the ingredients by kneading them together. Care was taken in dough making by adding the vegetable extracts carefully to yield homogenous mass without formation of lumps. The dough preparation was taken around 10 to 15 minutes. A rolling pin was used to assist to roll out into a 2 mm sheet. After that, a knife was used to carve out the edible cutlery using oven-safe cutlery as a stencil. Using a specially made cutlery mould, the sheeted plane dough was carved into the desired form.

Following the flattening of the dough cutlery, a little amount of vegetable oil was applied to the oven-safe cutlery, and the flattened dough cutlery was placed on top of them to maximise their functionality. To guarantee optimum sturdiness and uniform overall frying, small holes were prickled onto them. The cup moulds were put on the baking pan and baked for 25 minutes at 180°C until required texture is obtained. The cups were taken out of the oven, allowed to cool at room temperature, and then unmoulded. The cutlery was kept in air-tight

container at cool and dry environment.

Plate-1:Beetroot edible cups

Plate-2: Moringa leaves edible cups

2.5 Sensory evaluation

The acceptability of the standardized multigrain vegetable based edible cups was tested organoleptically through 9-point hedonic scale with the highest code as 'like extremely' and lowest as 'dislike extremely'. The sensory panel comprised of 30 panelists who were requested to provide their sensory evaluation details as per the necessary instructions. The sensory parameters analyzed for the study were appearance, colour, taste, odour, texture and overall acceptability.

2.6 Nutritional composition

The chemical constituents in the developed edible cups were assessed in terms of the nutrient composition. The essential nutrients such as protein, fat, calcium, iron and β-carotene were analyzed as per standard protocols provided by AOAC, 2010. The evaluation was carried out in duplicates to arrive at accurate results.

2.7 Water absorption percentage

Cutlery sample was immersed in water for a specific period. After a certain time, the sample was removed from the beaker and the excess of water was removed with tissue paper. The following formula is used to determine the percentage of water absorption capacity (Pastor-Cavada et al., 2011).

$$\text{Water absorption percentage} = \frac{\text{Weight after absorption} - \text{Weight before absorption}}{\text{Weight before absoption}} \times 100$$

2.7 Biodegradability tests (soil burial test)

The edible cutlery samples were buried into the sterile soil for specified amount of time and gradual biodegradation of samples was checked on daily (Leja and Lewandowicz., 2010).

2.8. Microbial quality analysis

Ensuring food safety microbiologically is of paramount importance apart from acceptability through sensory evaluation for safe consumption. In this regard, the present study focused on evaluating the crucial microbial parameters of total plate count, yeast and mold count and coliform count as per the standard protocols.

2.9 Statistical analysis

The data obtained was interpreted and expressed in the form of percentage, mean and standard deviation. Comparative results between beetroot and moringa leaves edible cups were arrived at using t-test and p-values for understanding the significant difference levels.

3. RESULTS AND DISCUSSION

3.1 Sensory evaluation

The need of sensory evaluation is very much crucial to determine the quality, attractiveness, and general consumer approval of edible cups. The edible cups being the source of both utilitarian and culinary uses, knowing their sensory qualities aids in product improvement, customer preference alignment and market success. The edible cups utilization may be thus encouraged by a pleasurable sensory experience, which lowers waste and supports sustainability objectives which also helps to guarantee their commercial success and fosters a satisfying customer experience. The data obtained on the mean sensory scores were indicated in table 3 along with levels of significances between beetroot and moringa edible cups.

Table-3 : Mean sensory scores of multigrain vegetable based edible cups

S.No.	Sensory attribute	Beetroot edible cups	Moringa edible cups	t-value	p-value
1	Appearance	8.40±0.72	8.30±0.70	0.5431	0.5892^{NS}
2	Colour	8.53±0.63	8.47±0.68	0.3938	0.6952^{NS}
3	Taste	8.27±0.74	8.03±0.76	1.2011	0.2346^{NS}

4	Odour	8.13±0.78	8.07±0.69	0.3513	0.7266 ^{NS}
5	Texture	8.50±0.57	8.20±0.71	1.7951	0.0779 ^{NS}
6	Overall Acceptability	8.33±0.71	8.10±0.84	1.1573	0.2519 ^{NS}

Note: ^{NS} indicates not significant difference

The mean sensory scores from the table represented that both beetroot and moringa edible cups found to be within well acceptable scores. Beetroot edible cup was sweet based and seemed to be more delicious than moringa edible cups which might be due to the incorporation of milk and sugar powder adding better palatability in beetroot cups than moringa edible cups. In fact, the spicy ting in the moringa edible cups also advantageous in obtaining well acceptable mean scores and eventually received acceptability from the panel members. Though the results showed that mean sensory scores were slightly higher in beetroot edible cups for each sensory parameter than moringa edible cups, the statistical analysis not identified by significant differences.

Consequently, the overall acceptability mean score was slightly better in beetroot edible cups (8.33±0.71) than moringa edible cups (8.10±0.84) though not differed significantly. For the appearance such as the shape, wheat provides the gluten network that helps in maintaining the structure of the product. According to the Shah et al., (2011) study, increasing the amount of wheat flour increases the dough's cohesiveness and adhesiveness. Similarly, the inclusion of wheat flour as a portioning of multigrain flour in edible cup making had imparted acceptable scores in yielding delicious multigrain vegetable based edible cups.

3.2 Nutrient composition

Understanding the nutritional content of edible cups helps in food labelling and to enhance reputation as a sustainable, useful, and health-conscious product. Providing precise nutritional data increases consumer confidence in the product. As an environmentally sustainable substitute for single-use plastic cups, edible cups can be promoted in view of the essential nutrients. Edible cups that are high in nutrients might serve as dual purpose which can meet nutritional demands as well as sustainability. The analysis results on the selected nutrients viz., protein, fat, calcium and iron contents both in beetroot and moringa edible

cups were tabulated in table 4.

Table-4 : Nutrient composition of multigrain vegetable based edible cups

S.No.	Nutrient	Beetroot edible cups	Moringa edible cups
1.	Protein(g)	9.3	6.8
2.	Fat(g)	1.6	1.2
3.	Calcium (mg)	86	123
4.	Iron (mg)	2.4	5.4

The results from the table indicated that relatively higher protein content was observed in beetroot edible cups probably due to the addition of protein rich milk powder in beetroot edible cups. The edible cups formulated seemed to be low in fat as evidenced by low values both in beetroot (1.6g) and moringa edible cups (1.2g). The calcium content was far better in moringa edible cups (123mg) than beetroot edible cups (86mg). Similarly, iron content was also slightly greater in moringa edible cups (5.4mg) than beetroot edible cups (2.4mg). The micronutrients evaluated indicated that comparatively moringa edible cups noticed to be better which might be due to the incorporation of micronutrient rich moringa leaves extract.

Matheswari et al., 2024 developed nutritive edible cups using wheat flour and food industrial by-products such as rice bran, dehulled chickpea flour, groundnut cake, beetroot and apple pomace, and molasses. The well acceptable edible cups formulated had 354Kcals energy, 74.2g carbohydrates, 1.5g fat, 10.8g protein, 4.6g fiber, polyphenols, flavonoids, and phytochemicals. The current analysis results showed comparable amounts of protein in beetroot edible cups but slightly lower content in moringa edible cups. Both beetroot and moringa edible cups found to be nearer values in fat content.

3.3 Water absorption capacity

The water absorption capacity was calculated as percentage at specified time period at an interval of 5 minutes for duration of 30 minutes. The results observed in both varieties of beetroot and moringa edible cups were illustrated graphically and denoted in figure 1.

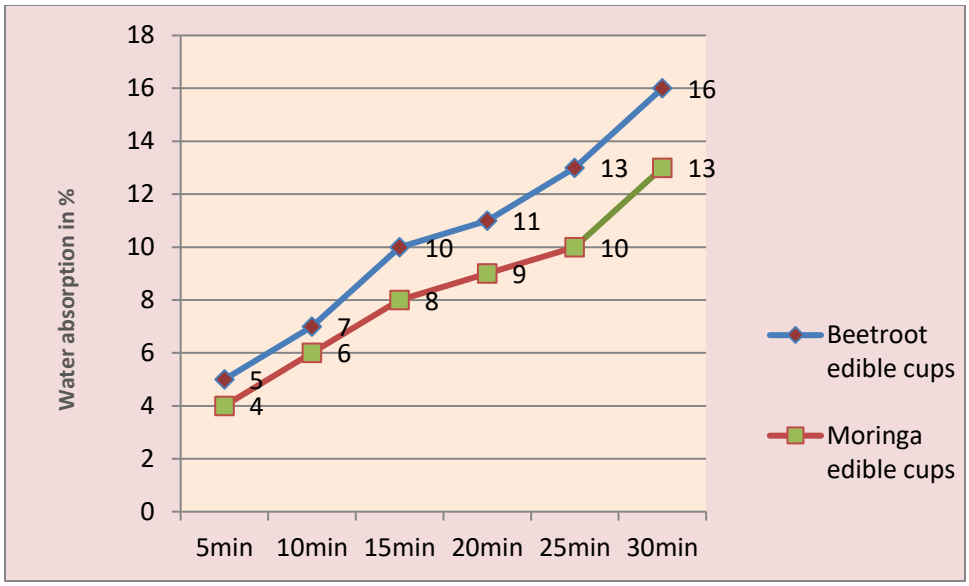

Figure-1 : Water absorption capacity of multigrain edible cups

The data from the figure illustrated a gradual increase in water absorption percentage with the progressive increase in water absorption period from 5 to 30 minutes in both type of edible cups. However, the beetroot edible cups showed slightly higher water absorption with a range of 5 to 16 % compared to moringa edible cups as identified by the increase in water absorption from 4 to 13%.

Blend contains a maximum amount of wheat flour which is capable of forming gluten networks and building starch-water bonds that retain moisture well (Iqbal et al., 2022). This could be the fact for the sturdiness of the edible cups resulted during the processing of baking and lead to relatively lower amount of water absorption. The more amount of multigrain flour content in moringa edible cups might be responsible for lesser water absorption levels than beetroot edible cups.

3.4 Microbial quality analysis

Biodegradable ingredients, which are frequently used in edible cups, may be more vulnerable to microbial deterioration. Microbial analysis is essential in ensuring safety for consumer protection, regulatory compliance, and fostering the development of the edible cup sector as a secure and sustainable substitute for plastic cups. During the present study, the important microbial quality parameters such as total plate count, yeast and mold count and coliform count were analysed and presented in table 5.

Table-5 : Microbial quality analysis of multigrain vegetable based edible cups

S.No.	Microbial assay	Common threshold(CFU/g)	Beetroot edible cups	Moringa edible cups
1	Total plate count	$\leq 10^3$ to 10^4	2.47×10^3 /g	3.12×10^3 /g
2	Yeast and mold count	$\leq10^2$ to 10^3	ND	ND
3	Coliform count	≤10 or absence	ND	ND

Note: ND-Not detected

The findings on microbial assay clearly demonstrated the safety of the developed multigrain vegetable based edible cups. The total plate count calculated observed to be within safe limits with slightly more count in moringa edible cups (3.12×10^3cfu/g) than beetroot edible cups (2.47×10^3 cfu/g). The growth of yeast and mold as well as coliform count was not observed in both varieties of edible cups indicating that the edible cups were processed with clean water and in hygienic environment. Several other studies also assured microbial safety of edible cutlery developed in their research findings provide a comprehensive benefit to commercialize at food and packaging industrial sectors as safe and sustainable approach to replace plastic cutlery (Mishra et al., 2024).

3.5 Biodegradability test (soil burial test)

Testing edible cups for biodegradability is beneficial to assess their extent of degradability, safety and to confirm the environmental safety. The consequent results become directive approach as eco-friendly substitutes for single-use or plastic cups and thus edible cups can be becoming more and more popular. Biodegradability guarantees for the consumption of products as safe, effective and in line with environmental protection. Biodegradability testing evaluates the complicated biochemical process that takes place when microbes deplete a specific material. Natural raw materials such as moringa leaves and beet root were used without the addition of any additional preservatives to edible cutlery. The observations on the soil burial test of edible cups for biodegradability on the formulated edible cups are given in table 6.

Table-6: Biodegradable observations on soil burial test of multigrain vegetable based edible cups

S.No.	Days of testing	Observations	
		Beetroot edible cups	Moringa edible cups
1.	Day-1	Original cup	Original cup

2.	Day-2	Fragmented into large pieces	Fragmented into large pieces
3.	Day-3	Broken down into small pieces	Broken down into small pieces
4.	Day-4	Degraded completely in soil	Degraded completely in soil

The observations from the table revealed that in both beetroot and moringa edible cups the degradation was gradual with the appearance of large fragments on second day, then progressively resulted in small pieces and finally decayed completely on fourth day. The existing literature showed that in sterile soil, the edible cutlery entirely decayed in 3–4 days. As each sample was gradually broken down in to smaller pieces, it started decaying the next day and was completely decayed within 3–4 days. Both the soil and edible cutlery are capable of absorbing water. The rate of deterioration increases with soil moisture. The degradation of edible cutlery is also due to the presence of the microbial organism in soil (Kabir and Hamidon, 2021). This demonstrated that it can be considered an environmentally friendly alternative to conventional plastic cutlery, which can persist in the environment for a much more extended period.

Biodegradation of cutleries are dependent upon the material from which it is produced. Kumbhar and Masali (2020) reported complete degradation of spoons made from moringa husk powder in 20 days while Hazra and Sontakke (2023) reported that their developed cutlery (ragi-sorghum-wheat-based cutlery incorporated with ginseng root powder) took 4-5 days for complete degradation. Iqbal et al. (2022) also reported the complete degradation of wheat, rice and sorghum flour-based cutlery in 5 to 7 days.

CONCLUSION

Plastic product is an organic synthetic compound that makes plastic hard and clear. Bisphenol A (BPA) can leach into food when plastic containers are heated, especially fatty foods like meats and oils. When the humans, animals or birds consume these foods unknowingly they ingest microplastics, which can have several adverse effects on the health demands for eco-friendly products. The present investigation had made an attempt to develop multigrain vegetable based edible cups to overcome these complications. The research findings had clearly provided evidence in the acceptability of the formulated edible cups in terms of sensory parameters and microbial safety.

The nutrient analysis indicated that the edible cups developed had promising nutritive value which can be helpful to grab the interest of consumers in view of nutritional and health benefits. Furthermore, biodegradability tests indicated that the both cutlery had achieved complete degradation within a span of 4 days which demonstrates the environmentally friendly nature of the cutlery. The study concludes that the prepared cutlery is very tasty and healthy as well as environmentally beneficial which benefits to encourage manufacturing and marketing of edible cutlery.

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