Research Article

Edible Cutlery – A Prototype to Combat Malnutrition and Plastic Waste Management

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ABSTRACT

Background: Edible cutlery is a natural and bio-degradable commodity which can be concocted to be nutritious and replace the usage of plastic cutlery. This study aims at sustainable development, elimination of plastics as cutlery from the food sector, ecological waste management, maintenance of optimal nutritional status and prevention of non-communicable diseases. These edible cutleries, which are made by combining all the five food groups given in the MyPlate, will prodigiously influence the intake of complex carbohydrates, protein, fibre, micronutrients and nutraceuticals on a routine basis. **Materials and Methods:** This report is targeted at the fabrication of edible cutleries using composite flour blends of whole wheat, foxtail millet, and roasted bengal gram, along with enrichment of skimmed milk powder, orange fruit powder and beetroot extract in proportions as suggested in a balanced diet, in order to evaluate its ability to meet the recommended daily allowances, phytochemical profile, functionality and economic competence. Three variations were baked at 180°C for 17 min. **Results:** According to the results of the analysis, variation 2, with an equimolar ratio of whole wheat flour and foxtail millet flour along with other ingredients, proved to be the most proficient alternative to plastic cutlery. **Conclusion:** The accepted cutlery indicated to considerably meet the RDA in terms of certain nutrients majorly lacking in the Indian diet, along with catering to the nutraceutical needs of the body. Economically, the cost of these cutleries was found to be lower than those present in the market.

Keywords: Edible cutlery, Nutraceuticals, Sustainable development, Waste management.

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INTRODUCTION

There was an increase in the production of plastic from 1.5 million metric tons in 2018 to 367 metric tons in 2020, with its main producers being Asia (51%), North America (18%), and Europe (17%). The industry in which plastic industries strive is food (packaging and vendor trade) and hospitality industries (restaurant and eateries). The high consumption of plastic is an environmental disaster, and of the total usage, only 9% is recycled. In a short duration – 1950 to 2020, the production of plastic and its usage with no sustainable waste management policy has resulted in the dumping of the same at mountains and the bottom of the sea as well as oceans. The presence of plastic polymers in the environment results in defragmentation, as a wide range of plastics presently in use do not degrade and break into smaller pieces and particles. The smaller fragments are called microplastics, and recent studies have rechristened the name to "nano plastics". These large and small microplastics are found in the guts of several wild animals and livestock, from where it is transferred to the human body through the digestive system. Additionally, substances that are used to improve the stability and functionality of plastics – termed plasticizers – might also enter the bodies of organisms and accumulate in the biological systems.[1] With the escalating usage of single-use plastics and the widespread awareness about its detrimental effects, an array of substitutes have found their way into our lives. Businesspersons are introducing new products into the market which are either recyclable or

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biodegradable.[2] Hence innovative fabrications which will be able to redeem this environmental crisis are the need of the hour, and the present study on edible cutleries partly focuses on it.

Moving onto the dietary point of view, as per the MyPlate icon, the five food groups are as follows: Fruits, Vegetables, Grains, Protein Foods, and Dairy.[3] MyPlate is a pictorial guide that represents the five primary food groups and aids its users in choosing the right proportion of ingredients from the respective groups. The plate is bifurcated into four quarters, wherein 20% is allocated to fruits, 30% to vegetables, 20% to a protein source, and 30% to cereal grains. Apart from these, it also provides a bowl of dairy. These quantities support the principles of a balanced diet, which states that 60-70% of our total calories should come from carbohydrate sources, 10-12% from proteins, and 20-25% from fats.[4]

Worldwide food pattern is different due to cultural parameters, affordability and temptation. However, with ever-increasing economic growth in developing and underdeveloped countries, the food sector seems to be similar worldwide, and this is due to globalization.[5]

Cereals and millets (375 g/day for sedentary males, 270 g/day for sedentary females), pulses (75 g/day for sedentary males, 60 g/day for sedentary females), milk and its products (300 g/day for sedentary males and females), roots and tubers (200 g/day for sedentary males and females), green leafy vegetables (100 g/day for sedentary males and females), other vegetables (200 g/day for sedentary males and females), fruits (100 g/day for sedentary males and females), sugar (20 g/day for sedentary males and females) and visible fats and oils (25 g/day for sedentary males, 20 g/day for sedentary females) encompass the list of ICMR recommended food groups.[4] Dietary patterns which are at par with the recommendations lead to a lowered risk of non-communicable diseases like cancer and cardiovascular disorders and a reduction in the overall mortality rate. Despite the prospective advantages, compliance with the aforementioned recommendations is very low, and a large number of individuals are not successful in consuming the recommended portion sizes for each individual food group.[6] It has been observed that several nutrients, including vitamin C, vitamin D, folate-folic acid, calcium, iodine, potassium, selenium, and fibres are insufficient or lacking in the diet of European, North American, and Australian people. It is also observed that the ubiquity of obesity and several non-communicable chronic diseases associated with obesity have increased in manifolds. Hence, the dietary recommendation on the basis of individual countries' perspectives is emphasized consuming more fruits, vegetables, whole grains, and low-fat or non-fat dairy products to uplift the nutrient density of the routine diet.[5]

Edible cutlery is a novel idea in which the means to eat can be eaten along as well. The idea has been domesticated for quite some time now but has not received commercial or research momentum at a large scale yet. In the plastic world scenario, where its market is maturing at a 30% growth rate and producing landfills of non-recyclable waste, edible cutleries are the key to solving the environmental problem while catering to the same functions as disposable cutlery besides being healthy and tasty.[7]

Therefore, a creation like that of edible cutleries acts as a supplementary form of nutrition when concocted from the optimized ratio of food groups, which complements both its functionality and palatability. The usage of locally available ingredients – like whole wheat, foxtail millet, roasted Bengal gram, skimmed milk, oranges and beetroot used in this study – increases its value as a functional food and also attracts the attention of the masses as they are familiar with the raw materials. Apart from this, the incorporation of all the said ingredients in this study aids in meeting the daily recommended dietary allowances in an affordable manner and prevents malnutrition.

Reports and findings on the analysis of edible cutlery are scanty, but a study by Dordevic *et al.*[2] on edible spoons has highlighted the textural factors and antioxidant profile of the product when incorporated with xanthan gum and grape seed flour. The current study provides additional dynamics that might be of concern while manufacturing edible cutleries, like palatability, functionality, nutritional profile, nutraceutical profile and cost-effectiveness. Thus, the present study simultaneously aims at introducing the concept of edible cutleries in the food sector to minimize plastic waste generated from disposable cutlery and incorporate all five food groups into the diet of people, thereby bridging the gap between recommended dietary intake and malnutrition.

MATERIALS AND METHODS

Selection of Materials

The ingredients used in making the different variations of the edible cutlery, namely, whole wheat, foxtail millet, Bengal gram, skimmed milk, orange, and beetroot, were selectively procured from the local markets of Salem, Tamil Nadu, India.

Sample Preparation

Whole wheat kernels were purchased from the market, cleaned, and washed thoroughly in distilled water. Thereafter it was sun-dried in a covered mesh cloth for a day. As soon as they were dried out entirely, the kernels were sent in for the milling process to be made into flour. The whole wheat flour was then weighed out in individual proportions for each variation, as summarised in Table 1.

Foxtail millet was subjected to germination for its processing. It was bought in the whole form and hence was soaked overnight to reduce all the antinutritional factors to a level where they would exhibit nutraceutical properties. After soaking overnight, it was sun-dried in a covered muslin cloth for a day. Once completely dried, it was ground into a fine powder. Three separate portions of foxtail millet flour, as enlisted in Table 1, were divided for incorporation into three distinct variations.

The whole Bengal gram was bought and cleaned thoroughly to eliminate the foreign particles and washed with distilled water. Once cleaned, they were dry roasted on the stovetop for 7 min at 130°C while stirring constantly. They were cooled and then ground into a fine powder to produce roasted Bengal gram flour. For each variation, 20 g of roasted Bengal gram flour was balanced out from the entire batch.

Skimmed milk was processed via the principles used in the drum-drying technique but owing to the unavailability of the said equipment, Bajaj Majesty 2200 TMSS (22 Litre) Oven Toaster Griller (OTG) (manufactured in Ranjangaon, India) was used. A litre of skimmed milk was taken and poured into an oven-safe dish up to a height of 1 inch from its base. Thereafter, it was set to dehydrate in an oven at 50°C for 12 hr. The oven door was propped slightly open with a kitchen towel to allow the moisture to escape and stirred at intervals for the water to evaporate evenly. During the end of this period, the skim milk started to turn into a thick paste. Once no changes were observed in the paste, it was removed from the oven and transferred onto a parchment-lined baking tray. Thereafter, the tray was placed back into the oven for further dehydration. Once the paste turned into a flaky consistency without turning brown, it was taken out, ground into a very fine powder, and filtered through a sieve to remove lumps. A teaspoon of this skimmed milk powder, which amounted to 5g, was taken for each variation.

The orange powder was sourced from the whole fruits via the dehydration technique using a Bajaj Majesty 2200 TMSS (22 Litre) Oven Toaster Griller (OTG) (manufactured in Ranjangaon, India). Firm, full-coloured, smooth, and thin-skinned oranges were purchased from the local market for processing and incorporation in edible cutleries. The oranges were washed thoroughly under running water to remove the adhesive from the label. The oven temperature was set at 65°C for preheating. Meanwhile, the oranges were as thinly sliced as possible with a sharp knife. The seeds were discarded from the orange slices. Thereafter, the baking tray was lined with parchment paper, and the thin slices were evenly placed on it. The slices were set to dehydrate in the oven for 20 hr at the same temperature. The oven door was propped slightly open with a kitchen towel to allow the moisture to escape. Once the moisture was eliminated from the orange slices, they were ground to a very fine powder consistency and filtered via a sieve. Half a teaspoon of an orange powder weighing 2.5g was segregated for incorporation into the three variations.

Beetroot is the only wet ingredient used in these edible cutleries, and the domestic pureeing method was used to process it. Hence, good quality beets, judged by the presence of an attached stem, intact peel, and unbruised succulent texture, were taken and washed thoroughly to eliminate dust and mud particles. Thereafter, they were peeled and cut into small pieces. The beetroot chunks were then added to a blender and pureed to a smooth paste. The three different variations developed in this study integrated 2.5g of this pureed beetroot paste.

Dough Making

Once the processing of all the ingredients was carried out, the ingredients were ready to be kneaded into a dough. The proportion of ingredients - based on the MyPlate ratio for food groups - for the three different experimentally produced variations are summarised in Table 1.

The dry ingredients were sieved together to form a homogeneous powder, and then the wet ingredient, viz., beetroot extract, was added. The mixture was tossed with a spoon until the dry ingredients absorbed the

Table 1: Ingredients for the preparation of different variations of edible cutlery.

Ingredients	Variation 1 (g)	Variation 2 (g)	Variation 3 (g)
Foxtail millet flour	25	35	45
Whole wheat flour	45	35	25
Roasted Bengal gram flour	20	20	20
Skimmed milk powder	5	5	5
Orange powder	2.5	2.5	2.5
Beetroot extract	2.5	2.5	2.5

colour of the beetroot extract to its maximum possible extent. Thereafter, water was added, one teaspoon at a time, and the dough was kneaded well. After eight teaspoons of water incorporation, which amounts to 40 mL of water, the value-added dough was ready.

Edible Cutlery Making

All three variations of the value-added dough were weighed and found to be 100 g. They were individually rolled out into a 2 mm sheet with the help of a rolling pin. Thereafter, oven-safe cutleries were used as a stencil, and the edible cutleries were carved out with a knife. Seven tablespoons from each variation could be carved out with 100 g of value-added dough.

Once the dough cutleries were cut out in a flat shape, a bit of vegetable oil (Rice Bran Oil) was smeared onto the oven-safe cutleries and the flat dough cutleries were cast on top of them to give them the depth of cutlery and optimize its functionality. Small holes were pricked onto them to ensure overall cooking and proper sturdiness of the cutleries.

The oven temperature was experimentally set to preheat at 150°C. This temperature setting was kept for 10 min. Thereafter, the cutleries, along with their moulds, were placed inside the preheated oven for 17 min at 180°C to ensure proper cooking and browning. Once baked, they were cooled to room temperature and then stored in air-tight containers in a cool dark place until assessment.

Physical Evaluation

All three variations of the edible cutlery were measured before and after baking on the parameters of its total length, the width of the bowl of the cutlery, the width of the neck of the cutlery, and the width of the shaft of the cutlery with a calibrated ruler, following the method of Ikechukwu *et al.*[8]

Sensory Evaluation

The three variations of edible cutlery developed in this study were subjected to organoleptic evaluation to assess the maximum acceptability of each variant. The quality of each variation was judged based on its appearance, colour, aroma, flavour, texture, and overall acceptability, as suggested by Heymann and Lawless [9] by 30 untrained panelists. The 9-point Hedonic Rating Scale was used wherein the highest score was coded as 'like extremely', and the lowest score was coded as 'dislike extremely'.

Functionality Evaluation

Along with palatability, the functionality of each variant of the developed edible cutlery was also evaluated to assess the maximum usability of each variant. The usability of each variation was judged based on its functionality with wet ingredients, functionality with dry ingredients, and overall functionality by 30 untrained panelists. The 5-point Descriptive Rating Scale was used wherein the highest score was coded as 'extremely competent, and the lowest score was coded as 'extremely incompetent'.

Nutritional Evaluation

The nutritive values of the organoleptically and functionally accepted variation were assessed. The parameters evaluated were carbohydrates, protein, fat, fibre, iron, calcium, zinc, magnesium, carotene, riboflavin, thiamine, niacin, and folate. Riboflavin, thiamine, and niacin were assessed by the methods laid down by Woollard and Indyk.[10] The rest of the nutrients were evaluated by following the AOAC[11] methods.

Phytochemical Evaluation

The phytochemicals assessed in the organoleptically approved sample included zeaxanthin, saponin, catechin, betacyanin, hesperidin, lignan, ferulic acid, alkyl resorcinol, and glutathione peroxidase via methods stated by AOAC,[11] Sofowara,[12] Trease and Evans,[13] and Harborne.[14]

Cost Calculation

The cost involved in the processing and manufacturing of the edible cutlery was calculated, taking into account the fixed and variable costs during the course of processing and developing the product.

Statistical Analysis

The data obtained from the various organoleptic and functionality trials were subjected to statistical analysis to determine the influence of varying proportions of ingredients used on the quality and functionality of the developed product. The mean value for the scores was determined using descriptive statistical analyses in IBM SPSS Statistics 16 Software Package for Windows (SPSS Inc., Chicago, IL, USA). The data was then analyzed using One-way ANOVA along with Duncan's *post hoc* test, where $p<0.05$ was used to ascertain a significant difference between the means.

RESULTS

Physical Properties of Edible Cutlery

Baking is a convoluted entity procedure that results in multiple changes in the products subjected to it. These changes include the transition of water and fat phases, dehydration, volumetric modifications, increased porosity, biochemical alterations and browning. These

changes prove to be of benefit in products with distinctive macroscopical attributes like the proportions of the product, as well as anticipated sensory factors of the product.[15]

Apart from the mechanical alterations inflicted by the baking process, intrinsic components of the product also affect the dimensional changes in a product. Dietary fibre is a vital component which influences the stability, texture and organoleptic parameters of the food it is present in.[16] Besides, it also improves the strength of the product during the manufacturing procedure and its shelf life. It has been reported that an increase in fibre concentration facilitates reduced specific volume and elevated hardness.[17]

Owing to the given factors, the dimensional changes in the edible cutlery before and after baking are summarized in Figure 1.

The 1st variation was measured before and after baking, and it was observed that it shrunk with respect to its length, width of the bowl of the cutlery and width of the neck of the cutlery. But no such action was seen on the width of the shaft of the edible cutlery. It can be reported that its length decreased by 0.7 cm, the width of the bowl decreased by 0.1 cm, and the width of the neck decreased by 0.1 cm.

The 2nd variation was seen to shrink on all the measured parameters, namely, length, width of the bowl of the cutlery, the width of the neck of the cutlery and width of the shaft of the cutlery. It can be reported that its length decreased by 0.35 cm, the width of the bowl decreased by 0.2 cm, the width of the neck decreased by 0.1cm, and the width of the shaft decreased by 0.2 cm.

The 3rd variation, too, was measured before and after baking, and it was observed that it shrunk with respect to the length and width of the bowl of the cutlery. But no changes were seen in the width of the neck and the width of the shaft of the edible cutleries. It can be reported that its length decreased by 0.6cm, and the width of the bowl decreased by 0.3cm.

Hence, it can be inferred from Figure 1 that variation 2 showed maximum changes after baking, including all its parameters.

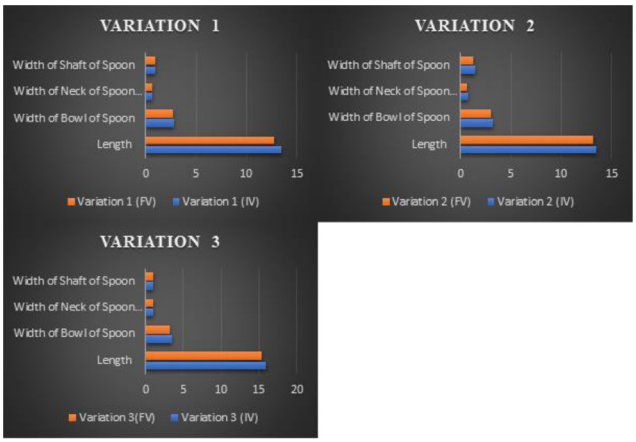

Figure 1: Dimensional comparison between pre-baking and post-baking parameters of the three variations of edible cutlery.

Acceptability of Edible Cutlery

Sensory Evaluation of Edible Cutlery

An array of ingredients like the composite blend of whole wheat flour, foxtail millet, roasted Bengal gram flour, skimmed milk powder, and orange powder, along with the addition of pureed beetroot extract, have been amalgamated together to produce these Edible cutleries and thereby exhibit its various functionalities on human health. Hence, all three variations were subjected to organoleptic evaluation using a sensory analysis procedure by the sense of sight, smell, taste, and touch. The mean of the scores awarded by the untrained judges to all three variations is illustrated in Table 2, along with Duncan's *post hoc* interpretation.

As per the results collated, it can be comprehended that the three variations had significant differences between the groups, namely, variation 1, variation 2, and variation 3, with respect to their appearance, colour, aroma, flavour, and texture as indicated by the "P" value or the significant value being less than 0.05. Concerning the given superscripts, it can be reasoned that variation 2 had the maximum organoleptic potential in all parameters, and variation 3 had the lowest.

According to Table 2, in variation 1, the high mean value was obtained for appearance as 6.53 compared to other sensory attributes. In variation 2, the high mean value was obtained for appearance as 8.37 compared to other sensory attributes. In variation three as well, the high mean value was obtained for appearance as 3.97 compared to other sensory attributes. The mean ± SD of the overall acceptance score accorded by the untrained panelist was also the maximum for variation 2.

It can be reported from the values and trend curve in Figure 2 that variation 2 is the most organoleptically acceptable variation among all the three variations, with a mean score of 8.17.

Functionality Evaluation of Edible Cutlery

As the name of the product suggests, edible cutlery was developed with a presumed role in mind, apart from enhancing the nutritional status of individuals consuming them. Its utility as cutlery is a primary aspect of it which makes it unique. Thus, the ingredients

Table 2: Sensory evaluation of three variations of the edible cutlery by hedonic score.

Variations	Appearance	Colour	Aroma	Flavour	Texture	Overall Acceptance
1	6.53 ± 1.25[b]	6.20 ± 1.34[b]	6.13 ± 1.33[b]	6.43 ± 1.25[b]	6.06 ± 1.22[b]	6.20 ± 1.15[b]
2	8.36 ± 0.76[c]	8.06 ± 0.69[c]	8.20 ± 0.88[c]	8.26 ± 0.78[c]	8.00 ± 0.83[c]	8.16 ± 0.83[c]
3	3.96 ± 1.93[a]	3.83 ± 2.22[a]	3.86 ± 1.99[a]	3.90 ± 1.86[a]	3.56 ± 1.79[a]	3.60 ± 1.86[a]
"*P*" value	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*

Each value in the table is represented as mean ± SD. Means with different superscripts are significantly different using Duncan's Multiple Range Test, where in $p < 0.05$. * $p<0.05$.

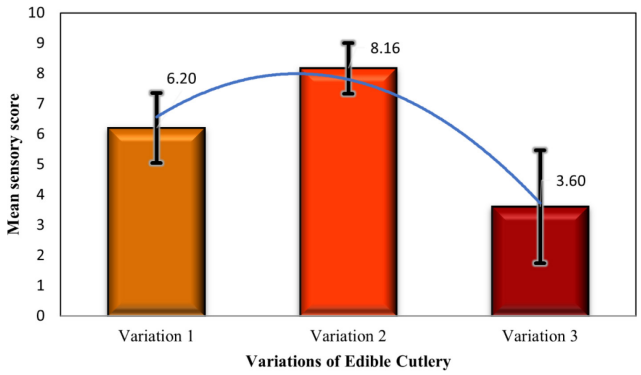

Figure 2: Consolidated mean sensory score ± SD for the overall acceptance of edible cutlery along with the trendline.

used in its making were aimed to be incorporated in a ratio that would ensure the sturdiness of the edible cutlery. Other factors like water addition in the dough, optimization of oven temperature, and post-baking exposure to moisture were also taken into consideration to augment the durability of the edible cutlery. Hence, the competency of all three variations as cutlery was subjected to functionality evaluation using a system usability scoring procedure on the perception of its serviceability with wet and dry food ingredients.

The mean of the points bestowed by the untrained judges to all three variations for their functionality is exemplified in Table 3, accompanied by Duncan's *post hoc* interpretation.

Following the results compared, it can be implied that all three variations had significant differences between the groups, namely, variation 1, variation 2, and variation three, regarding their functionality with wet and dry ingredients as specified by the "*P*" value or the significant value being under 0.05.

As per Table 3, in variation 1, the high mean value was obtained for its competency with dry foods as 3.83 compared to its competency with wet foods. In variation 2, the high mean value was obtained for its competency with dry foods as 4.77 compared to its competency with wet foods. In variation 3, the high mean value was obtained for its competency with dry

Table 3: Mean functionality analysis of all three variations of the edible cutlery.

Variations	Functionality with wet ingredients	Functionality with dry ingredients	Overall functionality
1	3.03 ± 1.93[b]	3.83 ± 2.22[b]	3.26 ± 0.69[b]
2	4.30 ± 0.46[c]	4.76 ± 0.43[c]	4.43 ± 0.50[c]
3	1.36 ± 0.49[a]	1.73 ± 0.63[a]	1.60 ± 0.67[a]
P value	0.00*	0.00*	0.00*

Each value in the table is represented as mean ± SD. Means with different superscripts are significantly different using Duncan's Multiple Range Test, wherein $p < 0.05$. * = $p<0.05$

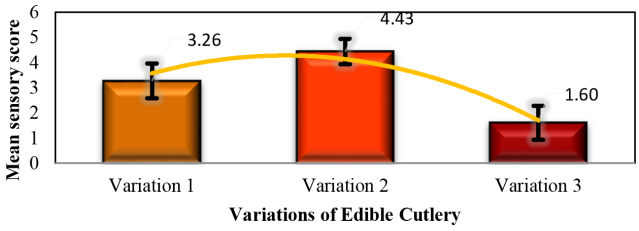

Figure 3: Consolidated mean sensory score ± SD for the overall functionality of edible cutlery along with the trendline.

foods as 1.73 compared to its competency with wet foods. The mean ± SD of the overall functionality of all three products were scored by the untrained panelist and is also recorded in Table 3.

From the afore given tabular depiction, it can be aptly interpreted that the three variations differed significantly with respect to their overall functionality.

It can be testified from the values and trend curve in Figure 3 that variation 2 is the most functionally suitable variation among all the three variations and can be approved as the accepted cutlery variation.

In contrast to this study, the literature states that the consumers are not comfortable eating edible cutlery and cannot be an alternative to metal cutlery.[18]

Nutritional Evaluation of Edible Cutlery

The macronutrients which showed their presence in variation 2 of the edible cutlery were carbohydrates, protein, fat, and dietary fibre, with their quantities

Table 4: Macronutrient content of variation 2 of Edible Cutlery.

Macronutrients	Quantity (g)
Carbohydrate	76.40
Protein	10.60
Fat	1.20
Crude fibre	1.90

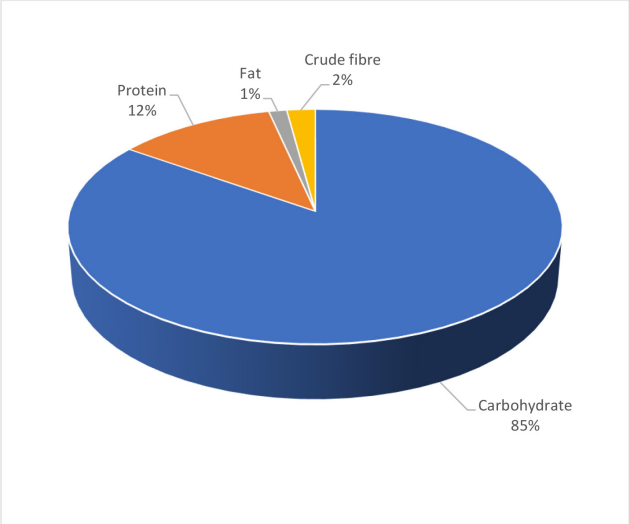

Figure 4: Distribution of macronutrients (in g) in the edible cutlery in 2nd variation of edible cutlery.

enumerated in Table 4. The macronutrient distribution is illustrated in Figure 4.

From the given tabular and graphical representation, it can be deduced that the macronutrients are aptly distributed in the edible cutlery as 85% of carbohydrates, 12% of protein, 1% fat, and 2% crude fibre. A study on edible cutlery by Rajendran SP *et al.*, had a nutritional value of 83.68 g/100g of carbohydrate, 2.36 g/100g of total fat and 5.67 g/100g of protein.[19]

The micronutrients which exhibited their presence in the 2nd variation of the edible cutlery were iron, calcium, zinc, magnesium, carotene, thiamine, riboflavin, niacin, and folate, quantified in Table 5. The distribution of micronutrients is illustrated in Figure 5.

From the given tabular and graphical demonstration, it can be inferred that the edible cutlery includes a wide array of micronutrients that cater to an improved quality of food intake.

Table 6 cumulates the consolidated nutritional profile of the edible cutlery to showcase the competency of the edible cutlery in meeting the daily recommended allowance of an individual.

Hence, it can be extrapolated that usage of edible cutlery to consume a healthy balanced meal can help an

Table 5: Micronutrient content of the 2nd variation of the edible cutlery.

Micronutrients	Quantity (mg)
Iron	5.60
Calcium	21.30
Zinc	4.40
Magnesium	4.50
Carotene	39.70
Thiamine	0.30
Riboflavin	0.10
Niacin	2.80
Folate	13.30

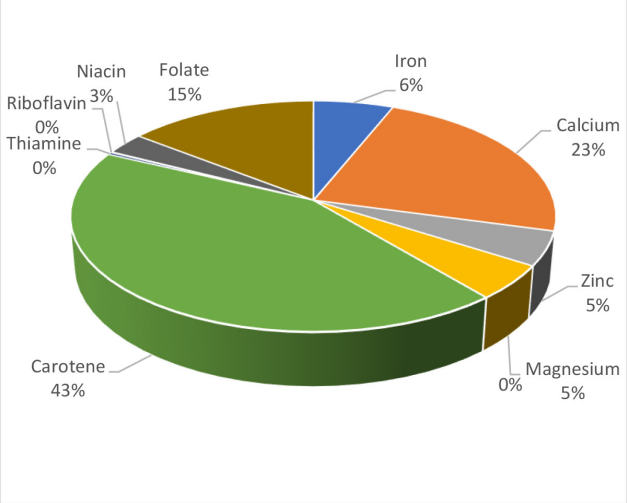

Figure 5: Distribution of micronutrients (in mg) in the edible cutlery.

individual to considerably meet their RDA,[20], especially in terms of carbohydrate, protein, iron, zinc, carotene, thiamine, niacin, and folate as depicted in Figure 6.

Phytochemical Evaluation

The phytochemicals present in the accepted variation of edible cutlery are catalogued in Table 7.

Figure 7 represents the presence of the said isoprenoids, flavonoids, phytoestrogens, phenolic acids, phenolic lipids, and enzymes with respect to their relativity with each other.

As per the distribution graph, it can be construed that the edible cutlery consisted of 12% alkyl resorcinol, 8% betacyanin, 2% catechin, 6% ferulic acid, 14% glutathione peroxidase, 4% hesperidin, 44% lignan, 5% saponin, 5% zeaxanthin.

Cost Calculation

In the process of implementation of edible cutlery in the routine life of the masses, determining its

Table 6: Consolidated nutritional profile of variation 2 of the edible cutlery.

Macronutrients (in g)	Quantity in edible cutlery (100 g)	RDA for an adult man (ICMR RDA 2020)	% of RDA met with edible cutlery – man	RDA For adult woman (ICMR RDA 2020)	% of RDA met with edible cutlery – woman
Carbohydrate	76.40	130.00	59.00	130.00	59.00
Protein	10.60	54.00	20.00	45.70	23.00
Fat	1.20	25.00	5.00	20.00	6.00
Micronutrients (in mg)					
Iron	5.60	19.00	29.00	29.00	19.00
Calcium	21.30	1,00	2.00	1,00	2.00
Zinc	4.40	17.00	26.00	13.20	33.00
Magnesium	4.50	385.00	1.00	325.00	1.00
Carotene	39.70	12.00	331.00	10.08	394.00
Thiamine	0.30	1.40	21.00	1.40	21.00
Riboflavin	0.10	2.00	5.00	1.90	5.00
Niacin	2.80	14.00	20.00	11.00	25.00
Folate	13.30	0.30	4,43	0.22	6,04

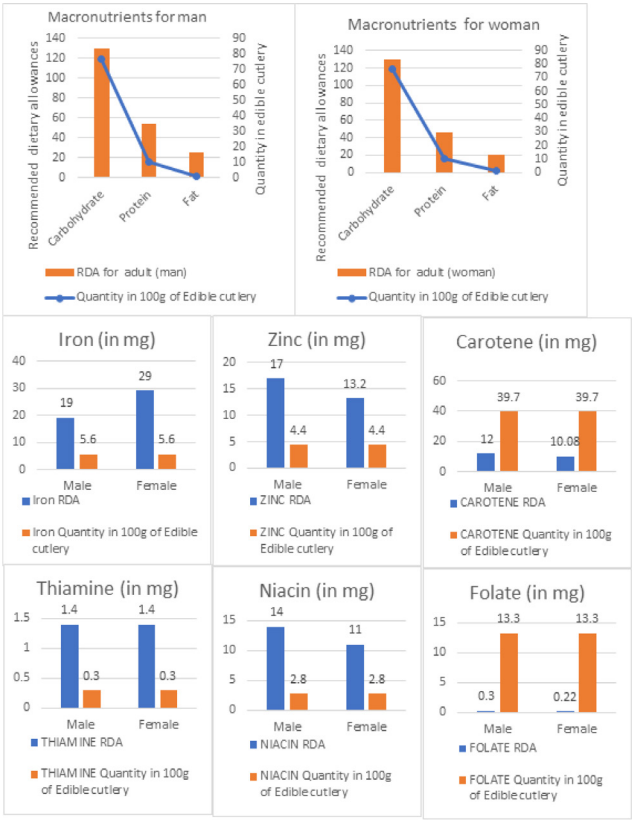

Figure 6: Comparison of micronutrients for RDA in the edible cutlery.

Table 7: Phytochemical analysis of variation 2 of edible cutlery.

Phytochemicals	Composition (mg/kg)
Zeaxanthin	0.81
Saponin	0.95
Catechin	0.29
Betacyanin	1.40
Hesperidin	0.81
Lignan	7.94
Glutathione peroxidase	2.63
Alkyl resorcinol	2.23
Ferulic acid	1.16

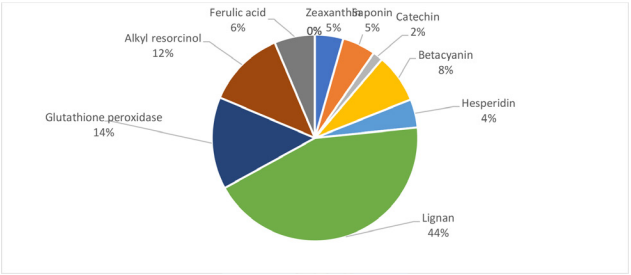

Figure 7: Relative distribution of phytochemicals in the edible cutlery (in mg/kg).

manufacturing cost is a concerning factor. Affordability plays a major role in the acceptance of a product. When calculated, the cost of making 100g of dough was found to be Rs.12.67. Since 100g of value-added dough carved out seven tablespoons, the aforestated cost calculation brings to light the total cost of preparing one tablespoon of edible cutlery as Rs.1.81. Taking into consideration the charges for appliance usage, the total cost of preparing one tablespoon of edible cutlery can be estimated to be approximately Rs.2.

DISCUSSION

Nutritionally, the choice of ingredients used and their nutritional content contribute to the multifaceted benefits of the cutlery. Individuals are able to meet their food and nutrient requirements on a daily basis as the cutleries house nutrients and phytochemicals primarily lacking in the millennial diet.

From the therapeutic viewpoint, the high carbohydrate, protein, and carotene content can be of benefit in subjects with or at risk of Protein-energy-malnutrition and Vitamin A deficiency. Elevated iron and folate levels can be of advantage to adolescent girls, pre-conceptual and pregnant women prone to anaemia. Functionally, the edible cutlery in this study is apt to cater to its functionality with both hot and cold as well

as wet and dry food products. They do not overpower the flavour of the food consumed with their help of it. In addition, it exhibits a satisfactory flavour of its own when consumed individually as a snack. In a similar study by Sood, S., *et al.,*[21] on Edible Crockery comprising sorghum flour, rice flour, and spinach extracts, the overall acceptance was evaluated to be at 7.20. This ensues that the concept of edible crockery is well received by the population, and further studies to enhance the sensory parameters of the products will be met with the same fate.

The study on edible cutleries produced from millet flour, grape flour, and xanthan gum by Dordevic *et al.,*[2] showed that fortification of baked goods with millets and fruit extracts increased the total polyphenol content and showed the highest antioxidant activity when compared to cutleries made from the combination of plain and millet flour. Hence it can be deduced that functional foods containing more than one food group showed a better nutraceutical profile. Hence, in the current study, the accepted variation of the edible cutlery, viz., variation 2 incorporated ingredients that increased its functionality on positively affecting health on multiple levels. A broader fragment of its utilities regarding oxidative stress, inflammation, cardiovascular health, diabetes mellitus, cancer, etc., are contributed majorly by the presence of individual phytochemicals in it.

Alkyl resorcinol, being phenolic lipids, is considered a vital biomarkers for the major immunological and metabolic processes of the body. In addition, alkyl resorcinols exhibit properties to enhance the functioning of antimicrobial drugs, regulate sirtuin proteins which delay ageing via DNA modulators, prevent the decrease of myofibers induced by denervation, control the Nrf2-ARE pathway to prevent degeneration of neural tissues, inhibit the metastasis of cancerous cells in the colon and prostate by destroying the DNA of the tumorous cells and regulate metabolism in terms of cholesterol and insulin.[22]

The next phytochemical present in the sample is widely known to be present in beetroot. Collated studies have shown betacyanin supplementation reduces tumor formation by curbing the multiplication of cells[23] and elevates the ratio of *Bacteroidetes* to *Firmicutes* and augments the colony of *Akkermansia* species in the human colon to mitigate the concentration of adipocytes, metabolic abnormalities and fat infiltration in the hepatocytes.[24] Catechins - a flavonoid - have been studied extensively to deduce their properties on antioxidant potential, shielding effect against the harmful ultraviolet rays on the skin, inhibitory reaction against allergy and inflammation, and repression against the proliferation of cancer cells.[25]

The subsequent nutraceutical – ferulic acid – is a phenolic acid and is known for its activity in resisting inflammation by decreasing its mediators, inhibiting elevated glycaemic levels in the blood owing to its stimulatory amides on the secretion of insulin and counteracting effect on oxidative damage in pancreatic cells, hindering the occurrence of the carcinoma of the lung and skin by deterring nitrosation reaction to reduce the synthesis of cancerous nitrosamines intrinsically triggering apoptosis, reducing the effect of dietary etiological factors of hepatic disorders like the detrimental causes of alcohol and polyunsaturated fatty acids, constraining the production of leukotriene and oxidative stress in the brain and facilitator of antioxidant sparing action on the cells and tissues exposed to radiations.[26]

Glutathione peroxidase - an enzyme – present in this sample has been sourced from skimmed milk powder. The activity of this enzyme is known to be the principal defence mechanism of the body in terms of antioxidants which portrays an essential purpose in strategizing the holistic protective structure of cells and tissues. Thus, it has been associated with the progression and deterrence of a variety of non-communicable diseases. Synergizing this with selenium has also been shown to also initiate better neural health owing to the ability of this combination to set back and impede the loss of neuronal functions.[27]

Primarily extracted from oranges, this hesperidin – an isoflavone - has been proved by experimental studies to showcase multiple health-promoting benefits. These include its role as a dietary alternative to alleviate metabolic disorders, antagonistic action against depression via a mechanism that is unlike that of the conventional drugs in use, nitric oxide-mediated resistance to cerebral malfunctioning, inhibitory effect on excitotoxic damage in the retina, which results during diabetic retinopathy and glaucoma, prophylactic influence on the advancement of neural degeneration diseases like Alzheimer's Disease, Parkinson's Disease and amyotrophic lateral sclerosis, blood glucose lowering mechanism post meals, lipid regulating action in the plasma and hepatoprotective effects.[28]

Various types of diets rich in lignan - a phytoestrogen - have been studied all around the world to give conclusive evidence on its repressive effect in the development of carcinoma of the colonic cells and cells of the mammary glands post menopause, depress the probability for the occurrence of cardiovascular malfunctions by exhibiting cholesterol lowing, endothelial protective

and hypotensive functions. In addition to these, lignan has also shown a beneficial effect in reducing the stakes of cognitive malfunctions and regulating the levels of inflammatory biomarkers.[29]

Predominantly known for their ruinous effects and soapy foam formation, saponins - a non-carotenoid terpenoid - have now created an enticing profile for themselves about their constructive roles. It has been clinically proposed that saponins influence the impedance of cancer by positively regulating the immune system, bringing down blood cholesterol concentrations, and delaying glycaemic response in the blood. Apart from these, saponin has proven its effects in reversing lead poisoning, preventing renal calculi, depressing excessive levels of calcium in the urine, hindering platelet accumulation, and counteracting dental caries.[30]

Multiple studies have presented the role of zeaxanthin - a carotenoid terpenoid - in preventing oxidative damage via reactive oxygen species, in a reversal of age-related macular degeneration as its supplementation leads to the lowered synthesis of lipofuscin, as a potent hepatoprotective agent, in promoting anti-atherogenicity by facilitating hyperplasia of high-density lipoproteins as its carrier, and in positively fostering skin health by offering a shield against the detrimental ultraviolet rays and delaying the ageing process. But those same studies have also stated the unavailability of long-term evidence of the said claims and hence suggested the conduction of further research to substantiate the assertions.[31]

Economically, the cutlery concocted in the present study has proven to be affordable when compared to its equals present in the market, as it has been manufactured from locally available ingredients.

Compared with industry standards, the manufacturing cost has proved to be quite competitive, as tabulated in Table 8.

Table 8: Cost comparison with commercially available edible cutlery.

Product	Ingredients	Cost per piece (in Rs.)
Trishula incredibles-Gujarat	Wheat flour, Brown rice flour, Corn flour, Chickpea flour, Oat flour, Natural flavouring agent	3-6
Bocado – USA	Bleached wheat flour, Water, Salt, and Olive oil	390
Ediwares – Haryana	Millet flour, Wheat flour, wheat bran, Brown rice flour, Oat flour, Chickpea flour	4.50
Edible cutlery (Product in the current study)	Whole wheat flour, Foxtail millet flour, Roasted Bengal gram flour, Skimmed milk powder, Orange powder, and Beetroot extract.	2

It can be concluded that the edible cutlery formulated in this study has a manufacturing price which allows a profit margin for the developer and a better raw ingredient profile compared to its contemporaries.

Environmentally, edible cutlery can pave the way for sustainable development as it will cut down the expanding plastic waste annually. It will also dissipate the adverse effects of plastic usage on health due to its chemical leaching into our food. A similar study has stated that this type of edible utensils help to achieve sustainable development goal -3 by ensuring healthy lives and promoting well-being for all at all ages and sustainable development goal-13 by taking urgent action to combat climate change and its impacts.[32]

LIMITATIONS

In this study, the focus is on edible cutlery. Not many people use cutlery for food intake. The quantity of consumption of nutrients through edible cutlery will also be meagre. Hence experimentation on edible crockeries may prove to have a higher impact on the nutritional status, health and environment.

STRENGTHS

This study specifies that incorporating Edible Cutleries into our daily diet will not only enhance our nutritional status but also save the planet from the plastic waste load. Hence, a demand-supply relationship driven by guidelines to ban plastic cutleries and the implementation of trade policies to popularise the sale of these Edible Cutleries is required.

CONCLUSION

The development of edible cutlery from the composite blend of five food groups led to an innovative way to combat nutritional as well as environmental hurdles faced by society in the present times. Variation 2 of the edible cutlery, consisting of an equimolar ratio of whole wheat flour and foxtail millet along with ingredients from the other four food groups, exhibited the maximum stability in structural, sensory, and functionality potential, thereby making it the best choice. Thus, these edible cutleries are recommended to be commercialized, marketed, and advertised effectively to increase their popularity among the masses. Awareness should be spread about its effect on our nutritional status, health, and environment. Varied innovative production technologies to enhance the diversification of this product should be introduced to facilitate easier incorporation in life.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATION

SD: Standard Deviation.

REFERENCES

1. Dybka-Stępień K, Antolak H, Kmiotek M, Piechota D, Koziróg A. Disposable food packaging and servingmaterials—trends and biodegradability. Polymers. 2021;13(20):3606. doi: 10.3390/polym13203606, PMID 34685364.
2. Dordevic D, Necasova L, Antonic B, Jancikova S, Tremlová B. Plastic cutlery alternative: case study with biodegradablespoons. Foods. 2021;10(7):1612. doi: 10.3390/foods10071612, PMID 34359482.
3. Chang S. Back to basics: all about My Plate food groups. United States Department of Agriculture; 2013.
4. Srilakshmi B. Menu planning. In: Dietetics. 7th ed. Place: New Age International Publishers; 2014;9.
5. Auestad N, Hurley JS, Fulgoni VL, Schweitzer CM. Contribution of food groups to energy and nutrient intakes in five developed countries. Nutrients. 2015;7(6):4593-618. doi: 10.3390/nu7064593, PMID 26061017.
6. Carson TL, Desmond R, Hardy S, Townsend S, Ard JD, Meneses K, *et al*. A study of the relationship between food group recommendations and perceived stress: findings from black women in the Deep South. J Obes. 2015;2015:203164-. doi: 10.1155/2015/203164, PMID 25821595.
7. Tanwar B, Modgil R, Sharma P. Preparation and nutritional quality evaluation of edible spoons. Indian Agriculture: present Situation, Challenges, Remedies and Road Map presented at CSKHPAU. Vols. 08/2012. Himachal Pradesh.
8. Ikechukwu P, Damaris Chinwendu O, Kabuo N, Ikechukwu AP, Okafor DC, Kabuo NO, *et al*. Production and evaluation of cookies from whole wheat and date palm fruit pulp as sugar substitute. Int J Adv Eng Tech Managapp Sci. 2017;4:1-31.
9. Heymann H, Lawless HT. Sensory evaluation of food: principles and practices. Springer; 2013.
10. Woollard DC, Indyk HE. Rapid determination of thiamine, riboflavin, pyridoxine, and niacinamide in Infant Formulas by liquid chromatography. J AOAC Int. 2002;85(4):945-51. doi: 10.1093/jaoac/85.4.945, PMID 12180692.
11. In AOAC. Approved methods of association of official analytical chemist. 11th ed, Place: Washington.DC; 2010;345.
12. Sofowara A. Medicinal plants and Traditional medicine in Africa. Ibadan, Nigeria: Spectrum Books Ltd; 1993;191-289.
13. Trease GE, Evans WC. Phenols and phenolic glycosides. In: Textbook of.
14. Harborne JB. Phytochemical methods. A Guide to Modern Technique of Plant analysis. London: Chapman and Hall; 1984;78-210.
15. Marcotte M. Heat and mass transfer during baking. In: Wittrans actions on state of the art in science and engineering; 2007;239-65. doi: 10.2495/978-1-85312-932-2/08.
16. Aydogdu A, Sumnu G, Sahin S. Effects of addition of different fibers on rheological characteristics of cake batter and quality of cakes. J Food Sci Technol. 2018;55(2):667-77. doi: 10.1007/s13197-017-2976-y, PMID 29391631.
17. Jemziya MBF, Mahendran T. Physical quality characters of cookies produced from composite blends of wheat and sweet potato flour. Ruhuna J Sci. 2017;8(1):12. doi: 10.4038/rjs.v8i1.23.
18. Patil HN, Sinhal P. A study on edible cutlery: an alternative for conventional ones. Atithya J Hosp. 2018;4(1):45-51.
19. Rajendran SP, Saravanan A, Namachivayam GK, Jambunathan J, Ramachandran G. Optimization of composition for preparation of edible cutlery using Response Surface Methodology (RSM). AIP Conf Proc. 2020;2240(1):050001. doi: 10.1063/5.0011042.
20. Recommended dietary allowances. In: Nutrient requirements for Indians, place. Indian Council for Medical Research – National Institute of Nutrition; 2020.
21. Sood S, Deepshikha. Development and quality evaluation of edible plate. Arch J Nutr Growth. 2018;4(2):1-4. doi: 10.20431/2455-2550.0402001.
22. Zabolotneva AA, Shatova OP, Sadova AA, Shestopalov AV, Roumiantsev SA. An overview of alkyl resorcinols biological properties and effects. J Nutr Metab. 2022;2022:4667607. doi: 10.1155/2022/4667607, PMID 35036005.
23. Clifford T, Howatson G, West DJ, Stevenson EJ. The potential benefits of red beetroot supplementation in health and disease. Nutrients. 2015;7(4):2801-22. doi: 10.3390/nu7042801, PMID 25875121.
24. Zhu M-J. Chapter 24. Dietary polyphenols, gut microbiota, and intestinal epithelial health. In: Bagchi D, Nair S, editors. Nutritional and therapeutic interventions for diabetes and metabolicsyndrome. 2nd ed. Academic Press; 2018;295-314.
25. Bae J, Kim N, Shin Y, Kim S-Y, Kim Y-J. Activity of catechins and their applications. Biomed Dermatol. 2020;4(1):8. doi: 10.1186/s41702-020-0057-8.
26. Srinivasan M, Sudheer AR, Menon VP. Ferulic acid: therapeutic potential through its antioxidant property. J Clin Biochem Nutr. 2007;40(2):92-100. doi: 10.3164/jcbn.40.92, PMID 18188410.
27. Sarıkaya E, Doğan S. Glutathione peroxidase in health and diseases. In: Bagatini MD, editor. Glutathione system and oxidativestress in health and disease; 2020.
28. Maldonado MJM, Xavier PCN, Martins AS, Palhares DB. Hesperidin flavonoids from orange peel show benefits for human health. Agric Res Tech Open Access. 2020;25(1):37-8. doi: 10.19080/ARTOAJ.2020.25.556292.
29. Rodríguez-García C, Sánchez-Quesada C, Toledo E, Delgado-Rodríguez M, Gaforio JJ. Naturally lignan-richfoods: A dietary tool for Health Promotion? Molecules. 2019;24(5):917. doi: 10.3390/molecules24050917, PMID 30845651.
30. Shi J, Arunasalam K, Yeung D, Kakuda Y, Mittal G, Jiang Y. Saponins from edible legumes: chemistry, processing, and health benefits. J Med Food. 2004;7(1):67-78. doi: 10.1089/109662004322984734, PMID 15117556.
31. Murillo AG, Hu S, Fernandez ML. Zeaxanthin: Metabolism, properties, and antioxidant protection of eyes, heart, liver, and skin. Antioxidants (Basel). 2019;8(9):390. doi: 10.3390/antiox8090390, PMID 31514298.
32. Roy TR, Morya S. Edible cutlery: an eco-friendly replacement for plastic cutlery. J Appl Nat Sci. 2022;14(3):835-43. doi: 10.31018/jans.v14i3.3627.

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