The Pharma Innovation Journal 2023; 12(5): 4259-4263

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(5): 4259-4263

www.thepharmajournal.com
Received: 15-03-2023
Accepted: 23-04-2023

K Sindhu
College of Food Science and Technology, Rudrur Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

R Swamy
Associate Dean, College of Food Science and Technology, Rudrur Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

M Prashanthi
Assistant Professor, College of Food Science and Technology, Rudrur Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Corresponding Author:
K Sindhu
College of Food Science and Technology, Rudrur Professor Jayashankar Telangana State Agricultural University, Hyderabad, Telangana, India

Enrichment of edible spoons with natural colours

K Sindhu, R Swamy and M Prashanthi

Abstract
Plastics are a mixture of organic polymers that play a major role in environmental pollution around the world. One way to reduce the waste caused by using plastic, especially single-use plastic, could be to produce eco-friendly cutlery. In this study, the control sample was made from a combination of sorghum, wheat and rice flour, guar gum in different proportions, the control sample with (40:40:20) proportion of sorghum, wheat and rice flour was standardized and the spoons were made in three different colours using extracts of beetroot, spinach and jamun instead of water, not only to give colour but also to add nutritional value to the spoon. The edible spoons were analysed for nutritional parameters such as moisture, ash, fat and protein content using standard methods. The textural properties of the edible spoons were studied using CT3 Texture analyser by determining their hardness, and the spoons made with spinach extract exhibited more resistance to compression with hardness of 4.76N compared to the other spoons. The colour properties were studied using Hunter lab colorimeter. Among all the samples the chroma is higher for control sample-2 (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). As the main aim of the study is to develop the bio-degradable spoons with natural colours, the biodegradability properties were studied using soil burial test where complete decay was observed in 5 to 7 days, thus the single use plastic can be replaced by the edible spoons contributing to the reduce in usage of plastic spoons.

Keywords: edible cutlery, plastic, millets, pollution, natural colors, biodegradability

Introduction
In this fast-paced modern world, almost everyone is engaged in work. Therefore, they find it difficult to cook or wash daily utensils (Vadera *et al*., 2021). The demand for plastic containers has been steadily increasing over the past decades. The use is harmful to the human body due to the presence of toxins and carcinogens. This is also a matter of great concern, currently the environmental impact is due to the excessive amount of non-biodegradable waste that is thrown away every day (Sangeetha Sood *et al*., 2018) [20]. Edible cutlery is an upcoming line of plant-based utensils that are completely safe to eat and considered a boon to the ecosystem.
These edible cutleries are a perfect alternative to harmful plastic cutlery, they are not only safe for the environment but are also enriched with nutritious ingredients (Bakeys, 2019) [19]. The product is aimed to enhance the lives of the people by eliminating the need and use of plastic cutleries and protecting the ecosystem. It can be made from edible ingredients such as rice, wheat and sorghum (millet or jowar), which serves as the core elements (Sadat Rashid 2019). Sorghum was chosen as a primary ingredient for its tough quality (it doesn't go soggy in liquids) and because it is suitable for cultivation in semi-arid areas. It tastes like a dry cracker because there is low fat in it. It can complement any food. Even if the spoons are dumped after use, they decompose in a few days (Yogithabhagil *et al*., 2019).
This edible cutlery can be called as ready to eat because these do not need any further preparation. Edible cutlery can be used as utensils and solid & semi-solids things can be served in it. They do not get soggy quickly. These are environment friendly as they can easily discarded and eaten by animals. In addition, if we look at it from the user's point of view edible cutlery can be a joyful experience on the table as it also keeps the user excited to taste it after finishing the meal. One can also enjoy the taste of different flavours and colours, it can be nutritious as well. Since we always throw the plastic cutlery after its use, edible cutlery can just dissolve in the soil as it is made of food grains. Every food sector service can use it to make the environment cleaner.

Material and Methods

Experimental materials

The raw materials used are broken rice collected from nearby rice mill, sorghum, wheat, guar gum, beetroot, spinach, jamun fruits were purchased from local market Bodhan, Nizamabad district, Telangana state. The chemical, sorbic acid was purchased from Telangana Scientific Pvt Ltd, Hyderabad, Telangana state.

Extraction of juice from beetroot/spinach/jamun fruits

Beetroot, spinach and jamun fruits were collected from the local market. The collected beetroot, spinach and jamun fruits were cleaned and washed with clean water. Blanching was done at 102 ºC for different time intervals i.e., 1, 2 and 3 minutes to get the better color retention in the extracted juice. The blanched material was pressed to remove the excess water. The pulp was collected by grinding them in a mixer and extracted pulp was then strained using muslin cloth. This extracted juice was added to the flour for preparation of dough instead of water while mixing the dough. The main aim of adding extracted juice in preparation of dough is to improve color by adding natural color to the spoons.

Preparation of edible spoons

The samples were made taking equal proportions of sorghum, wheat flour and the proportion of rice flour varies in each sample. Using these proportions (40:40:20), (42.5:42.5:15), (45:45:10) the edible spoons were prepared and based on the texture and strength the control sample was standardized. The standardised control sample proportion was used to prepare edible spoons in different colours.

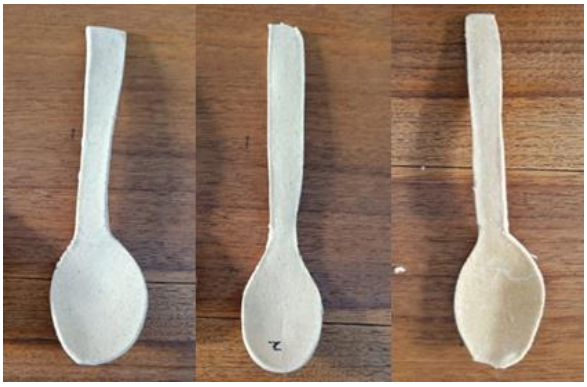
First, broken rice, wheat and sorghum were taken and milled, and the flour was weighed according to the standardised composition into a bowl. Sorbic acid of 1.0% was added to the bowl, the main purpose of adding sorbic acid is to increase the shelf life of the spoons as it acts as anti-fungal agent. Guar gum was added to water for proper binding and mixing of dough. The dough was obtained by kneading the flour with water and gets firmer, with good consistency and viscosity. Water (nearly 120 ml) is used for preparation of dough. Then the dough was rolled into sheets of same thickness and moulded into spoon shape. The moulded spoons were allowed for drying at 160 ºC for 2 h in hot air oven. The dried spoons were cooled to room temperature. Packing was done in airtight packaging and stored in dry places.

Sorghum flour, wheat and rice flour
↓
Addition of sorbic acid @1.0%
↓
Mixing of all ingredients
↓
Addition of guar gum to water/extracted juice
↓
Knead to make smooth dough
↓
Fill into the spoon mould
↓
Bake the spoons at 160ºC for 2 hr in hot air oven
↓
Allow to cool
↓
Packing in airtight polythene bags
↓
Store in dry place

Fig 1: Flowchart for the preparation of Edible spoon

Table 1: Standardization of control sample with different proportion of ingredients

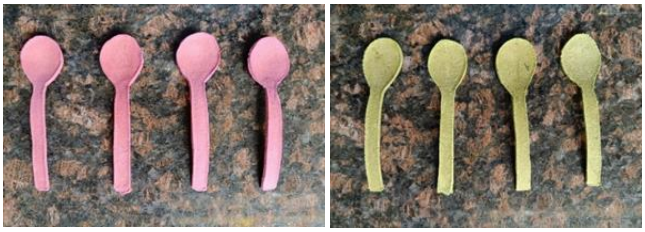
Ingredients	Sample 1	Sample 2	Sample 3
Sorghum flour	40 g	42.5 g	45 g
Wheat flour	40 g	42.5 g	45 g
Rice flour	20 g	15 g	10 g
Guar gum	2 g	2 g	2 g
Water	120 ml	120 ml	120 ml



Sample 1 Sample 2 Sample 3

Plate 1: Control sample of different proportions

Using the standardized proportion of control sample, the edible spoons were made in three different natural colours by using the extract of beetroot, spinach and jamun instead of water.



a) T_1 **b) T_2**

c) T_3

Plate 2: Edible spoons prepared using extract of a) T_1-beetroot, b) T_2-spinach and c) T_3-jamun

Physico-chemical analysis

Proximate Analysis

Using Official Methods of Analysis, the edible spoons were estimated for proximate analysis *viz*., moisture, ash, protein and fat content.

Estimation of moisture content is done by oven drying method (AOAC, 2005) [3]

5g of the sample was taken into a pre-weighed petri dish. The dish was then placed in a hot air oven at 130°C for 2 hours.

The dish was cooled in a desiccator and weighed. Moisture percent by weight was then calculated using the formula;

$$\text{Moisture (\%)} = \frac{W2-W3}{W2-W1} \times 100$$

Where,
W_1 = weight of the Petri dish
W_2 = weight of the sample along with petri dish
W_3 = weight of Petri dish after drying

Estimation of ash content is determined by using (AOAC 2016) [4] method

5 g of the sample was taken in a pre-weighed silica crucible. The crucible was placed in a muffle furnace at 550-600°C for 4-6 hours. It was then cooled in a desiccator and weighed. Ash content was determined using the formula

$$\text{Ash (\%)} = \frac{W3-W2}{W1} \times 100$$

Where,
Weight of the crucible (W_1) g
Weight of the crucible + sample (W_2) g
Weight of the crucible + ash (W_3) g

Estimation of protein content is done by Kjeldhal method

Protein content was determined using kjeldahl method using automated kjeldahl apparatus by weighing 0.5 g of sample into the digestion tube, adding 10 ml of conc. H_2SO_4 and 2g of digestion activator to the digestion tube allowed for digestion followed by neutralization & distillation, titration with 0.1 N HCl.

The percentage of nitrogen present in sample given by: $\frac{(\text{sample titre value} - \text{blank titre}) \times \text{normality of HCl} \times 14 \times 100}{\text{wt of sample} \times 1000}$
Protein content (g) = % nitrogen ×6.25

Estimation of fat content is determined by using Soxhlet apparatus method given by (AOAC, 1990) [2]

The amount of fat was determined by using Soxhlet apparatus method given by (AOAC, 1990) [2]. The dry sample (5-10 g) is weighed accurately into a thimble and extracted with petroleum ether (60-80 B.P) for about 16 hours using Soxhlet apparatus. The ether extract is filtered into a weighed beaker. The flask is rinsed 4-5 times with small quantities of petroleum ether added to the beaker, Petroleum ether is removed by evaporation and the flask with the residue dried in an oven at 80-100 °C, cooled in a desiccator and weighed.

$$\text{\% Crude fat} = (W2 - W1) \times 100 \backslash S$$

Where,
Weight of empty flask (g) = W1
Weight of flask and extracted fat (g) = W2
Weight of sample = S

Texture analysis

The texture of edible spoons was analysed using 60mm three-point bend knife edge probe in Texture Analyser (Model: CT3 Texture analyser). For TPA test, the edible spoons were placed on the fixture base table and the test speed was set to 1mm/sec and the probe compressed the spoon based on the force deformation the hardness of the spoon was determined.

Color analysis

Color of edible spoons was measured based on the international commission on illumination of colour parameters L* (0-100, Black- lightness), a*(positive values - red, negative values - green and 0 is neutral) and b* (positive values – yellow, negative values – blue and 0 is neutral). Hunter lab colorimeter (Colour flex benchtop spectrophotometer) was used to measure the color parameters. Results were expressed as the mean of three measurements. The overall color difference (**ΔE***) can be calculated using Eqn.

$$\Delta E^* = (L_0^* - L_1^*)^2 + (a_0^* - a_1^*)^2 + (b_0^* - b_1^*)^2$$

Biodegradability tests (soil burial test)

Sheets used for preparing edible cutlery were cut into pieces and the samples of sheets were buried into the sterile soil for specified amount of time and gradual biodegradation of samples was checked on daily basis (Leja and Lewandowicz 2010).

Results and discussion

Standardisation of control sample

Among three different proportions of control samples, sample 1 made with 40% sorghum flour, 40% wheat flour and 20% rice flour is having good texture compared to sample 2 with 42.5 % sorghum flour, 42.5% wheat flour and 15% rice flour and sample 3 with sorghum, wheat and rice flours in ratio 45:45:10. Based on the strength and textural properties the control sample was standardized. The Sample 2 and 3 were brittle in nature, due to which there was a breakage in the spoons observed and the sample 1 was standardized as it was good in texture, strength and no breakage was observed in the sample. Using the sample 1 composition edible spoons were made into 3 different colours by adding 2g of guar gum in 120ml of extracted juice of beetroot/spinach/jamun.

Proximate analysis

Table 2 represents the result of proximate analysis of control sample and edible spoons made of natural colours. This analysis encompassed the moisture, ash, protein and fat content.

Table 2: Proximate analysis of edible spoons made using extract of beetroot, spinach and jamun

S. No.	Moisture (%)	Ash (%)	Protein(g)	Fat (%)
Control sample	5.32	1.38	3.85	1.6
T_1 - Beetroot	5.57	2.17	4.55	1.57
T_2 - Spinach	5.83	1.78	4.375	1.49
T_3 - Jamun	5.65	1.63	4.025	1.55

Estimation of moisture content

It was observed that there was a significant difference in the moisture content. The moisture content of T_2 was high when compared to T_1, T_3 and control sample [Table2]. The spinach has high water holding capacity and this property might have contributed to high moisture content in T_2.

Estimation of ash content

The highest ash content was found in edible spoons prepared from beetroot extract (T_1) is 2.17% whereas, the lowest ash content was observed in control sample i.e., 1.38%.

Estimation of protein content

Protein content in all the edible spoons i.e., control sample, T_1, T_2 and T_3 was estimated which revealed approximately equal amounts of protein in T_1, T_2 and T_3. The level of protein in edible spoons made of beetroot extract is found to be high. From the above findings, it can be inferred that T_1 has higher nutritive value, followed by T_2 and finally T_3.

Estimation of fat content

The amount of fat in each spoon i.e., control sample, T_1, T_2, and T_3 was measured in order to understand the Physico-chemical characteristics of the edible spoons (mouth feel, flavour, and appearance). As shown in Table 1, it was found that the control sample had the most fat, whereas the other three samples (T_1, T_2, and T_3) had comparatively less fat (Table 2).

Color analysis

The results of colour analysis for the edible spoons enriched with natural colours is depicted in the Table 3. The L*a*b* values produced by the analysis were used to measure chroma, hue and ΔE. ΔE is the difference between the displayed color and the original color standard of the input content.

Table 3: Color analysis of edible spoons

Samples	L*	a*	b*	Chroma	Hue	ΔE
Control sample 1	61.67	4.16	22.05	22.43	79.31	4.52
Control sample-2	63.22	5.95	25.91	26.58	77.06	
Beetroot-1	33.95	10.94	13.39	17.29	50.75	10.05
Beetroot-2	43.05	13.62	16.72	21.56	50.83	
Spinach-1	37.68	2.13	18.69	18.81	83.49	5.40
Spinach-2	41.87	2.29	22.11	22.22	84.08	
Jamun-1	46.05	9.87	15.05	17.99	56.74	3.90
Jamun-2	49.70	10.57	16.24	19.37	56.94	

Texture analysis

The textural properties of the spoons were studied using texture analyser. The hardness values for edible spoons were depicted in the Table 4

Table 4: Hardness of edible spoons

Sample names	Hardness
Control sample	7.95
T1 - Beet root	15.15
T2 - spinach	4.76
T3 - jamun	15.4

Hardness of edible spoons were recorded by the Brookfield Texture analyser. Hardness for control sample is 7.95 N, T_1-Beetroot is 15.15 N, T_2-Spinach is 4.76N and T_3-jamun is 15.40N. T_2 Spinach sample exhibited more resistance to compression compared to control sample, T1 Beetroot, T_3 jamun sample.

Biodegradability Test

The results were found to be satisfactory; various samples of sheets used to make edible spoons were totally decomposed in sterile soil in 5 to 7 days. Each sample decomposed gradually into smaller bits over the period of 3 to 4 days, and the full degradation was seen in 5 to 7 days. The biodegradability test is a laborious procedure, yet the cutlery used in the current study degraded completely in about 5 to 7 days (Leja and Lewandowicz 2010). The microorganisms in the soil and the organic materials present may be responsible for the prepared sheet's degrading process. The material is converted by the microorganisms through metabolic or enzymatic reactions. The two mechanisms that enable are growth and co-metabolism. In growth, complete degradation of substance buried in the soil is carried out to convert it into carbon and energy.

Conclusion

From an application-oriented point of view, and in order to improve performance of edible tableware. The edible spoons developed in this study, as a sustainable alternative to single-use plastic and these spoons are nutritious that can be eaten or disposed in a compost pit, or they can be eaten by animals. It will take a week for them to biodegrade, as opposed to plastic which takes nearly 500 years. Everyone is aware of the damage of single-use plastic cutlery items can cause to the environment and water bodies. Plastics last for hundreds of years that can affect our health in more ways than one. As per the findings of the research work, the edible spoons prepared from the extracts of beetroot, spinach and jamun was the best in terms of overall appeal. They exhibited minimal moisture content and the highest protein content as well. Future work in this field can be carried out by focusing on improving the cutlery by processing the fruit waste to achieve a more durable product. Various other fruit wastes too can be incorporated into making edible tableware with low-cost binders. The concept of edible spoons with natural colours using extracts of beetroot, spinach and jamun as the key ingredient may be a relatively new one, an initiative which can benefit both humanity and the environment at large.

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