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MILLET-BASED EDIBLE CUTLERY (SPOONS): A SUSTAINABLE ALTERNATIVE TO PLASTIC WASTE

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ABSTRACT
The push to minimize plastic waste has led to innovative solutions, with edible cutlery emerging as a sustainable alternative. A study focused on creating millet-based edible cutlery. The formulation included wheat, sorghum, rice, and ragi flours, along with salt, sugar, jaggery, guar gum, butter, skimmed milk powder and chocolate powder to improve texture, flavour, and nutrition. The edible spoons were baked at 200°C for 18–20 minutes in a convection microwave oven, ensuring uniform structure and durability. The research assessed essential Physico-Chemical Properties, Texture Analysis and Organoleptic properties like carbohydrate and protein levels, water absorption capacity (WAC), moisture content, hardness, fracturability, and colour quality. Using Response Surface Methodology (RSM), the optimal formulation was determined to include 6g of ragi flour, 2g of guar gum, and 4g of jaggery, achieving a desirability score of 94%. The resulting spoons displayed excellent properties, such as high hardness (3300.27g), optimal fracturability (-27.15mm), and balanced protein (12.21%) and carbohydrate (26.19%) content. Their Water Absorption Capacity of 14.19% indicated good moisture retention while maintaining firmness. Additionally, the spoons showed acceptable moisture content and appealing colour, enhancing their sensory attributes and shelf life. Moreover, we also calculated the cost estimation of millet based edible cutlery(spoon) which is Rs. 0.92/- per unit. These millet-based spoons are an affordable and eco-friendly alternative to plastic utensils. This innovation not only offers a healthier, biodegradable option for daily use but also plays a significant role in reducing plastic pollution and supporting sustainable practices, paving the way for a greener future.

Keywords:
Edible Cutlery, Response Surface Methodology (RSM), Physico-Chemical Properties, Texture Analysis, Cost Estimation

INTRODUCTION

Edible cutlery offers a sustainable alternative to plastic utensils, addressing the significant environmental challenges posed by plastic waste. While plastic cutlery gained popularity for its affordability and convenience, its non-biodegradable nature has caused severe ecological harm by polluting waterways, endangering marine life, and persisting in ecosystems for centuries (Thagunna et al., 2023). Made from natural ingredients like sorghum, rice, wheat, and millet, edible cutlery is biodegradable and doubles as both functional utensils and edible snacks.

Sorghum
It is a resilient and nutritious ingredient, is commonly used, and the manufacturing process involves shaping dough and baking or drying it for durability. It is a significant cereal crop in India, is known for its high absorbent capacity, making it an ideal material for edible cutlery (Anitha et al., 2021).

Wheat flour
It is valued for its proteins, gliadin and glutenin, which form a gluten network when mixed with water, providing elasticity and shape retention during baking (Thagunna et al., 2023).

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Rice flour
The properties of rice flour, including its dispersibility (ranging from 58% to 67.5%), are influenced by factors such as the type of grinding method (semi-dry vs. wet) and its amylopectin content, which is crucial for viscosity and waxiness in food (Joy, 2016).
Finger millet
It is a common food in South India (Rajendran et al., 2020), is rich in essential amino acids, and its tannin content can affect protein digestibility, influencing the physical and sensory properties of the cutlery (Gull et al., 2014).
Guar gum
Guar gum and glycerol monostearate improve the consistency of dough and texture in products like biscuits, especially when combined with maltodextrin, which helps reduce fat content (Kumar et al., 2021).
Jaggery
It is a traditional sweetener, serves as a binding agent, ensuring structural integrity (Deshmukh et al., 2017).
Skimmed milk powder (SMP)
SMP made by evaporating pasteurized skimmed milk, is rich in protein and low in fat, offering essential nutrients.
Cocoa powder
It is valued for its flavour and antioxidant content, contributes to heart health, mood, and cognitive function when consumed in moderation (Kumar et al., 2021). These ingredients work together to create sustainable, high-quality edible cutlery.
Available in various flavours and textures, edible utensils enhance dining experiences while promoting creativity in meal presentation. Their ability to decompose naturally within days significantly reduces environmental impact, offering a practical solution to the growing plastic crisis (Sharma M. P., 2023). By integrating edible cutlery into everyday practices, we can reduce plastic pollution, encourage sustainable consumption, and create a harmonious balance between convenience and environmental responsibility.

OBJECTIVES

The main objective of the study is to develop the millet based edible cutlery and study the various Physico-Chemical, texture analysis and organoleptic properties evaluation of millet based edible cutlery.

METHODOLOGY

Preparation of edible cutlery

Sr. No.	Materials	Weight (g) (for 100 gm batch)
1.	Wheat flour	15
2.	Rice flour	15
3.	Sorghum flour	15
4.	Skimmed milk powder	10
5.	Butter	1.5
6.	Sugar	20
7.	Salt	01
8.	Cocoa powder	03
9.	Water	20-25

Table 1 Ingredients used for making dough

Different flours and ingredients were purchased locally from Godhra market during study. The ingredients used in making of the edible cutlery, namely, Wheat flour, Rice flour, Sorghum flour, Ragi or Finger millet, Guar gum, Jaggery, Skimmed milk powder, Butter, Sugar, Salt, Cocoa powder, and Water. The edible cutlery was prepared as per the standard flow chart shown.

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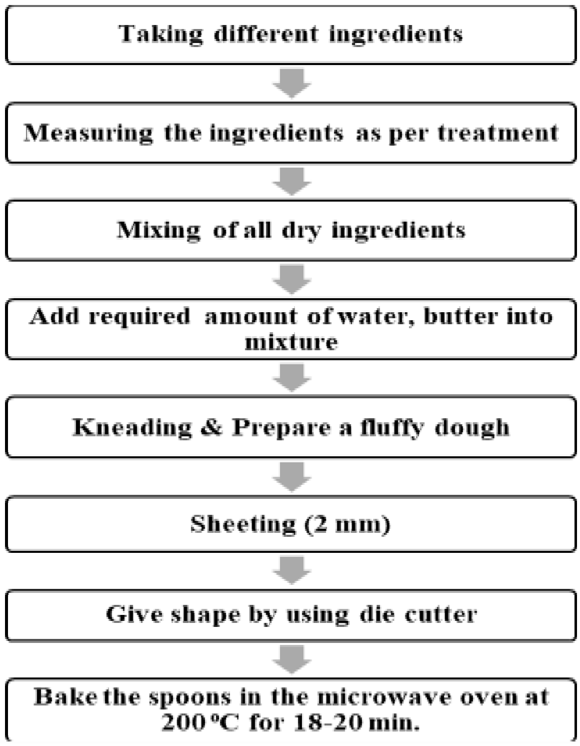

Fig 1 Process Flowchart of edible cutlery(spoons)

Optimization Using RSM

Response Surface Methodology (RSM) was employed in the experimental design to model and analyse the impact of multiple variables on the desired response, with the goal of optimizing this response. A key benefit of RSM is its ability to minimize the number of experimental runs required to generate statistically reliable results. Edible cutlery was produced using various process formulations and a conventional drying technique. The experiment utilized a Central Composite Rotatable Design (CCRD) with three process variables; each tested at five levels. A total of 20 experiments were conducted, and the interactions among the variables were analysed using RSM to evaluate their effects on the physico-chemical properties, sensory attributes, and colour values of the dried product.

Fig 2 Edible cutlery (spoons)

Physico-Chemical Analysis of Edible Cutlery

Physico-Chemical Analysis: Protein and carbohydrate contents were determined using standard biochemical methods. Moisture content and water absorption capacity were evaluated.

Determination of protein

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The protein content in the edible cutlery samples was determined using the Folin-Lowry assay, a widely used method described by (Lowry et al., 1951). A 0.1 g sample was extracted with 10 ml of 0.1 N NaOH, heated at 65°C for 6 hours, then cooled and centrifuged. For analysis, the supernatant was collected. After the sample was reacted with an alkaline copper solution and the Folin-Ciocalteau reagent, sample and standard aliquots were made, and the absorbance was obtained at 660 nm. The protein concentration was calculated by comparing the absorbance of the sample to a BSA standard curve, providing an accurate measurement of true protein levels in the sample (Lowry et al., 1951).

Determination of carbohydrates

The total carbohydrate content was estimated using the phenol-sulfuric acid method. In this process, a 0.1 g sample was hydrolysed with 2.5 N HCl for 3 hours, then centrifuged and diluted. After that, 96% sulfuric acid and 5% phenol were added to the sample. The absorbance at 490 nm was measured with a UV-Visible spectrophotometer. This method allowed for an accurate estimation of the carbohydrate content present in the edible cutlery, as the phenol-sulfuric acid reaction produces a color change that correlates with the carbohydrate concentration (Dordevic et al., 2021).

Determination of vitamin C

To determine the Vitamin C content in the edible cutlery, the titrimetric method was employed. Reagents used included 4% oxalic acid, an ascorbic acid standard solution, and a dye solution containing sodium bicarbonate and 2,6-dichlorophenol indophenol. A working standard was prepared by diluting 1 ml of the standard solution with 10 ml of 4% oxalic acid. The test involved titrating 5 ml of the working standard with dye until a pink endpoint was reached (V1). A 5 g sample was then extracted using 4% oxalic acid, centrifuged, and diluted to 50 ml. After this, a 5 ml aliquot of the sample was titrated with dye (V2), and the Vitamin C content was calculated based on the volume of dye used (Sharma et.al., 2023).

Determination of moisture content (dry basis)

The moisture content of the edible cutlery was determined using the oven-drying method. A precisely weighed 2g sample was placed in a pre-weighed petri plate. For 3 to 4 hours, the sample-containing petri plate was heated to 110°C in a hot-air oven. After drying, the sample was chilled in the desiccator and weighed. The process was repeated until a constant weight was achieved, allowing the determination of moisture content based on the weight loss during drying (Thagunna et al., 2023).

Determination of Water Absorption Capacity

The water absorption capacity of the edible cutlery was measured by submerging the spoons in water for a fixed period. After the set time, the sample was taken from the water and any extra surface water was cleaned off using tissue paper (Pastor-Cavada et al., 2011). This process helped to assess the water absorption characteristics of the edible cutlery, which is important for understanding its texture andusability during consumption (Kabir & Hamidon, 2021).

Texture Analysis

The texture of edible cutlery was assessed using the TA.XT plus Texture Analyzer (Stable Micro Systems, Surrey, UK) paired with Exponent software. A three-point bending rig with dimensions of 240 × 90 mm was employed for the tests. Prior to measurement, the device was calibrated, and each sample was analysed using a program designed to evaluate the hardness and bending resistance of biscuits or cookies. This method, integrated with Exponent software, ensured reliable results. To maintain accuracy, each measurement was conducted at least five times. Compression mode force measurement was one of the testing parameters, along with pre-test, test, and post-test speeds of 1 mm/s, 3 mm/s, and 10 mm/s, respectively. A trigger force of 50 g was applied, and a 3-point bending rig (HDP3PB) equipped with a 5 kg load cell was used for the analysis (Krishnapriya & Jadeesh, 2021).

Determination of Color Values (L*, a*, b*)

The color of the edible cutlery was assessed using the CIELAB color scale, with measurements taken for L*, a*, and b* values. A digital photoelectric colorimeter, was used for this purpose. Calibration of the instrument was performed with a standard white tile, following the procedure outlined in the reference manual. The device was then positioned on the cutlery samples to record the colour values. The CIELAB colour scale defines L* values ranging from 0 (darkness) to 100 (whiteness), positive a* values indicating redness, negative a* values

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indicating greenness, positive b* values signifying yellowness, and negative b* values signifying blueness. Colour measurements were conducted in triplicate to ensure accuracy.

Sensory Evaluation

A panel of 10 participants assessed colour, texture, flavour, and overall acceptability using a 9-point hedonic scale (Amerine et al., 1965).

Figure 3 sensory evaluation of edible cutlery

RESULTS AND DISCUSSION

This section presents the experimental results. It includes the physico-chemical analysis of various ingredient combinations aimed at optimizing the production of edible cutlery. Additionally, the chapter covers the evaluation of the quality of the edible cutlery, assessing the impact of different ingredients and processes on the final product's characteristics. These results provide valuable insights into the development and improvement of edible cutlery, focusing on the key factors that influence its texture, nutritional content, and overall quality.

Protein Content

The protein levels in the edible cutlery varied from 5.03 to 15.33g, with an average of 9.13g. The highest protein concentration was observed when 6g of ragi, 2g of guar gum, and 4g of jaggery were used. This combination provided a balanced amount of protein from ragi, which contains essential amino acids. In contrast, the lowest protein content was found in the mixture of 5g ragi, 1.5g guar gum, and 3.3g jaggery, which resulted in a lower protein concentration. These results highlight how adjusting the ingredient ratios can influence the protein content of the cutlery.

Carbohydrate Content

The carbohydrate content of the edible cutlery ranged from 24.68 to 27.23g, with an average of 26.39g. The highest carbohydrate content was achieved with 5g ragi, 1.5g guar gum, and 6.7g jaggery. Jaggery, being a rich source of sugars, contributed to the higher carbohydrate content. On the other hand, the lowest carbohydrate value was found in the formulation containing 5g ragi, 1.5g guar gum, and 5g jaggery. This indicates that varying the amount of jaggery can significantly affect the carbohydrate content in the edible cutlery.

Moisture Content

The moisture content of the edible cutlery varied between 0.50 and 8.50%, with an average of 4.1%. The highest moisture content was found in the combination of 4g ragi, 1g guar gum, and 6g jaggery, likely due to the water-attracting properties of guar gum. In contrast, the formulation containing 6g ragi, 1g guar gum, and 4g jaggery resulted in the lowest moisture content. The moisture content is crucial for determining the texture and shelf-life of the cutlery, as higher moisture levels generally lead to a softer product and can affect its durability.

Water Absorption Capacity

The water absorption capacity of the edible cutlery ranged from 13.7 to 25.4%, with an average value of 19.8%. The highest water absorption was noted in the combination of 5g ragi, 0.7g guar gum, and 5g jaggery, which likely absorbed more water due to the presence of guar gum, known for its moisture-retaining qualities. In contrast, the lowest water absorption capacity was seen in the combination of 4g ragi, 1g guar gum, and 6g jaggery, which suggests that this mixture was less capable of absorbing water compared to others.

Hardness

The hardness of the edible cutlery ranged from 1743.63 to 4043.96g, with an average of 2704.88g. The formulation of 5g ragi, 0.7g guar gum, and 5g jaggery resulted in the highest hardness, producing a firmer and more rigid product. On the other hand, the lowest hardness was found in the combination of 5g ragi, 1.5g guar gum, and 5g jaggery, yielding a softer texture. The degree of hardness is influenced by the ratio of guar gum, as it affects the dough's consistency and the firmness of the final edible cutlery. These variations in hardness demonstrate the importance of ingredient proportions in determining the structural qualities of the product.

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Cost analysis

The cost of millet-based edible spoons is estimated at Rs. 0.92 per unit. This amount comprises raw material cost, processing cost, electricity cost and labour cost. These spoons' price makes them a sustainable alternative to traditional plastic cutlery, helping to save the environment and provide cost-effective alternatives.

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CONCLUSION

The study was conducted at the Department of Processing and Food Engineering, College of Agricultural Engineering and Technology, Anand Agricultural University, Godhra, Gujarat, with the goal of creating edible cutlery from natural ingredients such as wheat, rice and sorghum flour, ragi, guar gum, jaggery, skimmed milk powder, butter, sugar, salt, cocoa powder, and water. A statistical design technique was utilized to change the quantities of ragi, guar gum, and jaggery. The formulation containing 6g of ragi, 2g of guar gum, and 4g of jaggery was highly effective. It provides essential nutrients, including 12.21% protein, 2.41% Vitamin C, and well-balanced carbohydrates and moisture content. The cutlery also demonstrates desirable physical properties such as hardness (3300.27g), fracturability (-27.15mm), and a water absorption rate of 14.19%, ensuring its usability. This combination offers a sustainable and cost-effective alternative to traditional plastic cutlery, with a cost of Rs. 0.92 per spoon.

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