STUDY OF BIODEGRADATION OF DEVELOPED EDIBLE CUTLERY ENRICHED WITH SAGO & RAGI FLOUR

Abstract

The growing concerns over plastic waste and environmental sustainability have led to exploring alternative solutions, such as edible cutlery. This project focuses on developing edible cutlery using ragi, sago, and black gram flour, which are nutritious, eco-friendly, and locally available ingredients. Ragi (finger millet) provides a rich source of fiber and essential minerals, while sago offers a biodegradable base with a neutral flavor. Black gram flour contributes to the structure and texture, ensuring durability and functionality for use during meals. The project aims to evaluate the feasibility, nutritional profile, and practicality of these edible utensils as a sustainable alternative to conventional plastic cutlery. By producing biodegradable, edible, and nutrient-enriched cutlery, this innovation can significantly reduce plastic pollution and contribute to a more sustainable food service industry. In this study, the selected sample containing raw materials like sago, ragi & black gram flour (20:10:10), with getting high carbohydrate value is 89.54%. The development of this edible cutlery provides a promising step toward addressing global plastic pollution and offers an alternative solution for single-use utensils in the food industry.

Keywords: Edible, Biodegradable, Nutritious, Cutlery.

Commented [HP1]: The study objectives are not well aligned with the methodology employed and the results obtained

Commented [HP2]: The results presented in the abstract are not aligned with those reported in the results and discussion sections

1. Introduction

Edible cutlery is a plant-based product that can be served or taken as a meal. Because it is a blend of flours, it is commonly known as EBO (eco-friendly, biodegradable, and organic). Since 2010, Bakey's, an Indian company, has started selling edible cutlery as a commercial item. Since plastic seriously endangers the environment and humankind, biodegradability and environmental friendliness are the two main arguments for using edible cutlery rather than plastic. Edible cutlery can be made with various ingredients, but some flours provide the desired qualities for the finished product. We need to switch out plastic cutlery with better options, like edible cutlery, because plastic poses a great hazard to the environment (Roy, 2022).

A novel concept is an edible cutlery, which allows the eating implement to be consumed with the food. Despite being domesticated for some time, the concept has not yet gained significant traction in the marketplace or research. Edible cutlery is the answer to the environmental crisis in the plastic world, where the market is expanding at a rate of thirty percent and creating landfills full of non-recyclable waste. Aside from being delicious and healthy, edible cutlery serves the same purpose as disposable cutlery (Chowdhury, 2021).

Some flours, such as sorghum flour, soy flour, whole rice flour, whole rice grain flour, and whole ragi flour, can enhance the physicochemical properties of various raw materials while also offering unique nutritional benefits. Grains reduce the risk of major digestive problems and body problems, coronary heart disease, and others, and are beneficial to health because they are essential to the manufacturing of cutlery. The nutrients included in this cutlery include protein, carbohydrates, micronutrients, and niacin. Various alternative materials, such as by-products of plant waste, are being used to make biodegradable cutlery (Gupta, 2023).

Sago Flour Sago starch is isolated from sago palm *(Metroxylon spp.),* which is better known as 'rumbia' and distributed throughout Southeast Asia. Sago contains pure starch, with 88 percent of carbohydrate. Content, overall, 0.5 percent protein present, and small amounts of fat, and contains only a trace of B vitamins. Finger millet Finger millet is a member of the *Poaceae* family. Finger millet has having secondary name is ragi or madua in India, rapoko in South Africa, or dagusa in Ethiopia (Chowdhury, 2021). This content high level of fiber, protein, and nutritional composition. Black gram *(Phaseolus mungo*) is a legume belonging to the family *Fabaceae* and genus *Phaseolus*. Black gram is a nutritious legume and a good source of protein. The black gram has a good swelling capacity. Corn flour is a kind of flour made from ground dried corn kernels. It is classified as a whole grain flour since it includes the

Commented [HP3]: Give the definition of cutlery,

Referring to the figure 2, it does not align with the definition of the word cutlery.

Commented [HP4]: Please provide the source of reference for this statement.

Commented [HP5]: Please provide the source of reference for this statement.

corn's hull, germ, and endosperm. Its consistency is fine and smooth, similar to that of whole wheat flour. As with all types of flour, corn flour is typically mixed with a binder such as eggs to give form and stability to baked products and other dishes (Gupta, 2023). Powdered sugar, referred to as confectioners' sugar or icing sugar, can occasionally contain an anti-caking agent, like tricalcium phosphate, to avoid clumping. Guar gum functions as a gelling, thickening, clouding, and binding agent. It additionally serves purposes such as emulsification, stabilization, preservation, water retention, and boosting the water-soluble fiber content. In baking, guar gum is utilized to enhance dough yield in baked products. Soybean oil possesses a characteristic primarily dictated by its high polyunsaturated fatty acid content, particularly linoleic acid, which makes up 54.87%. As a result, it remains liquid at lower temperatures and is beneficial for health (Roy et al., 2022).

2. Material and Methods

2.1 Ingredients

The material used in formulating the product was sago flour, ragi flour, black gram flour and corn flour, which were procured from the market.

2.2 Raw Material Collection:

All the raw materials that were required were collected from the local market and prepared for the process. They were first cleaned and washed separately, and dry ingredients by themselves means you will evenly disperse the raising agents, sugar, and flour base, which is important for an even batter. After mixing the grains Sieving is probably the easiest and most widely used method for separating components on a size basis in powders and also for measuring particle size distribution

2.3 Formulation of cutlery

After sieving thin sheet were prepare and mold it with desired shape and size. Preheat the oven at 200 °C ± 5 for 10 min. The molded sheet were dry at 150°C ± 5 for 15 to 20 min. Dry heat involved in baking alters the starch structure of the food item. It allows a baked product to cool to room temperature before removing it from the pan, usually about 5-10 minutes. The grains were ground into edible cutlery, and the formulation was done by taking a total of three trials, as shown in Table 1. All the ingredients were weighed separately and utilized in the proper proportion. The edible cutlery was ready (figure 2).

Commented [HP6]: Please provide the source of reference for this statement.

Commented [HP7]: Please provide the source of reference for this statement.

Commented [HP8]: Overall, the presentation of the methodology is not well organized. The section should clearly describe the analyses to be conducted and be structured systematically with appropriate numbering

Commented [HP9]: The information regarding the **local market** is unclear and requires further clarification

Commented [HP10]: Please provide the source of reference for this statement.

Commented [HP11]: The information presented illustrates the process of preparing raw materials, not the collection of raw materials

Commented [HP12]: The topic title ‘Formulation of Cutlery’ is not consistent with the explanation given

Commented [HP13]: Shape and size – clear information on the shape and size should be provided in the study

Commented [HP14]: Please provide the source of reference for this statement.

Take all raw ingredients

↓

Sieve the all-raw dry ingredients

↓

Mix all dry ingredients

↓

Kneed it & make a smooth dough

↓

Make a fine sheet

↓

Make a different Mold

↓

Preheat oven at 200°C for 10 min

↓

Baked the Mold at 150°C for 15-20 min

↓

Cool it (at room temp.)

↓

Packed it suitable packaging material. (LDPE, Box Pack)

Figure 1: Flow chart of the development of Edible Cutlery

Figure 2: Final Product of Edible Cutlery

Treatment Details

Commented [HP15]: A clearer and more precise title should be used

The present investigation was carried out in the Department of Food Technology, Yashavantrao Chavan Institute of Science, Satara. Results obtained during the investigation are tabulated and statistically analyzed. Based on a review of the literature and preliminary trials, the experimental work plan was prepared with details of the trials as given in the table and shown in Table 1.

Table 1: Composition of Edible/biodegradable Cutlery

Sr. No.	Ingredients	Sample 1	Sample 2	Sample 3	Sample 4
1	Sago Flour	30%	30%	30%	30%
2	Ragi Flour	20%	20%	20%	20%
3	Black Gram Flour	20%	20%	20%	20%
4	Powder Sugar	20%	20%	20%	20%
5	Corn Flour	10%	10%	10%	10%
6	Gaur gum	0%	0%	0.4%	0.8%
7	Oil	0%	8%	8%	8%
8	Emulsifier	0%	0%	0.4%	0.4%

Proximate analysis

Proximate tests on the final product, such as moisture and ash, as well as chemical analyses of fat, protein, and fiber, were performed.

Commented [HP16]: What is the justification for conducting a proximate analysis for this product? An explanation should be provided before the proximate analysis methodology is described

Moisture content

After the 5 g sample was ground up and dried for 5 hours at 105°C in an oven, its moisture content was measured by weighing it. It was weighed once more after being chilled in desiccators until it reached a consistent weight. The weight loss as a result was calculated using the moisture content (Manual-FSSAI).

Commented [HP17]: Please check the formatting, particularly the font size, to ensure compliance with the required standard

Commented [HP18]: This citation does not appear in the reference list

Commented [HP19]: A citation from other researchers regarding the methodology should be provided

Fat Content

Using a Soxhlet device, five grams of crushed product were carefully weighed in a thimble and defatted with petroleum ether. The lipid content was then ascertained by evaporating the ether extract (Manual-FSSAI).

Crude Fibre Content

Initially, 2 to 5 g of a moisture and fat-free sample was digested using 200 ml of boiling 0.255 N H_2SO_4. To keep the volume constant, water was added to the mixture at regular intervals while it boiled for 30 minutes. After this period, the mixture was filtered through filter paper, and the residue was rinsed with hot water until it was free of acid. Following the sample's transfer, 200 ml of boiling 0.313 N NaOH solution was added to the same beaker. After 30 minutes of boiling, the mixture was filtered through filter paper. Hot water was used to rinse the residue until no alkali remained. After being moved to a crucible and allowed to dry overnight at 80–100°C, it was weighed. After four hours of heating at 550–600°C in a muffle furnace, the crucible was cooled and weighed once more. The difference between the weights indicated the weight of the crude fiber (Moller, 2014).

Ash Content

A silica crucible containing five grams of product was weighed, burned, and cooled over a brief flash until the solid was completely burned. After cooling in the desiccator, the sample was spent four hours at 550°C in a muffle furnace. After cooling in the muffle furnace, it was weighed once more, and the process was repeated until two measurements were identical. The percent ash was calculated using the difference between the initial and final weights (Manual-FSSAI).

Protein Content

The Micro-Kjeldhal technique, which entailed digesting 200 mg of material in concentrated sulfuric acid with 1 g of catalyst combination for two to three hours at 100°C, was used to measure the protein content. Following a 40% NaOH distillation, the ammonia that was released was captured in 4% boric acid and titrated against 0.01N H_2SO_4 using a mixed indicator method (Methyl red: Bromocresol green, 1:5). The percentage of protein in the sample was then estimated using a factor of 6.25, and the proportion of nitrogen was then calculated using a method (Manual-FSSAI).

Carbohydrate Content

Commented [HP20]: A citation from other researchers regarding the methodology should be provided

Commented [HP21]: This citation does not appear in the reference list

The percent of total carbohydrate content was determined using the difference method (Kumar et al. 2023).

Commented [HP22]: The information presented lacks clarity and requires further elaboration

Water Absorption Capacity

For a predetermined amount of time, a silverware sample of undetermined weight was submerged in water. The sample was taken out of the beaker after a predetermined amount of time, and tissue paper was used to wipe away the surface water. The percentage of water absorption is calculated using the formula below.

Commented [HP23]: Please provide the source of reference for this statement.

$$\text{Water absorption (\%)} = \frac{W2-W1}{W1} \times 100$$

were,

W1= Weight of Cutlery before water,

W2 =Weight of Cutlery after water

Oil Absorption Capacity

An unknown weight of the cutlery sample was immersed in oil for a specific period. After a certain time, the sample was removed from the beaker, and the surface oil was removed with tissue paper. The following formula is used to determine the percentage of oil absorption.

Commented [HP24]: Please provide the source of reference for this statement.

$$\text{Oil absorption (\%)} = \frac{W2-W1}{W1} \times 100$$

were,

W1 = Weight of Cutlery before oil,

W2=Weight of Cutlery after oil

Biodegradability Test (soil burial test)

Using edible cutlery pieces, the sample sheets were buried in sterile soil for a specified period, and the gradual biodegradation of the samples was monitored daily.

Sensory Assessment:

The scientific method for eliciting, quantifying, evaluating, and interpreting reactions as perceived by the senses of sight, smell, touch, taste, and hearing is sensory assessment. Trained and semi-trained panel members, who were academic staff members of the Yashavantarao Chavan Institute of Science, Satara, were asked to rate the overall products on a hedonic scale, mainly on a 9-point scale with descriptive words ranging from 1 (strongly dislike) to 9 (very like). They were evaluated for sensory qualities such as appearance, color, taste, flavor, and texture. The Sensory graph of the final samples is shown in Figure 3.

Commented [HP25]: Please provide the source of reference for this statement.

Result and Discussion:

Commented [HP26]: The presentation of the results should follow the same sequence as the analyses described in the methodology

The present investigation was carried out in the Department of Food Technology, Yashavantrao Chavan Institute of Science, Satara, during 2023-2024. Results obtained during the investigation are tabulated and statistically analyzed.

Sensory Evaluation

Commented [HP27]: The discussion is not clearly presented, particularly regarding the identification of the best formulation based on the results provided.

The sensory qualities in terms of color, flavor and texture, and aroma were assessed by a panel of 10 judges with a 9-point hedonic scale. The data regarding the sensory evaluation is presented in Table 2 and Graph 1:

Commented [HP28]: Please provide the source of reference for this statement.

Commented [HP29R28]: Please specify the number of trained and semi-trained panel members who participated in the sensory evaluation

Table 2: Sensory Evaluation Score

Commented [HP30]: Please indicate in the data whether the results are statistically significant or not

Sr. No.	Sensory Parameter	Sample 1	Sample 2	Sample 3	Sample 4
1	Appearance	7.5	7.8	8.8	7.2
2	Color	7.7	7.1	8.8	6.7
3	Odour	7.4	7.5	8.2	7.2
4	Flavour	7.6	7.7	8.2	7.1
5	Taste	7.8	7.7	8.4	7.1
6	Texture	7.7	7.2	8.8	6.6
7	Overall Acceptability	7.6	7.6	8.8	7.2

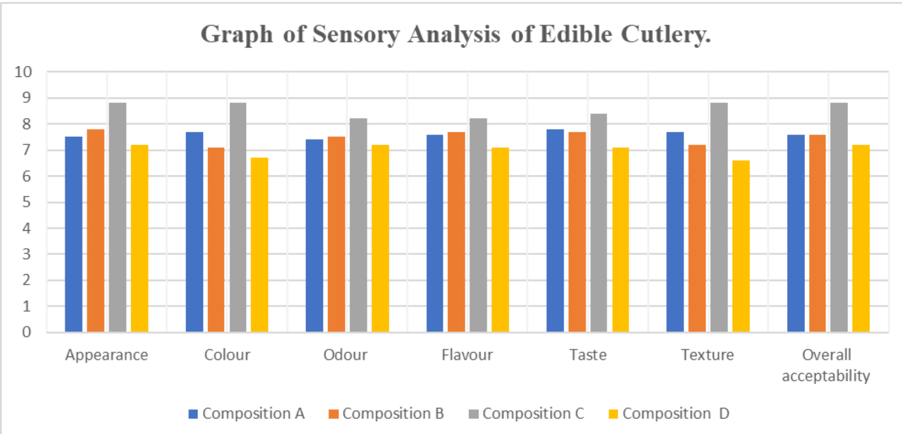

Figure. 3: Sensory Evaluation Score

Proximate Analysis

Table 3 represents the result of the proximate analysis of sample 3. Chemical properties of Edible Cutlery were studied by analyzing moisture content, fat, protein, fibre, ash, and carbohydrates. Various tests are taken for that, and all the equipment and chemicals are handled with care.

Commented [HP31]: The manuscript does not provide a clear explanation for why only sample 3 was included in the proximate analysis.

Table 3: Results of Proximate Analysis

Sr. No.	Parameter	Sample 3
1	Moisture	1.4%
2	Fat	1.7%
3	Protein	5.25%
4	Fiber	1.31%
5	Ash	0.8%
6	Carbohydrates	89.54%
7	Energy	390.95kcal

Water Absorption Capacity

For testing water absorption capacity, edible cutlery was used. The four samples were manufactured by using different proportions of sago flour, ragi flour, black gram flour, and corn flour, but Sample 3 was selected as the final sample. So, the water absorption capacity of sample 3 was determined. The water absorption capacity of Sample 3 is 24.22%.

Commented [HP32]: The manuscript does not provide a clear explanation for why only sample 3 was included in the proximate analysis.

Oil Absorption Capacity

For testing the oil absorption capacity, edible cutlery was used. The oil absorption capacity of Sample 3 was determined. The oil absorption capacity of Sample 3 is 19.75%.

Biodegradability Test

Natural raw materials were used without the addition of any artificial preservatives to create edible cutlery. As a result, mixing the edible cutlery with water is simpler and produces the desired effects. In soil, the edible cutlery entirely decayed in 15 days. Figure 4 represents the degradation process of edible cutlery.

Discussion

The present study focused on the development of edible cutlery using different proportions of sago, ragi, black gram, and corn flours, and the results indicated that Sample 3 was the most acceptable formulation. Sensory evaluation by a panel of 10 judges using a 9-point hedonic scale revealed that Sample 3 scored the highest in appearance (8.8), color (8.8), texture (8.8), taste (8.4), and overall acceptability (8.8), suggesting that the combination of flours produced a visually appealing, flavorful, and texturally acceptable product. Proximate analysis of Sample 3 showed low moisture (1.4%) and fat content (1.7%), moderate protein (5.25%) and fiber (1.31%), ash content of 0.8%, high carbohydrate content (89.54%), and an energy value of 390.95 kcal, indicating good nutritional quality and shelf stability. Functional properties such as water absorption capacity (24.22%) and oil absorption capacity (19.75%) suggested that the cutlery could retain structural integrity when in contact with liquids and oily foods. The biodegradability test demonstrated that the cutlery completely decomposed in soil within 15 days, confirming its environmental sustainability due to the absence of artificial preservatives. Overall, the study highlights that Sample 3 represents an optimal formulation combining sensory appeal, nutritional quality, functional performance, and eco-friendliness, supporting the feasibility of producing biodegradable edible cutlery as a sustainable alternative to conventional

Commented [HP33]: The methodology does not clearly present the analytical steps, especially with respect to the criteria for selecting samples for proximate analysis following the sensory evaluation

Commented [HP34]: The methodology does not clearly describe the decomposed analysis plastic utensils (Singh et al., 2020; Kumar et al., 2019; Patil et al., 2021; Rao et al., 2018; Sharma & Singh, 2019).

Figure 4: Degradation of Edible Cutlery

Commented [HP35]: The diagram does not clearly illustrate the decomposition level of the sample

Conclusion

In the present work formulation, the determination of chemical, functional, and sensory characters of Edible Cutlery was carried out. In conclusion, edible cutlery made from different flours is nutritious and healthy, an alternative to the common cutlery made from refined wheat flour. It is one of the most significant products with the advantage of biodegradability and edibility. Overall, the edible cutlery made from various flours is a better replacement for plastic cutlery.

Commented [HP36]: The conclusion needs to be aligned with the stated objectives, the methodology applied, and the results of the analysis

References

- Ahmad, F. B., Williams, P. A., Doublier, J. L., Durand, S., & Buleon, A. (1999). Physico-chemical characterisation of sago starch. *Carbohydrate polymers*, *38*(4), 361-370.
- AOAC. Official Method of Analysis. 17th ed. Washington, DC: AOAC; 2000.

Baral, K. A. B. U. L., & Kaur, J. A. S. P. R. E. E. T. (2023). Development and quality evaluation of biodegradable edible cutlery: a replacement for conventional cutlery. *Asian*

- Chowdhury, G. R., Dutta, S., Pal, N., & Mitra, A. (2021). Edible cutlery: futuristic dining to functional sustenance. *Parana Journal of Science and Education*, *7*(8), 84-91.
- Gull, A., Jan, R., Nayik, G. A., Prasad, K., & Kumar, P. (2014). Significance of finger millet in nutrition, health, and value-added products: a review. *Magnesium (mg)*, *130*(32), 120.
- Gupta, M., & Sanghi, D. (2023). Edible cutlery: an emerging sustainable approach towards

Commented [HP37]: This reference is not cited within the article

Commented [HP38]: This reference is not cited within the article

Commented [HP39]: This reference is not cited within the article

a healthy future.

- Hazra, S., & Sontakke, M. (2023). Process development and quality evaluation of edible cutlery spoons supplemented with Withania somnifera root powder. *Pharma Innovation*, *12*(5), 1874-1883.

International Journal of Creative Research Thoughts (IJCRT). 11(9), 75-83.

- Iqbal, B., Raza, R., Khan, N., & Siddiqui, K. A. (2022). Bio-friendly edible cutlery effective alternative to plastic disposable cutlery. *J Res (Science)*, *33*(1), 30-36. *J. Pharm. Clin. Res.*
- Jagati, P., Mahapatra, I., & Dash, D. (2021). Finger millet (Ragi) as an essential dietary supplement with key health benefits: A review. *International Journal of Home Science*, *7*(2), 94-100.
- Kamal, S. M. M., Mahmud, S. N., Hussain, S. A., & Ahmadun, F. R. (2007). Improvement on sago flour processing. *International Journal of Engineering and Technology*, *4*(1), 8-14.
- Kanth, A., Goswami, K., & Shukla, P. (2021). Nutritional quality evaluation of improved varieties of black gram (Phaseolus mungo). *Pharm Innov J*, *10*, 201-220.
- Kotancılar, H. G., Güdük, H., & Seyyedcheraghi, K. (2018). The effect of using corn flour level and additive type on the quality of corn bread. *Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *7*(3), 102-115.
- Mejia L., Mejia R., and Chasi S. (2016). Study of the Functional Properties of the Flour Proteins. *MODEC*. *5*(8), 1-4.
- Modgil R., Kundal S., and Sandal A. (2019). Bio-Chemical & Functional Characteristics of Black Gram. *International Journal of Current Microbiology and Applied Sciences 6 (8)*, 312-320.
- Mukherjee, K., & Raju, A. (2023). Edible cutlery prototype to combat malnutrition and plastic waste management. *Asian Journal of Biological and Life Sciences*, *12*(1), 92-102.
- Natrajan N, Vasudevan M, Velusamy V., Selvaraj M. (2019). Eco-Friendly and Edible Cutlery for a Sustainable Environment. *International Journal of Engineering and Advanced Technology 9* (2), 615-624.
- Roy, T. R., & Morya, S. (2022). Edible cutlery: An eco-friendly replacement for plastic cutlery. *Journal of Applied and Natural Science*, *14*(3), 835.

Commented [HP40]: This reference is not cited within the article

Commented [HP41]: This reference is not cited within the article

Commented [HP42]: This reference is not cited within the article

Commented [HP43]: This reference is not cited within the article

Commented [HP44]: This reference is not cited within the article

Commented [HP45]: This reference is not cited within the article

Commented [HP46]: This reference is not cited within the article

Commented [HP47]: This reference is not cited within the article

Commented [HP48]: This reference is not cited within the article

Commented [HP49]: This reference is not cited within the article

- Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G., Anjana, R. M., Palaniappan, L., & Mohan, V. (2013). Finger millet (Ragi, Eleusine coracana L.): a review of its nutritional properties, processing, and plausible health benefits. *Advances in food and nutrition research*, *69*, 1-39.
- Soni A. and Tripathi R. (2023). Edible Cutlery – A Revolutionary Contribution to Society.
- Subroto, E., Pangawikan, A. D., Yarlina, V. P., & Isnaeni, N. F. (2020). Characteristics, purification, and the recent applications of soybean oil in fat-based food products: A review. *International Journal*, *8*(7).
- Swaraj A., Sheth Y., Sheth E., Gudhka S., Nirgude O., and Gada C. (2012). A study on Edible Cutlery and Its Significance on the Indian habit with special Reference to Restaurants in Mumbai. *IJFANS. 11*(10*),* 554-562.
- Thagunna, B. I. S. H. A. L., Shrestha, G. R. I. S. H. M. A., Karki, R. A. C. H. A. N. A.,
- Thombare, N., Jha, U., Mishra, S., & Siddiqui, M. Z. (2016). Guar gum as a promising starting material for diverse applications: A review. *International journal of biological macromolecules*, *88*, 361-372.
- Tripathy, S., & Das, M. K. Journal of Pharmaceutical and Scientific Innovation.
- Vyshali, P., Serena, P. B., & Muthamma, P. B. (2022). Development of an edible and biodegradable tableware using fruit waste alternative to plastic tableware. *International Journal of Food and Nutritional Sciences*, *11*(4), 85.

Commented [HP50]: This reference is not cited within the article

Commented [HP51]: This reference is not cited within the article

Commented [HP52]: This reference is not cited within the article

Commented [HP53]: This reference is not cited within the article

Commented [HP54]: This reference is not cited within the article

Commented [HP55]: This reference is not cited within the article

Commented [HP56]: This reference is not cited within the article

Commented [HP57]: This reference is not cited within the article

- Kumar, A., Sharma, R., & Singh, P. (2019). Development and evaluation of composite flour-based edible products. *Journal of Food Science and Technology*, 56(5), 2432–2441.

- Patil, S., Deshmukh, R., & Rao, V. (2021). Nutritional and functional evaluation of biodegradable edible cutlery. *International Journal of Food Science*, 2021, 1–9.

- Rao, S., Mehta, A., & Singh, R. (2018). Functional properties of cereal-legume blends for eco-friendly edible utensils. *Food Hydrocolloids*, 77, 780–787.

- Sharma, K., & Singh, A. (2019). Biodegradability assessment of natural edible cutlery. *Journal of Environmental Science and Health*, 54(8), 712–720.

- Singh, N., Kaur, L., & Gupta, S. (2020). Sensory and nutritional evaluation of multigrain-based edible cutlery. *Journal of Culinary Science & Technology*, 18(3), 210–224.