

# Transforming Waste into Utility: A Critical Investigation of Edible Cutlery as a Sustainable Alternative

Noor Bakht<sup>1</sup>, Amaila Sehar<sup>2</sup>, Futrus Abid<sup>3</sup>, Sadia Hassan<sup>4</sup>, Moazama Anwar<sup>1</sup>, Huzaifa Malik<sup>5</sup>, Ishmal Mazhar<sup>1</sup>, Jannat Sohail<sup>6</sup>, Khadija Fatima<sup>7</sup>

<sup>1</sup> Department of Human Nutrition and Dietetics, Faculty of Allied Health Sciences, University of Okara, Okara, Pakistan

<sup>2</sup> Department of Nutrition and Dietetics, The University of Faisalabad, Faisalabad, Pakistan

<sup>3</sup> Department of Food Science and Technology, Faculty of Life Sciences, University of Okara, Okara, Pakistan

<sup>4</sup> Department of Food Science and Technology, Government College University Faisalabad, Faisalabad, Pakistan

<sup>5</sup> Department of Human Nutrition and Dietetics, University of Sargodha, Sargodha, Pakistan

<sup>6</sup> Department of Nutritional Sciences, Government Graduate College of Home Economics, Faisalabad, Pakistan

<sup>7</sup> Department of Nutritional Sciences, Government College Women University Faisalabad, Faisalabad, Pakistan

\* Correspondence: Khadija Fatima. khadijaehsanullah0@gmail.com



## ABSTRACT

*Plastic-cutlery can be replaced by creative and eco-sustainable edible cutlery based on innovation. Stale bread is a major waste and can become a strong yet biodegradable cutlery as alternative to plastic disposables. The present study was done to develop edible cutlery with stale bread, lentils and wheat in different ratios. Five treatments were prepared for comparison study. After edible cutlery development, proximate, mineral, microbial, texture and sensory evaluation was done. A required statistical procedure was done after data collection. T3 have highest mean value for protein 11.4% and ash 2.62% while T5 have highest mean value for fiber 15.03% and T1 have highest mean value for fat 10.42% in physico-chemical analysis. T5 and T4 showed highest mean values for iron  $5.03 \pm 0.02$  mg/100g and zinc  $2.31 \pm 0.03$  mg/100g respectively. All treatments were in safe limits for microbial analysis under 1000 CFU/g. T3 was having least mean value of microbial count ( $200 \pm 1.24$  CFU/g). T3 showed highest mean value of hardness ( $170.2 \pm 3.9$  N). T3 was the most accepted according to mean value  $8.33 \pm 0.58\%$  of sensory analysis. The cutlery produced in this research is being discovered to be tasty, nutritious, healthy and environment friendly plastic alternative.*

## INTRODUCTION

Global urgency and initiative toward sustainable substitutes have been prompted by the alarming increase in food and waste composed of plastic. Bread items alone contribute approximately 44 percent of cereal-based food losses, according to research, and thus are a significant factor in the global food waste index. Simultaneously, the rise in plastic use, particularly in throwaway products such as single-use cutlery, is further worsening environmental degradation through the disruption of ecosystems and adding microplastics to food webs (Avio et al., 2017; Prata et al., 2019; Boro et al., 2020). Approximately 36% of the 400 million tons of plastic waste generated globally every year is believed to be utilized for wrapping purposes, such as one-time items like plastic cutlery. It can take as long as 400 years for these plastic cutlery products to decompose after being used once and discarded (Bellou et al., 2021).

Moreover, aquatic ecosystems are adversely affected by plastic waste, which constitutes approximately 85% of marine trash. According to Jam beck et al. (2015), Sustainable

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Development Goals (SDGs) 12 and 13 show support for making edible cutlery which helps with responsible production and actions on climate (SDGs 12 and 13).

This persistent plastic pollution poses a serious threat to wildlife because animals may be injured or killed if they ingest it or become entangled in it (Avio et al., 2017; Chowdhury et al., 2021). Edible cutlery made from natural, biodegradable materials such as rice, pulses, wheat, or maize flour has two advantages: it can be safely biodegraded to lessen environmental pollution, or it can be eaten after use. This alternative gives you a special eating experience and reduces the negative outcomes of plastic waste (Natarajan, 2019; Avena-Bustillos, 2017; Kabir, 2022).

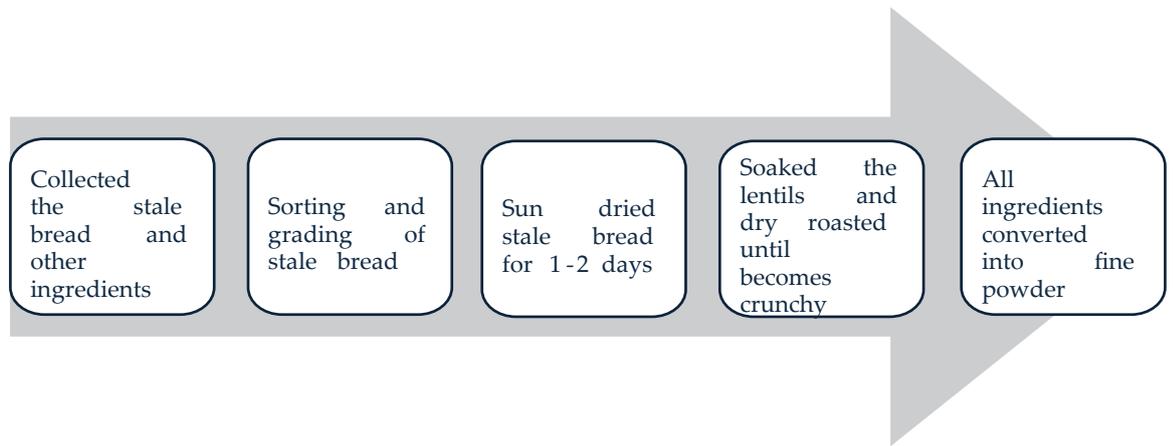
Bread wastage, especially stale bread, is a major issue on a global scale. With an estimated 29.1% food loss rate, bread ranks as the fourth most wasted food globally, according to the Food and Agriculture Organization. Every day, 20 million pieces of bread are thrown away in the UK, resulting in 292,000 tons of waste annually (Helaimia, 2023). There are two benefits towards the upcycling of stale bread into useful products such as edible cutlery: it reduces the environmental footprint of food waste and encourages sustainable product innovation. Processed foods baked with old bread can improve their nutritional value and texture, according to recently reported studies (Gumul et al., 2024; Starzyńska-Janiszewska et al., 2024).

Resistant starch is formed when stale bread cools down and this happens as gelatinized molecules known as amylose and amylopectin reassociate. Because this change happens, more resistant starch and dietary fiber, both undigestible, are favored (Nugent, 2005; Bojarczuk et al., 2022). Increased resistant starch content of stale bread has a number of health benefits, including better gut health, lowered insulin response, and enhanced satiety. Yellow lentils are full of dietary fiber, vitamins, minerals and plant protein (Slavin, 2013; Shaikh et al., 2024). The main items in the edible cutlery proposed for this research are rice flour, lentils and both stale and fresh wheat roti flour. Besides carbs, fiber and essential minerals, wheat flour adds structure and texture (Ficco and Borrelli, 2023). The role of dietary fiber in maintaining cardiovascular health, gut health, and metabolic control has been extensively reported (Birt et al., 2013; Slavin, 2013). Resistant starch contributes to gut health through its function as a prebiotic and its ability to stimulate the production of short-chain fatty acids, including butyrate, that maintains colon health and suppresses inflammation (Topping and Clifton, 2001). The main objective of this study is to formulate edible cutlery by using stale bread and lentils in different ratios and to analyze best formulation by conducting physicochemical and sensory analysis of edible cutlery.

## MATERIALS AND METHODS

### *Procurement and processing of raw material*

Stale bread was collected from homes, restaurants, and cafes in Okara, then sorted and graded. Black and yellow lentils, babool gum, wheat, rice, salt, garlic oil, and spices were purchased locally. Lentils were soaked for 12 hours, dry roasted until crunchy, and cooled for 1 hour. Bread was sun-dried for 36–48 hours and milled into fine flour. All ingredients, including roasted lentils, babool gum, wheat, and rice, were ground into powder to prepare edible cutlery.



*Figure 1: Processing methodology for raw components*

#### *Product Formulation*

By adding selected ratios of all ingredients, a smooth dough was prepared by adding water through kneading. With the help of rolling pin, a flat dough was obtained. Flat dough was placed in molds. Preheat the electric oven for 20 minutes for 160oC. Molds were placed in oven for 60 minutes on 160oC.



*Figure 2: Ingredients processing and formulation*

#### *Formation of Edible Cutlery*

Selected ratios of all ingredients including stale bread flour, wheat flour, yellow and black lentils, rice flour, babool gum, oil and spices were added, a smooth dough was prepared by adding water through kneading. With the help of rolling pin, a flat dough was obtained. Flat dough was placed in molds, cutlery like spoons and forks were shaped with knife or scissor. Preheated the electric oven for 20 minutes for 160oC.

Placed the molds in oven for 60 minutes on 160oC.



**Figure 3: Formation of edible cutlery**



**Figure 4: Edible Cutlery**

Edible cutlery was prepared by stale bread flour, wheat flour, yellow and black lentils, rice flour, babool gum, oil and spices with the ratios given in table.

**Table 1: Treatment plan of edible cutlery**

Ingredients	Treatments				
	T1	T2	T3	T4	T5
Stale Bread Powder (g)	15	15	15	15	-
Rice Powder (g)	5	5	5	5	5
Wheat Flour (g)	5	5	5	-	15
Babool Gum (g)	1	1	1	1	1
Black Lentil Powder (g)	2	-	2	2	2
Yellow Lentil Powder (g)	-	2	2	2	2
Salt (mg)	500	500	500	500	500

Garlic Oil (ml)	0.20	0.20	0.20	0.20	0.20
Chilli Flakes Powder (mg)	300	300	300	300	300
Oil (ml)	3	3	3	3	3

#### *Proximate Analysis*

Proximate analysis was analyzed to of edible cutlery samples, which included moisture, ash, crude protein, crude fat, crude fiber, and total carbohydrates by using (AOAC, 2005) were used for all analyses.

#### *Mineral Analysis*

The presence and quantity of iron and zinc in these foods were checked with the standard method was used to determine the quantities of minerals Iron (Fe) and Zinc (Zn) in the samples, following the methodology given by AOAC (2016).

#### *Microbial Analysis*

Microbial tests were carried out on the five samples of edible cutlery to find out if the products were safe and clean. ISO 4833-1:2013 was used as the reference, and 10g of every sample was put into a sterile stomacher bag with 90 mL of buffered peptone water for a 1:10 dilution.

#### *Textural Analysis*

The mechanical texture of edible cutlery was evaluated using Texture Profile Analysis (TPA) with a Warner-Bratzler blade probe. Samples were cut to standard size, sheared to measure hardness, and compressed twice to assess texture characteristics.(Barbut, 2008).

#### *Sensory Evaluation*

A panel of 10 semi-trained judges (postgraduate students and faculty from the Department of Dietetics and Nutritional Sciences) evaluated the edible cutlery samples for appearance, texture, aroma, taste, and overall acceptability. A 9-point hedonic scale was used (1 = dislike extremely, 9 = like extremely). Samples were coded with random three-digit numbers and presented in randomized order. Panelists rinsed their mouths with water between samples to minimize bias.

#### *Statistical Analysis*

All experimental data were expressed as mean  $\pm$  standard deviation (SD) based on at least three replicates. One-way analysis of variance (ANOVA) was applied to determine the significant differences among sample means. The level of significance was set at  $p < 0.05$  for all statistical comparisons. Minitab 22.x was used for the statistical analysis.

## **RESULTS AND DISCUSSION**

The present study examined the quality of edible cutlery by carrying out proximate analysis, sensory evaluation, microbial testing, texture analysis, and measuring mineral content. All results of the experiments were examined statistically before being considered reliable and important. The proximate analysis pointed out that there are differences in moisture, protein, fat, fiber, and ash contents among the formulations, showing how nutritious the developed cutlery could be. Evaluators doing sensory analysis thought most of the samples fulfilled taste, texture, appearance, and satisfaction standards and even preferred some over the others based on statistics. Microbial testing showed that the storage of the products did not cause

microorganisms to exceed the safe levels over the whole period. Composition of the ingredients led to significant differences in hardness and crispness as was revealed by texture analysis. Further analysis of minerals indicated that cutlery has a good balance of iron and zinc. On the whole, these results prove that edible cutlery can be designed to be healthy, tasty, enjoyable, and safe for bacteria, which makes it a good alternative to conventional plastic cutlery.

#### *Proximate Analysis*

Proximate analysis is a fundamental method used to find out the main macronutrients present in a sample of food. It breaks down the main nutrients in food in a simple and helpful way: moisture, ash, crude protein, crude fat, crude fiber, and nitrogen-free extract, which is mostly made up of digestible carbohydrates.

#### *Moisture Analysis*

Moisture analysis is the analysis of water content of a sample. Moisture in edible cutlery is important factor that determines the texture, crispiness, microbial stability and the overall shelf life. Edible cutlery moisture levels were found to have a great difference across all the various formulations with a range of 0.05-0.17%. Higher moisture levels can cause softness and spoilage whereas lower moisture levels guarantee improved crunch and storage stability. T2 had the lowest moisture content (0.05%), whereas T4 had the highest (0.17%).

#### *Protein Analysis*

The protein content among treatments varied between 9.0-11.4%. T3 showed the greatest protein level (11.4%), possibly because the concentration of protein in the T3 was higher than that in the studied formulations (Maphosa and Jideani, 2017). With wheat flour, another 11-12% protein is added, and even after drying, stale bread, made of wheat, contains 8-11% protein (Menon et al., 2015). ANOVA demonstrated that the difference among the treatments was statistically significant ( $p < 0.05$ ), which proves that the formulation composition influences the protein content. The increased protein level in T3 would improve the nutritional value and possible satiety value of the edible cutlery.

#### *Fat Analysis*

Fat analysis applies to the determination of the lipid content of a given sample of food, usually by solvent-based extraction, as in the Soxhlet method. Fat level among treatments ranged between 3.88-10.42%. The highest fat value was observed in treatment T1 (10.42%), it is because black lentils contain more fat but when it comes in mixture with other ingredients like in T3 (7.46%) the amount of fat is compromised due to presence of fiber came from other ingredients. T4 had the lowest fat content (3.88%) due to stale bread. T4 recorded the least amount of fat, mainly due to the absence of wheat flour, which has a lipid rate of 1.5 % to 2.0 % (Bhatt and Gupta, 2015). Lack of this ingredient became less of a total lipid in the formulation. T1, in its turn, was made of wheat flour and stale bread, which can contain a high amount of lipids. Using of only one type of lentil (black lentil) inhibited the positive fat displacement effect achieved by including yellow lentils and hence T1 had a relatively high total fat content (Maphosa and Jideani, 2017). Lower fat treatment like T4 (3.88%) and T5 (5.91%) is preferred in longer shelf stability.

#### *Ash Analysis*

The procedure of ash analysis determines the total amount of minerals in a food sample by burning the sample in high temperatures. Ash content among treatments ranged between 1.77 to 2.62%. T3 (2.62%) showed the highest value, T5 had the lowest ash content (1.77%) while T1, T2 and T4 have (2.02%), (2.14%) and (2.36%) respectively. The ANOVA variance

indicated that the difference in the ash content between all the formulations was found to be statistically significant ( $p < 0.05$ ), implying the apparent influence of the type and ratio of ingredients on the mineral levels.

T3 recorded the highest percent ash which is an index depicting the abundance and form of inorganic constituents.

#### *Fiber Analysis*

Fiber content among treatments was 3.66 to 15.03%. Treatment T5 had the greatest level of fiber (15.03%) as it contained more whole wheat flour. T4 contained the lowest proportion of fiber (3.66%). T5 contained the most content of fiber, since it was a mixture of wheat flour and both black and yellow lentils - grains which provide high quantities of dietary fiber. Lentils contain 12-15 % total dietary fiber and thus when combined in recipes, becomes a major source of fiber (Maphosa and Jideani, 2017). Insoluble fiber and structural stability that does not deteriorate after baking are also additional effects of wheat flour in T4. The statistically significant differences ( $p < 0.05$ ) among the treatments based on ANOVA proved that variation of fiber content is highly related to ingredient composition.

The increased level of fibers in T5 indicates the effect of legumes and whole grains usage, which are rich in dietary fiber. This does not only add mechanical strength to the edible cutlery but also has digestive advantage when ingested. T3 contains 12.5 % fiber content and this treatment includes all ingredients.

#### *Dry Matter Analysis*

In dry matter analysis, the total solids content of a sample is determined by dissolving all the moisture content in the sample. The percentage of dry matter among treatments was between 98.83% to 99.89%. T5 had the highest dry matter (99.89%), which might have been as a result of having a higher proportion of wheat flour, whereas T2 had the lowest mean (98.83%) because of the high moisture retention. ANOVA outcomes demonstrated that there were significant differences ( $p < 0.05$ ) in the dry matter content between treatments, which proved the effect of ingredient composition.

*Table 2: Mean squares of proximate parameters including moisture, protein, and fat*

Source	DF	Mean Square		
		Moisture	Protein	Fat
Treatments	4	0.007670*	2.6790*	23.8058**
Error	10	0.002491	0.6140	0.0024
Total	14			

NS = Non-significant ( $P > 0.05$ ), \* = Significant ( $P < 0.05$ ), \*\* = Highly significant ( $P < 0.01$ )

*Table 3: Mean values for proximate parameters including moisture, protein, and fat*

Treatments	Mean $\pm$ S. D		
	Moisture (%)	Protein (%)	Fat (%)
T1	0.11 $\pm$ 0.05ab	9.0 $\pm$ 0.9b	10.42 $\pm$ 0.06a

T2	0.05 ± 0.03b	9.7 ± 0.8b	10.26 ± 0.04b
T3	0.053 ± 0.04b	11.4 ± 0.8a	7.46 ± 0.04c
T4	0.17 ± 0.06a	9.2 ± 0.7b	3.88 ± 0.03e
T5	0.06 ± 0.05b	9.9 ± 0.7b	5.91 ± 0.06d

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

*Table 4: Mean squares of proximate parameters including ash, fiber, and dry matter*

Source	DF	Mean Square		
		Ash	Fiber	Dry Matter
Treatments	4	0.31548**	60.4279**	0.91890**
Error	10	0.01604	0.0008	0.01000
Total	14			

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\* = Highly significant (P< 0.01)

*Table 5: Mean values for proximate parameters including ash, fiber, and dry matter*

Treatments	Mean ± S. D		
	Ash (%)	Fiber (%)	Dry Matter (%)
T1	2.02 ± 0.10c	7.5 ± 0.02d	99.79 ± 0.1a
T2	2.14 ± 0.11bc	11.61 ± 0.02c	98.83 ± 0.1b
T3	2.62 ± 0.17a	12.5 ± 0.02b	99.85 ± 0.1a
T4	2.36 ± 0.17b	3.66 ± 0.02e	98.84 ± 0.1b
T5	1.77 ± 0.17d	15.03 ± 0.02a	99.89 ± 0.1a

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

#### *4.2 Mineral Analysis*

Mineral analysis detects good micronutrients such as zinc and iron in foodstuffs. In edible cutlery they provide nutritional value, particularly where lentils and whole grains are employed. Table shows the level of zinc between treatments varied between 2.11 mg/100 g to 2.31 mg/100 g. T4 contained the highest amount of zinc (2.31 mg/100 g) whereas T1 contained the lowest amount (2.11 mg/100 g). Likewise, iron content ranged between 3.39-5.03 mg/100 g, with T5 having the highest amount (5.03 mg/100 g). T2 had the lowest amount of iron (3.39 mg/100 g). ANOVA showed significant differences (p < 0.05) of both minerals among treatments.

Higher concentration of zinc and iron in T4 and T5 respectively, may be explained by the number of stale bread powder and whole wheat flour, which are good sources of these trace

elements. Results of the current research reveal that T4 had high levels of zinc in comparison with the other trial groups.

*Table 6: Mean squares of minerals including zinc and iron*

Source	DF	Mean Square	
		Zinc	Iron
Treatments	4	0.018990**	1.79498**
Error	10	0.001157	0.00029
Total	14		

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\* = Highly significant (P< 0.01)

*Table 7: Mean values for minerals including zinc and iron*

Treatments	Mean ± S. D	
	Zinc (mg/100 g)	Iron (mg/100 g)
T1	2.11 ± 0.03c	3.66 ± 0.01d
T2	2.14 ± 0.02c	3.39 ± 0.01e
T3	2.17 ± 0.01bc	4.98 ± 0.009a
T4	2.31 ± 0.03a	4.71 ± 0.02c
T5	2.21 ± 0.04b	5.03 ± 0.02a

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

#### *4.3 Microbial Analysis*

Microbial testing was performed to determine the hygienic and safety status of the prepared edible cutlery during production time. The five treatments all resulted microbiologically safe and within limits, with no apparent signs of spoilage or growth of fungi. T3 emerged to be the best overall quality treatment perhaps because of its well-balanced composition and optimum moisture reduction during baking (Moin et al., 2025). The sample of T4 had the greatest microbial load which can be explained by the enhanced moisture holding ability of stale bread and rice flour that create a more favorable environment where microbes bloom even following the baking process (Fadda et al., 2014).

*Table 8: Mean squares of total plate count*

Source	DF	Mean Square
		Total Plate Count
Treatments	4	26100*
Error	10	0.63

**Total**                      **14**

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\*= Highly significant (P< 0.01)

*Table 9: Mean values for total plate count*

Treatments	Mean ± S. D
	Total Plate Count (CFU/g)
T1	260±1.31a
T2	280±1.37a
T3	200±1.24b
T4	600±1.57c
T5	210±1.24b

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

#### *Texture Analysis*

The texture is estimated to be an essential factor in the practical performance and acceptance of eatable cutlery as it affects the ability to handle and mouthfeel. Edible cutlery is a functional food product and the structural integrity of the product, concrete feel, and palatability greatly rely on hardness. T3 showed the highest average values of hardness (170.2 N), T1 (165.4 N) and T5 (167.5 N), whereas T4 was the lowest (149.7 N). T3 has better hardness as a result of its composite composition that included the use of wheat flour, stale bread flour and black and yellow lentils. Interestingly, the T4 hardness of the lowest value could probably have been caused by the lack of wheat gluten and the dependence on rice flour, which is also a starch source but, unlike wheat gluten, lacks elasticity and, thus, a brittle structure when baked (Yodkum and Yokesahachart, 2024). The results of empirical experiments with lentil-enhanced crackers and edible utensils show the range of hardness of 140 to 180 N, the same as in the present study (Li, 2020; Kabir and Hamidon, 2021). Together, gluten-rich flour, retrograded starch, and legume proteins in T3 produce a fully optimized degree of hardness that can be used in edible utensil purposes.

*Table 10: Mean squares of texture parameter including hardness*

Source	DF	Mean Square
		Hardness
Treatments	4	202.03*
Error	10	18.91
<b>Total</b>	<b>14</b>	

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\*= Highly significant (P< 0.01)

*Table 11: Mean values for texture parameter including hardness*

Treatments	Mean ± S. D
	Hardness (N)
T1	165.4 ± 4.3b
T2	158.9 ± 5.1c
T3	170.2 ± 3.9a
T4	149.7 ± 4.6d
T5	167.5 ± 3.7ab

Mean ± S.D values sharing similar letters in a column are statistically non-significant ( $P > 0.05$ )

### *Sensory Evaluation*

Sensory evaluation refers to a scientific technique employed in the measurement, analysis as well as interpretation of responses to food attributes as perceived through sense of sight, smell, taste, touch, and hearing. Scoring was done on the 9-point hedonic scale where 9 meant like extremely and 1 meant dislike extremely. Obtained data were subjected to statistical analysis in order to select the most acceptable formulation. Taste scores of the five treatments were between 7.33% to 8.33% based on the 9-point hedonic scale. T3 scored the highest mean value (8.33%) meaning moderately balanced and palatable flavor. T3 produced the best taste score compared to all other formulations, since the combination of wheat flour, rice flour, stale bread flour with both black and yellow lentils was the one to maximize sensory quality. Conversely, T5 scored the lowest mean value (7.33%). T2 and T4 were in the middle 7.66% and 7.67% respectively, had neutral to slightly nutty flavor.

The appearance scores were between 8.0% to 8.33%. T5 received the highest rating (8.33%) because of its even shape, smooth surface and attractive structure. T1 and T2 had the least score (7.33%) each, because it had cracks and irregular edges.

Color assessment showed a scale of 7.0% to 8.0%. T3 once more received the highest (8.0%) score due to its golden-brown color that was found appetizing as well as a sign of appropriate baking. T4 had a dull brownish color and was least preferred with a score of 7.0% by panelists. T1 was darker in color (7.67%) because it contained black lentils, which some panelists liked because it appeared natural.

Texture assessment showed a scale of 6.68% to 8.33%. T3 had the highest score (8.33%) of firms but crisp structure that maintained its structure throughout the consumption.

The texture of T4 (7.67%) was fairly acceptable although it lacked uniformity. T5 scored (8.0%) because of whole wheat flour as it gives smooth texture. In another study the mean value of texture of edible cutlery ranging from 7.76% to 8.36% (Matheswari and Arivuchudar, 2024).

Aroma scores were between 7.0% to 8.0%. T3 and T5 had the highest score (8.0%) each, because they had a mild and pleasant aroma that suited its overall profile. T4 was slightly stale smelling and receiving the (7.0%) rating probably because it contained too much stale bread flour. T2 (6.68%), possessed a strong legume aroma that was well accepted by panelists although not all of them liked it.

The overall acceptability scores were found to be between 7.0% to 8.33% which provides a summary of the panelists liking with regards to all the sensory attributes. T3 was the most preferred (8.33%) which means that the ingredient synergy was successful, and the mouthfeel was acceptable. T4 had the lowest rating (7.0%), and the texture and aroma were the main constraints. The scores of T1, T2 and T5 were in the middle (7.33%, 7.66% and 7.68%) respectively.

*Table 12 Mean squares of sensory parameters including appearance, taste and color*

Source	DF	Mean Square		
		Appearance	Taste	Color
Treatments	4	0.5667NS	0.4333NS	0.4333NS
Error	10	0.4667	0.8667	0.6000
Total	14			

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\*= Highly significant (P< 0.01)

*Table 13 Mean values of sensory parameters including appearance, taste and color*

Treatments	Mean ± S. D		
	Appearance	Taste	Color
T1	7.33 ± 0.57a	8.0 ± 1.0a	7.67 ± 0.58a
T2	7.33 ± 0.57a	7.66 ± 0.57a	7.68 ± 0.58a
T3	8.0 ± 1.0a	8.33 ± 0.58a	8.0 ± 1.0a
T4	7.66 ± 0.58a	7.67 ± 1.52a	7.0 ± 1.0a
T5	8.33 ± 0.58a	7.33 ± 0.58a	7.33 ± 0.58a

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

*Table 14: Mean squares of sensory parameters including texture, aroma and general acceptance*

Source	DF	Mean Square		
		Texture	Aroma	General Acceptance
Treatments	4	1.7667*	0.7667NS	0.7333NS
Error	10	0.4667	1.0667	0.2667
Total	14			

NS = Non-significant (P>0.05), \* = Significant (P<0.05), \*\*= Highly significant (P< 0.01)

*Table 15: Mean values of sensory parameters including texture, aroma and general acceptance*

Treatments	Mean ± S. D
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	<b>Texture</b>	<b>Aroma</b>	<b>General Acceptance</b>
<b>T1</b>	<b>6.68 ± 0.58b</b>	<b>7.0 ± 1.0a</b>	<b>6.68 ± 0.58b</b>
<b>T2</b>	<b>6.68 ± 0.57b</b>	<b>7.68 ± 1.52a</b>	<b>6.68 ± 0.58b</b>
<b>T3</b>	<b>8.33 ± 0.58a</b>	<b>8.0 ± 0.0a</b>	<b>7.68 ± 0.58a</b>
<b>T4</b>	<b>7.67 ± 0.57ab</b>	<b>7.0 ± 1.0a</b>	<b>6.67 ± 0.57b</b>
<b>T5</b>	<b>8.0 ± 1.0a</b>	<b>8.0 ± 1.0a</b>	<b>8.0 ± 0.0a</b>

Mean ± S.D values sharing similar letters in a column are statistically non-significant (P>0.05)

## CONCLUSION

In conclusion, a sustainable and environmentally beneficial substitute for plastic utensils is edible cutlery produced from stale bread and plant-based nutrients. By encouraging responsible consumerism and climate action, the study supports SDGs 12 and 13. T3 was found to be the best balanced of the five studied formulations in terms of nutrition, sensory appeal, and structural integrity, making it appropriate for small-scale industrial production or community-level use. All things considered, this study shows how food waste valorisation may promote environmentally friendly packaging and trash disposal techniques.

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## DECLARATIONS

**Ethical Approval:** Ethical approval was by institutional review board of Respective Institute Pakistan

**Informed Consent:** Informed Consent was taken from participants.

**Authors' Contributions:**

Concept: KLF; Design: NB, AS; Data Collection: NB; Analysis: NB, AS; Drafting: NB, KLF

**Conflict of Interest:** The authors declare no conflict of interest.

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**Data Availability:** The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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