**Development and Sensory Evaluation of Gluten-Free Waffle Cone Using Foxtail Millet**

**Abstract**

This study focuses on the development and evaluation of a gluten-free waffle cone using foxtail millet, analyzing its proximate composition and sensory attributes. The foxtail millet cone exhibited higher protein (10.3 ± 0.3%), crude fiber (3.6 ± 0.2%), crude fat (13.5 ± 0.5%), and ash content (2.5 ± 0.1%) compared to the market cone, which contained 8.5 ± 0.3% protein, 0.8 ± 0.1% fiber, 11.0 ± 0.5% fat, and 1.2 ± 0.1% ash. However, the carbohydrate content was lower (65.5 ± 0.5%) than the market cone (75.0 ± 0.5%), contributing to a slightly reduced energy value (445 ± 5 kcal vs. 470 ± 5 kcal). Sensory evaluation using a nine-point hedonic scale showed that the foxtail millet cone achieved an overall acceptability score of 8.1 ± 0.14, which was comparable to the market cone (8.5 ± 0.12). Minor reductions in appearance (8.2 ± 0.13), texture (8.4 ± 0.11), crispiness (8.4 ± 0.12), and taste (8.0 ± 0.14) were observed, likely due to the distinct properties of millet flour. The results indicate that foxtail millet-based waffle cones provide a nutritious, fiber-rich, and acceptable alternative to conventional wheat-based cones. Further optimization in processing and formulation could enhance sensory properties, making them a promising option for gluten-free product development.

**Keywords:** Gluten-free, Foxtail millet, Waffle cone, Sensory evaluation,

1. **Introduction**

The number of individuals purchasing gluten-free products is increasing worldwide for various reasons, including celiac disease, [gluten](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/gluten%22%20%5Co%20%22Learn%20more%20about%20gluten%20from%20ScienceDirect%27s%20AI-generated%20Topic%20Pages) intolerance, or following food trends and the global demand for gluten-free products has increased by approximately 16 % between the years of 2018 and 2022 making them one of the top 10 food trends existing nowadays (Hassan et al., 2024). ~~This rise is driven by individuals with celiac disease, gluten intolerance, or those following dietary trends.~~ The FDA defines 'gluten-free' as containing less than 20 ppm of gluten (Food & Drug Administration, 2023). Celiac disease, affecting 1% of the global population, is an autoimmune reaction triggered by gluten ingestion, leading to inflammation and potential complications if untreated (Lebwohl et al., 2018).

Foxtail millet (Setaria italica) is a nutrient-dense, gluten-free grain widely used in food product development due to its exceptional nutritional profile and functional properties (Sharma et al., 2018). It is rich in dietary fiber, proteins, essential amino acids, vitamins, and minerals such as iron and magnesium, making it a valuable ingredient for gluten-free product (Muthamilarasan et al., 2016; R. Singh et al., 2023). With a low glycemic index (52–68), foxtail millet aids in steady glucose release, making it beneficial for individuals managing diabetes and weight control (Yang et al., 2022). Its high fiber content promotes digestive health, while its magnesium levels support heart health (Reddy, 2017). The presence of bioactive compounds, including phenolic acids and flavonoids, enhances its antioxidant and anti-inflammatory properties (Suma & Urooj, 2012)**.** Additionally, foxtail millet contains phytochemicals with potential cancer-preventive and hypoglycemic effects (Hutabarat & Bowie, 2022)**.** Foxtail millet flour is increasingly being used in gluten-free baked goods, including waffle cones, as it contributes to improved texture and nutritional quality while maintaining desirable sensory attributes (Leder, 2004)**.**

Waffle cones, also referred to as ice cream cones, represent a desiccated, conical-shaped flat waffle that facilitates the holding and consumption of ice cream in a handheld manner. Prior to the advent of ice cream cones, various receptacles such as cups and dishes were employed for the service of ice cream. The ice cream cone constitutes a consumable product that can be enjoyed universally for the purpose of serving ice cream. The two predominant varieties of ice cream cones encompass wafer (or cake) cones and molded cones, as well as rolled sugar cones (Huang, 1981). By incorporating foxtail millet flour into waffle cone production, it is possible to create a product that maintains the desirable crisp texture while offering enhanced nutritional benefits.

Khandsari sugar is an unrefined, traditional sugar produced from sugarcane juice without the use of chemical processing. Unlike refined white sugar, Khandsari sugar retains essential minerals such as calcium, iron, and phosphorus, making it a healthier alternative in food formulations(P. Singh, 2024). Due to its minimal processing, it maintains a natural sweetness and subtle caramel flavor, which enhances the sensory characteristics of gluten-free baked products. In the development of gluten-free waffle cones, Khandsari sugar not only provides a rich taste but also contributes to the overall nutritional value, aligning with consumer preferences for minimally processed and health-conscious ingredients.

This study focuses on the development and sensory evaluation of a gluten-free waffle cone using foxtail millet and Khandsari sugar. The objective is to optimize the formulation to achieve a texture, taste, and crispness comparable to conventional waffle cones while ensuring a product suitable for gluten-intolerant consumers. The research also evaluates the sensory properties and consumer acceptance of the developed product, contributing to the growing market for functional and gluten-free foods.

1. **Materials and Methods**

foxtail millet was procured from local markets in Prayagraj and milled into flour at a local atta chakki (flour mill). The flour was then packed in HDPE (High-Density Polyethylene) packaging material to prevent contamination and ensure quality preservation. The packed millet flour was stored at a cooling temperature of 10–15°C to prevent rancidity and maintain freshness. Milk and butter were purchased from the Amul store, Prayagraj. Khandsari sugar and baking powder were sourced from local markets in Prayagraj.

* 1. ***Development of waffle cone:***

For the preparation of the waffle cone, powdered Khandsari sugar was taken in a bowl and mixed with melted butter. Subsequently, the dry ingredients, including baking powder with foxtail millet flour, were thoroughly mixed. Milk was then incorporated into the mixture with continuous stirring until the batter achieved a soft and creamy consistency. The batter was keep to stand for 10 min in order to raise the air bubble to the top. The batter was poured on the waffle cone maker pan, baked for 2 min at 180 °C temperature. Each waffle was immediately folded into a cone shape by using a cone molder after it was removed from the pan. The waffle cone was initially wrapped in butter paper and then packaged in low-density polyethylene and aluminum laminated pouches for further analysis. The flowsheet of preparation of waffle cone is as Fig 1.



**Fig 1: Step wise process for preparation of Foxtail millet waffle cone.**

* 1. **Proximate analysis of gluten free foxtail millet based waffle cone:**

The proximate composition of the gluten-free waffle cone was determined to evaluate its nutritional profile. The analysis was conducted using standard methods outlined by the Association of Official Analytical Chemists (AOAC, 2012, 2023) The analysis included the estimation of moisture, protein, fat, fiber, ash, and carbohydrate content using standard methods. The moisture content was determined using the hot-air oven method, protein content was analyzed using the Kjeldahl method, fat content was estimated using the Soxhlet extraction method, and crude fiber was measured using the acid and alkali digestion method. The ash content was determined by incinerating the sample in a muffle furnace at 550°C, while carbohydrate content was calculated by the difference method. These analyses help assess the nutritional quality and stability of the product, ensuring it meets consumer expectations and dietary requirements.

* 1. **Sensory Analysis:**

According to (Mhatre et al., 2022; Urjita Patil, 2022) the Nine-Point Hedonic Scale approach was used to assess the millet waffle ice cream cones' sensory qualities. Market ready waffle cone was used as control sample alongside the experimental waffle cone. Five men and five women from the Department of Dairy Technology made up the ten-person, untrained panel that took part in the assessment. To guarantee randomized sample presentation, the same panel was used in three sets, totaling 13 runs. The runs were rearranged in sequence for each set. Plates containing the samples were served, and they were assessed at room temperature (30°C). The panelists evaluated the items according to their appearance, mouthfeel, taste, texture (crispiness), flavor, and general acceptability. Every panelist was knowledgeable about common sensory evaluation methods and had prior experience in food technology. Using a nine-point hedonic scale, 1 stood for "dislike extremely" and 9 for "like extremely." To ascertain the samples' sensory acceptability, the mean scores for each attribute were computed after the scores were recorded.

1. **Results and discussion**
	1. **Proximate Composition**

The proximate analysis of the control and foxtail millet-based waffle cones revealed significant differences in their nutritional composition. As shown in Table 1, the foxtail millet waffle cone had higher ash, crude fat, protein, and fiber content compared to the control sample. The moisture content was slightly higher in the foxtail millet waffle cone (3.0%) than in the control (2.8%), indicating its potential to retain more moisture, which could impact texture and shelf life. The moisture content of waffle cones significantly influences their sensory texture and shelf life properties. Moisture affects the crispness, hardness, and overall sensory appeal of waffle cones, which are critical for consumer satisfaction. Additionally, moisture content plays a crucial role in determining the shelf life by influencing microbial stability and textural changes over time. Understanding these effects is essential for optimizing the production and storage of waffle cones to maintain their quality and consumer appeal. In gluten-free waffle formulations, higher moisture content can increase batter elasticity and viscosity, which affects the final texture of the waffle cone. This can lead to a denser and less crispy product (Aussanasuwannakul et al., 2024).

The protein content in the foxtail millet waffle cone (10.3%) was significantly higher than the control (8.5%), contributing to its improved nutritional profile. The crude fiber content was also considerably higher in the foxtail sample (3.6%) compared to the control (0.8%), making it a healthier alternative for digestive health. However, the carbohydrate content was lower in the foxtail millet-based cone (65.5%) than in the control (75.0%), which may affect the crispiness of the final product. The energy value of the foxtail millet waffle cone was slightly lower (445 kcal) compared to the control (470 kcal), indicating a potential benefit for calorie-conscious consumers. The proximate composition of waffle cones significantly influences their sensory texture and shelf life properties. The inclusion of various flours and ingredients can alter the nutritional profile, texture, and longevity of the cones. For instance, the substitution of traditional wheat flour with alternative flours such as apple pomace or millet can enhance dietary fiber content and affect textural attributes like hardness and crispiness. These changes can also impact the sensory acceptance and shelf life of the product, as seen in studies involving different flour compositions and additives (Austin et al., 2022; Kushwaha et al., 2023).

**Table 1. Proximate composition of control and foxtail millet waffle cones**

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| --- | --- | --- |
| **Parameter** | **Control** | **Foxtail** |
| Moisture Content (%) | 2.8 ± 0.2 | 3.0 ± 0.2 |
| Ash Content (%) | 1.2 ± 0.1 | 2.5 ± 0.1 |
| Crude Fat (%) | 11.0 ± 0.5 | 13.5 ± 0.5 |
| Protein Content (%) | 8.5 ± 0.3 | 10.3 ± 0.3 |
| Crude Fiber (%) | 0.8 ± 0.1 | 3.6 ± 0.2 |
| Carbohydrates (%) | 75.0 ± 0.5 | 65.5 ± 0.5 |
| Energy Value (kcal) | 470 ± 5 | 1. 5
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Each value represents the average of three determinations±SD.

* 1. **Sensory analysis:**

The sensory evaluation of foxtail millet-based waffle cones in comparison to conventional market cones revealed notable differences across various attributes, including appearance, color, texture, crispiness, taste, flavor, and overall acceptability. The market waffle cone exhibited a higher score for appearance (8.6) and color (8.5) compared to the foxtail millet cone (8.2 ± 0.13 and 8.2 ± 0.12, respectively), which could be attributed to the natural pigmentation and fiber content of foxtail millet flour, as previously reported by (Chaitra et al., 2020). Texture and crispiness, key factors influencing consumer preference, also showed a slight reduction in the foxtail millet cone (8.4 ± 0.11 and 8.4 ± 0.12, respectively) compared to the market cone (8.7 and 8.7 ± 0.10, respectively), aligning with findings from (Zanariah, M. D.\*, Nur Zaleqha, M. H., and Lisnurjannah, 2019), who highlighted the challenges in achieving optimal crispness in gluten-free products due to the absence of gluten. Taste and flavor, which play a crucial role in product acceptability, were marginally lower in the foxtail millet cone (8.0 ± 0.14 for both) compared to the market cone (8.5 ± 0.12), possibly due to the inherent nutty and earthy notes of millet, as noted by (CHAKRABORTY et al., 2009). Despite these minor variations, the overall acceptability of the foxtail millet cone (8.1 ± 0.14) remained within an acceptable range, slightly lower than the market cone (8.5 ± 0.12), suggesting that millet-based waffle cones are a promising gluten-free alternative. Similar trends were observed by (Indumathy & Varshini, 2024), who reported that minor modifications in ingredient formulations could enhance the sensory properties of millet-based baked goods. These findings underscore the potential of foxtail millet in gluten-free waffle cone formulations and suggest that further optimization of processing techniques and ingredient balancing could enhance their sensory attributes, making them a viable option for health-conscious consumers.

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**Fig 2: Sensory analysis of gluten free waffle cone compared with market cone**

1. **Conclusion**

The present study demonstrates that foxtail millet can be successfully incorporated into waffle cone formulations, offering a gluten-free and nutritionally superior alternative to conventional market cones. The developed millet-based cone achieved an overall acceptability score of 8.1 ± 0.14, which is comparable to the market cone (8.5 ± 0.12), with minor reductions in sensory attributes such as crispiness and texture. However, the nutritional advantages of foxtail millet, including higher dietary fiber, essential minerals, and a lower glycemic index, highlight its potential for functional food applications. The results align with previous studies supporting the use of millet-based bakery products for enhanced health benefits. Future research can focus on optimizing processing techniques to further improve the textural attributes and consumer preference. Overall, millet-based waffle cones represent a promising innovation in gluten-free product development, contributing to health-conscious dietary trends while promoting the use of sustainable and nutrient-dense grains.

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