Research Article
Vol. 21, No. 6, Jan.-Feb. 2026, p.

Quality Evaluation and Sensory Properties of Cookies Prepared from Foxtail Millet (*Setaria italica*) Flour and Orange Peel (*Citrus sinensis)* Powder

J. Yogalakshmi[1], S.A.O. Adeyeye[1*]

1- Department of Food Technology, Hindustan Institute of Technology & Science, Chennai, Tamil Nadu, India
(*- Corresponding Author Email: saadeyeye2015@gmail.com)

Received: 12.06.2025
Revised: 27.07.2025
Accepted: 09.09.2025
Available Online: 02.12.2025

How to cite this article:
Yogalakshmi, J., & Adeyeye, S.A.O. (2026). Quality evaluation and sensory properties of cookies prepared from foxtail millet (*Setaria italica*) flour and orange peel (*Citrus sinensis*) powder. *Iranian Food Science and Technology Research Journal, 21*(6),. https://doi.org/10.22067/ifstrj.2025.94047.1447

Abstract

The growing demand for functional foods has encouraged with incorporation of natural, nutrient-rich ingredients into traditional products to support health and wellness. Foxtail millet, a gluten-free grain rich in protein, fiber, and micronutrients, and orange peel powder, a by-product abundant in dietary fibre and bioactive compounds, were used to develop cookies with functional properties. This study aimed to develop and evaluate functional cookies prepared from foxtail millet enriched with orange peel powder. Five formulations were produced with 49:1, 48:2, 47:3, 46:4, 45:5 of foxtail millet and orange peel powder for sample 1 to sample 5 while the control sample had 50:0. The samples were analyzed for proximate composition, antioxidant activity, microbial safety, and sensory properties to determine the optimal level of incorporation using standard methods. The results revealed that for proximate composition, protein content ranged from 11.7% to 7.2% for sample 1 to sample 5 while the control sample had 11.9%. Fat content ranged from 20.5% to 19.3% for sample 1 to sample 5 while the control sample had 20.7%. Crude fibre content ranged from 2.8% to 4.8% for sample 1 to sample 5 while the control sample had 2.1%. Ash content ranged from 1.10% to 1.54% for sample 1 to sample 5 while the control sample had 1.04%. Moisture content ranged from 2.61% to 4.25% for sample 1 to sample 5 while the control sample had 2.5%. Nutritional analysis indicated a progressive enhancement in dietary fiber and antioxidant activity, contributing to improved digestive health and free radical scavenging capacity. Sensory evaluation showed the optimal orange peel powder concentration (2%) for sensory overall acceptability. The study demonstrated that incorporating orange peel powder significantly enhances the nutritional and functional attributes of cookies.

Keywords: Antioxidant activity, Foxtail millet, Functional cookies, Orange peel powder

https://doi.org/10.22067/ifstrj.2025.94047.1447

Introduction

The food industry has introduced a range of new nutritious food products aimed at meeting consumers' needs for both health and convenience. Among these, bakery products especially biscuits have gained notable popularity in the market. Their widespread consumption across various age groups, along with their extended shelf life, makes them a preferred choice for many age-groups (Andaregie *et al*., 2024; Arepally, Reddy, Coorey, & Goswami, 2023).

In countries like India, policy support and initiatives such as the International Year of Millets 2023 have boosted millet consumption and innovation in processed millet products (Muthamilarasan & Prasad, 2021). Furthermore, Srivastava *et al*. (2020) emphasizing the role of millet-based products in enhancing dietary diversity and addressing micronutrient deficiencies. While challenges remain in terms of consumer awareness and product development, millets show strong potential in reformulating the convenience food sector toward more health-promoting options.

Foxtail millet (*Setaria italica* L.) *P. Beauv*.) has emerged as a highly significant crop among the various species of millets cultivated across the world. In terms of global production and productivity, it holds the distinction of being the sixth most productive grain crop, making it an important contributor to food security in several regions. This ancient cereal is known for its adaptability and ease of cultivation, thriving even in marginal soils and under low-input agricultural practices. Taxonomically, it is classified within the *Setaria* genus, which falls under the Poaceae family- commonly referred to as the grass family- and is further categorized within the subfamily Panicoideae (Sharma & Niranjan, 2018).

One of the key advantages of foxtail millet is that it is a non-glutinous grain, similar to pseudo cereals like buckwheat and quinoa. Moreover, it does not promote acid formation in the digestive system, making it a gentle and easily digestible option for individuals with sensitive stomachs or gluten intolerance. From a nutritional standpoint, millets, including foxtail millet, are increasingly recognized as functional food ingredients due to their rich nutrient profile and health-promoting effects. They are especially valued for their relatively high lysine content—a vital amino acid that is often limited in many commonly consumed cereal grains—thus serving as an excellent complementary protein source in cereal-based diets (Singh *et al*., 2018).

Foxtail millet is known for its rich and diverse composition of health-promoting nutrients, which not only enhance its value as a staple food source but also distinguish it from other cereals due to its well-balanced nutritional profile. This millet contains several essential components that contribute significantly to human health and nutrition. The primary constituents of foxtail millet include complex carbohydrates, particularly starch, as well as a considerable amount of protein, dietary fibre, beneficial fats, a variety of essential vitamins, and important minerals. This unique combination of macro- and micronutrients not only supports its role as a nutritious grain but also contributes to its desirable sensory attributes. The specific nutrient makeup of foxtail millet plays a vital role in defining its taste, aroma, texture, and visual appeal, making it a favourable choice for both traditional and modern dietary applications (Sharma & Niranjan, 2018).

Foxtail millet also includes certain compounds known as anti-nutrients. These anti-nutritional factors can negatively impact the bioavailability and overall absorption of essential nutrients, thereby diminishing the nutritional quality of the grain to some extent. Importantly, the distribution of these anti-nutrients is not uniform throughout the grain, which opens up possibilities for targeted processing interventions. To counteract the adverse effects of these compounds and to enhance the nutritional effectiveness of foxtail millet, a range of traditional and modern food processing techniques can be applied. These

include methods such as milling, cooking, extrusion, germination, and fermentation, all of which have been shown to significantly reduce anti-nutrient levels and improve the availability of micronutrients in the grain (Sharma & Niranjan, 2018).

Orange peel powder, derived from the outer skin of the sweet orange fruit (*Citrus sinensis*), is often considered an underutilized but highly nutritious food component. Rich in dietary fibre, phenolic compounds, flavonoids, β-carotene, vitamins, and antioxidants. Therefore, orange peel powder holds significant potential in functional food applications (Belose, Kotecha, Godase, & Chavan, 2021). Orange peels, which account for nearly 50% of the fruit's mass after juice extraction, are usually discarded as waste in the citrus industry (Zaker, Sawate, Patil, & Sadawarte, 2016). However, research indicates that these peels contain a higher concentration of phenolics and flavonoids than the edible pulp itself (Gorinstein *et al.*, 2001).

Globally, oranges represent a significant horticultural commodity with India contributing about 8608000 tons of the global 122.5 million tons production (Rangnekar, 2024). Despite such high production volumes, orange peels remain significantly underexploited. Sweet orange peels are particularly abundant in bioactive constituents, making them suitable for incorporation into food systems for enhanced nutritional value (Kumar, Tomer, & Kaur, 2018).

In light of the high perishability of orange peels and their rich phytochemical composition, suitable processing techniques are necessary to convert them into stable, functional food ingredients. A pivotal step in orange peel powder preparation involves drying followed by grinding. The drying phase serves to reduce moisture content, thus enhancing shelf life and reducing microbial risks (Sankalpa *et al*., 2017).

The application of orange peel powder in food products, particularly bakery items like cookies, has received growing attention due to its dual role in enhancing both nutritional and sensory attributes. Cookies, widely consumed across all age groups, present an ideal medium for nutrient fortification owing to their popularity, convenience, and extended shelf life (Dhankar, 2013).

Studies have demonstrated that incorporating orange peel powder into cookie formulations significantly boosts their dietary fibre, vitamin, and antioxidant levels without adversely affecting taste and texture when used in optimal amounts (Belose *et al.*, 2021). The objective has been to determine the maximum permissible level of inclusion that retains consumer acceptability while offering health benefits. Such enrichment aligns with the rising consumer demand for functional foods that not only satiate but also contribute to disease prevention (Dukwal, 2004).

Furthermore, the fortification of baked products with orange peel powder has broader implications in the Indian food industry, where demand for ready-to-eat snacks is escalating. This development not only satisfies nutritional improvement objectives but also aligns with waste minimization strategies by utilizing agro-industrial by-products (Obafaye & Omoba, 2018). Therefore, this study was carried out to evaluate proximate composition, antioxidant properties, microbial and sensory properties of functional cookies prepared from foxtail millet and orange peel powder.

Materials and Methods

Raw Materials

The major ingredient foxtail millet flour was purchased from Sri Narayanan Herbal shop, Lattice bridge road, Adyar. The Parry's Amrit Brown sugar was purchased from Nilgiris, Kelambakkam. Weikfield Baking powder was procured from Adyar Departmental Stores, Besant Nagar. Amul butter was procured freshly on the day of the product preparation from Pooja's Supermarket, Padur.

Table 1- Formulation of cookie samples

Ingredients	Control (g)	Test Sample 1 (g)	Test Sample 2 (g)	Test Sample 3 (g)	Test Sample 4 (g)	Test Sample 5 (g)
Foxtail millet flour	50	49	48	47	46	45
Orange peel powder	0	1	2	3	4	5
Butter	25	25	25	25	25	25
Sugar	25	25	25	25	25	25
Baking powder	1	1	1	1	1	1

Formulation of cookie samples

Keys:

Sample 1 49:1 Foxtail millet : Orange peel powder

Sample 2 48:2 Foxtail millet : Orange peel powder

Sample 3 47:3 Foxtail millet : Orange peel powder

Sample 4 46:4 Foxtail millet : Orange peel powder

Sample 5 45:5 Foxtail millet : Orange peel powder

Control Sample 50:0 Foxtail millet : Orange peel powder

Preparation of Orange Peel Powder

Oranges were peeled and the peels were washed thoroughly to remove any dirt or debris. The peels were placed in a dehydrator at a low temperature of 57°C for several hours, until they were completely dried. The dried peels were grinded into a fine powder. The powder was sieved through 0.45 mm mesh sieve to ensure very fine powder free of any large pieces. The orange peel powder was stored in an airtight container in a cool, dark place. A dehydrator operating at a low temperature (57°C) was preferred to sun drying because it generally preserves bioactive compounds better than traditional sun drying, which can expose food to high temperatures and UV radiation, potentially degrading these beneficial components. While both methods aim to remove moisture, the controlled and lower temperature of a dehydrator helps retain more of the natural colors, flavors, and nutritional value, including antioxidants and vitamins.

Preparation of Cookies

The foxtail millet cookies incorporating orange peel powder was prepared in different composition according to the above formulation (Table 1). In a mixing bowl, butter and sugar were weighed and creamed together to a fluffy consistency. Then in a separate bowl, dry ingredients like foxtail millet flour, orange peel powder and baking powder were weighed accurately and mixed together. Now, dry ingredients were transferred to the creamed butter bowl and mixed together to form dough. The dough was then kneaded, rolled and cut with cookie cutter. First, the oven was preheated for 10 minutes at 180 degree Celsius. Then the cookies are baked in the pre-heated oven for 20 to 30 mins at 160^{o} degree Celsius. After baking, the cookies were cooled down at room temperature. Then, they were packaged in Ziploc bags until laboratory analysis (Fig. 1).

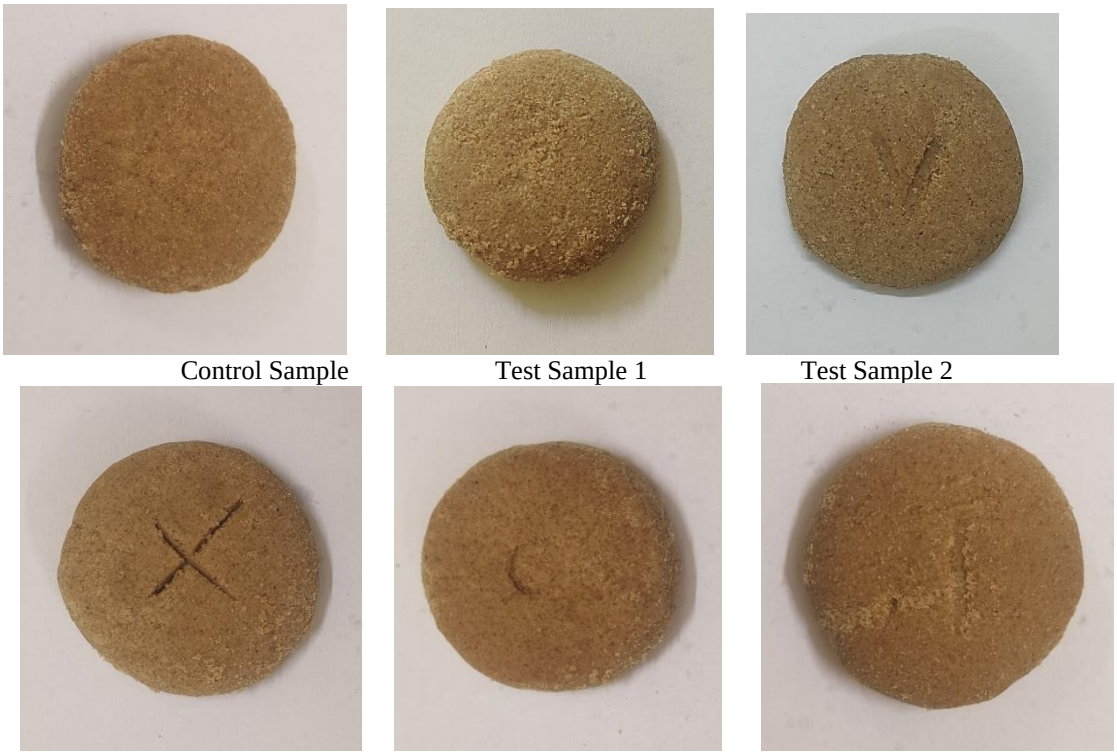

Fig. 1. Foxtail millet cookies incorporated with orange peel powder samples

Proximate Analysis

Proximate analysis of the cookie samples were determined by the following methods.

Moisture

The moisture content was determined following the procedure outlined in AOAC method, 2005 (Method No. 930.09**)**. Approximately 5 grams of the finely ground sample were accurately weighed into a clean, dry dish. The dish was then subjected for three hours, or until a constant weight was reached, to a hot air oven set at 105°C ± 2°C. Following drying, the sample was weighed after being cooled for 30 minutes in a desiccator. Until the difference between two consecutive weights did not surpass 0.5 mg, indicating consistent weight, the drying, cooling, and weighing procedures were repeated for each sample. The following formula was used to determine the moisture content, which was then stated as a percentage of the initial sample weight based on the weight loss after drying:

$$\textbf{Moisture (\%)} = \frac{\textbf{(Initial weight – Final weight)}}{\textbf{Initial weight}} \times \mathbf{100}$$

Protein

The protein content was estimated by the Kjeldahl method as described in AOAC method, 2005 (Method No. 930.09**)**, which determines the total nitrogen content and converts it to protein using a standard conversion factor. Approximately 1 gram of the finely ground sample was weighed accurately and digested with concentrated sulfuric acid in the presence of a catalyst mixture (usually containing potassium sulfate and copper sulfate) to convert organic nitrogen into ammonium sulfate. After complete digestion and the solution becoming clear, it was diluted and made alkaline with sodium hydroxide. The ammonia released was distilled and collected in a known volume of standard boric acid solution containing a mixed indicator. The trapped ammonia was then titrated with standard hydrochloric acid to determine the amount of nitrogen present. The

protein content was calculated by multiplying the nitrogen content by a factor (commonly 6.25 for general food products). The result was expressed as a percentage of the original sample using the following formula:

$$\text{Protein (\%)} = \frac{(\text{Volume of acid} \times \text{Normality} \times 1.4007 \times \text{Conversion factor})}{\text{Weight of sample}}$$

Crude Protein (%) = % Nitrogen × 6.25

Fat

The total fat content was determined using the Soxhlet extraction method as described in AOAC method, 2005 (Method No. 930.09**)**. Approximately two grams of the ground and moisture-free sample were weighed accurately and transferred into a thimble. A pre-weighed clean and dry round bottom flask was fixed below the extractor, and the thimble was placed inside the Soxhlet apparatus. Petroleum ether (boiling point 40–60°C) was used as the solvent for fat extraction. The thimble was covered with cotton wool to prevent sample loss. The extraction was carried out continuously for 6–8 hours. After completion, the solvent was evaporated on a water bath, and the flask containing the extracted fat was further dried in a hot air oven at 80°C for 30 minutes to remove any residual solvent. The flask was then cooled in a desiccator and weighed to determine the amount of fat extracted. The total fat content was calculated using the following formula:

$$\text{Fat content (\%)} = \left(\frac{\text{Weight of extracted fat}}{\text{Weight of sample}}\right) \times 100$$

Crude Fiber

The crude fiber content was determined as per AOAC method, 2005 (Method No. 930.09**)**. Two grams of the dried and finely ground sample were weighed and subjected to sequential digestion. The sample was first boiled with 1.25% sulfuric acid for 30 minutes to remove the acid-soluble components. The mixture was then filtered using a muslin cloth, and the residue was washed with hot distilled water until free from acid. This was followed by alkali digestion, where the residue was boiled with 1.25% sodium hydroxide solution for another 30 minutes. After digestion, the residue was filtered again, washed thoroughly with hot water, followed by an alcohol rinse to ensure removal of any remaining alkali. The final residue was then dried in a hot air oven at 105°C to a constant weight. After cooling in a desiccator, the dried residue was transferred to a pre-weighed crucible and ignited in a muffle furnace at 550°C until complete ashing. The crude fiber content was calculated from the loss in weight on ignition and expressed as a percentage of the original sample weight using the following formula:

$$\text{Crude Fibre (\%)} = \frac{(\text{Weight after drying} - \text{Weight after ashing})}{\text{Weight of sample}} \times 100.$$

Total Ash

The total ash content was determined according to the procedure described in AOAC method, 2005 (Method No. 930.09**)**. About 2 to 5 grams of the dried sample were accurately weighed into a pre-weighed, dry silica crucible. The sample was first charred gently over a low flame until the smoke ceased, preventing any loss of material due to burning. The crucible was then transferred to a muffle furnace and ignited at 550°C ± 25°C for about 4 to 6 hours until a white or light grey ash was obtained, indicating complete oxidation of the organic matter. After ignition, the crucible was carefully removed and cooled in a desiccator to room temperature. It was then weighed to determine the weight of the total ash. The total ash content was calculated using the following formula:

$$\text{Total Ash (\%)} = \left(\frac{\text{Weight of ash}}{\text{Weight of sample}}\right) \times 100$$

Carbohydrate

The carbohydrate content of the sample was determined by the difference method as per AOAC method, 2005 (Method No. 930.09**)**. The moisture, ash, crude fiber, crude protein, and fat contents were first estimated using their respective standard methods. The total carbohydrate percentage was then calculated

by subtracting the sum of these components from 100.

Carbohydrate (%) = 100 – (% moisture +% ash + % crude fiber +% crude protein + % fat)

Antioxidant Analysis

DPPH Radical Scavenging Assay The percentage of antioxidant activity (AA %) of each substance was assessed by DPPH free radical scavenging assay (Tailor & Goyal, 2014, Baliyan *et al.*, 2022, Gulcin & Alwasel, 2023). In 1 mL or 3 mL cuvettes, analyses were carried out using a UV-VIS spectrophotometer. To achieve this, a freshly made stock solution of 10^{-3} M DPPH radicals in ethanol or methanol was made prior to analysis. The DPPH solution was made by diluting 3 mL of the stock solution with 50 mL of methanol in a volumetric flask and covering it with aluminium foil to keep it out of the light. 1.00 ± 0.200 was the specified absorbance value. Next, 3 mL of DPPH working solution was added to the 0.5 mL extract, stirred, and allowed to sit in the dark for half an hour. The presence of an antioxidant agent in the reaction medium causes the purple colour to vanish. A reference sample was made in the same way with 0.5 mL of solvent. At 517 nm, a freshly made DPPH radical solution exhibits maximum absorption. Three repetitions of each analysis were performed, and absorbance at 517 nm was measured. Reaction mixtures without test chemicals are called blanks. Using the following formula, the scavenging activity percentage (AA%) was determined:

% Antioxidant activity = {(absorbance at blank) – (absorbance at test) / (absorbance at blank)} X 100

Microbial Analysis

Total Plate Count

The total plate count (TPC) was carried out immediately after baking as per AOAC method, 2005 (Method No. 966.23) to determine the number of viable aerobic mesophilic microorganisms in the sample. Ten grams of the sample were aseptically weighed and homogenized in 90 mL of sterile peptone water to prepare a 1:10 dilution. Serial decimal dilutions were then made using sterile diluents. From each selected dilution, 1 mL was transferred aseptically into sterile Petri plates in duplicate, followed by the addition of molten and cooled Plate Count Agar (PCA). The plates were gently swirled to mix and allowed to solidify. The inoculated plates were then incubated at 30°C ± 1°C for 72 ± 3 hours in an upright position. After incubation, colonies were counted manually using a colony counter, and the results were expressed as colony-forming units per gram (CFU/g) of the sample.

Yeast and Mold Count

The yeast and mold count was carried out as per AOAC method, 2005 (Method No. 966.23) to determine the number of viable fungal organisms in the sample. Ten grams of the sample were aseptically weighed and homogenized in 90 mL of sterile peptone water to make a 1:10 dilution. Serial dilutions were prepared using the same diluent. From the appropriate dilutions, 1 mL was aseptically transferred into sterile Petri plates, followed by pouring of sterile and cooled Potato Dextrose Agar (PDA) acidified with tartaric acid to a pH of around 3.5 to inhibit bacterial growth. The plates were incubated at 25°C ± 1°C for 5 days in an inverted position. After incubation, visible colonies of yeast and mold were counted and recorded separately. Only plates containing 10 to 150 colonies were considered for accuracy, and results were expressed as colony-forming units per gram (CFU/g) of the sample.

Sensory Analysis

The sensory quality of the cookies was conducted with a trained panel of 20 members. The panel members consisted of Faculty Members and Postgraduate Students from the Department of Food Technology from Hindustan Institute of Technology and Science, Padur. Ten grammes of cookie samples were presented to each panellist in a

cubicle in randomized order at room temperature. Glass of drinking water was provided as palate cleansers between samples, to ensure unbiased evaluation. Using a 9-point hedonic scale, where 1 stands for "dislike extremely," 2 for "dislike very much," 3 for "dislike moderately," 4 for "dislike slightly," 5 for "neither like nor dislike," 6 for "like slightly," 7 for "like moderately," 8 for "like very much," and 9 for "like extremely," the panellists were asked to rate the cookies' appearance, color, taste, aroma, mouth feel, texture, and overall acceptability.

Data Analysis

Ten samples were produced from each formulation and analyses were done in triplicates to obtain mean values. One-way analysis of variance was used and Shapiro-Wilk test was used to formally assess the normality of a dataset at $p \geq 0.05$. Data were analysed using SPSS Version 22 for windows (IBM Corporation, New York, USA). Duncan's multiple range tests were used to compare the means at the 5% probability level.

Results

Proximate Analysis of the Cookie Samples

The results of proximate analysis of cookies are presented in Table 2. The moisture content gradually increased from the control (2.5 g/100g) to Sample 5 (4.25 g/100g) as the level of orange peel powder increased. This increase is likely due to the higher water-holding capacity of orange peel powder, which absorbs moisture during the baking process. The moisture in orange peel powder is high due to its high pectin content, which has a strong ability to bind water and form hydrogen bonds. This property allows the powder to absorb and retain significant amounts of water, leading to increased moisture in the surrounding environment or material it's incorporated into. The most notable increase in moisture content occurred between Sample 3 (3.12 g/100g) and Sample 4 (3.74 g/100g), indicating that higher concentrations of orange peel powder further enhance moisture retention. This could affect the texture and shelf-life of the cookies, making them softer and potentially more prone to moisture-related changes during storage (Gómez *et al*., 2020). Although, an increase in moisture content may contribute to a softer texture, potentially improving palatability but also increasing susceptibility to microbial spoilage during storage if not properly managed.

The observed decrease in protein contentwhen orange peel powder was added to the mixture can be attributed to the substitution of protein-rich ingredients with orange peel powder, which has lower protein content (Natocho, et al., 2024, Abdel Wahab, Abou Elyazeed, & Abdalla, 2018). Specifically, the protein content went from 11.9 g/100g in the control to 7.2 g/100g in Sample 5, coinciding with the increase in orange peel powder. The decrease in protein content is a direct consequence of the dilution effect caused by replacing other ingredients with orange peel powder. Orange peel powder is known to be a good source of fibre and antioxidants, but it is not a primary source of protein. Therefore, as the proportion of orange peel powder increases, the overall protein content of the mixture naturally decreases (Natocho, Mugabi, & Muyonga, 2024, Abdel Wahab *et al*., 2018). The most significant drop occurred between Sample 2 (10.2 g/100g) and Sample 3 (8.4 g/100g), indicating that as the inclusion of orange peel powder increased, acidity of the orange peel powder also increased. The addition of orange peel powder to foxtail millet cookies can slightly reduce the protein content due to acidity-induced denaturation. Acidity, introduced by the orange peel powder, can cause proteins to unfold and lose their functional structure. While the protein content may be slightly lower than in cookies without orange peel powder, the cookies still maintain a moderate protein level. This makes them a suitable option for those looking for a protein-rich snack or part of a balanced diet (Sharma, Mahato, & Lee, 2017).

The fat content showed a slight decrease from the control (20.7 g/100g) to Sample 5 (19.3 g/100g) with increasing levels of orange peel powder. This reduction in fat may be due to the replacement of fat-containing ingredients with orange peel powder, which contains negligible fat. The decrease was gradual, with the smallest drop observed between Sample 1 (20.5 g/100g) and Sample 2 (20.2 g/100g). The reduction in fat is minimal but suggests that incorporating orange peel powder can slightly lower the overall fat content of the cookies while maintaining a relatively balanced nutritional profile.

The fat content exhibited a mild reduction from 20.7 g/100g in the control to 19.3 g/100g in Sample 5. This is attributable to the partial replacement of higher-fat ingredients with orange peel powder, which contains negligible fat. Such modifications are beneficial for consumers seeking lower-fat options, especially when integrated into functional food development without compromising too much on sensory attributes (Adams & Foster, 2021).

The crude fiber content increased progressively from the control (2.1 g/100g) to Sample 5 (4.89 g/100g) as the percentage of orange peel powder increased. This rise is expected, as orange peel powder is a rich source of dietary fiber, particularly soluble and insoluble fibers. The gradual increase in fiber content reflects the substitution of other ingredients with orange peel powder, which enhanced the fiber content in the cookies. The most significant rise occurred between Sample 4 (4.3 g/100g) and Sample 5 (4.89 g/100g), indicating that higher levels of orange peel powder have a strong impact on the fiber content. This increase in fiber makes the cookies more functional, promoting digestive health and contributing to their nutritional value.

Crude fiber content rose significantly from 2.1 g/100g in the control to 4.89 g/100g in Sample 5, reflecting the high fiber density of orange peel powder. This increment enhances the functional value of the cookies, contributing to improved digestive health and increased satiety. The rich presence of soluble and insoluble fiber in citrus peels supports these outcomes and has been previously linked to improved gastrointestinal function and potential prebiotic effects (Gómez *et al.*, 2020).

The crude ash content showed a gradual increase from the control (1.04 g/100g) to Sample 5 (1.54 g/100g) as the level of orange peel powder increased. Ash content reflects the mineral content in the samples, and the increase is likely due to the higher mineral content in orange peel powder compared to the other ingredients. As the concentration of orange peel powder rises, more minerals such as calcium, potassium, and magnesium are incorporated into the cookies, leading to a higher ash content. The most significant increase in ash content occurred between Sample 1 (1.1 g/100g) and Sample 2 (1.4 g/100g), suggesting that the early levels of orange peel powder contribute notably to the mineral composition of the product. This indicates that higher levels of orange peel powder can enhance the mineral profile of the cookies.

Ash content, which serves as an indicator of mineral content, also increased with rising levels of orange peel powder, moving from 1.04 g/100g in the control to 1.54 g/100g in Sample 5. This is consistent with existing literature that notes the mineral richness of orange peel, including potassium, calcium, and magnesium, thereby enhancing the micronutrient profile of the cookies (Gorinstein *et al.*, 2021).

The carbohydrate content increased slightly from the control (61.9 g/100g) to Sample 5 (64.0 g/100g) as the level of orange peel powder increased. This gradual rise in carbohydrates is likely due to the additional carbohydrate content provided by the orange peel powder itself, which contains soluble and insoluble fibres that contribute to the total carbohydrate count. Although the orange peel powder is rich in fiber, it still adds some carbohydrates, which may explain the slight increase in the samples with higher

concentrations of orange peel powder. The increase in carbohydrates is not significant but suggests that the inclusion of orange peel powder can contribute to the overall carbohydrate content while also enriching the product with beneficial dietary fiber.

Carbohydrate content showed a slight rise from 61.9 g/100g to 64.0 g/100g across the samples, which may be explained by the carbohydrate component of orange peel itself, including free sugars and complex polysaccharides (Kha, Nguyen, & Roach, 2014). Although modest, this increase complements the rising fiber content and contributes to the energy yield of the product.

The energy content decreased gradually from the control (481.9 kcal/100g) to Sample 5 (458.5 kcal/100g) with increasing levels of orange peel powder. This decline is attributed to the substitution of higher-calorie ingredients with orange peel powder, which is naturally lower in energy and rich in dietary fiber. As the fiber content rises, the proportion of digestible nutrients decreases, leading to a reduction in total energy value. A noticeable drop in energy was observed particularly between Sample 3 and Sample 4, indicating a stronger effect at higher inclusion levels. These findings suggest that orange peel powder can be effectively used to develop lower-calorie, fiber-enriched functional cookies.

Energy values declined from 481.9 kcal/100g in the control to 458.5 kcal/100g in Sample 5, likely due to the lower caloric density of orange peel powder compared to conventional baking ingredients. This reduction positions the cookies as a viable option for calorie-conscious consumers, without significantly compromising other macronutrients (Boukroufa, Boutekedjiret, Petigny, Rakotomanomana, & Chemat, 2015).

Table 2- Proximate analysis of the cookies

Parameter	Control	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Moisture (g/100g)	2.5±0.1 [a]	2.6±0.1 [a]	2.9±0.1 [a]	3.1±0.1 [a]	3.7±0.1 [a]	4.2±0.1 [a]
Protein (g/100g)	11.9±0.2 [a]	11.7±0.2 [a]	10.2±0.2 [a]	8.4±0.2 [b]	8.4±0.2 [b]	7.2±0.2 [b]
Fat (g/100g)	20.7±0.2 [a]	20.5±0.2 [a]	20.2±0.2 [a]	19.7±0.2 [b]	19.4±0.2 [b]	19.3±0.2 [b]
Fibre (g/100g)	2.1±0.1 [a]	2.8±0.1 [a]	3.1±0.1 [a]	3.9±0.1 [b]	4.3±0.1 [b]	4.9±0.1 [b]
Ash (g/100g)	1.0±0.1 [a]	1.1±0.1 [a]	1.4 ±0.1[a]	1.5±0.1 [a]	1.5±0.1 [a]	1.5±0.1 [a]
Carbohydrates (g/100g)	61.9±0.2 [a]	62.3±0.2 [a]	62.7±0.2 [a]	63.4±0.2 [a]	63.8±0.2 [a]	64.0±0.2 [a]
Energy (kcal/100g)	481.0±0.5 [a]	480.5±0.5 [a]	478.4±0.5 [a]	476.2±0.5 [a]	463.4±0.5 [a]	458.5±0.5 [a]

In order to determine mean values, ten samples were produced from each formulation, and analyses were conducted in duplicate. Duncan's multiple range tests was used to separate means, and significance was accepted at a 5% level of confidence ($p < 0.05$). * The column's mean ± standard deviation, which is indicated by the same superscript, does not differ significantly at $p \leq 0.05$.

Sample 1 49:1 Foxtail millet: Orange peel powder
Sample 2 48:2 Foxtail millet: Orange peel powder
Sample 3 47:3 Foxtail millet: Orange peel powder
Sample 4 46:4 Foxtail millet: Orange peel powder
Sample 5 45:5 Foxtail millet: Orange peel powder

Keys:

Control Sample 50:0 Foxtail millet: Orange peel powder

Antioxidant Analysis

The antioxidant activity increased significantly from the control (3% inhibition) to Sample 5 (34.8% inhibition) with rising levels of orange peel powder (Fig. 2). This value directly quantifies the antioxidant activity by measuring the decrease in DPPH absorbance after the addition of the antioxidant. A higher percentage inhibition indicates a stronger antioxidant capacity, as more DPPH radicals have been neutralized (Zhou *et al.,* 2022, Hofmann *et al.,* 2024). Absorbance values at 517 nm are used to calculate the percentage inhibition. The DPPH assay works by measuring the decrease in absorbance of a DPPH solution (typically purple) when it reacts with an antioxidant. The reaction produces a colourless or yellowish compound (DPPH-H), and the extent of this discoloration (indicated by a decrease in absorbance) is directly related to the antioxidant's activity (Zhou *et al.,* 2022, Hofmann *et al.,* 2024).

While the percentage inhibition is the key metric, absorbance values can provide additional information, especially when considering the reaction mechanism or if there are unusual results (Zhou *et al.,* 2022, Hofmann *et al.,* 2024). For example: If the absorbance does not reach zero even at high concentrations of the antioxidant, it might indicate that not all DPPH is being scavenged or that the reaction products also absorb at 517 nm. Tracking absorbance over time can provide insights into the speed of the reaction. If other compounds in the sample absorb at or near 517 nm, they can interfere with the assay, and tracking absorbance can help identify and potentially account for this interference (Zhou *et al.,* 2022, Hofmann *et al.,* 2024).

This sharp increase is attributed to the high concentration of bioactive compounds in orange peel powder, such as flavonoids, polyphenols, and vitamin C, all of which exhibit strong antioxidant properties. As more orange peel powder was incorporated, these compounds contributed more effectively to scavenging free radicals. The most notable jump occurred between Sample 3 (19.6%) and Sample 4 (25.2%), indicating a dose-dependent enhancement. These results highlight the functional benefit of using orange peel powder in cookie formulations, making them not just nutritious but also potentially health-protective. This significant rise underscores the functional potential of orange peel powder, attributed to its rich content of phenolics, flavonoids, and vitamin C, which are known for their free radical scavenging properties (Gulcin & Alwasel, 2023, Baliyan *et al.,* 2022, M'hiri, Ioannou, Ghoul, & Boudhrioua, 2017). This antioxidant enrichment supports the development of health-promoting bakery products.

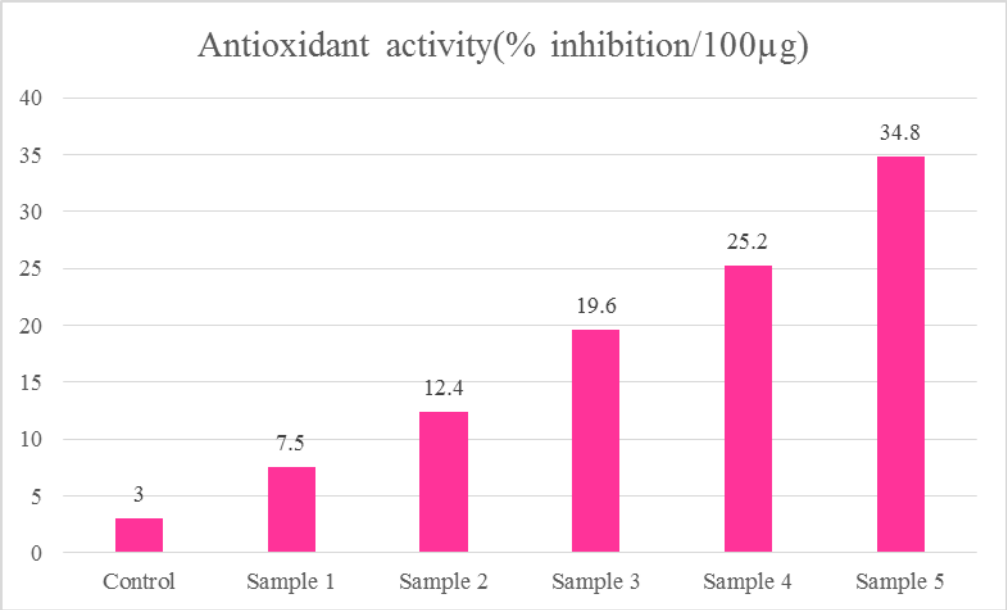

Fig. 2. Antioxidant activity (% inhibition) of cookie samples

Microbial Analysis

The total plate count increased gradually from the control (326 CFU/g) to Sample 5 (458 CFU/g) with the rising levels of orange peel powder (Table 3). This increase could be due to the natural microbial load present in dried orange peel powder, which, despite drying, may still retain some microbial spores. Additionally, the higher moisture content observed in samples with more orange peel powder can create a more favorable environment for microbial growth. However, the microbial counts remained within acceptable safety limits for baked products, suggesting no spoilage risk. Proper drying and hygienic handling of orange peel powder during processing are essential to minimize microbial load in future applications.

The yeast and mold count was consistently low across all samples, including the control. All samples, from the control (CS) to the highest concentration of 5% orange peel powder (S5), recorded a Yeast and Mold count of less than 10 CFU/g. These results indicate that there was minimal fungal contamination in all the cookies, demonstrating that orange peel powder does not promote yeast and mould growth. The consistently low Yeast and Mold counts suggest the cookies possess good stability and are less prone to fungal contamination, which is critical for ensuring the quality and safety of the product throughout its shelf life.

Microbial analysis revealed a gradual increase in the total plate count from 350 CFU/g in the control to 500 CFU/g in Sample 5. The increase is plausibly due to residual microbial spores in dried orange peel, although the levels remained within safe limits for baked goods (IS (Indian Standard) 5402:2021). Conversely, yeast and mold counts remained below 10 CFU/g across all samples, indicating effective control of fungal contamination and affirming the hygienic preparation conditions and good manufacturing practices (GMP)

Table 3- Microbial profile of cookies

Parameter	Control	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total Plate Count (CFU/g)	350	400	450	470	490	500
Yeast and Mould (CFU/g)	<10	<10	<10	<10	<10	<10

In order to determine mean values, ten samples were produced from each formulation, and analyses were conducted in duplicate. Duncan's multiple range tests was used to separate means, and significance was accepted at a 5% level of confidence ($p < 0.05$).

Keys:

Sample 1 49:1 Foxtail millet : Orange peel powder
Sample 2 48:2 Foxtail millet : Orange peel powder
Sample 3 47:3 Foxtail millet : Orange peel powder
Sample 4 46:4 Foxtail millet : Orange peel powder
Sample 5 45:5 Foxtail millet : Orange peel powder
Control Sample 50:0 Foxtail millet : Orange peel powder

Sensory Analysis

The average of the hedonic score given to the cookies by the sensory panel members are represented in Table 4 to show comparative results and the mean average values. According to the results of the sensory evaluation, there was significant differences at $p \leq 0.05$ between samples and the sample's flavor, consistency, and general acceptability vary significantly depending on the amount of supplementation.

The cookies made with orange peel powder maintained an attractive look, likely due to the balanced color and consistent surface texture. From Sample 2 score (8.3) to Sample 5 score (7.7), a gradual decline in appearance scores was noted. This suggests that increasing the OPP concentration subtly altered the external features of the cookies. Orange peel powder, being high in fiber and naturally coarse in texture, may have affected the smoothness and uniformity of the dough surface during baking. Despite these changes, the appearance remained moderately acceptable even at 5% orange peel powder, suggesting that while higher levels of orange peel powder do influence the visual presentation, they do not render the product visually unappealing.

The control and Sample 1 scored 9.0 and 8.9, reflecting good color attributes and high visual appeal. From Sample 2 (8.7) to Sample 5 (8.0), the color scores showed a gradual downward trend, suggesting that higher concentrations of orange peel powder slightly affected the visual appearance of the cookies. This is likely due to the natural pigmentation of orange peel powder, which contains carotenoids and flavonoids that can deepen the color of baked products. At lower levels, these pigments may enhance visual appeal by imparting a warm, golden hue. Despite the decline, the scores remain relatively high, indicating that the visual changes introduced by orange peel powder were not drastically unfavorable but may have slightly influenced consumer perception as the intensity of color increased.

The samples with less concentration of orange peel powder, reflects high taste acceptability among the panellists. This indicates that the base formulation using foxtail millet flour, with no or minimal incorporation of orange peel powder (1%), maintained a pleasing flavor profile. From Sample 2 (8.0) to Sample 5 (6.8), a gradual decline in taste scores was observed. This downward trend suggests that increasing levels of orange peel powder introduced stronger citrus notes and possibly a mild bitterness, characteristic of citrus peel. While orange peel powder contributes beneficial bioactive compounds, at higher concentrations, its phenolic content and essential oils (like limonene) can impart astringency or overpowering flavors (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024). These sensory shifts likely contributed to reduced taste acceptability in higher orange peel powder samples.

The initial samples with less concentration of orange peel powder preserved a pleasant and appealing aroma (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024). This suggests that a small quantity of orange peel

powder may complement the natural aroma of foxtail millet and other cookie ingredients, potentially enhancing the citrusy fragrance without overpowering it. From Sample 2 (8.1) to Sample 5 (7.0), a noticeable decline in aroma scores was observed. These trend likely results from the increasing intensity of the volatile compounds present in orange peel powder, such as limonene, linalool, and other essential oils (Adams & Foster, 2021, *Zhou et al.*, 2022, Hofmann *et al.*, 2024). While these components are aromatic and beneficial at lower concentrations, their strong citrus scent can become overwhelming or less pleasant as the level increases, especially when combined with the earthy aroma of foxtail millet. Moreover, during baking, the heat may alter the aromatic compounds in orange peel powder, sometimes resulting in slightly bitter or acidic or rancid notes that can affect the overall aroma perception (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024).

The initial samples received the highest mouth feel scores, indicating a soft and pleasant texture. Foxtail millet flour likely contributed to the light and crisp bite in these samples. As orange peel powder levels increased, mouth feel scores declined from 7.8 in Sample 2 to 7.1 in Sample 5. This drop may be due to the high fiber content and coarse texture of orange peel powder. At higher levels, orange peel powder can make the cookies feel drier or grainier. The absorption of moisture by fiber may also have led to a firmer, less smooth bite (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024).

The control (9.0) and Sample 1 (8.8) had the highest texture scores, indicating a desirable crispness and consistency. The use of foxtail millet flour likely helped achieve a light, crumbly texture. From Sample 2 (8.3) to Sample 5 (7.6), a gradual decline in scores was observed, with a slight recovery in Sample 5. The increased addition of orange peel powder, rich in fiber, may have made the cookies denser or slightly coarse. This could lead to less uniform texture, affecting the bite and chewiness (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024). However, the minor rise in Sample 5 suggests the fiber may have contributed some structural benefit at that level.

The initial samples with the minimal concentration of orange peel powder did not affect overall acceptability. From Sample 2 (7.95) to Sample 5 (7.0), a steady decline in acceptability was observed. This reflects the combined effect of changes in taste, aroma, texture, and mouth feel with increasing orange peel powder. Higher levels of orange peel powder likely introduced bitterness, coarseness, and stronger aroma, which reduced panel preference. Lower levels of orange peel powder (1–2%) appeared optimal for maintaining product quality and consumer appeal.

Sensory evaluation revealed a general decline in scores for parameters such as taste, aroma, texture, and overall acceptability as the level of orange peel powder increased. While initial levels of inclusion maintained favorable sensory properties, higher concentrations introduced bitterness, coarseness, and intensified citrus notes that were less preferred by the panelists. Despite this, even the highest inclusion level maintained moderate acceptability, indicating that formulation optimization could balance functional benefits with sensory quality (Adams & Foster, 2021, Zhou *et al.*, 2022, Hofmann *et al.*, 2024).

Table 4- Sensory analysis of cookie samples

Parameters	Control	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Appearance	9.0±0.2 ^{a}	9.0±0.2 ^{a}	8.3±0.2 ^{b}	8.2±0.2 ^{b}	8.2±0.2 ^{b}	7.7±0.2 ^{c}
Colour	9.0±0.2 ^{a}	8.9±0.2 ^{a}	8.7±0.2 ^{a}	8.3±0.2 ^{b}	8.3±0.2 ^{b}	7.5±0.2 ^{c}
Taste	9.0±0.2 ^{a}	8.7±0.2 ^{a}	8.0±0.2 ^{b}	7.6±0.2 ^{c}	7.6±0.2 ^{c}	6.8±0.2 ^{d}
Aroma	9.0±0.2 ^{a}	9.0±0.2 ^{a}	8.1±0.2 ^{b}	7.7±0.2 ^{c}	7.7±0.2 ^{c}	7.0±0.2 ^{c}

Mouth feel	9.0±0.2 [a]	8.7±0.2 [a]	7.8±0.2 [b]	7.5±0.2 [c]	7.4±0.2 [c]	7.1±0.2 [c]
Texture	9.0±0.2 [a]	8.8±0.2 [a]	8.3±0.2 [b]	8.2±0.2 [b]	7.4±0.2 [c]	7.6±0.2 [c]
Overall acceptability	9.0±0.2 [a]	8.7±0.2 [a]	8.0±0.2 [b]	7.9±0.2 [b]	7.8±0.2 [b]	7.0±0.2 [c]

In order to determine mean values, ten samples were produced from each formulation, and analyses were conducted in duplicate. Duncan's multiple range tests was used to separate means, and significance was accepted at a 5% level of confidence ($p < 0.05$). * The column's mean ± standard deviation, which is indicated by the same superscript, does not differ significantly at $p \leq 0.05$.

Keys:

Sample 1 49:1 Foxtail millet : Orange peel powder
Sample 2 48:2 Foxtail millet : Orange peel powder
Sample 3 47:3 Foxtail millet : Orange peel powder
Sample 4 46:4 Foxtail millet : Orange peel powder
Sample 5 45:5 Foxtail millet : Orange peel powder
Control Sample 50:0 Foxtail millet : Orange peel powder

Conclusion

Functional foods are increasingly recognized for their potential to improve overall health by delivering nutritional and bioactive components from natural and nutrient-dense ingredients. This study successfully formulated cookies by incorporating orange peel powder at concentrations ranging from 1% to 5% into a foxtail millet base. The addition of orange peel powder significantly improved the fiber content and antioxidant activity of the cookies, contributing to potential health benefits such as enhanced digestion and oxidative stress reduction. Among the tested formulations the optimal orange peel powder concentration of 2% (Sample 2) for overall acceptability and best sensory scores, offering a desirable balance of texture, taste, appearance, aroma, and mouth feel. Though higher orange peel powder levels further increased functional properties, they adversely affected sensory qualities, particularly in terms of bitterness and mouth feel. Microbial analysis confirmed that all samples met safety standards, supporting the feasibility of the product. The successful integration of foxtail millet, a nutrient-rich, underutilized grain and orange peel powder, a valuable agro-industrial by-product demonstrates a sustainable approach to developing, functional bakery products. These cookies made of foxtail millet and orange peel powder that is completely free of gluten, with enhanced nutritional attributes serves as a good snack option for population with celiac disease, as it contributes well to their diet. These align with modern dietary trends focused on wellness, plant-based nutrition, and waste valorization, making them a viable option for health-conscious consumers and food innovators.

Author Contribution

Yogalakshmi J.: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing– original draft. **Adeyeye, S.A.O.:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Resources, Software, Validation, Visualization, Writing– original draft, Writing – review and editing

Funding Source

The authors received no funding from any source.

Conflict of Interest

The authors certify that they have no conflict of interest.

References

1. Abdel Wahab, A.S., Abou Elyazeed, A.M., & Abdalla, A.E. (2018). Bioactive compounds in some citrus peels as affected by drying processes and quality evaluation of cakes supplemented with citrus peels powder, *Journal of the Advances in Agricultural Researches*, *23*(1), 44-66.
2. Adams, R., & Foster, L. (2021). The role of sugar types in cookie texture and flavor development. *Journal of Food Science*, *86*(4), 1123-1130. https://doi.org/10.1111/jfds.12345
3. Andaregie, A., Shimura, H., Chikasada, M., Sasaki, S., Alamnie Mulugeta, M., Worku, A., & Takagi, I. (2024). Assessing eating habits and preferences for bakery products among urban dwellers in Ethiopia. *Cogent Business & Management*, *11*(1). https://doi.org/10.1080/23311975.2024.2375621
4. AOAC. (2005). Methods of the Association of Official Analystical Chemists. Official methods of analysis, 18th Edition. Alitington Virgina Association, 806-842.
5. Arepally, D., Reddy, R.S., Coorey, R., & Goswami, T.K. (2023). Evaluation of functional, physicochemical, textural and sensorial properties of multi-millet-based biscuit. *International Journal of Food Science and Technology*, *58*(5), 2437–2447. https://doi.org/10.1111/ijfs.16381
6. Baliyan, S., Mukherjee, R., Priyadarshini, A., Vibhuti, A., Gupta, A., Pandey, R.P., & Chang, C.M. (2022). Determination of antioxidants by DPPH radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*. *Molecules (Basel, Switzerland)*, *27*(4), 1326. https://doi.org/10.3390/molecules27041326
7. Belose, B.B, Kotecha, P.M, Godase, S.N., & Chavan, U.D. (2021). Studies on utilization of orange peel powder in the preparation of cookies. *International Journal of Chemical Studies*, *9*(1), 1600–1602. https://doi.org/10.22271/chemi.2021.v9.i1w.11455
8. Boukroufa, M., Boutekedjiret, C., Petigny, L., Rakotomanomana, N., & Chemat, F. (2015). Bio-refinery of orange peels waste: A new concept based on integrated green and solvent-free extraction processes using ultrasound and microwave techniques to obtain essential oil, polyphenols, and pectin. *Ultrasonics Sonochemistry*, *24*, 72–79. https://doi.org/10.1016/j.ultsonch.2014.11.015
9. Dhankar, P. (2013). A study on development of coconut-based gluten free cookies. *International Journal of Science and Engineering Invention*, *2*, 10-19.
10. Dukwal, V. (2004). Fortification of food for value addition: Prospects and constraints, Department of Food and Nutrition College of Home Science Rajasthan Agricultural University Bikaner (Rajasthan).
11. Gómez, B., Gullón, B., Remoroza, C., Schols, H.A., Parajó, J.C., & Alonso, J.L. (2020). Purification, characterization, and prebiotic properties of pectic oligosaccharides from orange peel wastes. *Journal of Agricultural and Food Chemistry*, *62*(40), 9769–9782. https://doi.org/10.1021/jf503475b
12. Gorinstein, S., Martín-Belloso, O., Park, Y.S., Haruenkit, R., Lojek, A., & Trakhtenberg, S. (2021). Comparison of some biochemical characteristics of different citrus fruits. *Food Chemistry*, *74*(3), 309–315. https://doi.org/10.1016/S0308-8146(01)00157-1
13. Gulcin, İ., & Alwasel, S.H. (2023). DPPH Radical Scavenging Assay. *Processes*, *11*(8), 2248. https://doi.org/10.3390/pr11082248
14. Hofmann, L.C., Strauss, S., Shpigel, M., Guttman, L., Stengel, D.B., Rebours, C., & Meléndez-Martínez, A.J. (2024). The green seaweed *Ulva*: tomorrow's "wheat of the sea" in foods, feeds, nutrition, and biomaterials. *Critical Reviews in Food Science and Nutrition*, *65*(19), 3728–3763. https://doi.org/10.1080/10408398.2024.2370489
15. IS 5402:2021. Indian Standard Microbiology Of Food And Animal Feeding Stuffs — Horizontal Method For The Enumeration Of Micro-Organisms — Colony-Count Technique at 30°C (Second

Revision). Bureau of Indian St And Ards Manak Bhavan, 9 Bahadur Shah Zafar Marg New Delhi 110002. https://doi.org/10.3403/02761936u

16. Kha, T.C., Nguyen, M.H., & Roach, P.D. (2014). Effects of spray drying conditions on the physicochemical and antioxidant properties of the Gac (*Momordica cochinchinensis*) fruit aril powder. *Journal of Food Engineering, 98*(3), 385–392. https://doi.org/10.1016/j.jfoodeng.2010.01.016
17. Kumar, A., Tomer, V., & Kaur, A. (2018). Millets: a solution to agrarian and nutritional challenges. *Agric & Food Secur*, *31*. https://doi.org/10.1186/s40066-018-0183-3
18. M'hiri, N., Ioannou, I., Ghoul, M., & Boudhrioua, N.M. (2017). Phytochemical characteristics of citrus peel and effect of conventional and nonconventional processing on phenolic compounds: A review. *Food Reviews International, 33*(6), 587–619. https://doi.org/10.1080/87559129.2016.1196489
19. Muthamilarasan, M., & Prasad, M. (2015). Advances in Setaria genomics for genetic improvement of cereals and bioenergy grasses. *Theoretical and Applied Genetics, 128*(1), 1–14. https://doi/10.1007/s00122-014-2399-3
20. Natocho, J., Mugabi, R., & Muyonga, J.H. (2024). Optimization of formulation and processing conditions for the production of functional noodles containing orange-fleshed sweet potatoes and biofortified beans. *Food Science & Nutrition*, *12*(7), 5201–5219. https://doi.org/10.1002/fsn3.4167
21. Obafaye, R.O., & Omoba, O.S. (2018). Orange peel flour: A potential source of antioxidant and dietary fiber in pearl-millet biscuit. *Journal of Food Biochemistry*, *42*(4). https://doi.org/10.1111/jfbc.12523
22. Rangnekar, S.M. (2024). Effect of incorporation of orange peel powder and baking temperature on quality of cookies. *International Journal of Food and Fermentation Technology*, *14*(2). https://doi.org/10.30954/2277-9396.02.2024.5
23. Sankalpa, K.B., Ramachandra, C.T., Dinesha, B.L., Nidoni, U.K., Hiregoudar, S., & Beladhadi, R.V. (2017). Effect of different drying and grinding methods on biochemical properties of sweet orange peel powder. *Asian Journal of Dairy and Food Research*, *36*(03). https://doi.org/10.18805/ajdfr.v36i03.8975
24. Sharma, K., Mahato, N., & Lee, Y.R. (2017). Extraction, characterization, and biological activity of citrus flavonoids. *Reviews in Chemical Engineering, 35*(2), 265–284. https://doi.org/10.1515/revce-2017-0027
25. Sharma, N., & Niranjan, K. (2018). Foxtail millet: Properties, processing, health benefits, and uses. In *Food Reviews International, 34*,(4), 329–363. https://doi.org/10.1080/87559129.2017.1290103
26. Singh, R.B., Khan, S., Chauhan, A.K., Singh, M., Jaglan, P., Yadav, P., Takahashi, T., & Juneja, L.R. (2018). Millets as functional food, a gift from Asia to western world. In *The Role of Functional Food Security in Global Health* (pp. 457–468). Elsevier. https://doi.org/10.1016/B978-0-12-813148-0.00027-X
27. Srivastava, R.K., Singh, R.B., Lakshmi, V., Srikanth, P., Pusuluri, B., & Satyavathi, M. (2020). Genome wide association studies and genomic selection in Pearl millet: Advances and Prospects. *Frontiers in Genetics*, *10*, 1389. https://doi.org/ 10.3389/fgene.2019.01389
28. Tailor, Chandra Sh., & Goyal, A. (2014). Antioxidant activity by DPPH radical scavenging method of *Ageratum conyzoides* Linn. leaves. *American Journal of Ethnomedicine*, *1*(4), 244-249.
29. Zaker, M.A., Sawate, A.R., Patil, B.M., & Sadawarte, S.K. (2016). Studies on effect of orange peel powder incorporation on physical, nutritional and sensorial quality of cookies. *International Journal of Engineering Research & Technology* (IJERT), *5*(9), 78-82. https://doi.org/10.17577/ijertv5is090125
30. Zhou, Y., Wang, D., Zhou, S., Duan, H., Guo, J., & Yan, W. (2022). Nutritional composition, health benefits, and application value of edible insects: A review. *Foods*, *11*(24), 3961. https://doi.org/10.3390/foods11243961

مقاله پژوهشی

جلد ۲۱، شماره ٦، بهمن- اسفند ١٤٠٤، ص.

ارزیابی کیفی و ویژگی‌های حسی کوکی‌های تهیه‌شده از آرد ارزن دم روباهی و پودر پوست پرتقال

جایاسامراج یوگالاکاشمی[۱]- ساموئل آدیی[۱*]

تاریخ دریافت: ۱۴۰۴/۰۳/۲۲

تاریخ پذیرش: ۱۴۰۴/۰۶/۱۸

چکیده

تقاضای روزافزون برای غذاهای فراسودمند، باعث شده است که مواد طبیعی و غنی از مواد مغذی در محصولات سنتی به‌منظور حمایت از سلامت و تندرستی گنجانده شوند. ارزن دم‌روباهی، یک غله بدون گلوتن غنی از پروتئین، فیبر و ریزمغذی‌ها، و پودر پوست پرتقال، یک محصول جانبی سرشار از فیبر غذایی و ترکیبات زیست‌فعال، برای تولید کوکی‌هایی با خواص فراسودمند استفاده شدند. این پژوهش با هدف تولید و ارزیابی کوکی‌های سلامتی بخش تهیه شده از ارزن دم‌روباهی غنی‌شده با پودر پوست پرتقال انجام گردید. پنج فرمولاسیون با نسبت‌های ۴۹:۱، ۴۸:۲، ۴۷:۳، ۴۶:۴، ۴۵:۵ از ارزن دم‌روباهی و پودر پوست پرتقال برای نمونه ۱ تا نمونه ۵ تولید شد، در حالی‌که نمونه کنترل نسبت ۵۰:۰ داشت. نمونه‌ها از نظر آنالیز شیمیایی، فعالیت آنتی‌اکسیدانی، ایمنی میکروبی و خواص حسی مورد تجزیه و تحلیل قرار گرفتند تا سطح بهینه ترکیب با استفاده از روش‌های استاندارد تعیین شود. نتایج آنالیز شیمیایی نشان داد که محتوای پروتئین از ۱۱/۷ ٪ تا ۷/۲ ٪ برای نمونه ۱ تا نمونه ۵ متغیر بود، در حالی‌که نمونه کنترل ۱۱/۹ ٪ پروتئین داشت. میزان چربی برای نمونه ۱ تا ۵ از ۲۰/۵ ٪ تا ۱۹/۳ ٪ متغیر بود، در حالی‌که در نمونه کنترل ۲۰/۷ ٪ بود. میزان فیبر خام برای نمونه ۱ تا ۵ از ۲/۸ ٪ تا ۴/۸ ٪ متغیر بود، در حالی‌که برای نمونه کنترل ۲/۱ ٪ بود. میزان خاکستر برای نمونه ۱ تا ۵ از ۱/۱۰ ٪ تا ۱/۵۴ ٪ متغیر بود، در حالی‌که در نمونه کنترل ۱/۰۴ ٪ بود. میزان رطوبت برای نمونه ۱ تا ۵ از ۲/۶۱٪ تا ۴/۲۵ ٪ متغیر بود، در حالی‌که در نمونه کنترل ۲/۵ ٪ بود. از نقطه نظرتغذیه‌ای، افزایش تدریجی فیبر غذایی و فعالیت آنتی‌اکسیدانی در نمونه‌ها را شاهد بودیم که به بهبود سلامت گوارش و ظرفیت مهار رادیکال‌های آزاد کمک می‌کند. ارزیابی حسی میزان بهینه افزودن پودر پوست پرتقال (۲٪) مناسب برای پذیرش کلی حسی نشان داد. نتایج این پژوهش نشان داد که افزودن پودر پوست پرتقال به‌طور قابل توجهی ویژگی‌های تغذیه‌ای و سلامتی بخشی کوکی‌ها را افزایش می‌دهد.

واژه‌های کلیدی: ارزن دم‌روباهی، بیسکویت عملکردی، پودر پوست پرتقال، فعالیت آنتی‌اکسیدانی

۱- گروه فناوری مواد غذایی، مؤسسه فناوری و علوم هندوستان، چنای، تامیل نادو، هند

(*- نویسنده مسئول: Email: saadeyeye2015@gmail.com)

https://doi.org/10.22067/ifstrj.2025.94047.1447