European Journal of Nutrition & Food Safety

Volume 16, Issue 12, Page 16-27, 2024; Article no.EJNFS.128196
ISSN: 2347-5641

Evaluation of Physical and Sensory Attributes of Cookies Formulated from Multi-Millet Based Composite Flours

Avishkar R. Ikade [a++], Kailas Kamble [a#], Vikram P. Kad [a†], Vilas Salve [a†], Ganesh Shelke [a‡] and Yogesh A. Shaniware [b^*]

[a] Department of Agricultural Process Engineering, Dr. ASCAE&T, MPKV, Rahuri, India.
[b] Department of Agricultural Botany, College of Agriculture, Dhule, MPKV, Rahuri, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ejnfs/2024/v16i121598

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/128196

Original Research Article

Received: 06/10/2024
Accepted: 09/12/2024
Published: 12/12/2024

ABSTRACT

This study aims to investigates the influence of multi-millet flour incorporation on the physical, textural, color, and sensory attributes of cookies. Cookies were prepared using composite flours made from blends of whole wheat, sorghum, pearl millet, finger millet, and soyabean flours in the following proportions: (T_1) 75:10:05:05:05, (T_2) 75:05:10:05:05, (T_3) 75:05:05:10:05, (T_4)

[++] *M.Tech Student;*
[#] *Associate Professor and Head;*
[†] *Associate Professor;*
[‡] *Assistant Professor;*
[^] *Postgraduate Scholar;*
**Corresponding author: Email: yogeshshaniware1@gmail.com;*

Cite as: *Ikade, Avishkar R., Kailas Kamble, Vikram P. Kad, Vilas Salve, Ganesh Shelke, and Yogesh A. Shaniware. 2024. "Evaluation of Physical and Sensory Attributes of Cookies Formulated from Multi-Millet Based Composite Flours". European Journal of Nutrition & Food Safety 16 (12):16-27. https://doi.org/10.9734/ejnfs/2024/v16i121598.*

60:15:10:10:05, (T_5) 60:10:15:10:05, (T_6) 60:10:10:15:05, (T_7) 45:20:15:15:05, (T_8) 45:15:20:15:05, (T_9) 45:15:15:20:05, with 100% whole wheat flour as the control (T_0). Substituting wheat flour with a millet flour blend reduced the cookies weight and spread ratio, while it increased the diameter and thickness. Textural analysis revealed a reduction in hardness, as evidenced by lower penetration and cutting forces, in cookies made with millet-based composite flours. As the proportion of millet increased, the cookies colour became darker, characterized by a decrease in lightness (L*) and yellowness (b*), and an increase in redness (a*). Sensory evaluation identified treatment T_8 cookies as the most preferred, with improved scores for colour, appearance, texture, and flavour.

Keywords: Composite flour; cookies; millet flour; wheat substitution; physical attributes; textural analysis; colour characteristics; sensory acceptability.

1. INTRODUCTION

People are becoming more aware of how diet affects their health, leading to a higher demand for nutrient-rich functional food options, those that offer health benefits beyond basic nutrition (Anonymous, 2024_a). The challenge lies in formulating such snack products that are nutritious, economically affordable, and attractive to consumers. Among the snack items, cookies are one of those which are shelf-stable, affordable, and convenient, making them popular among people of all age groups (Iwegbue, 2012). Originating from the Dutch word 'Koekje,' the term 'cookie' describes soft biscuits traditionally made with wheat flour, sugar, hydrogenated fat, and additional ingredients (Mitkal et al., 2021). The global cookies market has experienced consistent growth, with revenues increasing at a compound annual growth rate (CAGR) of 5.2%, from 39.8 billion USD in 2022 to a projected 62.2 billion USD by 2032 (Anonymous, 2024_b), highlighting a continued global preference for cookies as a snack. Cookies provide an effective means of incorporating alternative flours, offering a convenient approach to enhance nutritional value (Arshad et al., 2007; Dhillon et al., 2018). Refined wheat flour, commonly used in bakery products because of its gluten content, which contributes to the products typical texture, flavour and physical attributes (Jemziya and Mahendran, 2017). However, it lacks significant levels of dietary fiber and micronutrients, which results in products made with refined wheat flour having lower fat, fiber, and mineral content (Ali et al., 2013). Consequently, it is important to substitute refined wheat flour with higher-quality flours to improve the nutritional value of bakery products. The demand for better alternatives, including gluten-free cookies made with high-quality ingredients is rising. According to the Market Intelligence Report for Biscuits (Anonymous, 2019), while the wheat segment dominates the market, the multigrain segment is expected to grow substantially.

Composite flour has been shown to offer superior nutrient density, including higher levels of fiber, minerals, proteins, and vitamins, compared to flour made from a single cereal type (Shanthi et al., 2005; Banua et al. 2021). The term 'Composite Flour Technology' refers to the practice of blending different flours to effectively utilize locally available raw materials in the production of high-quality food products. Formulating composite flours is crucial for developing products with enhanced functionality and added nutritional value (Rehman et al., 2007; Banua et al., 2021). Millets, known for their significant nutritional and health advantages, can improve the nutritional profile and modify the properties of composite flours, making them ideal for the production of bakery products (Vijayakumar & Mohankumar, 2009; Saleh et al., 2013; Selladurai et al., 2023).

Millets have recently gained recognition for their exceptional nutritional value, serving as a rich source of protein, fiber, vitamins, and minerals. Their gluten-free nature makes them particularly suitable for individuals with celiac disease (gluten intolerance). Furthermore, millets are associated with numerous health benefits, including anti-cancer, antioxidant, antihypertensive and cholesterol-lowering properties (Rao & Deepika, 2016). The carbohydrates in millets are primarily complex and characterized by a low glycemic index, contributing to effective blood sugar management (Michaelraj and Shanmugam, 2013). Renowned for their high levels of phytochemicals and essential amino acids, millets are often referred to as "Nutri-Cereals" because of their impressive health advantages (Singh et al., 2012). Acknowledging these extensive benefits, the United Nations declared 2023 as the "International Year of Millets", to

Table 1. Nutritional profile of selected grains per 100 g

Particulars	Wheat	Sorghum	Pearl Millet	Finger Millet	Soyabean
Energy (Kcal)	341.0	349.0	361.0	328.0	432.0
Ash (g)	1.6	2.0	2.0	3.0	4.0
Crude Protein (g)	12.5	11.0	12.0	8.0	43.0
Crude Fat (g)	1.9	3.2	5.1	1.6	18.0
Crude Fiber (g)	2.1	2.7	2.0	3.6	4.0
Carbohydrate (g)	74.2	72.0	67.5	72.6	23.0
Iron (mg)	4.01	5.0	7.49	4.6	10.0
Calcium (mg)	39.36	25.0	42.0	344.0	240.0

(Source: Anonymous, 2015$_a$, Anonymous, 2015$_b$, Anonymous, 2022$_b$; Saladivar et al.*, 2016)*

encourage global and domestic demand while promoting healthier dietary habits (Anonymous, 2022$_a$).

Composite flours offer numerous advantages, while a key challenge lies in ensuring that the formulated products meet acceptable standards of physical and sensory attributes (McWatters et al., 2003; Arshad et al., 2007; Dhillon et al., 2018). This study aims to evaluate the impact of millet-based composite flours on the physical, textural, colour and sensory characteristics of cookies. These attributes are essential in determining the overall quality and consumer acceptance of the final product. The research seeks to provide practical insights into how different combinations of millet-based composite flours affect these properties, helping to develop multi millet-based cookies that are appealing to consumers while promoting the sustainability of bakery products. During research finger millet, pearl millet and sorghum were not selected only for their rich nutritional profile but also for their local availability and economic feasibility. This makes them practical choices for promoting the use of regionally accessible grains.

2. MATERIALS AND METHODS

2.1 Materials

Cookies were formulated using a composite flour comprising whole wheat, millet grains (such as sorghum, pearl millet, and finger millet), and soyabean as a protein-enriching component. Other raw materials used in cookie production consisted of sugar, water, shortening agent (hydrogenated vegetable fat/vanaspati ghee), and leavening agents, including sodium bicarbonate and ammonium bicarbonate. These all material were sourced from the local market in Rahuri, Maharashtra. The grains were carefully cleaned and subsequently milled with an electric grinding mill. The finely grounded flours were stored safely in airtight container until further use for experiment. The resulting fine flours were carefully stored in airtight containers to ensure their quality was maintained until required for experimentation. The instruments needed for the research were provided by Department of Agricultural Process Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.

2.2 Millet based Composite Flour Cookie’s Formulation and Preparation

The composite flour used for cookie preparation was formulated by partially replacing wheat flour with sorghum flour, pearl millet flour, finger millet flour, and soyabean flour in varying proportions, as outlined in Table 2. The whole wheat flour, with no substitutions, served as the control sample (T_0). The cookies were prepared using the method outlined by Chavan et al., (2016), with slight modifications. The quantities of raw ingredients used in the cookie’s preparation are detailed in Table 3. Hydrogenated vegetable fat, powdered sugar and water were first mixed thoroughly and then combined with a blend of flour, sodium bicarbonate, and ammonium bicarbonate. The mixture was kneaded to form a uniform dough, which was rolled into a sheet and shaped into circular pieces using an impression cutter. The cookies were baked in an electric rotary baking oven (Konark Heat System, India) at 180°C for 18–20 minutes. After baking, the cookies were allowed to cool at room temperature and were subsequently stored in airtight packets to maintain their quality.

2.3 Physical Characteristics of Multi-Millet Cookies

The physical characteristics such as weight (g), diameter (mm), thickness (mm) and spread ratio of developed cookies were evaluated using the methods described under Chavan et al., (2018).

Randomly selected cookie samples were evaluated for their dimensions, including diameter and thickness, using a digital vernier calliper, while their weights were determined with a high-precision weighing balance. The spread ratio of cookies is calculated as the ratio of the average diameter to the average thickness (D/T).

$$Spread\ Ratio = \frac{Diameter\ (mm)}{Thickness\ (mm)} \quad (1)$$

Table 2. Composite flour blending combination for preparation of cookies

Treatment	Wheat (%)	Sorghum (%)	Pearl Millet (%)	Finger Millet (%)	Soyabean (%)
T_0	100	0	0	0	0
T_1	75	10	05	05	05
T_2	75	05	10	05	05
T_3	75	05	05	10	05
T_4	60	15	10	10	05
T_5	60	10	15	10	05
T_6	60	10	10	15	05
T_7	45	20	15	15	05
T_8	45	15	20	15	05
T_9	45	15	15	20	05

Table 3. Quantity of raw ingredients required for the cookie's preparation (Chavan et al., 2016)

Sr. No.	Raw Ingredients	Quantity (%)
1)	Composite Flour	100
2)	Shortening agent (Hydrogenated Vegetable Fat)	50
3)	Sugar	50
4)	Sodium bicarbonate ($NaHCO_3$)	0.5
5)	Ammonium bicarbonate (NH_4HCO_3)	0.5
6)	Water	As per the requirement

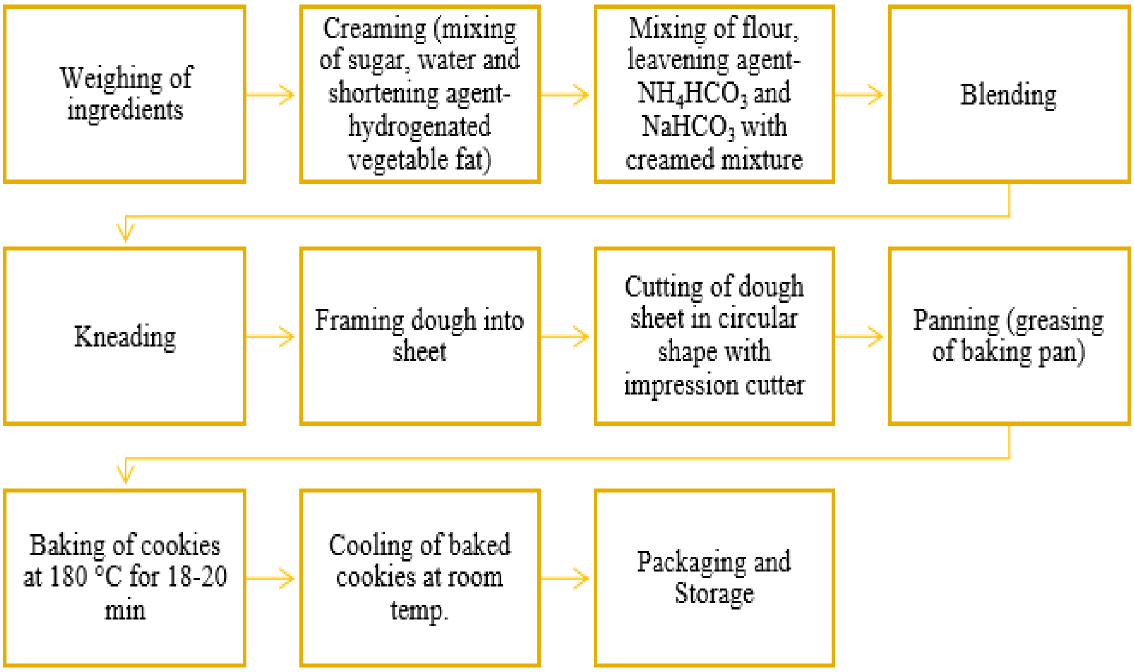

Fig. 1. Procedure flow chart for preparation of cookies

2.4 Textural Characteristics of Multi-Millet Cookies

Textural analysis of the cookies was carried out to assess penetration and cutting forces using a Texture Analyzer (TMS-Pro, Food Technology Corporation, USA, 500 N capacity). The cookie samples were positioned on the loading cell, and a compressive force was applied. The textural parameters were measured with a crosshead speed of 50 mm/min, a maximum load cell force of 1 kg, and a compression distance of 75%. The maximum force required for penetration and cutting of the multi-millet cookies was recorded and expressed in Newton (N) (Karma et al., 2018).

2.5 Colour Characteristics of Multi-Millet Cookies

The developed multi-millet cookies were evaluated for colour variation against the control sample using a Colour Scanning Machine (Premier Colourscan, India). The International Commission on Illumination (CIE) given colour values (L*, a*, b*) were assessed according to the method described by Chavan et al., (2018). Luminance (L*) corresponds to the transition between lightness (+) and darkness (-), while a* represents the range from redness (+) to greenness (-), b* reflects the variation between yellowness (+) and blueness (-). The calorimeter was calibrated for white and black standards. Once calibrated, the cookie samples were placed in a holder cup and accurately positioned on the scanning aperture. The colour deviation (ΔE*) of the various samples compared to the control sample was measured and showed on the software interface.

2.6 Sensory Evaluation of Multi-Millet Cookies

The sensory qualities of the prepared millet-based composite flour cookies were assessed in comparison to the control sample using a quantitative descriptive analysis method. A panel of 10 semi-trained evaluators assessed sensory characteristics such as colour, appearance, texture, flavour, and overall acceptability on a 9-point hedonic scale. The panel consisted of students and faculty members from the Department of Agricultural Process Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. The acceptability of the cookies was decided by averaging ten individual scores.

2.7 Statistical Analysis

The data obtained from the physical characteristics, textural, and colour analysis were subjected to statistical analysis using one-way ANOVA with a Completely Randomized Design (CRD)at sig ≤0.05 to determine the effect of treatments compared to the control (Panse and Sukhatme, 1967). Each measurement was conducted in triplicate.

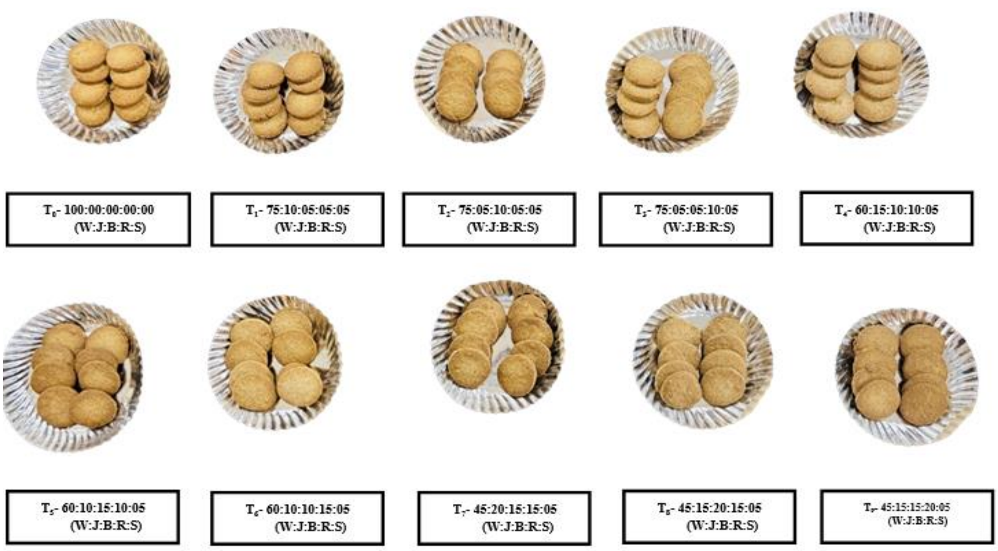

Fig. 2. Samples of multi-millet based composite flour cookies

3. RESULTS AND DISCUSSION

3.1 Effect of Multi-Millet Flour Inclusion on Physical Attributes of Cookies

The influence of various millet flour blend combinations on the physical attributes of cookies, including weight, diameter, thickness, and spread ratio were evaluated and are outlined in Table 4.

3.1.1 Weight (g)

The data in Table 4 reveal that an increasing millet proportion in the composite flour led to a marked decrease in the weight of the cookies, with the average weight ranging from 10.53 g to 9.93 g. The cookies of control treatment (T_0), composed of 100% wheat flour, exhibited the highest weight (10.53 g), while the lowest weight (9.93 g) was recorded for treatment T_9 cookies. The observed decrease in the weight of millet-based cookies could be attributed to higher moisture loss during baking (Arepally et al., 2023), as millets possess a lower water-binding capacity compared to wheat (Kumar et al., 2015; Thilagavathi et al., 2015). According to Arepally et al. (2023), the inclusion of a millet flour blend (pearl millet, barnyard millet, kodo millet, and finger millet) in cookies led to a reduction in their weight in comparison to the control sample. A similar trend of reduced weight of cookies was reported by Kulthe et al., (2017) and Kulkarni et al., (2021) for pearl millet, as well as by Adeyeye (2016) for sorghum-incorporated cookies.

3.1.2 Diameter (mm)

Table 4 illustrates the influence of different treatments involving varying combinations of wheat and millet blends on cookie's diameter. The average diameter of the cookies across the treatments ranged from 46.35 mm to 48.31 mm. The control treatment cookies (T_0) exhibited the smallest diameter (46.35 mm), while the largest diameter of 48.31 mm was observed for treatment T_8 cookies. The results suggested that an increase in the proportion of millet in the composite flour led to an increase in the diameter of the cookies. The observed increase in cookie diameter may be linked to the lower viscosity of millet-composite flour in comparison to wheat flour (Chauhan et al., 2016; Soumya and Mamatha, 2022). According to Aljobair (2022), cookies with a higher percentage of sorghum flour in the composite flour demonstrated an increased diameter, while those made with 100% wheat flour had the smallest diameter. A similar trend of increased cookie diameter was reported by Joseph and Waghray (2022) with the incorporation of little millet and sorghum, and by Soumya and Mamatha (2022) with the inclusion of foxtail millet.

3.1.3 Thickness (mm)

The results presented in Table 4 demonstrate that replacing wheat flour with millet flour at higher levels led to a notable increase in cookie thickness, with the average thickness ranging from 6.95 mm to 7.77 mm. Among all treatments, the smallest thickness (6.95 mm) was recorded for control (T_0) treatment cookies, while treatment T_9 cookies exhibited the largest thickness (7.77 mm). Millets are known to have a higher fiber content, which may restrict the spread of cookies, resulting in cookies of increased thickness (Aljobair, 2022; Kulthe et al., 2017). Joseph and Waghray (2022) noted that cookies made with composite flour including blend of little millet and sorghum flour were thicker than those made with wheat flour alone. The results are in agreement with Aljobair (2022), as cookies made with millet-composite flour (including higher proportion of sorghum flour) showed rise in cookie thickness. Kulthe et al., (2017) also reported similar trend of increased thickness for pearl millet incorporated cookies.

3.1.4 Spread Ratio (D/T)

The spread ratio of cookies refers to the ratio of diameter to thickness of cookies. The results shown in Table 4 suggested a clear trend of reduction in the spread ratio of cookies as the millet proportion in the composite flour increased. The average spread ratio of cookies prepared with varying millet proportions ranged from 6.67 to 6.21. The control treatment (T_0), consisting of 100% wheat flour, exhibited the highest cookie spread ratio (6.67), while treatment T_9 cookies showed the lowest spread ratio of 6.21. The spread ratio of cookies is notably influenced by factors such as their diameter, thickness, and the gluten network of flour (Ahmad et al., 2021). Millets, recognized for their high fiber content, may interfere with the gluten network and reduce the water available for gluten hydration, potentially leading to a lower spread ratio in cookies (Arepally et al., 2023; Sharma et al., 2013). Arepally et al., (2023) reported a similar trend of reduced spread ratio with the inclusion of a millet flour blend (comprising barnyard millet, pearl millet, kodo millet, and finger millet) in

Table 4. Physical attributes of cookies prepared with multi-millet composite flour

Treatment	Weight (g)	Diameter (mm)	Thickness (mm)	Spread ratio (D/T)
T_0	10.53	46.35	6.95	6.67
T_1	10.39	46.99	7.26	6.47
T_2	10.35	47.03	7.24	6.50
T_3	10.33	46.97	7.29	6.44
T_4	10.21	47.48	7.49	6.34
T_5	10.17	47.52	7.46	6.37
T_6	10.14	47.45	7.53	6.32
T_7	9.99	48.29	7.74	6.24
T_8	9.97	48.31	7.71	6.27
T_9	9.93	48.26	7.77	6.21
S.E.	0.041	0.086	0.046	0.043
C.D.@5%	0.123	0.254	0.138	0.126

(Note: n=3, S.E.(m)- Standard Error at Mean; C.D.- Critical Difference); W-Wheat; S-Sorghum; PM-Pearl Millet; FM-Finger Millet; Sb-Soyabean, T0-(W:S:PM:FM:Sb):(100:00:00:00:00); T1-(W:S:PM:FM:Sb):(75:10:05:05:05); ; T2-(W:S:PM:FM:Sb):(75:05:10:05:05); ; T3-(W:S:PM:FM:Sb):(75:05:05:10:05); ; T4-(W:S:PM:FM:Sb):(60:15:10:10:05); T5-(W:S:PM:FM:Sb):(60:10:15:10:05); T6-(W:S:PM:FM:Sb):(60:10:10:15:05); T7-(W:S:PM:FM:Sb):(45:20:15:15:05); T8-(W:S:PM:FM:Sb):(45:15:20:15:05); T9-(W:S:PM:FM:Sb):(45:15:15:20:05)

cookies. Kulkarni et al., (2021) and Adeyeye (2016) also observed a decrease in the spread ratio of cookies when pearl millet flour and sorghum flour was incorporated into composite flour blend, respectively.

3.2 Effect of Multi-Millet Flour Inclusion on Textural Cha-Racteristics of Cookies

The textural assessment of cookies is essential for guaranteeing consumer satisfaction and ensuring uniform product quality. The texture analysis in this study focused on two key parameters, i.e., penetration force (N) and cutting force (N), which offer an understanding of the hardness profile of the millet-based cookies. The findings from the textural evaluation are illustrated in Table 5. The control treatment (T_0) cookies, composed entirely of wheat flour, demonstrated the highest penetration force (50.05 N) and cutting force (57.23 N), reflecting a cookies harder texture. Meanwhile, the lowest values for penetration and cutting force, 25.54 N and 33.46 N, respectively, were observed for treatment T_8. These findings demonstrate a noticeable decrease in the hardness of cookies as the proportion of millet in the composite flour increased. The decrease in hardness of cookies made with composite flour is likely due to the high fiber content of millets, which may cause disruption in the gluten network by diluting the gluten proteins (Hussain et al., 2020; Jan et al., 2015). These findings are in agreement with the results of Arepally et al., (2023), which showed that the inclusion of a millet flour blend (consisting barnyard millet, pearl millet, kodo millet, and finger millet) reduced the hardness of cookies compared to those made with wheat flour only. Shimray et al., (2012) suggested that the brittleness of biscuits containing finger millet flour may result from the binding of tannins and phytates in finger millet to gluten proteins, thereby reducing the dough's cohesiveness. A similar trend of decreasing hardness was observed in cookies made with pearl millet flour and sorghum flour, as reported by Hussain et al., (2020) and Aljobair (2022), respectively.

3.3 Effect of Multi-Millet Flour Inclusion on Colour Characteristics of Cookies

The colour of baked goods plays a key role in influencing consumers' initial acceptance. The colour parameters of cookies containing millet flours were evaluated using L*, a*, and b values. The results of the colour analysis are presented in Table 6. The highest lightness value (L*) of 54.93 was recorded for treatment (T_0) cookies, consisting of 100% wheat flour, while the lowest value of 48.79 was observed in the treatment T_8 cookies. Decreasing L* value indicates that the inclusion of millet flour resulted in darker cookies. Regarding redness (a*), the control treatment (T_0) cookies had the lowest value of 5.44, while cookies of treatment T_9 displayed the highest a* value (8.37). The rise in a* value implies that increasing the proportion of millet flour in place of wheat flour significantly increased the redness of the cookies. Furthermore, for yellowness (b*), treatment T_0 cookies (control) exhibited the highest value of 19.52, while treatment T_8 cookies showed the lowest value of 13.98. These declining b* value demonstrate a clear trend of decreasing cookies' yellowness with the increasing proportion of millet in the composite flour. The inclusion of whole grains, which contain bran components such as fiber, phenolics, and flavonoids, can lead to a decrease in lightness and yellowness while increasing the redness of cookies made from millet-based composite flour (Brites et al., 2018; Paesani et al., 2020; Aljobair, 2022). The darker colour of the cookies could be linked to the rich mineral profile and phenolic content of millet flour (Arepally et al., 2023). Furthermore, Ajila et al., (2008) propose that enzymatic browning may contribute to the reduced brightness and yellowness of the cookies. These results are consistent with findings from other studies, where substituting wheat flour with pearl millet led to a darker colour in the cookies (Kulthe et al., 2017). Cookies made with a higher proportion of sorghum flour were found to have a darker colour compared to those made with only wheat flour (Aljobair, 2022). Arepally et al., (2023) reported that the inclusion of a millet flour blend (comprising pearl millet, kodo millet, barnyard millet, and finger millet), resulted in a reduction in lightness and yellowness, along with an increase in redness of the cookies.

Table 6 illustrates a significant increase in ΔE from treatment T_1 to T_9 as the proportion of millet in the composite flour increased. Among all the millet-based cookies, treatment T_1 had the lowest ΔE value of 3.01, while treatment T_8 cookies exhibited the highest ΔE value (8.69). As noted by Goswami et al., (2015), a total colour difference (ΔE) greater than 3 typically reflects a noticeable colour difference that can be that is easily identifiable to the naked eyes. The ΔE values obtained in this study suggest a significant colour difference between each treatment and control cookie sample. Arepally et al., (2023) found a similar trend of increasing ΔE for cookies as the proportion of a millet blend (barnyard millet, pearl millet, kodo millet, and finger millet) in the composite flour increased.

3.4 Sensory Acceptability of Multi-Millet Flour Incorporated Composite Flour Cookies

Sensory evaluation is a critical component in product development, providing insights into consumer preferences and acceptability. It provides a systematic approach to assess attributes like colour, texture, flavour and appearance, ensuring alignment with consumer expectations (De Albuquerque et al., 2022). Table 7 presents the sensory evaluation scores for cookies made with multi-millet composite flour. An increase in the substitution of wheat flour with millet into composite flour resulted in improved organoleptic scores for the cookies. The cookies prepared using the T8 treatment

Table 5. Textural characteristics of cookies prepared with multi-millet composite flour

Treatment	Penetration Force (N)	Cutting Force (N)
T_0	50.05	57.23
T_1	37.80	46.55
T_2	36.37	45.42
T_3	37.03	46.21
T_4	31.61	40.15
T_5	30.42	38.96
T_6	30.98	39.55
T_7	26.76	34.69
T_8	25.54	33.46
T_9	26.05	34.17
S.E.	0.180	0.204
C.D.@5%	0.531	0.602

(Note: n=3, S.E.(m)- Standard Error at Mean; C.D.- Critical Difference); W-Wheat; S-Sorghum; PM-Pearl Millet; FM-Finger Millet; Sb-Soyabean; T_0-(W:S:PM:FM:Sb):(100:00:00:00:00); T_1-(W:S:PM:FM:Sb):(75:10:05:05:05); T_2-(W:S:PM:FM:Sb):(75:05:10:05:05); T_3 (W:S:PM:FM:Sb):(75:05:05:10:05); T_4-(W:S:PM:FM:Sb):(60:15:10:10:05); T_5-(W:S:PM:FM:Sb):(60:10:15:10:05); T_6-(W:S:PM:FM:Sb):(60:10:10:15:05); T_7-(W:S:PM:FM:Sb):(45:20:15:15:05); T_8-(W:S:PM:FM:Sb):(45:15:20:15:05); T_9-(W:S:PM:FM:Sb):(45:15:15:20:05)

flour formulation obtained the highest colour score (8.20) among all the composite flour cookies. The inclusion of millet flour imparted a distinctive bright brown colour to the cookies. In terms of appearance, treatment T8 cookies scored the highest (8.40), attributed to the millet flour's contribution to a smoother and more uniform surface textures, which ultimately enhanced cookies' overall visual appeal. For texture, treatment T8 cookies achieved the highest score (8.60). The inclusion of millet flour strengthened the cookie structure, resulting in a desirable balance of crispness and softness that enhanced the mouthfeel and making the cookie more enjoyable to eat. The flavour score for T_8 cookies was the highest (8.50), with the slightly gritty taste of millet complementing the sweetness of the cookies and resulting in a more natural, less artificial flavour. Overall, T_8 cookies were rated the best in terms of acceptability, scored 8.43, demonstrating that the addition of millet flour positively influenced the texture and flavour of cookies, making them the preferred choice among panellists and showcasing their potential for developing high-quality baked products.

Table 6. Colour characteristics of cookies prepared with multi-millet composite flour

Treatment	L*	a*	b*	ΔE
T_0	54.93	5.44	19.52	0.00
T_1	53.11	6.55	17.42	3.01
T_2	52.72	6.41	17.15	3.39
T_3	52.97	6.74	17.3	3.28
T_4	51.15	7.37	15.63	5.79
T_5	50.64	7.24	15.32	6.28
T_6	50.87	7.53	15.51	6.08
T_7	49.26	8.23	14.27	8.23
T_8	48.79	8.05	13.98	8.69
T_9	49.06	8.37	14.12	8.51
S.E.	0.176	0.117	0.122	-
C.D.@5%	0.521	0.345	0.359	-

(Note: n=3, S.E.(m)- Standard Error at Mean; C.D.- Critical Difference); W-Wheat; S-Sorghum; PM-Pearl Millet; FM-Finger Millet; Sb-Soyabean T_0-(W:S:PM:FM:Sb):(100:00:00:00:00); T_1-(W:S:PM:FM:Sb):(75:10:05:05:05); T_2-(W:S:PM:FM:Sb):(75:05:10:05:05); T_3-(W:S:PM:FM:Sb):(75:05:05:10:05); T_4-(W:S:PM:FM:Sb):(60:15:10:10:05); T_5-(W:S:PM:FM:Sb):(60:10:15:10:05); T_6-(W:S:PM:FM:Sb):(60:10:10:15:05); T_7-(W:S:PM:FM:Sb):(45:20:15:15:05); T_8-(W:S:PM:FM:Sb):(45:15:20:15:05); T_9-(W:S:PM:FM:Sb):(45:15:15:20:05)

Table 7. Sensory scores for cookies prepared with multi-millet composite flour

Treatment	Colour	Appearance	Texture	Flavour	Overall Acceptability
T_0	6.90	7.00	7.10	7.10	7.03
T_1	7.20	7.30	7.40	7.60	7.38
T_2	7.30	7.40	7.50	7.60	7.45
T_3	7.10	7.30	7.40	7.40	7.30
T_4	7.60	7.80	8.00	8.00	7.85
T_5	7.60	7.90	8.10	8.10	7.93
T_6	7.50	7.70	7.90	7.90	7.75
T_7	8.00	8.30	8.40	8.40	8.28
T_8	8.20	8.40	8.60	8.50	8.43
T_9	7.90	8.10	8.40	8.30	8.18

(Note: n=10, W-Wheat; S-Sorghum; PM-Pearl Millet; FM-Finger Millet; Sb-Soyabean); T_0-(W:S:PM:FM:Sb):(100:00:00:00:00); T_1-(W:S:PM:FM:Sb):(75:10:05:05:05); T_2-(W:S:PM:FM:Sb):(75:05:10:05:05); T_3-(W:S:PM:FM:Sb):(75:05:05:10:05); T_4-(W:S:PM:FM:Sb):(60:15:10:10:05); T_5-(W:S:PM:FM:Sb):(60:10:15:10:05); T_6-(W:S:PM:FM:Sb):(60:10:10:15:05); T_7-(W:S:PM:FM:Sb):(45:20:15:15:05); T_8-(W:S:PM:FM:Sb):(45:15:20:15:05); T_9-(W:S:PM:FM:Sb):(45:15:15:20:05)

4. CONCLUSION

The evaluation of the physical, textural, and colour characteristics of millet-based cookies demonstrates the impact of millet incorporation on key quality attributes. Parameters such as spread ratio, hardness, and colour were significantly affected, underscoring the functional role of millet flours in shaping both the structural and visual aspects of the cookies. Incorporating millet flour into cookie formulations results in cookies that are thicker, with a larger diameter and a lower spread ratio, while also exhibiting reduced hardness. Furthermore, the addition of millet flour contributes to a darker colour in the cookies. The cookies prepared with composite flour, consisting 45% wheat, 15% sorghum, 20% pearl millet, 15% finger millet and 5% soyabean, was identified as the most optimal in terms of physical, textural, colour, and sensory qualities. This study underscores the potential of millet-based cookies to address varied consumer preferences while promoting advancements in bakery product development through the utilization of alternative grains.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Adeyeye, S. A. O. (2016). Assessment of quality and sensory properties of sorghum-wheat flour cookies. *Cogent Food and Agriculture, 2*(1), 1245059.

Ahmad, S., Naz, A., Muhammad, U., Amjad, A., Pasha, I., & Farooq, U. (2021). Impediment effect of chemical agents (additives) on gluten development in cookie dough. *Journal of Food Science and Technology, 59*(4), 1396-1406.

Ajila, C. M., Leelavathi, K., & Prasada Rao, U. J. S. (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *Journal of Cereal Science, 48*(2), 319-326.

Ali, A. Y., Ahmed, A., Ahmad, A., Hameed, T., Randhawa, M. A., Hayat, I., & Khalid, N. (2013). Nutritional and functional evaluation of wheat flour cookies supplemented with gram flour. *International Journal of Food Sciences and Nutrition, 64*(1), 63-68.

Aljobair, M. O. (2022). Physicochemical properties and sensory attributes of cookies prepared from sorghum and millet composite flour. *Food Science and Nutrition, 10*(10), 3415-3423.

Anonymous. (2015a). *Millets index*. Retrieved July 6, 2024, from https://agritech.tnau.ac.in/agriculture/millets_index.html

Anonymous. (2015b). *Pulses composition*. Retrieved July 6, 2024, from https://agritech.tnau.ac.in/postharvest/pht_pulses_composition.html

Anonymous. (2019). *Biscuit report*. Retrieved July 8, 2024, from https://agriexchange.apeda.gov.in/Weekly_eReport/Biscuit_%20Report.pdf

Anonymous. (2022a). *International year of millets 2023*. Retrieved July 5, 2024, from https://www.nabard.org/international-year-of-millets-2023.aspx

Anonymous. (2022b). *Millet portal*. Retrieved July 6, 2024, from https://apeda.gov.in/milletportal/about_us.html

Anonymous. (2024a). *Functional foods and smart proteins*. Retrieved October 15, 2024, from https://www.ils.res.in/functional-foods-and-smart-proteins/

Anonymous. (2024b). *Cookies statistics*. Retrieved July 12, 2024, from https://media.market.us/cookies-statistics/

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.

Arshad, M. U., Anjum, F. M., & Zahoor, T. (2007). Nutritional assessment of cookies supplemented with defatted wheat germ. *Food Chemistry, 102*(1), 123-128.

Banua, M. T., Kaur, J., Bhadariya, V., Singh, J., & Sharma, K. (2021). Role of consumption of composite flour in management of lifestyle disorders. *Plant Archives, 21*(2), 201-214.

Brites, L. T. G., Ortolan, F., Silva, D. W., Bueno, F. R., Rocha, T. de S., Chang, Y. K., &

Steel, C. J. (2019). Gluten-free cookies elaborated with buckwheat flour, millet flour, and chia seeds. *Food Science and Technology, 39*(2), 458–466.

Chauhan, A., Saxena, D. C., & Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent Food and Agriculture, 2*(1), 1-8 (1125773).

Chavan, U. D., Rimamcwe, K. B., Lande, S. B., Nimblkar, C. A., & Dalvi, U. S. (2018). Physical and sensory quality of roselle seed flour cookies. *International Journal of Advanced Research in Biological Sciences, 5*(5), 160-171.

Chavan, U. D., Yewale, K. V., & Rao, D. B. (2016). Preparation of bread and cookies from sorghum flour. *International Journal of Recent Scientific Research, 7*(5), 11145-11153.

De Albuquerque, J. G., Escalona-Buendía, H. B., Aquino, J. de S., & da Silva Vasconcelos, M. A. (2022). Nopal beverage (Opuntia ficus-indica) as a non-traditional food: Sensory properties, expectations, experiences, and emotions of low-income and food-insecure Brazilian potential consumers. *Food Research International, 152*, 110910.

Dhillon, B., Chopra, N., Rani, R., & Singh, A. (2018). Physico-nutritional and sensory properties of cookies formulated with quinoa, sweet potato and wheat flour blends. *Current Research in Nutrition and Food Science, 6*(3), 798-806.

Goswami, D., Gupta, R. K., Mridula, D., Sharma, M., & Tyagi, S. K. (2015). Barnyard millet-based muffins: Physical, textural, and sensory properties. *LWT-Food Science and Technology, 64*(1), 374–380.

Hussain, S., Mohamed, A. A., Alamri, M. S., Ibraheem, M. A., Qasem, A. A. A., Serag El-Din, M. F., & Almaiman, S. A. M. (2020). Wheat-millet flour cookies: Physical, textural, sensory attributes, and antioxidant potential. *Food Science and Technology International, 26*(4), 311-320.

Iwegbue, C. M. A. (2012). Metal contents in some brands of biscuits consumed in Southern Nigeria. *American Journal of Food Technology, 7*(3), 160-167.

Jan, U., Gani, A., Ahmad, M., Shah, U., Baba, W. N., Masoodi, F. A., Maqsood, S., Gani, A., Wani, I. A., & Wani, S. M. (2015). Characterization of cookies made from wheat flour blended with buckwheat flour and effect on antioxidant properties. *Journal of Food Science and Technology, 52*(10), 6334-6344.

Jemziya, M. B. F., & Mahendran, T. (2017). Physical quality characteristics of cookies produced from composite flour blend of wheat and sweet potato flour. *Ruhuna Journal of Science, 8*(1), 12-23.

Joseph, R. P., & Waghray, K. (2022). Development and evaluation of millet cookies processed with sorghum and little millet incorporated with palm jaggery and tamarind kernel powder. *International Journal of Food and Nutritional Sciences, 11*(7), 640-656.

Karma, B. R., Chavan, U. D., Kadlag, A., & Wani, V. S. (2018). Effect of addition of roselle seed flour on color and textural properties of cookies. *International Journal of Current Microbiology and Applied Sciences, 7*(4), 3726-3737.

Kulkarni, D. B., Sakhale, B. K., & Chavan, R. F. (2021). Studies on development of low gluten cookies from pearl millet and wheat flour. *Food Research, 5*(4), 114-119.

Kulthe, A. A., Thorat, S. S., & Lande, S. B. (2017). Evaluation of physical and textural properties of cookies prepared from pearl millet flour. *International Journal of Current Microbiology and Applied Sciences, 6*(4), 692-701.

Kumar, P., Masih, D., & Sonkar, C. (2015). Development and quality evaluation of cookies incorporated by millets and cardamom powder. *The International Journal of Science and Technoledge, 3*(8), 107-111.

McWatters, K. H., Ouedraogo, J. B., Resurreccion, A. V. A., Hung, Y. C., & Phillips, R. D. (2003). Physical and sensory characteristics of sugar cookies containing mixtures of wheat, fonio (Digitaria exilis) and cowpea (Vigna unguiculata) flours. *International Journal of Food Science and Technology, 38*(4), 403-410.

Michaelraj, J. S., & Shanmugam, A. (2013). A study on millets-based cultivation and consumption in India. *International Journal of Marketing, Financial Services and Management Research, 4*(2), 49-58.

Mitkal, K. T., Kotecha, P. M., Godase, S. N., & Chavan, U. D. (2021). Studies on nutritional quality of kodo millet cookies. *International Journal of Chemical Sciences, 9*(1), 1669-1674.

Ndife, J. A. (2009). Functional foods: Prospects and challenges in Nigeria. *Journal of Science and Technology, 1*(5), 1-6.

Paesani, C., Bravo-Nunez, A., & Gomez, M. (2020). Effect of extrusion of whole-grain maize flour on the characteristics of gluten-free cookies. *LWT-Food Science and Technology, 132*, 109931.

Panse, V. G., & Sukhatme, P. V. (1967). *Statistical methods for agricultural workers* (2nd ed.). Indian Council of Agricultural Research, New Delhi.

Rao, D., & Deepika, T. (2016). Nutritional comparison of millets, cereals, oats, and quinoa. *Indian Farming, 65*(12), 14-17.

Rehman, S., Paterson, A., Hussain, S., Murtaza, M. A., & Mehmood, S. (2007). Influence of partial substitution of wheat flour with vetch (Lathyrus Sativus L) flour on quality characteristics of doughnuts. *LWT-Food Science and Technology, 40*(1), 73-82.

Saladivar, S. (2016). Cereals: Dietary importance. In B. Caballero, L. Trugo, & P. Finglas (Eds.), *Encyclopedia of Food Sciences and Nutrition* (pp. 703-711). Academic Press, London.

Saleh, A. S. M., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety, 12*(3), 281-295.

Selladurai, M., Pulivarthi, M. K., Raj, A. S., Iftikhar, M., Vara Prasad, P. V., & Siliveru, K. (2020). Considerations for gluten-free foods - pearl and finger millet processing and market demand. *Grain & Oil Science and Technology, 6*(2), 59-70.

Shanthi, P., Kennedy, Z. J., Parvathi, K., Malathi, D., Kulandasamy, T., & Raghavan, V. (2005). Studies on wheat-based composite flour for pasta products. *The Indian Journal of Nutrition and Dietetics, 42*, 503-508.

Sharma, P., Velu, V., Indrani, D., & Singh, R. P. (2013). Effect of dried guduchi (Tinospora cordifolia) leaf powder on rheological, organoleptic, and nutritional characteristics of cookies. *Food Research International, 50*(2), 704-709.

Shimray, C. A., Gupta, S., & Rao, G. V. (2012). Effect of native and germinated finger millet flour on rheological and sensory characteristics of biscuits. *International Journal of Food Science & Technology, 47*(11), 2413–2420.

Singh, K. P., Mishra, A., & Mishra, H. N. (2012). Fuzzy analysis of sensory attributes of bread prepared from millet-based composite flours. *LWT-Journal of Food Science and Technology, 48*(2), 276–282.

Soumya, H., & Mamatha, H. S. (2022). Evaluation of physico-chemical properties of foxtail millet (Setaria italica) based biscuits. *Environment and Ecology, 40*(2B), 721-727.

Thilagavathi, T., Kanchana, S., Banumathi, P., Hemalatha, G., Vanniarajan, C., Sundar, M., & Ilamaran, M. (2015). Physico-chemical and functional characteristics of selected millets and pulses. *Indian Journal of Science and Technology, 8*(S7), 147-155.

Vijayakumar, T. P., & Mohankumar, J. B. (2009). Formulation and characterization of millet flour blend incorporated composite flour. *International Journal of Agriculture Sciences, 1*(2), 46-54.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/128196