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FORMULATION AND NUTRITIONAL EVALUATION OF ASHWAGANDHA AND FINGER MILLET COOKIES FOR EFFECT OF GLYCEMIC INDEX AND HEALTHY AGEING

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Abstract

The rising prevalence of unhealthy biological ageing and lifestyle-related metabolic disorders, particularly impaired glycemic control, is a major public health concern. Functional foods enriched with medicinal herbs and traditional grains, offer a sustainable approach to improve metabolic health. An experimental study was conducted on developing herbal cookies, fortified with Ashwagandha and finger millet, as a potential low-glycemic, anti-aging dietary intervention, in which four cookie formulations (T0–T3) were developed. The control sample (T0) consisted of 100% wheat flour, while the treatment groups (T1–T3) incorporated varying proportions of wheat flour (60–70%), finger millet flour (26–34%), and Ashwagandha root powder (4–6%), along with standardized quantities of other ingredients. Proximate analysis was conducted in accordance with the Association of Official Analytical Chemists (AOAC) standards. Sensory evaluation was performed using a 9-point hedonic scale Statistical analysis was conducted using SPSS, and differences among treatments were evaluated through one-way ANOVA at a significance level of $p < 0.05$. Among all treatments, T1 showed the highest overall acceptability (7.1). Nutritional analysis indicated progressive improvement with increasing

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fortification: moisture (3.82%–4.68%), ash (1.21%–2.29%), protein (8.42%– 10.41%), and crude fibre (0.62%–2.58%) increased significantly. Conversely, carbohydrates decreased (67.18%–60.86%) and energy values slightly declined (471.2–459.1 kcal/100g) while fat content remained relatively stable. Statistically, overall acceptability and all sensory attributes showed non-significant differences ($p > 0.05$) indicating good acceptability across treatments, while most proximate parameters were significantly to highly significantly affected ($p \leq 0.05$), except protein ($p = 0.22$) which remained non-significant. These findings support the concept that moderate fortification is more effective than excessive inclusion and it is an economical, culturally acceptable, and functional dietary option for managing metabolic health and promoting healthy ageing.

INTRODUCTION

Ageing is a complicated multidimensional process that involves, with time decline in physiological processes, biological composition, genetic morphology, epigenetics so continue to increase risks of chronic non-communicable diseases and as a result, more chances of mortality will occur. Ageing starts from birth and is influenced by genetic, epigenetic and lifestyle factors like environment, sleep, and diet. Healthy practices can control biological age and support wellness. Chronological ageing is inevitable because it is the fundamental frailty process that comes with aging, but it also gradually deteriorates physical health and raises the danger of illness and death. The perfect ageing process occurs in people who's biological and chronological ages are equal, however those whose biological ages are greater than their chronological ages appear older than their true ages, while those with lower biological ages appear younger. Regardless of age, everyone is impacted by the lifetime process of ageing. Therefore, good ageing is essentially about preventing chronic diseases and maintaining life, and aging is not just about the elderly but also about the cumulative consequences of our decisions and experiences throughout life (1).

The prevalence and cost of chronic disorders continue to increase, and cost of it is expected to reach $47 trillion by 2030, globally (2). Diabetes mellitus is a group of metabolic disorders resulting from chronic hyperglycemia and either disturbed insulin secretion or it's resistance, and can involve both too (3). Age-related diabetes mellitus increased in 131 countries for women and 155 countries for men from 1990 to 2022 (4). Modern cookies are widely consumed, calorie-dense, and low in nutritional value despite their long shelf life. Reformulating them with bioactive-rich herbal ingredients, such as Aswagandha and Finger millet, can improve their functional and health-promoting properties.

Ashwagandha (Withania somnifera), belonging to the Solanaceae family and commonly known as *Indian winter cherry* or *Indian ginseng*, is a well-established Ayurvedic herb with a documented history of more than 3000 years in the Indian subcontinent. It is known as the "Queen of Indian herbs" and is traditionally classified as a *Rasayana* and functions as a rejuvenator, nootropic, and natural adaptogen that supports physical and mental well-being and promotes vitality (5).

The herb contains several bioactive compounds, mainly withanolides including withanolide-A and withanolide-D, along with variations in phenolics, flavonoids, and alkaloids, contributing to its therapeutic efficacy. Nutritionally, Ashwagandha roots provide dietary fibre, minerals, carbohydrates, iron, calcium, carotenoids, vitamin C, and moderate energy, making them suitable for functional food formulations such as cookies (6). The name *Withania somnifera* reflects its sleep-promoting but non-sedative nature, while the Sanskrit term *Ashwagandha* symbolizes strength and vitality, reinforcing its traditional role as an antiageing and antidiabetic herb (7). Since Withania somnifera is used in a variety of products that are distributed and sold in the majority of global markets, most frequently as dietary supplements, it is subject to a number of regulations that are enforced by national competent authorities regarding safety of such products (8).

Finger millet (Eleusine coracana), commonly known as *Ragi*, *Nachani*, or *Mandua*, belongs to the millet family of small-seeded cereals cultivated mainly in semi-arid regions of Asia and Africa and is categorized among major millets. It is one of the oldest Indian crops and is referred to as *rajika* or *markata* ("dancing grain") in ancient Sanskrit literature, ranking fourth among major millets globally (9). The grain's layers are rich in phenolic compounds, flavonoids, carotenoids, phytates, and tannins, making it non-glutinous, non-acidic, easily digestible, and nutritionally dense. Its high dietary fibre and polyphenol content slows carbohydrate digestion, lowers glycemic response, supports gastrointestinal health, and reduces the risk of diabetes mellitus (10). Bioactive compounds such as tannins, epigallocatechin, trypsin inhibitors, and α-amylase inhibitors provide antioxidant, antifungal, anti-inflammatory, anticancer, and anti-ageing effects (11).

Among the elements that make ragi so nutrient-dense include calcium, minerals, and fibre, the range of carbs in cereal grains is 72–79.5%. The second most important component of millet is protein, ragi has a protein content of 71%, ranging from 5.6 to 12.70%, protein function is significantly impacted by essential amino acids, and the required percentage of amino acids in finger millet is 44.7%. Finger millet accounts for 20% and 26% of all millets worldwide in terms of total area covered and production, respectively (12). Millets are extremely nutritious foods that have been shown to have many health benefits. Thus, the rising prevalence of unhealthy ageing and poor diet and lifestyle-related disorders, needs urgent and accessible solutions, as this actually poses a significant disease burden worldwide, especially in Asian countries like Pakistan, and so considering the challenge, there is a growing need for healthy, affordable, and accessible snack options that can help prevent and manage morbidities.

An experimental study was done in 2022, by Jerald L et al. for the development of multi-grain herbal cookies made with Ashwagandha root powder to make a healthy alternative to bakery products, and used components like finger millet, pearl millet, sorghum, butter, ghee, sugar, powdered milk, and Ashwagandha 2 to 5% with seven combinations (T1 – T7), and was compared to a local bakery cookie as a control group (T0), so sensory evaluation via a 9-point hedonic scale revealed that 4.5% Ashwagandha (T6: 95.5% multi-grain flour + 4.5 % Ashwagandha) majorly improved the attributes, however, more Ashwagandha usage (5% and above) reduced acceptability (13).

Vol. 5 No. 2 (2026)
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Shehzad et al - 2026
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An experimental study done in 2023 by Singh S et al. focused on the development of a valueadded traditional food product, Panjiri, by incorporating nutritionally rich ingredients, including black wheat flour, finger millet flour, fox nut, and ashwagandha powder, to enhance its micronutrient and functional properties. Four formulations were prepared, with T_0 serving as the control (wheat flour and fox nut), while T_1, T_2, and T_3 contained varying ratios of black wheat flour, finger millet flour, fox nut, and ashwagandha powder. Sensory evaluation revealed that formulation T_2 showed the highest acceptability in terms of colour, texture, taste, and overall acceptability. For this study, nutritional analysis of the best-accepted formulation (T_2) demonstrated improved protein, fibre, iron, calcium, antioxidant activity, and energy content compared to the control. (14).

A study was conducted in 2025, by Hole VS et al. and proved anti-diabetic and anti-oxidant properties of herbal cookies, formulated with Ashwagandha and Finger millet, and 2 g of Ashwagandha root powder, with either unsalted white butter or ghee as fat support, and for both, 3 formulations were developed separately and proved the importance. Further, sensory analysis showed that 33 g wheat flour, 35 g ragi flour, 29 g stevia, 17 g unsalted white butter, and 2 g Ashwagandha contained the highest sensory attributes, such as taste, flavour, texture, apperance and crunchiness, also to improve the flavour, the same combination was made but with ghee only, instead of white butter, which showed the highest sensory attributes, so, proved the components for the best anti-ageing and anti-diabetic snack (15).

A systematic study was conducted in 2025, by Naik et al. to assess how millet consumption affects metabolic homeostasis, namely lipid profiles and glycemic management in adults. Fasting and postprandial blood glucose, HbA1c, insulin sensitivity, and lipid markers such total cholesterol, LDL, HDL, and triglycerides were important outcome measures. The results regularly demonstrated that eating millet improved lipid profiles by lowering total cholesterol, LDL, and triglycerides and occasionally raising HDL, and it also improved glycemic management by lowering blood glucose levels and improving insulin responsiveness, so, the review showed that millet-based diets can be a useful functional dietary strategy for enhancing metabolic health and controlling diseases like dyslipidemia and diabetes (16).

Overall, the findings of this study suggest that functional cookies enriched with Ashwagandha and finger millet can serve as a convenient, nutrient-dense, and health-oriented snack option suitable for various population groups.

METHODOLOGY

1. RESEARCH DESIGN

This research was an experimental RCT.

2. AREA OF STUDY:

The research work was carried out at the Pakistan Council of Scientific and Industrial Research Laboratories, and Culinary Laboratory of the Faculty of Allied Health Science, Superior University, Lahore, Pakistan.

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3. DURATION OF STUDY

This study was completed in 4 months after the approval of the synopsis from instituitional review board committee.

4. PROCUREMENT OF RAW MATERIALS

All required raw materials, including Finger millet (Ragi) flour, Ashwagandha root powder, wheat flour, stevia powder, butter/ghee, milk, baking powder, baking soda and vanilla essence, were procured from local markets within Lahore to ensure accessibility and feasibility for community-level production.

5. PREPARATION OF RAW MATERIALS

Raw materials were (14, 15): Received and verified Packed in air-tight containers

- Stored in cool dry place
- Labelled with batch numbers
- Kept away from direct sunlight

5.1. Treatment plan (15)

Flour combinations were prepared according to ((Singh S et al 2023) (14), and other ingredients amount by (Okoye ji et all 2008) (17).

Table 1

Ingredients	(T0)	(T1)	(T2)	(T3)
Wheat flour	100%	70%	65%	60%
Ragi flour	0%	26%	30%	34%
Ashwagandha powder	0%	4%	5%	6%

6. PREPARATION OF COOKIES:

The cookie formulations were prepared according to the treatment plan showed in table 1. The process involved sieving and combining the tested dry ingredients (ragi flour, wheat flour, stevia powder, Ashwagandha root powder, baking powder, baking soda) followed by incorporation of the fat source (ghee) and liquid components (milk and vanilla essence). The dough was chilled for 30 minutes and then molded and baked in pre-heated oven at 180 °C for 25 minutes. Cookies were cooled at room temperature and stored in airtight containers for further evaluation (15).

6.1. Machines and apparatus required:

Microwave oven, weighing machine, blenders, sieve, rolling pin, rolling board, cutter (15).

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6.2. Formulations:

Following was the quantitative data of the ingredients and included a total of 100% for the samples of flours having ashwagandha, finger millet and wheat flour. Furthermore, other basic ingredients provided the supporting role, and their values were constant (14, 15). Raw material selection

↓

Weighing of wheat flour
(TO:100%, T1:70%, T2:65%, T3:60%)

↓

Weighing of ragi flour
(10:0%, т1:26%, T2:30%, T3:34%)

↓

Weighing of ashwagandha (70:0%, T1:4%, T2:5%, T3:6%)

↓

Weighing of milk (25%) → stevia (30%)
→ ghee (60%)
→ vanilla (1%) → baking powder+soda
(1%) → cocoa (2%)

↓

Sieving of dry ingredients (sieve)

↓

Roasting of wheat & ragi flour (pan/roaster)

↓

Cooling

↓

Dry mixing of flours + ashwagandha (blender/manual)

↓

Addition of all wet ingredients (manual mixing)

↓

Kneading to form dough

↓

Dough resting (30 min)

↓

Rolling of dough (rolling pin & board)

↓

Cutting & shaping (cutter)

→

Baking
(microwave oven, 180 °C, 25 min)

↓

Cooling

Vol. 5 No. 2 (2026)

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Online ISSN 3007-2387 Print ISSN 3007-2379

Shehzad et al - 2026

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Packaging & storage

DATA ANALYSIS

Proximate Analysis:

Nutritional product analysis was conducted according to AOAC (2007) techniques to determine moisture, ash, protein, fat, fibre, energy and carbohydrate content.

Extract Preparation:

Methanol extraction of four cookie samples was performed using a Soxhlet apparatus. About 100 g of each sample was powdered and placed in thimbles. Approximately 1 L methanol in a round-bottom flask was heated; vapours condensed and continuously extracted compounds for 4–6 hours. After cooling, extracts were concentrated using a rotary evaporator and stored at 4°C.

$$\text{Extraction yield (\%)} = \frac{\textit{weight of sample used}}{\textit{weight of extract obtained}} \times 100$$

Estimation of Primary Metabolites:

Samples were analyzed for proteins, lipids, carbohydrates, moisture, ash, fat, and energy.

Moisture Content (AOAC 925.10):

~5 g sample was dried at 105°C for 4–6 hours until constant weight, cooled in a desiccator, and moisture calculated from weight loss.

Ash Content (AOAC 923.03):

2–3 g sample was charred and incinerated at 550°C for 5–6 hours in a muffle furnace. Residue weight represented ash content.

Crude Protein (AOAC 981.10):

Determined using the Kjeldahl method involving digestion, distillation, and titration.

Nitrogen content was multiplied by 6.25 to obtain protein.

Crude Fat (AOAC 963.15):

15 g sample was extracted with petroleum ether using Soxhlet apparatus (40–60°C). Extract was dried and weighed to determine fat.

Crude Fibre (AOAC 991.43):

Defatted sample (~2 g) was digested with 1.25% H_2SO_4 and NaOH, filtered, dried, incinerated at 550°C, and fibre calculated from weight loss.

Carbohydrate Calculation:

Carbohydrates (%) = 100 − (protein + moisture + fibre + fat + ash) Gross energy = (protein × 4) + (fat × 9) + (carbohydrate × 4)

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Energy Value (Atwater Factors):
Energy (kcal/100 g) was calculated using 4 kcal/g (protein), 9 kcal/g (fat), and 4 kcal/g (carbohydrates).

Sensory Evaluation:
The sensory evaluation of the developed product was conducted 24 hours after preparation by a panel of eight semi-trained individuals from Superior University. Various attributes, including appearance, aroma, taste, texture, aftertaste, and overall acceptability, were assessed using a 9-point hedonic scale, where 1 indicated "dislike extremely" and 9 indicated "like extremely." The panelists were pre-screened using a triangle test to ensure their sensory discrimination ability. All participants were free from food allergies and provided informed consent prior to evaluation. To maintain accuracy and avoid flavor carryover, panelists were instructed to cleanse their palate with lukewarm water before the assessment.

RESULTS

Proximate Analysis

Proximate analysis of the cookie formulations (T0–T3) was carried out to determine moisture, ash, crude protein, crude fat, crude fibre, carbohydrates (by difference), and energy using standardized methods. The LSD test at $p < 0.05$ showed that moisture, ash, crude fibre, carbohydrates, and energy differed significantly among all treatments, whereas crude protein showed non-significant (NS) differences. Crude fat content in T3 (19.18a) was statistically similar to T2 (19.04ab) and T1 (18.92ab), but significantly higher than T0 (18.75b). Overall, an increasing trend was observed in moisture, ash, and fibre, while carbohydrates and energy showed a decreasing trend with increasing levels of fortification.

Table 2: Proximate Composition of Cookies (T0–T3)

Sr no.	Parameter	Unit	T0	T1	T2	T3	LSD (least significant difference)
1	Moisture	%	3.82d ± 0.05	4.10c ± 0.06	4.36b ± 0.04	4.68a ± 0.07	0.106
2	Ash	%	1.21d ± 0.03	1.84c ± 0.02	2.05b ± 0.04	2.29a ± 0.03	0.058
3	Crude Protein	%	8.42 ± 0.08	9.36 ± 0.07	9.88 ± 0.05	10.41 ± 0.09	NS
4	Crude Fat	%	18.75b ± 0.10	18.92ab ± 0.12	19.04ab ± 0.11	19.18a ± 0.14	0.223

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Shehzad et al - 2026
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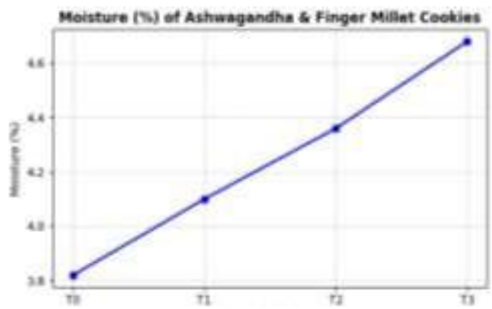
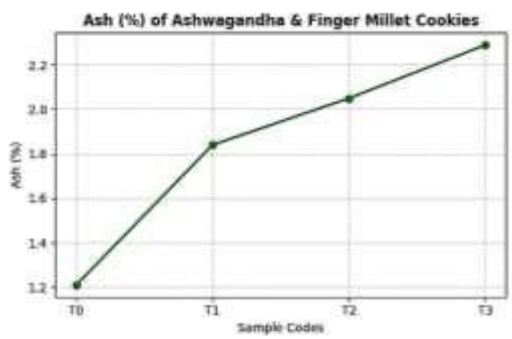
5	Crude Fiber	%	0.62d ± 0.02	1.84c ± 0.04	2.21b ± 0.03	2.58a ± 0.05	0.069
6	Carbohydrates (by difference)	%	67.18a ± 0.22	63.94b ± 0.28	62.46c ± 0.25	60.86d ± 0.31	0.503
7	Energy	kcal/100g	471.2a	465.3b	462.6c	459.1d	0.00





Moisture: The moisture content increased from 3.82% in T0 to 4.68% in T3, which may be attributed to the higher water-binding capacity of ragi and ashwagandha. Moreover, since all values remained below 5%, they help ensure good shelf stability while also maintaining a desirable crisp texture in the cookies.

Ash: The ash content increased from 1.21% in T0 to 2.29% in T3, indicating an improvement in mineral content, particularly calcium, iron, and magnesium, due to the incorporation of ragi.

Crude Protein: The crude protein content increased from 8.42% in T0 to 10.41% in T3, thereby enhancing the overall nutritional value of the cookies; however, this increase remained statistically non-significant.

Vol. 5 No. 2 (2026)
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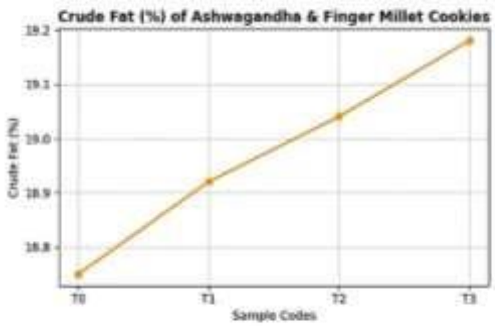
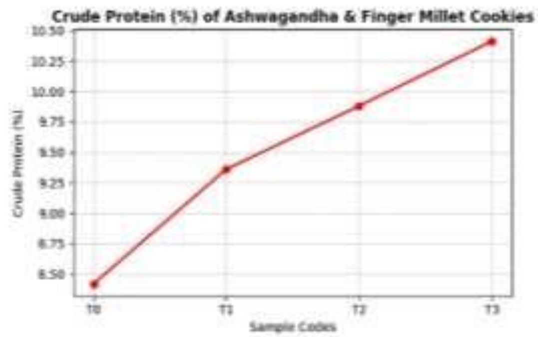
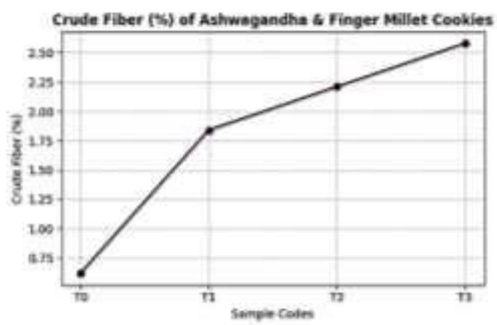




Crude Fat: The crude fat content showed only slight variation, ranging from 18.75% in T0 to 19.18% in T3, which is mainly due to the constant level of ghee used in all formulations; therefore, product palatability remained consistently maintained across treatments.



Crude Fibre: The crude fibre content increased markedly from 0.62% in T0 to 2.58% in T3, which may be attributed to the incorporation of fibre-rich ingredients, thereby supporting glycemic control as well as promoting better digestive health.
Carbohydrates: Decreased from 67.18% in T0 to 60.86% in T3, contributing to lower glycemic load.
Energy: Decreased from 471.2 to 459.1 kcal/100g, corresponding to reduced carbohydrate content.

Vol. 5 No. 2 (2026)

Pakistan Journal of Medical & Cardiological Review

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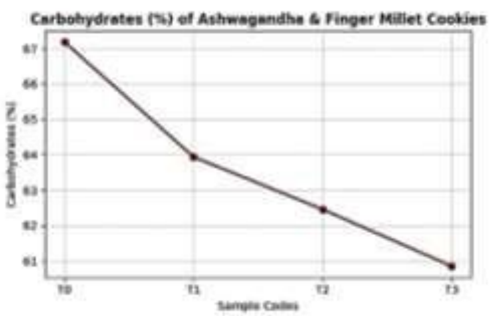

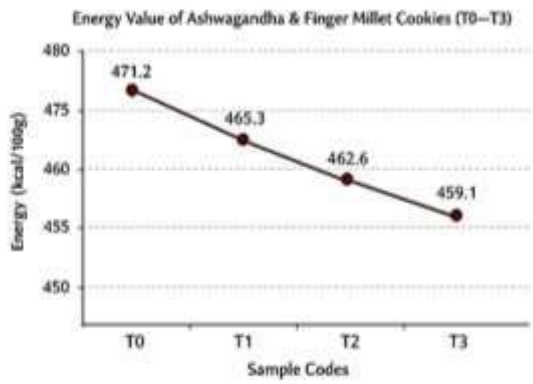

Sensory Evaluation

Sensory evaluation (Table 3) showed that T1 had the highest overall acceptability (7.1), followed by T2, T0, and T3. T1 exhibited improved aroma, taste, and aftertaste, while T2 showed best colour. T3 had comparatively lower scores, indicating reduced preference at higher fortification.

LSD analysis revealed **no significant differences ($p > 0.05$)** among treatments for all attributes (colour, aroma, taste, mouthfeel, aftertaste, overall acceptability), as all shared the same superscript (a). This indicates that fortification up to T1 remained organoleptically acceptable despite minor variations.

Table 3: Sensory evaluation of Ashwagandha and Ragi cookies

Samples	Colour	Aroma	Taste	Mouthfeel	Aftertaste	Overall acceptability
Control cookies T0	7.0a	6.4a	6.8a	7.1a	6.1a	6.5a
Cookies with T1 combination	6.8a	7.0a	7.1a	7.0a	6.5a	7.1a
Cookies with T2 combination	7.1a	6.8a	6.5a	6.9a	6.4a	6.8a
Cookies with T3 combination	6.0a	6.4a	6.3a	6.3a	5.6a	6.3a

Vol. 5 No. 2 (2026)

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3007-2387 3007-2379

Shehzad et al - 2026

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Statistical Evaluation

The collected data were statistically analyzed using SPSS version 26.0 under a Completely Randomized Design (CRD). A one-way Analysis of Variance (ANOVA), as described by Gomez and Gomez (2005), was applied to determine significant differences among the control (T0) and treatment groups (T1–T3). Duncan's Multiple Range Test (DMRT) was further used for post-hoc comparison of means. The variables analyzed included moisture, ash, protein, fibre, fat, carbohydrates, and energy. A significance level of $p < 0.05$ was considered for all statistical tests. The results were expressed as mean ± standard deviation (SD) and presented in both tabular and graphical forms for clear interpretation. Sensory attributes (colour, aroma, taste, mouthfeel, aftertaste, overall acceptability) were all **non-significant ($p > 0.05$)**, indicating no adverse effect of fortification on sensory quality. The proximate parameters showed that moisture and ash were highly significant ($p < 0.001$) and increased across treatments, while protein remained non-significant ($p = 0.22$). Fat content was found to be significant ($p = 0.012$), with the highest value observed in T3. Crude fibre, carbohydrates, and energy were also highly significant ($p < 0.001$), with fibre increasing progressively and carbohydrates and energy showing a decreasing trend. Overall, all treatments differed significantly for moisture, ash, fibre, carbohydrates, and energy.

Overall Interpretation

Proximate and sensory results indicate that fortification with ashwagandha and finger millet improves nutritional quality without affecting sensory acceptability. Treatment **T1 (Wheat 70% : Ragi 26% : Ashwagandha 4**%) showed the best overall acceptability. Increased protein, fibre, and minerals with reduced carbohydrates supports the development of a functional snack suitable for glycemic control and healthy ageing.

DISCUSSION

The present study evaluated the effect of incorporating Ashwagandha and finger millet (ragi) on nutritional composition, sensory attributes, and functional properties of cookies. The findings provide insight into how different fortification levels influence product quality, acceptability, and health benefits, in comparison with existing literature.

Sensory evaluation showed that incorporation significantly influenced acceptability. Among all treatments, **T1 exhibited the highest overall acceptability**, while further increase (T2, T3) resulted in gradual decline. Taste and flavour improved in T1 but decreased in T3 due to the bitter and astringent nature of Ashwagandha at higher levels. Similar findings were reported by Jerald et al. (2023) and Bhoite et al. (2018), where moderate incorporation improved acceptability, but excessive levels reduced sensory quality. Aroma and mouthfeel followed a similar trend, with T1 performing best, while T3 showed reduced mouthfeel due to increased fibre content affecting texture. This agrees with Kaur and Singh (2017) and Chandra et al. (2015), who reported that high fibre leads to harder texture and reduced palatability.

Vol. 5 No. 2 (2026)
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Online ISSN 3007-2387
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Shehzad et al - 2026
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Colour scores were relatively higher in T2, likely due to enhanced Maillard browning reactions, consistent with Sharma et al. (2020) and Verma et al. (2019). Overall, results confirm that **moderate fortification provides optimal sensory balance**, while excessive incorporation negatively affects acceptability.

Moisture content increased progressively from T0 to T3 due to higher water-binding capacity of fibre-rich ingredients. Similar trends were reported by Bhoite et al. (2018) and Chandra et al. (2015). Ash content also increased significantly, reflecting enhanced mineral content (Ca, Fe) from ragi, consistent with Qaisar et al. (2021) and Sharma et al. (2020). Protein content showed gradual improvement, aligning with Jerald et al. (2023) and Kaur and Singh (2017), though increases were moderate compared to studies using legumes.

Crude fibre increased markedly across treatments, confirming functional benefits such as improved digestion and glycemic regulation, consistent with Chandra et al. (2015) and Verma et al. (2019). Carbohydrates and energy values decreased with increasing fortification due to replacement of refined flour with fibre-rich ingredients, as also reported by Qaisar et al. (2021) and Sharma et al. (2020). Fat content remained stable across treatments due to constant fat source, supporting findings of Bhoite et al. (2018).

From a functional perspective, the developed cookies offer multiple health benefits. Increased fibre supports digestion, satiety, and blood glucose control, while enhanced mineral content contributes to bone health and anemia prevention. Studies by Qaisar et al. (2021) and Sharma et al. (2020) support these findings. Additionally, Ashwagandha provides therapeutic benefits due to its bioactive compounds, including anti-stress, antioxidant, and anti-inflammatory effects, as reported by Singh et al. (2011) and Chandrasekhar et al. (2012).

Statistical evaluation further supported these findings. Sensory attributes showed **nonsignificant differences** (**$p > 0.05$**), indicating that fortification up to T3 did not adversely affect acceptability. However, proximate parameters showed **significant to highly significant differences** (**$p < 0.05$ to $p < 0.001$**) for moisture, ash, fat, fibre, carbohydrates, and energy, while protein remained non-significant. These results are consistent with Singh et al. (2023), confirming that functional ingredient incorporation improves nutritional quality without compromising sensory properties.

Overall, while **T3 showed maximum nutritional enhancement**, **T1 emerged as the optimal formulation**, providing the best balance between nutritional improvement and sensory acceptability. These findings align strongly with previous literature, emphasizing that moderate fortification is more effective than excessive inclusion.

CONCLUSION

The present study successfully demonstrated the development of functional cookies enriched with Ashwagandha and finger millet (ragi), highlighting their potential as a nutritionally enhanced and health-promoting food product. Incorporation of these ingredients improved proximate composition by increasing protein, dietary fibre, and mineral content, while reducing carbohydrate

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levels. Statistical analysis further confirmed significant improvements in most nutritional parameters, supporting the effectiveness of formulation changes.

Sensory evaluation revealed that **T1 showed the highest overall acceptability**, indicating that moderate incorporation provides an optimal balance between nutrition and sensory quality. Although higher levels improved nutritional value, they negatively affected taste and flavour due to the strong sensory properties of Ashwagandha.

From a functional and health perspective, the developed cookies offer multiple benefits. Finger millet contributes to bone health, anemia prevention, and digestive support due to its high calcium, iron, and fibre content. Ashwagandha adds therapeutic value through its adaptogenic, antioxidant, and anti-inflammatory properties, supporting stress reduction and metabolic health. The combination also provides potential benefits for **healthy ageing**, including reduction of oxidative stress, improved cognitive and metabolic function, and maintenance of bone density.

Overall, these cookies can serve as a **nutrient-dense, functional snack** suitable for diverse populations. The product supports the concept of *Ashwagandha and Finger Millet Cookies for Effect on Glycemic Index and Healthy Ageing*, demonstrating its potential as a dietary intervention for improved metabolic health and quality of life.

Future research should focus on clinical validation of long-term health effects, shelf-life and storage stability, nutrient retention, and large-scale production feasibility. With further development, such functional food products can contribute significantly to public health, nutritional security, and overall well-being.

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