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VOLARIZATION OF PUMPKIN BY-PRODUCTS IN COOKIE FORMULATION

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ABSTRACT

This study investigates the potential of pumpkin by-products as a fortificant in wheat flour cookies to enhance nutritional value and assess storage stability. Cookies were formulated with varying ratios of pumpkin waste powder (T_0: 0 %, T_1: 5 %, T_2: 10 %, T_3: 15 %, T_4: 20 %), evaluated for physico-chemical properties (weight, diameter, thickness, spread ratio, moisture, ash, fat, protein, crude fiber) and sensory evaluation over 50 days in LDPE packaging at ambient temperature. Results showed initial increases in protein (up to 15.25 %), fiber (up to 4.95 %), ash (up to 4.56 %), fat (up to 14.13 %) and moisture with higher pumpkin incorporation, alongside physical stability during storage. These findings demonstrate pumpkin waste's efficacy in producing nutritionally superior, shelf-stable cookies, promoting food waste valorisation and healthier baked goods.
Keywords **:** Shelf life, *Pumpkin peel powder*, *Functional cookies*, Pumpkin waste, By-product volarization.

Introduction

Food quality enhancement remains crucial for food security, preventing chronic diseases and combating nutritional deficiencies in diverse populations. Food technologists are increasingly using native bio-available fortificants such as polyphenols from cumin and pomegranate peel, high-fiber oats, pumpkin seed carotenoids and healthy fats from canola or olive oil to boost the sensory, rheological and nutritional value of confectionery products (Joel Ndife *et al*., 2014).

Pumpkin seeds (*Cucurbita pepo*) and peels, often wasted, boast impressive nutritional composition. Seeds provide 25-50 per cent protein, 30-50 per cent fats (rich in omega-3 and 6 fatty acids like linoleic acid), 10-30 per cent carbohydrates, high dietary fiber up to 19.6 per cent and minerals. Peels and fibrous strands are loaded with bioactive compounds including carotenoids (35.55 mg/100g DW), polyphenols, flavonoids, tocopherols (30.7 mg/100g), vitamins, amino acids, phytosterols, and pectin (Kaur, 2017).

These components deliver potent anti-oxidant properties, scavenging DPPH/FRAP radicals, reducing oxidative stress and offering anti-inflammatory, anti-cancer, anti-diabetic and anti-microbial benefits, making them ideal for functional foods. Cookies, with cost-effectiveness, shelf stability and 10 million tons global annual consumption, suit such fortification beyond traditional flours like whole wheat or legumes (Bibiana *et al*., 2015).

While waste valorization gains traction, existing literature largely overlooks pumpkin by-products like peels, seeds or fiber as viable fortificants in bakery products like cookies. Few studies optimize their incorporation to elevate fiber, protein and mineral content while cutting carbohydrates, all without compromising sensory appeal, physical quality or storage stability.

This research addresses this gap by developing wheat flour cookies blended with pumpkin waste powder at varying ratios (0-20%), identifying the optimal formulation via sensory evaluation and assessing physico-chemical changes over 50 days of ambient storage in LDPE packaging.

The study was conducted under three objectives:

1. To optimize wheat flour cookie formulations by incorporating pumpkin by-products powder at varying ratios for maximum sensory acceptability
2. To evaluate physico-chemical properties of fresh cookies
3. To assess storage stability of fortified cookies in LDPE packaging

Material and Method

Materials

Pumpkin (*Cucurbita pepo* L.) fruits were procured from farmers of the Jammu region of variety 'Indian Pumpkin'. Mature fruits were procured in the harvest season. Fruits were harvested at commercial maturity stage (orange rind) and transported within 2 hours to the Division of Post Harvest Management, SKUAST-Jammu.

Production of cookies by using pumpkin waste powder

The product was developed using a combination of wheat flour and pumpkin waste powder in various ratios. Cookies were prepared according to these proportions and evaluated for sensory attributes, including color, taste, texture, flavor, appearance, overall acceptability, and aftertaste by a trained panel. The results indicated that the formulation identified as T_3 exhibited the highest degree of overall acceptability. The characteristics of the cookies were affected by factors such as the type of packaging material, environmental conditions, and the specific constituents of the flour. The cookies were packaged in LDPE bags and stored at ambient temperature, with evaluations conducted every 15 days for 45 days.

Fig. 1 : Developed cookies with the incorporation of pumpkin by-product powder

Table 1: Different ratios of the raw materials used in the preparation of the cookies

Treatment	Wheat Flour (%)	Pumpkin Waste Powder (%)
T_0	100	0
T_1	95	5
T_2	90	10
T_3	85	15
T_4	80	20

Production of pumpkin waste powder

The pumpkin by-products, like peel, seeds, fiber, etc, underwent a thorough washing, peeling, and slicing process. These were uniformly sectioned into dimensions of 2.5 cm in length and 0.5 cm in width. Approximately 250 g of this waste was manually crushed, then subjected to oven drying in a laboratory oven set at 40 °C. The dried material was subsequently blended into fine flour and passed through a 200 mm mesh sieve (according to British Standards) before being stored in an airtight container at a temperature of 25 °C for further analyses.

Proximate analysis of cookies

By implementing the improved condition, the cookies were made and evaluated for their properties following the standard method of the Association of Official Analytical Chemists.

Moisture content determination

The moisture content in the cookies made under optimal conditions was evaluated by drying a 2 g sample of the cookies in a hot air oven (Binder, Germany) at a temperature of 105 ± 3 °C for 24 hours. The weight of the sample was recorded both before and after the drying process. The moisture content was calculated using the following equation:

$$Moisture\ (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

Where W_1 is the weight of the fresh sample (in grams)

W_2 is the weight of the dried sample (in grams)

Ash determination

The ash content of the sample was determined by combusting 4 g of the sample at 550°C in a muffle furnace (Nabertherm, Germany) until a light gray residue or a consistent weight was achieved. After cooling the sample in a desiccator at room temperature, it was weighed. The calculation was performed by dividing the mass of the residue by the initial mass, as indicated in the equation:

$$\text{Ash}\ (\%) = \frac{W_1 - W_2}{W_s}\ \text{X}\ 100$$

Where W_1 is a weight of ash + crucible after formation of ash

W_2 is the weight of an empty crucible

W_S is the weight of the sample taken.

Crude protein determination

The crude protein content of the cookie sample was assessed by digesting 1 g of the dried sample in 8 mL of concentrated sulfuric acid (98%) along with a potassium and copper sulfate mixture in a 1:9 ratio, using a Kjeldahl flask. The flask was swirled to ensure thorough mixing of the components and then placed on a heater for digestion until the mixture became clear, which took approximately 2 hours. After cooling, 30 mL of distilled water and 10 mL of 35 per cent sodium hydroxide solution were added, and the mixture was subjected to distillation using a Kjeldahl unit (Tecator Kjeltec BSXT-06, Zhuanznan, China). Distillation was carried out for a minimum of 5 minutes, during which the generated ammonia (NH_3) was collected as ammonium hydroxide in a conical flask containing 20 mL of 2 per cent boric acid solution, supplemented with a few drops of modified methyl red indicator, resulting in a yellowish color indicative of ammonium hydroxide presence. The distillate was subsequently titrated with standard 0.1 N HCl solution until a pink color change was observed. The nitrogen content was calculated using the appropriate equation, from which the crude protein was derived using another specified equation:

$$\text{Nitrogen}(\%) = \frac{\text{Titre value Normality of HCl} \times 14}{\text{Weight of sample (g)}} \times 100$$

Crude Protein (%) = % Nitrogen x 6.25

Crude fat determination

In the current investigation, the total fat content of the optimized cookies was determined utilizing a solvent auto extractor (model number SER 158, VELP Scientifica, Italy). For this procedure, 8 grams of dried powder sample were placed in a cellulose thimble, and 100 mL of diethyl ether was added to the extraction cap within the extraction chamber. The extraction process was conducted for 3 hours. Subsequently, the extract was subjected to drying in an oven (Binder, Germany) at 105°C for 1 hour to facilitate the evaporation of the solvent. The fat content was quantified gravimetrically using the appropriate equation:

$$Fat\ (\%) = \frac{W_2 - W_1}{W_s} \times 100$$

Where W_2 is the weight of the extraction cup after the extraction process with fat

W_1 is the weight of empty extraction cup

W_s is the sample weight.

Crude fiber determination

The total dietary fiber (TDF) content in the cookie sample was analyzed following the procedure outlined in AOAC method 962.09. By this method, 2 g of the ground cookie sample was subjected to boiling in 200 mL of 0.128 per cent sulfuric acid (H_2SO_4) for 30 minutes. The resulting solution was then filtered, and the residue obtained was thoroughly rinsed with distilled water before being boiled in 0.313 per cent sodium hydroxide (NaOH) for another 30 minutes. The residue was subsequently rinsed with water and dried in a hot air oven (Binder, Germany) at 230°C for 2 hours. Following this, the sample was incinerated in a muffle furnace (Nabertherm, Germany) at 550°C for 2 hours. The percentage of crude fiber was determined as indicated by the equation provided below.

$$\text{Crude fiber}(\%) = \frac{\text{W}_1 - \text{W}_2}{\text{W}_s} \times 100$$

Where W_1 refers weight of the dry sample

W_2 denotes the weight of the ash sample

W_S is known as the weight of the sample (A.O.A.C. 2010)

Sensory Evaluation of the cookies (5-point Hedonic Scale)

Sensory attributes of cookies from all treatments (T_0-T_4) were evaluated by a semi-trained panel of 20 members. Panellists assessed duplicate samples under controlled conditions using a 5-point hedonic scale (1: very dislike; 5: very like).

Statistical data analysis

The experiment followed a Completely Randomized Design (CRD) with five treatments (T_0-

T_4) and three replications per treatment (n=15). Data analyzed using one-way ANOVA to compare treatment effects and two-way ANOVA for storage effects. Critical difference (CD) was calculated at 5 per cent.

Results

Effect of storage on the weight of the developed cookies

The weight measurements for sample T_0 recorded 10.97 g on day 0, maintaining the same weight after 15 days, and showing slight increases to 10.98 g and 10.99 g after 30 and 45 days, respectively. In comparison, sample T_1 amounted to 10.91 g at day 0, with slight increments observed at 15 days (10.92 g) and 30 days (10.93 g), remaining unchanged at 10.93 g after 45 days. Treatment T_2 exhibited a weight of 10.86 g on day 0, remaining consistent at 15 days and showing marginal increases to 10.88 g after both 30 and 45 days. For treatment T_3, the initial weight was recorded at 10.78 g on day 0; this remained the same after 15 days, with slight increases to 10.80 g after 30 days and 9.81 g after 45 days. Lastly, treatment T_4 started at 10.70 g on day 0 and showed minor adjustments to 10.71 g after both 15 and 30 days, culminating at 10.72 g after 45 days.

Table 2: Effect of storage on the weight of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	10.97^{a}	10.97^{b}	10.98^{c}	10.99^{ac}
T_1	10.91^{b}	10.92^{a}	10.93^{ab}	10.93^{c}
T_2	10.86^{a}	10.86^{a}	10.88^{a}	10.88^{cb}
T_3	10.78^{a}	10.78^{b}	10.80^{c}	10.81^{a}
T_4	10.70^{c}	10.71^{ac}	10.71^{ab}	10.72^{bc}
CD ($p \leq 0.05$)	0.09	0.08	0.10	0.11

Effect of Storage on diameter of the developed cookies

The diameter recorded for T_0 was 7.8 cm on day 0, 7.8 cm after 15 days, 7.7 cm after 30 days and 7.7 cm after 45 days. In the same way, T_1 measured 7.6 cm on day 0, 7.6 cm after 15 days, 7.5 cm after 30 days and 7.5 cm after 45 days. Likewise, treatment T_2 exhibited a diameter of 7.3 cm on day 0, 7.3 cm after 15 days, 7.2 cm after 30 days, and 7.2 cm after 45 days. Similarly, T_3 had a measurement of 7.1 cm on day 0, 7.1 cm after 15 days, 7.0 cm after 30 days and 7.0 cm after 45 days. Additionally, T_4 was 6.9 cm on day 0, 6.9 cm after 15 days, 6.8 cm after 30 days and 6.8 cm after 45 days. It was observed that there was a minor reduction in the diameter of the cookies during storage at ambient temperature over a period of 45 days.

Table 3: Effect of Storage on diameter of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	7.8^{a}	7.8^{b}	7.7^{a}	7.7^{a}
T_1	7.6^{b}	7.6^{ac}	7.5^{b}	7.5^{b}
T_2	7.3^{c}	7.3^{a}	7.2^{c}	7.2^{c}
T_3	7.1^{ab}	7.1^{b}	7.0^{ac}	7.0^{ac}
T_4	6.9^{ac}	6.9^{c}	6.8^{ab}	6.8^{ab}
CD ($p \leq 0.05$)	0.18	0.16	0.15	0.17

Effect of storage on thickness of the developed cookies

The measurements for treatment T_0 indicated a thickness of 1.50 cm at baseline, i.e., 0-day, followed by 1.52 cm after 15 days, with no further change observed at 30 days and 45 days. In contrast, sample T_1 exhibited a thickness of 1.67 cm on day 0, remaining consistent at this measurement after 15 days, 30 days and slightly increasing to 1.68 cm at 45 days. Treatment T_2 recorded a thickness of 1.65 cm at baseline, increasing modestly to 1.66 cm after both 15 and 30 days, and reaching 1.67 cm after 45 days. Similarly, treatment T_3 showed an initial thickness of 1.64 cm on day 0, remaining unchanged after 15 days, and then increasing to 1.66 cm after 30 days and 1.67 cm following a 45-day storage period. Lastly, treatment T_4 began at a thickness of 0.62 cm on 0-day, maintaining this measurement after 15 days and subsequently increasing to 1.64 cm after 30 days and 1.65 cm after 45 days.

Table 4: Effect of storage on thickness of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	1.50^{b}	1.50^{a}	1.52^{a}	1.52^{a}
T_1	1.67^{a}	1.67^{b}	1.67^{b}	1.68^{b}
T_2	1.65^{c}	1.66^{c}	1.66^{c}	1.67^{ab}
T_3	1.64^{ab}	1.64^{b}	1.66^{b}	1.67^{a}
T_4	1.62^{ac}	1.62^{c}	1.64^{c}	1.65^{cb}
CD ($p \leq 0.05$)	0.06	0.05	0.07	0.06

Effect of storage on the spread ratio of the developed cookies

The spread ratio recorded for treatment T_0 was 7.3 cm on day 0, remaining at 7.3 cm after 15 days, decreasing to 7.1 cm after 30 days, and stabilizing at 7.1 cm after 45 days. In comparison, treatment T_1 exhibited a spread ratio of 7.1 cm on day 0, which decreased to 7.0 cm after 15 days, 6.9 cm after 30 days, and further to 6.8 cm after 45 days. Similarly, treatment T_2 showed an initial measurement of 7.0 cm on day 0, which remained unchanged at 7.0 cm after 15 days, followed by a decrease to 6.9 cm after 30 days, and 6.8 cm after 45 days. Treatment T_3 began at a spread ratio of 6.8 cm on day 0, showing no change after 15 days, then declining to 6.7 cm after 30 days, and reaching 6.6 cm after 45 days. Finally, treatment T_4 started with a spread ratio of 6.7 cm on day 0, decreased to 6.6 cm after 15 days, 6.5 cm after 30 days, and concluded at 6.4 cm after 45 days.

Table 5: Effect of storage on the spread ratio of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	7.3^{a}	7.3^{a}	7.1^{ac}	7.1^{c}
T_1	7.1^{b}	7.0^{b}	6.9^{ab}	6.8^{a}
T_2	7.0^{c}	7.0^{b}	6.9^{b}	6.8^{ac}
T_3	6.8^{a}	6.8^{bc}	6.7^{c}	6.6^{ab}
T_4	6.7^{b}	6.6^{ac}	6.5^{c}	6.4^{b}
CD ($p \leq 0.05$)	0.24	0.22	0.26	0.25

Effect of storage on moisture content of the developed cookies

The moisture percentage for treatment T_0 was 3.01, T_1 was 3.65, T_2 was 4.08, T_3 was 4.28, and T_4 was 4.40 on day 0. In the same way, after 15, 30, and 45 days, an increase in moisture content was observed in the samples. Pumpkin flour mixes, along with baking powder, can absorb moisture from the surroundings.

Table 6: Effect of storage on moisture content of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	3.01^{a}	3.89^{a}	4.12^{a}	4.53^{ab}
T_1	3.65^{a}	4.01^{a}	4.29^{a}	4.69^{ab}
T_2	4.08^{a}	4.25^{c}	4.56^{c}	4.98^{ac}
T_3	4.28^{ac}	4.40^{c}	4.98^{ac}	5.12^{a}
T_4	4.40^{ab}	4.48^{b}	4.88^{ab}	5.25^{ab}
CD ($p \leq 0.05$)	0.26	0.29	0.33	0.36

Effect of storage on ash content of the developed cookies

The percentage of ash content for treatment T_0 was 3.35, for T_1 was 3.56, for T_2 was 4.29, for T_3 was 4.56, and for T_4 was 4.72 on day 0; similarly, the measurements taken at 15 days, 30 days, and 45 days show a slight reduction in ash content during storage. The ash content in food does not always reflect the same composition as the original mineral matter in the food, as there may be losses due to volatilization or interactions among the components.

Table 7: Effect of storage on ash content of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	3.35^{a}	3.19^{a}	3.11^{a}	3.03^{ac}
T_1	3.56^{a}	3.42^{a}	3.37^{b}	3.28^{ab}
T_2	4.29^{b}	4.22^{a}	4.07^{c}	3.97^{b}
T_3	4.56^{c}	4.39^{b}	4.18^{a}	4.07^{b}
T_4	4.72^{ac}	4.42^{b}	4.21^{a}	4.11^{a}
CD ($p \leq 0.05$)	0.27	0.25	0.30	0.32

Effect of storage on fat content of the developed cookies

The percentage of fat in treatment T_0 was recorded at 13.03, while T_1 was 13.05, T_2 was 13.59, T_3 was 13.93, and T_4 was 14.13 at day zero. A similar trend was observed at 15 days, 30 days, and 45 days, indicating a slight reduction in fat content over the storage period. The findings of the current study revealed a statistically significant decline in the fat content of the prepared biscuits during storage.

Table 8: Effect of storage on fat content of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	13.03^{a}	13.03^{b}	13.01^{b}	12.95^{a}
T_1	13.05^{a}	13.01^{b}	12.97^{b}	12.93^{ab}
T_2	13.59^{c}	13.56^{b}	13.54^{a}	13.50^{b}
T_3	13.93^{ac}	13.90^{a}	13.87^{ab}	13.85^{b}
T_4	14.13^{ac}	14.09^{ab}	14.05^{ac}	14.02^{ba}
CD ($p \leq 0.05$)	0.31	0.29	0.27	0.30

Effect of storage on the protein content of the developed cookies

The protein content of the cookie samples was measured at various time points as follows: for $T_{0,}$ the score was 14.54; for T_1 was 14.76; for T_2 was 14.94; for T_3 was 15.25; and for T_4 was 15.46 at day 0. Additionally, assessments conducted at 15, 30, and 45 days revealed a marginal decline in protein levels during the storage period.

Table 9: Effect of storage on the protein content of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	11.27^{a}	11.24^{b}	11.19^{b}	11.11^{a}
T_1	12.60^{b}	12.52^{a}	12.47^{b}	12.39^{b}
T_2	13.23^{b}	13.22^{a}	13.17^{ab}	13.11^{b}
T_3	13.93^{a}	13.86^{a}	13.81^{ac}	13.78^{ab}
T_4	14.40^{a}	14.35^{ab}	14.29^{ab}	14.16^{ac}
CD ($p \leq 0.05$)	0.28	0.26	0.30	0.32

Effect of storage on crude fiber content of the developed cookies

The fibre content for sample T_0 measured 3.98, T_1 was at 4.14, T_2 reached 4.60, T_3 had 4.95, and T_4 recorded 5.12 on day zero. Likewise, the measurements after 15 days, 30 days, and 45 days indicate a decline in fiber content during storage.

Table 10: Effect of storage on crude fiber content of the developed cookies

Treatment	0 Day	15 Days	30 Days	45 Days
T_0	3.98^a	3.92^{ab}	3.89^c	3.85^a
T_1	4.14^b	4.11^{ac}	3.87^c	3.86^c
T_2	4.60^a	4.57^{ac}	4.51^{ac}	4.49^b
T_3	4.95^b	4.93^{ab}	4.89^{ab}	4.83^{ac}
T_4	5.12^c	4.98^{ac}	4.68^{ab}	4.52^{ab}
CD ($p \leq 0.05$)	0.45	0.52	0.38	0.61

Sensory Evaluation of the developed cookies

Sensory evaluation scores of all the treatments were conducted at the 0 day. In the analysis, T_3 (4.65±0.4) scored the highest, followed by T_2 (4.35±0.5), T_1 (4.23±0.9), T_4 (3.80±0.3) and T_0 (3.78±0.3). T_3 excelled across all attributes color, appearance, mouthfeel, crispness and overall acceptability, reflecting optimal nutrient integration without sensory compromise. T_4 (20%) ranked lowest due to earthy aftertaste and denser texture from excess fiber, while control T_0 showed baseline acceptability lacking functional appeal. Significant treatment effects were observed for all parameters ($p<0.001$-0.003), confirming T_3 as the optimal formulation for storage studies based on superior sensory profile balancing nutrition and consumer preference.

Table 11: Sensory Evaluation of the cookies on 5-point Hedonic Scale

Treatments	Colour	Appea-rance	Mouth-feel	Crispness	Overall Acceptability
T_0	4.1±0.1	3.8±0.7	3.7±0.2	3.5±0.2	3.78±0.3
T_1	4.0±0.4	4.2±0.2	4.6±0.3	4.1±0.5	4.23±0.9
T_2	4.5±0.5	4.2±0.3	4.5±0.6	4.2±0.5	4.35±0.5
T_3	4.7±0.2	4.6±0.1	4.8±0.5	4.5±0.2	4.65±0.4
T_4	3.6±0.6	3.8±0.1	4.3±0.4	3.5±0.1	3.80±0.3
CD ($p \leq 0.05$)	1.70	1.10	0.90	1.50	1.30

Discussion

The present investigation demonstrated that incorporation of pumpkin by-product powder (peel, seeds and fibrous strands) significantly influenced the physico-chemical, sensory and storage characteristics of wheat flour cookies. The progressive increase in protein, crude fiber, ash and fat content with higher substitution levels (T_1-T_4) confirms the nutritional enrichment potential of pumpkin waste powder. This enhancement can be attributed to the intrinsic composition of pumpkin seeds and peel, which are rich in proteins, essential fatty acids, minerals and dietary fiber (Hussain *et al*., 2023). Similar improvements in nutritional quality following incorporation of plant-based by-products have been reported in composite flour cookies and other functional baked goods.

The increase in crude fiber up to 5.12 per cent and protein up to 15.46 per cent at day 0 with 20 per cent incorporation (T_4) indicates that pumpkin by-products serve as effective fortificants for developing functional bakery products (Asaduzzaman *et al*., 2025). However, sensory evaluation revealed that T_3 (15%) achieved the highest overall acceptability (4.65±0.4), suggesting that moderate inclusion levels optimize the balance between nutritional enhancement and organoleptic quality (Kumar *et al*., 2015). At higher levels (20%), the decline in sensory scores may be attributed to increased fiber content, denser structure and slight earthy aftertaste, which could negatively affect consumer preference. This observation aligns with previous findings that excessive fiber enrichment may impair texture and palatability of cookies.

Physical parameters such as diameter and spread ratio decreased progressively with increasing pumpkin powder levels and during storage. The reduced spread ratio in fortified treatments may be explained by higher water absorption capacity and fiber content of pumpkin waste powder, which restricts dough spread during baking (Alshery, 2020). Increased thickness in fortified samples further supports the influence of fiber on dough rheology and structure formation. During storage, minor increases in weight and moisture content were observed, likely due to hygroscopic absorption of environmental moisture through LDPE packaging (Sunil *et al*., 2022). Such moisture uptake can influence textural attributes but remained within acceptable limits over 45 days.

A gradual decline in protein, fat, ash and fiber content during storage was recorded across treatments. The slight reduction in fat content may be associated with oxidative degradation, while decreases in protein and fiber may result from compositional interactions or analytical variations over time (Asaduzzaman *et al*., 2025). Despite these reductions, the fortified cookies maintained superior nutritional values compared to the control throughout the storage period. The observed increase in carbohydrate percentage during storage is likely a relative effect due to reductions in other proximate components.

Importantly, the storage study confirmed that pumpkin by-product fortified cookies remained stable for up to 45 days under ambient conditions in LDPE packaging without marked deterioration in quality attributes. The moisture levels remained below critical thresholds for microbial spoilage in low-moisture bakery products, supporting the shelf stability of the developed functional cookies (Sello and Mostafa, 2017).

Overall, the findings substantiate that valorization of pumpkin processing waste into cookie formulations not only enhances nutritional density but also supports sustainable food systems by reducing agro-industrial waste. The optimized formulation (T_3) achieved a desirable compromise between functional improvement and consumer acceptability, highlighting its commercial feasibility. This study contributes to the growing body of literature on plant by-product utilization in functional food development and aligns with current trends emphasizing sustainability, nutritional security and waste minimization.

Conclusion

In the course of the storage study, the collected data revealed noteworthy changes in the composition of the samples. Specifically, the moisture content increased from 4.08 per cent to 4.98 per cent. Conversely, the fat content experienced a reduction from 13.59 per cent to 13.50 per cent, while protein content diminished from 13.23 per cent to 13.10 per cent. Additionally, ash content decreased from 4.29 per cent to 3.97 per cent, and fiber content was reduced from 4.60 per cent to 4.49 per cent. In contrast, carbohydrate content saw a slight increase, rising from 65 per cent to 75.86 per cent over the storage period of 0 to 45 days. Moreover, the developed cookies underwent analysis for various physical parameters, including weight, diameter, thickness, and spread ratio. The findings indicated a slight decrease in diameter, thickness, and spread ratio, whereas the weight of the cookies exhibited an increase.

References

AOAC (2000). Official Methods of Analysis 15th Edn., Association of Official Analytical Chemists, Washington DC.

A.O.A.C. (2010). Official methods of analysis of Association of Official Analytical Chemists International 7th ed. Gaithersburg, Method 991.3, Total Dietary Fibre, Enzymatic-Gravimetric Method.

Igbabul, D. B., Iorliam, B. M., & Umana, E. N. (2015). Physicochemical and sensory properties of cookies produced from composite flours of wheat, cocoyam and African yam beans. *Journal of Food Research*, **4**(2).

Ndife, J., Kida, F., & Fagbemi, S. (2014). Production and quality assessment of enriched cookies from whole wheat and full-fat soya. *European Journal of Food Science and Technology*.

Kaur, M. (2017). *Development and nutritional evaluation of pumpkin seed (Cucurbita moschata) supplemented products* [Doctoral dissertation, Punjab Agricultural University].

Hussain, A., Kausar, T., Aslam, J., Quddoos, M. Y., Ali, A., Kauser, S., Zerlasht, M., Rafique, A., Noreen, S., Iftikhar, K., & Iqbal, M. W. (2023). Physical and rheological studies of biscuits developed with different replacement levels of pumpkin (*Cucurbita maxima*) peel, flesh, and seed powders. *Journal of Food Quality*, **2023**(1), 4362094.

Asaduzzaman, M., Akter, M. S., & Rahman, M. (2025). Enhancing nutritional value and quality of cookies through pumpkin peel and seed powder fortification. *PLOS ONE*, **20**(2), 0307506.

Kumar, P., Masih, D., & Sonkar, C. (2015). Development and quality evaluation of pumpkin powder fortified cookies. *International Journal of Science, Engineering and Technology*, **3**(4), 1034–1038.

Alshehry, G. A. (2020). Preparation and nutritional properties of cookies from the partial replacement of wheat flour using pumpkin seeds powder. *World Journal of Environmental Biosciences*, **9**(2), 48–56.

Sunil, N. C., Chaudhary, V., Singh, S., & Singh, B. R. (2022). Effect on physico-chemical properties of cookies during storage. *The Pharma Innovation Journal*, **11**(1), 1046–1048.

Sello, A. A., & Mostafa, M. Y. (2017). Enhancing antioxidant activities of cupcakes by using pumpkin powder during storage. *Journal of Food and Dairy Sciences*, **8**(2), 103–110.