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Nutritional Enhancement of Traditional Indian Snacks with Oilseed Meal Incorporation

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Background: India faces significant challenges with hunger and malnutrition, despite being a major producer of oilseed meals. These meals, byproducts of oil extraction, are rich in nutrients but underutilized for human consumption.

Aim: This study aimed to develop nutrient-dense versions of the traditional Indian snacks, *mathi* and *sev*, by incorporating different oilseed meals, thereby addressing nutritional deficiencies and promoting the utilization of these byproducts.

Methodology: Groundnut meal, sesame meal, and flaxseed meal were incorporated individually and in composite form into *mathi* and *sev* recipes at 12%, 18%, and 24% levels. A panel of semi-trained judges conducted organoleptic evaluations and found that 24% of the products were acceptable; further evaluation was carried out on those products. The nutritional properties,

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including proximate composition, antioxidant activity, phytic acid content, and in vitro protein digestibility, were analyzed of 24% level products. The shelf life of the developed products was also assessed.

Results: The incorporation of oilseed meals enhanced the nutritional profile of both *mathi* and *sev*. All developed products were organoleptically acceptable.

Conclusion: Oilseed meals can be effectively utilized to develop nutrient-dense traditional Indian snacks. These products have the potential to improve nutritional status and reduce malnutrition within communities.

Keywords: Oilseed Meals; traditional Indian snacks; nutritional enhancement; food fortification; malnutrition.

1. INTRODUCTION

India continues to grapple with persistent hunger and malnutrition challenges, ranking 111th out of 125 countries in the Global Hunger Index (2023). Despite significant strides in food security, issues such as protein-energy malnutrition and micronutrient deficiencies afflict millions. Malnutrition, encompassing undernutrition, micronutrient deficiencies, and overnutrition, remains a critical global concern.

Paradoxically, India stands as the world's largest producer of oilseed meals, generating approximately 41 million metric tons in 2023 alone (Infomerics Valuation and Rating Pvt. Ltd., 2024). These meals, derived as by-products during oil extraction, account for more than half of the initial raw material. Traditionally utilized as animal feed, oilseed meals possess immense potential for human nutrition if adequately processed and incorporated into diets. Rich in proteins, fats, fibers, vitamins, and minerals, they represent a valuable yet underutilized resource in addressing malnutrition (Karnika and Kawatra, 2024).

Among the widely produced oilseeds, peanut (*Arachis hypogaea*), flaxseed (*Linum usitatissimum*), and sesame (*Sesamum indicum*) offer significant nutritional benefits. Peanut flour, obtained after dehulling and grinding, is an excellent source of crude protein, fiber, ash, and fat (Dwivedi et al., 2011; Park et al., 2017). Flaxseed meal, a by-product of oil extraction, is rich in protein, dietary fiber, and vitamin B6, a crucial coenzyme involved in various metabolic processes (Heuze et al., 2017). Sesame meal, another valuable by-product, contains approximately 45% protein in expeller-processed form and up to 48% protein when solvent-extracted (Karnika and Kawatra, 2024).

The nutritional composition of these meals varies depending on the oil extraction method, whether cold-pressed, hot-pressed, or solvent-extracted. Cold-pressed oilseed meals generally retain higher nutrient concentrations (Tzia et al., 2003). In the present study, oilseed meals were sourced from the local market for ease of accessibility and practical application.

Recognizing the nutritional potential of these by-products, this study aimed to enhance the nutrient profile of traditional Indian snacks, such as *mathi* and *sev*, by incorporating oilseed meals. These value-added products, developed for broader consumer acceptance, hold promise in improving dietary quality across various age groups. By integrating these nutrient-dense snacks into regular diets, the study aspires to contribute to addressing malnutrition and promoting better public health outcomes.

2. MATERIALS AND METHODS

2.1 Procurement of Material

Groundnut meal (GM), sesame meal (SM), flaxseed meal (FM), and other requisite materials for product preparation and packaging were procured from local markets in Hisar, Haryana, to manufacture value-added products. Foreign matter was removed from the oilseed meals, and they were ground into fine powders.

2.2 Development of Products

Groundnut meal, sesame meal, and flaxseed meal were utilized as ingredients to formulate value-added products. These oilseed meals were incorporated into various recipes at 12%, 18%, and 24% levels, both individually and in combination. A composite meal was prepared by blending equal proportions of the three oilseed meals (groundnut, sesame, and flaxseed), which was then incorporated at similar levels (12%, 18%, and 24%) in the following products:

- **Traditional products:** *Mathi*, and *Sev*.
  - *Mathi* recipe: A predetermined amount of: all-purpose flour and oilseed meal flour

were sifted together. Vegetable oil, carom seeds, and salt were added to the flour mixture. A dough was formed by gradually adding small amounts of water. Small balls were pinched off from the dough and rolled out slightly to form *mathi*. The *mathi* were deep-fried until lightly golden and crisp.

- *Sev* recipe: A predetermined amount of: all-purpose flour, chickpea flour, and oilseed meal flour were sifted together. Vegetable oil, salt, and turmeric were added to the flour mixture. A dough was prepared by adding water as needed. The dough was then placed in a *sev* press fitted with a perforated disk and extruded directly into hot oil. The *sev* were deep-fried until golden brown.

2.3 Organoleptic Evaluation

The product development process involved incorporating supplementation at three distinct levels for each meal item. The control group was prepared without any supplementation, while groups T1 and C1 received 12% supplementation, groups T2 and C2 received 18% supplementation, and groups T3 and C3 received 24% supplementation. Various other ingredients were integrated into the product development process. The developed products included *mathi*, and *sev*. All the developed products underwent organoleptic evaluation by a panel of 30 semi-trained judges, who assessed five attributes (color, appearance, aroma, texture, and taste) using a nine-point hedonic rating scale. On a scale of 1 to 9, the ratings were as follows: liked extremely, liked very much, liked moderately, liked slightly, neither liked nor disliked, disliked slightly, disliked moderately, disliked very much, and disliked extremely, respectively. A total acceptance score of six or higher was deemed suitable, and the nutritional properties of the 24% developed product were further evaluated, as it represented the highest incorporation level while maintaining organoleptic acceptability.

2.4 Proximate Analysis

The Association of Official Analytical Chemists (AOAC, 2010) methods were employed to quantify the moisture, carbohydrate, fat, protein, and ash content of oilseed meals and developed products. The micro-Kjeldahl apparatus determined the nitrogen concentration, which was converted to crude protein by multiplying by factors of 6.25 for control products, 5.45 for groundnut meal-based products, and 5.30 for sesame and flaxseed meal-based products. Weight difference methods measured moisture and ash contents, while the Socs Plus apparatus with petroleum ether as the solvent determined crude fat content. Crude fiber was analyzed through acid and alkali resistance.

2.5 Antioxidant Activity

The total phenolic content (TPC) was measured spectrophotometrically using the Folin-Ciocalteu reagent as described by Singleton and Rossi, (1965). An acidified MeOH extract (0.1 ml) was added to the reaction mixture, which was then oxidized using 0.5 ml Folin-Ciocalteu reagent (1:10 Folin-Ciocalteu:water) and 0.8 ml 7.5 percent Na_2CO_3. For the blank, 0.1 ml water was used instead of the extract. The mixture was heated in a water bath at 50°C for 5 minutes and then cooled to room temperature before being measured using a type U-1100 spectrophotometer at 760 nm.

The DPPH radical scavenging activity was measured using the methodology described by Brand-Williams et al. (1995) as previously described by Tadhani et al. (2009). Different known sample aliquots were collected using methanol, and the volume was adjusted to 1 ml. Subsequently, 3 ml of DPPH reagent was added and properly mixed before being incubated at 37°C for 20 minutes. The absorbance of the oxidized solution was read against methanol as a blank at 517 nm.

2.6 In *vitro* Protein Digestibility and Phytic Acid

In *vitro* protein digestibility (%) was estimated using a modified enzymatic method explained by Mertz et al. (1983). Phytic acid (mg/100 g) content was analyzed using the method of Davies and Reid (1979).

2.7 Shelf Life of Developed Products

A range of food items, encompassing *mathi*, and *sev*, were formulated with a 24 percent incorporation level of diverse oilseed meals. These products were subsequently stored in airtight containers at ambient temperature for a three-month duration, spanning from December 2020 to February 2021. At regular intervals of 15 days, the products underwent evaluation for their organoleptic qualities and fat acidity parameters.

2.7.1 Organoleptic evaluation

Stored products (*mathi* and *sev*) underwent organoleptic evaluation by a panel of thirty semi-trained judges utilizing a 9-point hedonic scale at regular 15-day intervals for three months.

2.7.2 Fat acidity analysis

Fat acidity serves as a crucial indicator of biochemical changes that occur during the shelf life of food products. It is quantified by determining the amount of potassium hydroxide necessary to neutralize the free fatty acids present in the product throughout storage. In this study, fat acidity was assessed at 15-day intervals up to 90 days, utilizing the standard method of analysis outlined by the Association of Official Analytical Chemists (AOAC, 2000).

2.8 Statistical Analysis

The data obtained from nutritional analysis and organoleptic evaluation underwent statistical analysis utilizing mean, standard error, and ANOVA (one-way and two-way analysis). The data was reported as mean ± standard deviation for a minimum of three triplicates per sample. A p-value of 0.05 or lower was considered statistically significant (Sheoran and Pannu, 1999).

3. RESULTS

A comprehensive nutritional analysis was performed on groundnut meal (GM), sesame meal (SM), flaxseed meal (FM), and a composite meal (CM). The moisture content varied from 0.33% to 1.73%. GM showed the highest protein content at 40.12%, followed by CM (38.06%), SM (37.16%), and FM (36.71%). FM had the highest crude fat level (32.03%), followed by CM (19.01%), SM (13.54%), and GM (10.95%). Comparison of protein and moisture of all the selected oilseed meals indicated that it was significantly ($P \leq 0.05$) high in groundnut meal. SM displayed the highest ash content (8.72%), with GM at 7.46%, CM at 6.64%, and FM at 3.10%. The crude fiber content was greatest in CM (9.58%), followed by SM (7.55%), FM (6.43%), and GM (5.66%). Significant ($P \leq 0.05$) difference observed in fat content among all oil seed meals may be due to fat content of oil seed and method of oil extraction used. The comparison of ash content among sesame, flaxseed, groundnut and composite meal revealed that ash content was significantly ($P \leq 0.05$) high in sesame meal and lowest in flaxseed meal. A variation was observed in crude fiber content among all oil seed meals evaluated. Maximum amount of crude fiber was found in composite meal and lowest found in groundnut meal. Significant ($P \leq 0.05$) differences were observed in crude fiber content among all the oil seed meals.

Antioxidant activity was most significant in GM (11.06mg TE/100g), followed by SM (10.77mg TE/100g), FM (10.76mg TE/100g), and CM (9.18mg TE/100g). FM had the highest total phenol content (1070.6mg GAE/100g), followed by CM (711.45mg GAE/100g), GM (693.44mg GAE/100g), and SM (583.64mg GAE/100g). Phytic acid levels were highest in SM (314.00mg/100g), followed by CM (304.79mg/100g), FM (285.80mg/100g), and GM (276.60mg/100g). In-vitro protein digestibility was optimal in GM (81.09%), with FM at 79.09%, SM at 78.50%, and CM at 75.11%. Almost similar antioxidant activity was observed in sesame and flaxseed meal while lowest amount was observed in composite meal. Total phenol content was high in all the seed meals however significant variations was noticed among all oil seed meals being highest in flaxseed meal and lowest in sesame meal. Data in respect to phytic acid content revealed that almost similar values was observed in groundnut and flaxseed meal whereas the significant ($P \leq 0.05$) higher amount was found in sesame meal and lowest amount was found in composite meal. Protein digestibility was significantly ($P \leq 0.05$) low in composite meal. However, sesame, peanut and flaxseed meal had almost similar digestibility.

3.1 Organoleptic Evaluation

Products were prepared with three different levels of oil meal incorporation: 12%, 18%, and 24%. Products prepared without oil meal incorporation using a standard recipe were considered controls.

3.1.1 *Mathi*

All developed *mathi* varieties were organoleptically acceptable, as evaluated by panelists using a nine-point hedonic scale. The control *mathi*, prepared without added oilseed meals, received high scores for color (8.70), appearance (8.84), aroma (8.63), texture (8.73), taste (8.91), and overall acceptability (8.76) (Table 1).

Table 1. Organoleptic acceptability of *mathi* incorporating sesame, flaxseed, and groundnut meal (Mean scores)

Types of *mathi*		Color	Appearance	Aroma	Texture	Taste	Overall acceptability
Control	**Control**	8.70±0.09	8.84±0.07	8.63±0.06	8.73±0.01	8.91±0.01	8.76±0.11
Sesame meal	**T1**	8.40±0.1	8.76±0.04	7.96±0.02	8.70±0.06	8.76±0.04	8.51±0.17
	T2	8.30±0.13	8.74±0.1	7.86±0.09	8.66±0.09	8.71±0.08	8.45±0.18
	T3	8.10±0.17	8.74±0.07	7.73±0.13	8.57±0.13	8.68±0.06	8.36±0.21
Flaxseed meal	**T1**	8.60±0.08	8.88±0.18	8.00±0.12	8.63±0.12	8.81±0.1	8.58±0.21
	T2	8.20±0.15	8.81±0.1	8.00±0.1	8.41±0.06	8.61±00	8.41±0.12
	T3	8.20±0.2	8.44±0.07	8.00±0.01	8.39±0.34	8.51±0.17	8.30±0.21
Groundnut meal	**T1**	8.30±0.1	8.80±0.11	8.17±0.15	8.48±0.19	8.80±0.11	8.51±0.18
	T2	8.10±0.12	8.59±0.09	8.14±0.12	8.33±0.23	8.75±0.06	8.38±0.14
	T3	8.10±0.03	8.58±0.18	8.00±0.01	8.25±0.06	8.53±0.12	8.29±0.16
Composite meal	**C1**	8.80±0.13	8.74±0.05	7.99±0.04	8.91±0.03	8.71±0.10	8.63±0.15
	C2	8.80±0.15	8.69±0.11	7.98±0.18	8.81±0.06	8.65±0.04	8.59±0.23
	C3	8.70±0.15	8.54±0.11	7.69±0.11	8.62±0	8.49±0.1	8.41±0.12
C.D.≤0.05		0.37	N/A	0.34	N/A	N/A	N/A

Values are mean of thirty panelists scores Control- without any oilseed meal incorporation ((T1 & C1, T2 & C2 and T3 & C3 are 12%, 18%, and 24%).

Table 2. Organoleptic acceptability of *sev* incorporating sesame, flaxseed, and groundnut meal (Mean scores)

Types of *sev*		Color	Appearance	Aroma	Texture	Taste	Overall acceptability
Control	**Control**	8.80±0.02	8.30±0.08	8.06±0.32	8.46±0.03	8.53±0.04	8.43±0.2
Sesame meal	**T1**	8.70±0.03	8.30±0.01	8.03±0.2	8.37±0.06	8.53±0.04	8.38±0.17
	T2	8.69±0.1	8.20±0.12	8.00±0.18	8.15±0.2	8.31±0.08	8.27±0.19
	T3	8.67±0.12	8.10±0.17	7.83±0.21	8.11±0.19	8.08±0.13	8.16±0.22
Flaxseed meal	**T1**	8.70±0.13	8.10±0.18	8.53±0.23	8.40±0.16	8.48±0.07	8.44±0.21
	T2	8.60±0.1	8.00±0.08	8.50±0.07	8.25±0.06	8.48±0.01	8.37±0.1
	T3	8.50±0.1	8.00±0.2	8.50±0.02	8.20±0.14	8.39±0.02	8.32±0.1
Groundnut meal	**T1**	8.78±0.08	8.34±0.04	8.40±0.14	8.25±0.09	7.81±0.03	8.32±0.11
	T2	8.68±0.05	8.20±0.13	8.40±0.12	8.16±0.03	7.87±0.06	8.32±0.16
	T3	8.56±0.07	8.19±0.03	7.85±0.15	8.13±0.17	7.63±0.02	8.07±0.15
Composite meal	**C1**	8.60±0.05	8.09±0.1	7.66±0.18	8.00±0.29	7.65±0.17	8.11±0.31
	C2	8.65±0.06	8.30±0.07	7.75±0.11	8.07±0.16	7.68±0.09	8.09±0.23
	C3	8.61±0.22	8.10±0.16	7.66±0.04	8.03±0.24	7.65±0.04	8.01±0.25
C.D.≤0.05		N/A	0.35	0.50	N/A	0.22	N/A

Values are mean of thirty panelists scores
Control- without any oilseed meal incorporation ((T1 & C1, T2 & C2 and T3 & C3 are 12%, 18%, and 24%).

Sesame meal *mathi* at 12, 18, and 24% incorporation levels scored 8.10-8.40 for color, 8.74-8.76 for appearance, 7.73-7.96 for aroma, 8.57-8.70 for texture, and 8.68-8.76 for taste. Overall acceptability ranged from 8.36-8.51 (Table 1).

Flaxseed meal *mathi* at 12, 18, and 24% levels scored 8.20-8.60 for color, 8.44-8.88 for appearance, 8.00 for aroma, 8.39-8.63 for texture, 8.51-8.81 for taste, and 8.30-8.58 for overall acceptability (Table 1).

Groundnut meal *mathi* scored 8.10-8.30 for color, 8.58-8.80 for appearance, 8.00-8.17 for aroma, 8.25-8.48 for texture, 8.53-8.80 for taste, and 8.29-8.51 for overall acceptability (Table 1).

Composite meal *mathi* with equal parts sesame, flaxseed, and groundnut meals at 12, 18, and 24% levels scored 8.70-8.80 for color, 8.54-8.74 for appearance, 7.69-7.99 for aroma, 8.62-8.91 for texture, 8.49-8.71 for taste, and 8.41-8.63 for overall acceptability (Table 1).

Based on the acceptability scores of organoleptic characteristics, all types of *mathi* were observed to be in 'liked very much' category for their overall acceptability. Means scores of *mathi* based on sesame meal, flaxseed, groundnut & composite meal showed very slight variation in the acceptability scores and were found at par statistically (P≤0.05).

3.1.2 *Sev*

Four types of sev were prepared using sesame meal, flaxseed meal, and groundnut meal, composite meal at 12%, 18%, and 24% levels. All sev types were organoleptically acceptable. For sesame meal sev, mean acceptability scores ranged from 8.16-8.38 for overall acceptability, 8.67-8.70 for color, 8.10-8.30 for appearance, 7.83-8.03 for aroma, 8.11-8.37 for texture, and 8.08-8.53 for taste. For flaxseed meal sev, mean overall acceptability scores were 8.32-8.44, color 8.50-8.70, appearance 8.00-8.10, aroma 8.50-8.53, texture 8.20-8.40, and taste 8.39-8.48. Groundnut meal sev had mean overall acceptability of 8.07-8.32, color 8.56-8.78, appearance 8.19-8.34, aroma 7.85-8.40, texture 8.13-8.25, and taste 7.63-7.87. For composite meal sev, mean overall acceptability ranged from 8.01-8.11, color 8.60-8.65, appearance 8.09-8.30, aroma 7.66-7.75, texture 8.00-8.07, and taste 7.65-7.68. The control sev had acceptability mean scores of 8.43 for overall, 8.80 for color, 8.30 for appearance, 8.06 for aroma, 8.46 for texture, and 8.53 for taste (Table 2). Means scores of *sev* based on sesame meal, flaxseed, groundnut & composite meal showed very slight variation in the acceptability scores and were found at par statistically (P≤0.05).

As the overall acceptability of all developed products of 24% incorporation was acceptable so for further nutritional analysis 24% incorporation products were used.

3.2 Nutritional Composition of Developed Oilseed Meal-Based Products

3.2.1 *Mathi*

The data presented examines the proximate composition and antioxidant properties of *mathi* (a traditional Indian snack) prepared with various oilseed meal supplements. The moisture content ranged from 1.04 to 2.1%, while crude protein was highest in oilseed meal-based *mathi* (15.58-18.21%) compared to the control (significantly (P≤0.05) lower). Significantly (P≤0.05) highest crude protein content was found in groundnut meal (18.21%) *mathi* with the comparison to *mathi* developed from all other meals. Ash content varied from 1.91 to 3.61%. Crude fat was highest in flaxseed meal *mathi* (20.04%) and lowest in groundnut meal *mathi* (17.52%), with the control being significantly (P≤0.05) lower. Crude fiber ranged from 2.25 to 3.58% in oilseed meal-based *mathi*, higher than the 2.1% in the control (Table 3).

Antioxidant activity, measured in mg Trolox equivalents (TE) per 100g, was highest in groundnut meal *mathi* (3.85) and lowest in the control (1.99), with all oilseed meal-based varieties exhibiting significantly (P≤0.05) higher values (Fig. 1). Total phenol content followed a similar trend, being highest in flaxseed meal *mathi* (426.93 mg gallic acid equivalents (GAE) per 100g) and lowest in the control (332.04 mg GAE/100g) (Table 4).

Phytic acid content ranged from 242.6 mg/100g in groundnut meal *mathi* to 303.4 mg/100g in sesame meal *mathi*, with all oilseed meal-supplemented varieties having significantly (P≤0.05) higher levels than the control (207.6 mg/100g). Protein digestibility was marginally lower in the supplemented varieties (65.65-66.99%) compared to the control (Table 4).

3.2.2 *Sev*

The study examined the proximate composition, antioxidant activity, total phenol content, phytic acid content, and protein digestibility of four types of *sev* (a traditional Indian snack) developed by incorporating 24% oilseed meals (sesame, flaxseed, groundnut, and a composite meal).

The moisture content was similar among all *sev* types, ranging from 1.03 to 1.85%. Crude fiber content varied from 2.25% (control) to 3.92% (composite meal *sev*). Crude protein ranged from 14.91 to 20.37% in oilseed meal-supplemented *sev*, significantly (P≤0.05) higher than the control (11.28%). Ash content was highest in sesame meal *sev* (3.08%) and lowest in control *sev* (1.61%). Crude fat content was significantly (P≤0.05) high, ranging from 22.31 to 28.28% (Table 5).

Antioxidant activity was highest in groundnut meal *sev* (4.13mg TE/100g) and lowest in control *sev* (2.21mg TE/100g) (Fig. 3). Total phenol content, expressed as gallic acid equivalents, ranged from 350.03mg GAE/100g (control) to 419.23mg GAE/100g (groundnut meal *sev*). Phytic acid content was significantly (P≤0.05) different, ranging from 257.00mg/100g (control) to 353.40mg/100g (sesame meal *sev*). Protein digestibility was statistically (P≤0.05) similar among all *sev* types, ranging from 54.41 to 56.8% (Table 6).

3.3 Shelf-Life Study of Most Acceptable Developed Products

The developed products, including *mathi*, and *sev* underwent shelf-life research to assess their quality over time. These products were stored in airtight containers at room temperature for 90 days, from December 2020 to February 2021. At 15-day intervals, the stored food products were evaluated for organoleptic properties and fat acidity.

3.3.1 Organoleptic evaluation

The organoleptic evaluation was conducted by 30 semi-trained panelists using a nine-point hedonic rate scale on the 0th, 15th, 30th, 45th, 60th, 75th, and 90th day of storage.

Table 3. Proximate composition of oilseed meal based *mathi* (%, on dry matter basis)

Types of *mathi*	Moisture*	Crude Protein	Crude Fat	Ash	Crude Fiber	Carbohydrate
Control	1.16±0.02	8.91±0.22	15.34±0.27	1.91±0.01	2.10±0.03	70.58±0.05
Sesame meal	1.8±0.01	16.24±0.03	18.87±0.47	3.61±0.06	3.25±0.01	56.23±0.29
Flaxseed meal	1.02±0.00	15.58±0.39	20.04±0.30	2.66±0.00	2.48±0.04	41.78±0.09
Groundnut meal	2.10±0.03	18.21±0.26	17.52±0.02	3.40±0.02	2.25±0.05	43.48±0.34
Composite meal	1.04±0.00	16.50±0.15	19.64±0.39	2.98±0.00	3.58±0.06	56.26±0.04
C.D.(P≤0.05)	0.06	0.78	1.06	0.09	0.15	0.03

Values are mean±SE of three independent determinations
** On fresh weight basis, SE=Standard error.*

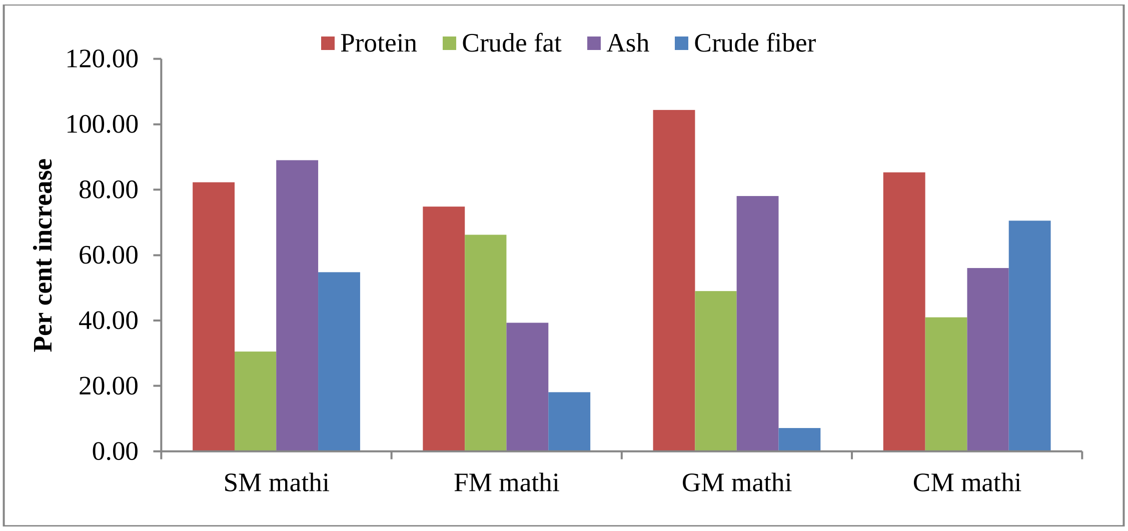
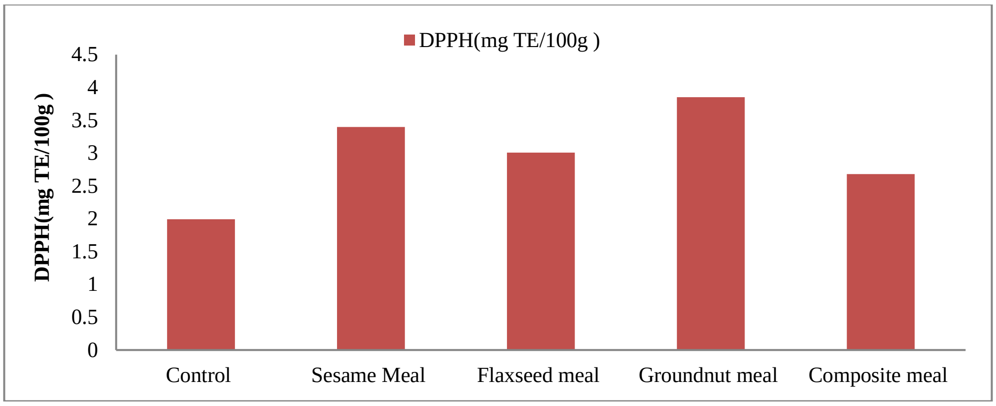


Fig. 1. Percent increase in protein, crude fat, ash, and crude fiber content of oilseed meal based *mathi* as compared to control

Table 4. Total phenol content, phytic acid, and protein digestibility of oilseed meal-based *mathi* (on dry matter basis)

Types of *Mathi*	TPC (mg GAE/100gm)	Phytic acid (mg/100gm)	Protein digestibility (%)
Control	332.04±0.59	207.00±0.18	67.09±0.11
Sesame meal	377.00±0.24	303.40±0.06	66.06±0.20
Flaxseed meal	426.93±0.66	267.80±0.90	66.14±0.65
Groundnut meal	411.54±0.49	242.60±0.89	66.99±0.07
Composite meal	417.3±0.42	299.80±0.62	65.65±0.92
C.D. (P≤0.05)	19.80	10.74	N/A

Values are mean±SE of three independent determination
** On fresh weight basis; SE=Standard error.*



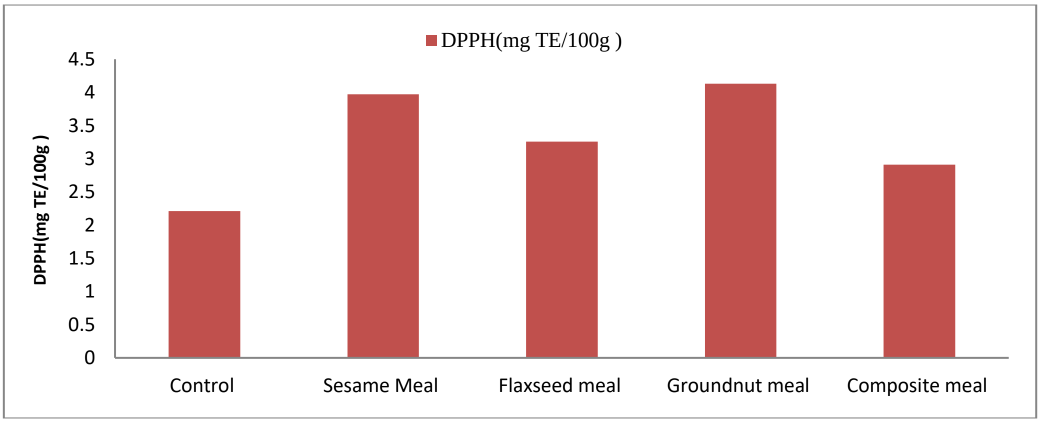
Values are mean of three independent determinations

Fig. 2. Antioxidant activity of *mathi* incorporated with sesame, flaxseed, and groundnut meal

Table 5. Proximate composition of oilseed meal based *sev* (%, on dry matter basis)

Types of *Sev*	Moisture*	Crude Protein	Crude Fat	Ash	Crude Fiber	Carbohydrate
Control	1.73±0.03	11.28±0.25	22.31±0.53	1.61±0.03	2.25±0.03	60.82±0.05
Sesame meal	1.64±0.04	16.85±0.27	26.26±0.57	3.08±0.07	3.59±0.08	51.42±0.25
Flaxseed meal	1.03±0.01	14.91±0.29	28.28±0.30	2.38±0.04	2.61±0.00	50.79±0.09
Groundnut meal	1.85±0.01	20.37±0.31	25.13±0.55	2.94±0.03	2.49±0.05	47.22±0.53
Composite meal	1.05±0.00	18.52±0.29	27.87±0.10	2.62±0.05	3.92±0.02	46.02±0.34
C.D.(P≤0.05)	0.08	0.92	1.44	0.15	0.16	0.20

Values are mean±SE of three independent determinations
** On fresh weight basis, SE=Standard error.*



Values are mean of three independent determinations

Fig. 3. Antioxidant activity of *sev* incorporated with sesame, flaxseed, and groundnut meal

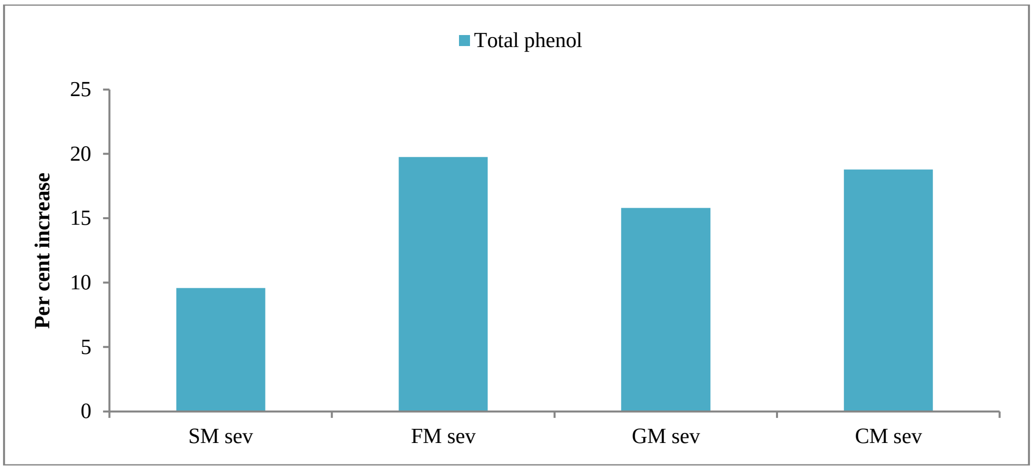


Fig. 4. Percent increase in total phenol content of oilseed meal-based *sev*as compared to control *sev*

Table 6. Total phenol content, phytic acid, and protein digestibility of oilseed meal-based *sev* (on dry matter basis)

Types of *Sev*	TPC (mg GAE/100g)	Phytic acid(mg/100gm)	Protein digestibility (%)
Control	350.03±0.36	257.00±0.01	56.84±0.91
Sesame meal	383.63±0.39	353.40±0.15	55.07±0.06
Flaxseed meal	419.23±0.82	298.20±0.39	55.43±0.43
Groundnut meal	405.38±0.27	270.20±0.23	55.47±0.98
Composite meal	415.77±0.65	321.60±0.01	54.41±0.07
C.D.(P≤0.05)	16.64	11.42	N/A

Values are mean±SE of three independent determinations
** On fresh weight basis; SE=Standard error.*

The organoleptic acceptability was assessed based on five attributes: color, appearance, aroma, texture, and taste at each storage interval.

- The mean overall acceptability values for *mathi* were found to be 8.84, 8.76, 8.62, 8.41, 8.00, 7.73, and 6.82 on the 0th, 15th, 30th, 45th, 60th, 75th, and 90th days of storage, respectively (Fig. 5). A significant difference (P≤0.05) was observed in the organoleptic attribute values from the first to the last day of storage. However, no significant interaction was noted between the types of *mathi* supplemented with different meals during storage.

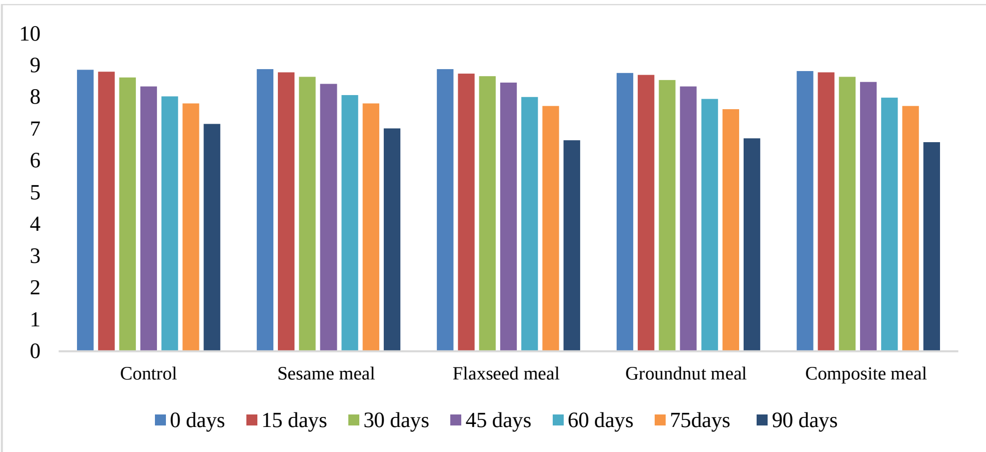


Fig. 5. Effect of storage on overall acceptability characteristic of oilseed meal based *mathi* (on dry matter basis)

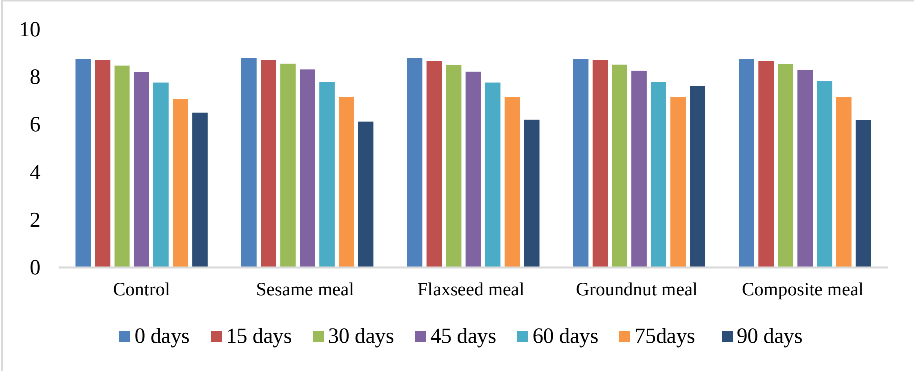


Fig. 6. Effect of storage on overall acceptability characteristic of oilseed meal based *sev* (on dry matter basis)

Table 7. Effect of storage period on fat acidity (mg KOH/100g) of developed oilseed meal-based m*athi*

Fat Acidity	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day	75^{th} day	90^{th} day
Control	25.50±0.70	44.00±0.08	78.50±0.15	104.00±0.82	131.50±0.12	134.00±1.10	169.50±0.70
Sesame meal	49.50±0.12	64.50±0.12	85.00±1.41	113.50±0.70	141.00±1.41	148.00±1.41	187.00±0.41
Flaxseed meal	58.90± 0.00	77.20±0.71	94.60±0.17	135.20±0.25	160.70±0.71	165.90±0.32	200.40±0.02
Groundnut meal	40.70±0.70	62.70±0.04	83.70±0.74	111.30±0.63	138.20±0.37	145.40±0.49	179.40±0.17
Composite meal	51.40±1.21	76.30±0.70	92.30±1.41	120.00±0.24	149.80±0.42	152.60±0.15	196.10±0.27
CD	Storage Period = 2.27, types of *mathi*=1.92, interaction between storage period × types of *mathi* =5.07						

Values are mean±SE of three independent determinations
** SE=Standard error.*

Table 8. Effect of storage period on fat acidity (mg KOH/100g) of developed oilseed meal-based *sev*

Fat Acidity	0^{th} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day	75^{th} day	90^{th} day
Control	33.50±0.19	39.00±1.41	40.90±0.12	96.00±0.48	102.50±0.12	128.50±0.28	164.00±0.82
Sesame meal	60.00±0.00	65.00±0.24	70.50±0.02	98.80±0.08	110.30±0.31	130.60±0.24	180.00±0.16
Flaxseed meal	75.00±0.00	80.00±0.00	89.00±0.41	112.50±0.48	120.90±0.81	148.70±0.05	197.90±0.04
Groundnut meal	61.50±0.12	71.00±0.41	79.00±0.41	103.00±1.41	112.40±1.41	136.00±0.58	182.5±0.12
Composite meal	69.00±0.41	72.00±0.82	80.50±0.12	108.00±0.04	119.70±0.62	141.00±0.64	187.80±0.09
CD	Storage Period = 2.05, types of *sev* =1.73, interaction between storage period × types of *sev* =4.59						

Values are mean±SE of three independent determinations
** SE=Standard error.*

- The mean overall acceptability scores for *sev* were 8.78, 8.72, 8.54, 8.28, 7.80, 7.16, and 6.54 on the 0th, 15th, 30th, 45th, 60th, 75th, and 90th days of storage, respectively (Fig. 6). A similar pattern was observed as with the other products. A significant difference (P≤0.05) was observed in the mean scores of organoleptic characteristics over time, along with a significant interaction between the types of *sev* during the 90-day storage period.

3.3.2 Fat acidity

Fat acidity is an indicator of biochemical changes during the shelf life of food products. It is calculated in terms of milligrams of potassium hydroxide required to neutralize free fatty acids formed during storage. The study evaluated fat acidity in *mathi* (a snack), and *sev* (a snack), supplemented with different oilseed meals over 90 days of storage.

In *mathi*, fat acidity ranged from 25.50 to 169.50 mg KOH/100g for control and 51.40 to 196.10 mg KOH/100g for composite meal on days 0 and 90, respectively (Table 7). Significant (P≤0.05) differences were noted between meal types and storage duration.

For *sev*, fat acidity values were 33.50 to 164.00 mg KOH/100g for control, 75.00 to 197.90 mg KOH/100g for flaxseed meal (highest), and 60.00 to 180.00 mg KOH/100g for sesame meal (lowest) on days 0 and 90, respectively (Table 8). Significant (P≤0.05) differences were observed during storage.

4. DISCUSSION

The nutritional evaluation of developed oilseed meal-based products revealed groundnut meal products exhibited the highest levels of protein, ash, and moisture content. Flaxseed meal products contained the highest crude fat content, while sesame meal products had the highest ash content. Flaxseed meal products demonstrated the lowest ash levels. Composite meal products were found to contain the highest crude fiber content. Findings of the present study were similar for nutritional analysis of peanut meal biscuits as reported by Yadav et al. (2012).

Antioxidant levels were comparable in sesame and flaxseed meal products, with groundnut meal products exhibiting the highest antioxidant content. Total phenol content ranged from 241.01 to 567.55 milligrams of gallic acid equivalents per 100 grams. Total phenol content was highest in flaxseed meal products because it contains SDG in higher amounts Toure et al. (2010).

Crude protein content in supplemented *mathi* had increased by 82.27 per cent, 74.86 per cent, 104.38 per cent, and 85.30 per cent, respectively in sesame, flaxseed, groundnut and composite meal *mathi*, over control. Per cent increase in crude fiber of supplemented *mathi* over control *mathi* ranged 7.14-70.47 per cent while the highest increase was observed in composite meal *mathi* and lowest in groundnut meal *mathi*. Crude fat content in supplemented *mathi* increased by 30.55 per cent, 66.25 per cent, 48.99 per cent, and 40.97 per cent, respectively in sesame, flaxseed, groundnut and composite meal *mathi*, over control. The percent increase in total phenol content of supplemented *mathi* over control was found between 13.54-28.57 per cent. Maximum increase of total phenol content was observed in flaxseed meal *mathi* while lowest in sesame meal *mathi* (Fig. 1).

The study revealed significant percent increases in protein, fat, ash, and crude fiber content across the developed products compared to the control. Flaxseed meal *mathi* had the highest fat increase (66.25%).

5. CONCLUSION

The products derived from oilseed meals are nutrient-dense, containing abundant amounts of protein, fat, ash, crude fiber, and total phenolic compounds. The results show that cheap and underutilized oilseed meals can be used to make a variety of food items that people can eat. Through their popularization and dissemination, the produced value-added goods can be used to successfully address malnutrition and improve the nutritional status of communities. Additionally, by promoting these items, oilseed meals—which are typically thrown away—will be used. Supplements to foods consumed as part of a daily diet can include groundnut meal, flaxseed meal, sesame meal, and composite meals made out of several meals. Future prospects for creating new product variations from these meals and investigating the use of other accessible oilseed meals for value addition are also shown by this study.

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 the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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