



Unexplored Nutritional Potential of Oilseed Meals to Combat Malnutrition

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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: Malnutrition persists as a formidable global health challenge, particularly in developing regions. Oilseed meals, often regarded as agro-industrial byproducts, possess remarkable nutritional potential that remains largely untapped. This study explores the unexplored nutritive value of sesame, groundnut, and flaxseed meals and their role in addressing malnutrition.

Aim: The study aimed to assess the nutritional composition, sensory acceptability, and potential contribution of oilseed meal-based products to addressing malnutrition.

Methodology: A comprehensive nutritional evaluation was undertaken to analyze the proximate composition and bioactive components present in sesame, groundnut, and flaxseed meals. Functional food products were formulated utilizing these nutrient-dense ingredients and subjected to sensory analysis to determine consumer acceptability. The most well-received products were further assessed for their nutritional profile to validate their functional food status.

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Results: The analysis revealed that oilseed meals are rich sources of protein, fiber, and fats. Sensory evaluation indicated high acceptability scores for the formulated products, demonstrating their potential for incorporation into diets.

Conclusion: Oilseed meals exhibit substantial nutritional benefits and sensory acceptance, making them viable options for combating malnutrition. Their incorporation into daily diets can enhance nutrient intake in vulnerable populations. The study highlights the need for further research and policy interventions to promote the utilization of oilseed meals in food systems.

Keywords: Flaxseed meal; groundnut meal; sesame meal; malnutrition; nutritional potential.

1. INTRODUCTION

The Global Hunger Index. (2023) has revealed a concerning data for India, ranking 111th out of 125 countries. This disheartening statistic underscores India's persistent challenges in combating hunger and malnutrition within its borders. Malnutrition, encompassing undernutrition, micronutrient deficiencies, and overnutrition, remains a global challenge affecting billions of individuals. Despite advancements in food security, protein-energy malnutrition and micronutrient deficiencies are pressing concerns.

Ironically, India is the world's largest producer of oilseed meals, generating an impressive 41 million metric tons in 2023 alone (Infomerics Valuation and Rating Pvt. Ltd. 2024). The process of oil extraction from oilseeds results in the production of substantial byproducts, constituting over half of the initial material. While traditionally utilized as animal feed, these meals possess the potential to address human malnutrition if appropriately processed and incorporated into dietary regimens. These oilseed meals are rich in valuable nutrients such as proteins, fats, fibers, vitamins, and minerals, offering a significant potential resource for addressing nutritional deficiencies (Karnika and Kawatra, 2024). However, this abundant source of nourishment remains largely untapped, representing a missed opportunity to alleviate hunger and malnutrition within the nation's population.

Peanut, scientifically known as *Arachis hypogaea*, is a leguminous crop primarily cultivated for its edible seeds. Due to its high oil content, it is classified as both a grain and legume, as well as an oil crop (Dwivedi et al. 2011). Peanut flour, obtained after dehulling and grinding, contains 49.97% crude protein, 2.80% crude fiber, 3.50% ash, and 27.54% fat (Park et al. 2017).

Flaxseed (*Linum usitatissimum*), also known as linseed, is a flowering plant belonging to the *Linaceae* family. After the oil extraction process, flaxseed meal is obtained, which is protein-rich and can be utilized in various ways for human consumption. This meal is rich in vitamin B6 and contains fiber ranging from 2-7%. Vitamin B6 is an essential nutrient that the body uses as a coenzyme in hundreds of enzymatic reactions within the human body (Heuze et al. 2017).

Sesame (*Sesamum indicum*) is a flowering plant in the genus *Sesamum*, also known as *benne* (Merriam-Webster.com 2021). Sesame oil meal is a protein-rich by-product. Expeller sesame meal has a protein content of approximately 45%, ranging from 32% to 53%, whereas solvent-extracted sesame meal contains about 48% protein (Karnika and Kawatra, 2024).

The quantity of macro and micronutrients present in a meal is contingent upon the method of oil extraction, whether it is cold-pressed, hot-pressed, or solvent-extracted. Cold-pressed oilseed meals typically retain the highest concentration of nutrients (Tzia et al. 2003). In the current investigation, we procured meals from the local market due to their ready availability.

Recognizing the nutritional potential of selected oilseed meals, which are often discarded as waste, this investigation aimed to develop nutrient-dense cakes and cookies that can be easily prepared and popularized among all age groups. The value-added products can be incorporated into daily diets, potentially improving the nutritional status of communities and contributing to the eradication of malnutrition.

2. MATERIALS AND METHODS

2.1 Procurement of Material

Groundnut meal (GM), sesame meal (SM), flaxseed meal (FM) and other materials needed

for product preparation and packaging were procured from local markets in Hisar, Haryana to produce value-added products. Foreign materials were removed from the oilseed meals and 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 mixing equal proportions of the three oilseed meals (peanut, sesame, and flaxseed), which was then used at similar incorporation levels (12%, 18%, and 24%) in the following products:

- **Baked products:** Cookies and Cake.

The recipes for all the developed value-added products are outlined below.

- **Cookies recipe:** A predetermined amount of all-purpose flour and oilseed meal flour were combined and sifted. Bakery shortening and sugar were creamed until light and fluffy. Baking soda, baking powder, and milk were added, and the mixture was creamed again. The flour mixture was then incorporated into the wet ingredients to form a dough. Small balls were formed from the dough and rolled in crushed cornflakes. These were placed on baking trays, slightly pressed down, and baked at 160°C (320°F) until golden brown.
- **Cake recipe:** A predetermined amount of all-purpose flour and oilseed meal flour were sifted together. Condensed milk, vegetable oil, and vanilla extract were whisked together in a separate bowl. Baking soda and baking powder were added to the dry flour mixture. The dry ingredients were then gradually added to the wet ingredients and mixed until well combined. Water was added as needed to achieve the desired batter consistency. The batter was poured into greased cake pans and baked at 180°C (350°F) until a toothpick inserted in the center came out clean.

2.3 Organoleptic Evaluation

The development of products involved utilizing each meal at three distinct levels of supplementation. The control group was prepared without any supplementation, while the

T1 and C1 groups received 12% supplementation, the T2 and C2 groups received 18% supplementation, and the T3 and C3 groups received 24% supplementation. Various other ingredients were incorporated into the product development process. The developed products encompassed cookies and cakes. 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 rating of developed products was conveyed 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 considered 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-Kjeldhal apparatus determined the nitrogen concentration, which was converted to crude protein by multiplying by 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. Acid and alkali resistance analyzed crude fiber.

2.5 Antioxidant Activity

Total phenolic content (TPC) was measured spectrophotometrically using the Folin-Ciocalteu reagent as described by Singleton and Rossi, (1965). 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 Na₂CO₃. Instead of extract, 0.1 ml water was used to prepare the blank. The mixture was heated in a water bath at 50°C for 5 min 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 given 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 built up to 1 ml. It was then filled with 3 ml of DPPH reagent and properly mixed before being incubated at 37°C for 20 min. 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

Cookies were prepared with a 24 percent incorporation level of different oilseed meals. This product was subsequently stored in airtight containers at room temperature for three months spanning from December 2020 to February 2021. At regular intervals of 15 days, the products underwent evaluation for their organoleptic evaluation and fat acidity parameters.

2.7.1 Organoleptic evaluation

Stored products (cookies) 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 an indicator of biochemical changes during the shelf life of products. It is quantified by determining the amount of potassium hydroxide required to neutralize the free fatty acids present in the food product during storage. At every 15-day interval, fat acidity was assessed using the standard method of analysis (AOAC, 2000) for up to 90 days.

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 \pm 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 conducted on groundnut meal (GM), sesame meal (SM), flaxseed meal (FM), and a composite meal (CM). The moisture content ranged from 0.33% to 1.73%. GM exhibited the highest protein content at 40.12%, followed by CM (38.06%), SM (37.16%), and FM (36.71%).

Comparison of protein and moisture of all the selected oilseed meals indicated that it was significantly ($P \leq 0.05$) high in groundnut meal. FM contained the highest crude fat level (32.03%), trailed by CM (19.01%), SM (13.54%), and GM (10.95%). SM had the highest ash content (8.72%), followed by GM (7.46%), CM (6.64%), and FM (3.10%). The crude fiber content was highest 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 pronounced 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 exhibited the highest total phenol content (1070.6mg GAE/100g), trailed 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%), followed by FM (79.09%), SM (78.50%), and CM (75.11%) (Table 1). 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

Table 1. Proximate composition of sesame, flaxseed, and groundnut meal (% , on dry matter basis)

Oilseed meals	Moisture	Crude Protein	Crude Fat	Ash	Crude Fiber	TPC (mg GAE/100g)	Phytic acid(mg/100gm)	Protein digestibility (%)
Sesame Meal (SM)	1.6±0.01	37.16±0.14	13.54±0.15	8.72±0.17	7.55±0.01	583.64±0.34	314±0.16	78.5±0.28
Flaxseed meal (FM)	0.33±0.01	36.71±0.28	32.03±0.26	3.10±0.00	6.43±0.03	1070.6±0.19	285.80±0.15	79.09±0.22
Groundnut meal (GM)	1.73±0.11	40.12±0.40	10.95±0.04	7.46±0.07	5.66±0.14	693.44±0.20	276.60±0.14	81.09±0.08
Composite meal (CM)	1.23±0.07	38.06±0.40	19.01±0.11	6.64±0.08	9.58±0.20	711.45±0.33	304.79±7.69	75.11±0.4
C.D. (P≤0.05)	0.24	1.08	0.55	0.34	0.42	0.97	12.74±0	0.9±0

Values are mean±SE of three independent determinations.

* SE=Standard error

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

Types of cookies		Color	Appearance	Aroma	Texture	Taste	Overall acceptability
Control	Control	8.70±0.21	8.80±0.11	8.75±0.43	8.53±0.08	8.60±0.26	8.68±0.11
Sesame meal	T1	8.40±0.13	8.60±0.04	8.23±0.29	8.29±0.06	7.96±0.27	8.30±0.09
	T2	8.33±0.08	8.60±0.12	8.09±0.14	8.16±0.07	7.92±0.27	8.22±0.11
	T3	8.33±0.23	8.50±0.03	7.87±0.19	8.02±0.15	8.04±0.35	8.15±0.13
	T3	8.39±0.01	8.70±0.16	8.41±0.19	8.40±0.06	7.95±0.27	8.37±0.08
Flaxseed meal	T1	8.39±0.01	8.70±0.16	8.41±0.19	8.40±0.06	7.95±0.27	8.37±0.08
	T2	8.30±0.07	8.50±0.22	8.21±0.14	8.24±0.01	8.22±0.34	8.29±0.06
	T3	8.20±0.26	8.50±0.04	8.01±0.16	8.07±0.03	8.12±0.27	8.18±0.1
	T3	8.20±0.26	8.50±0.04	8.01±0.16	8.07±0.03	8.12±0.27	8.18±0.1
Groundnut meal	T1	8.30±0.04	8.60±0.12	8.27±0.03	8.28±0.01	7.99±0.23	8.29±0.1
	T2	8.23±0.03	8.40±0.13	7.92±0.09	8.05±0.1	7.96±0.31	8.11±0.08
	T3	8.10±0.19	8.00±0.15	8.03±0.18	8.02±0.02	7.95±0.26	8.02±0.05
	T3	8.10±0.19	8.00±0.15	8.03±0.18	8.02±0.02	7.95±0.26	8.02±0.05
Composite meal	C1	8.70±0.03	8.50±0.15	8.70±0.03	8.70±0.0	8.59±0.07	8.64±0.04
	C2	8.60±0.19	8.20±0.20	8.60±0.16	8.60±0.01	8.32±0.17	8.46±0.12
	C3	8.52±0.22	8.00±0.0	8.50±0.22	8.51±0.0	8.22±0.05	8.35±0.09
	C3	8.52±0.22	8.00±0.0	8.50±0.22	8.51±0.0	8.22±0.05	8.35±0.09
C.D.≤0.05		N/A	0.38	N/A	0.19	N/A	N/A

Values are mean of thirty panelists scores

Control- without any oilseed meal incorporation (T1, T2 and T3 are 12%, 18%, and 24%).

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 meals incorporation: 12%, 18%, and 24%. Products prepared without oil meal incorporation using a standard recipe were considered controls.

3.1.1 Cookies

All the oilseed meal-based cookies were organoleptically acceptable. The taste, texture, appearance, and overall acceptability of all the cookies ranged from 'liked moderately' to 'liked very much' category (Table 2). Mean scores of cookies based on sesame meal, flaxseed, groundnut & composite meal showed very slight variation in the acceptability scores and were found at par statistically ($P \leq 0.05$).

3.1.2 Cake

Oilseed meal-based cakes were prepared with varying levels of sesame, flaxseed, and

groundnut meals, along with a control cake without any meal incorporation. All cakes were found organoleptically acceptable by the panelists (Fig. 1).

The control cake scored highly for color (8.80), appearance (8.70), aroma (8.71), texture (8.04), taste (8.40), and overall acceptability (8.56). Sesame meal cakes (12-24%) scored 8.10-8.65 for appearance, 8.40-8.57 for aroma, 7.66-7.87 for texture, 8.12-8.20 for taste, and 8.28-8.34 for overall acceptability.

Flaxseed meal cakes (12-24%) scored 8.42-8.50 for color, 8.20-8.60 for appearance, 8.00-8.48 for aroma, 8.32-8.36 for texture, 8.14-8.33 for taste, and 8.23-8.47 for overall acceptability.

Groundnut meal cakes (12-24%) scored 8.50-8.60 for color, 8.10-8.30 for appearance, 8.42-8.61 for aroma, 7.90-8.32 for texture, 7.93-8.27 for taste, and 8.21-8.30 for overall acceptability.

A composite meal was prepared by mixing equal amounts of sesame meal, flaxseed meal, and groundnut meal. This mixture was incorporated into cakes at 12%, 18%, and 24% levels. The mean acceptability scores for color, appearance, aroma, texture, taste, and overall acceptability were evaluated. For the 12% cake (C1), the scores were 8.50, 8.70, 8.40, 7.78, 8.27, and 8.22 respectively. The 18% cake (C2) scored 8.20, 8.60, 8.39, 7.67, 8.16, and 8.27. The 24% cake (C3) received scores of 8.15, 8.50, 8.38, 7.56, 8.09, and 8.35.

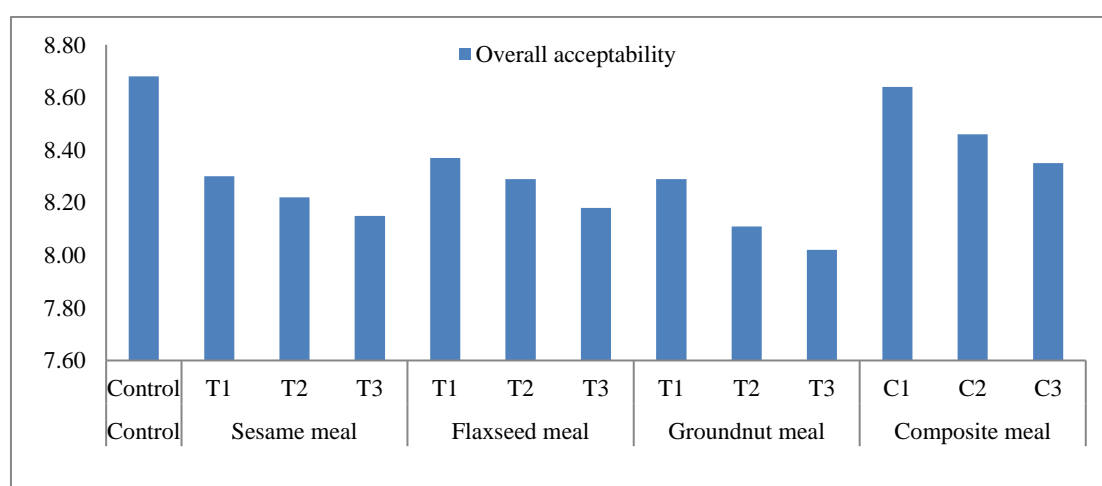


Fig. 1. Overall acceptability of cookies incorporating sesame, flaxseed, groundnut and composite meal (Mean scores)

Values are mean of ten panelist's

Control- without any oilseed meal incorporation (T1&C1, T2&C2 and T3&C3 are 12%, 18%, and 24%, respectively).

3.2 Nutritional Composition of Developed Oilseed Meal-based Products

3.2.1 Cookies

Cookies were prepared by substituting 24% of each oilseed meal. The proximate composition revealed moisture content ranging from 1.52-2.11%. Crude protein was highest in groundnut meal cookies (15.58%) and lowest in control (9.17%). Crude fat ranged from 22.32% (control) to 29.92% (flaxseed). Ash content was 1.98-2.98%, and crude fiber varied from 2.75-3.81% (Table 3).

Antioxidant activity, measured by DPPH radical scavenging, ranged from 3.23-4.31 mg TE/100g

for supplemented cookies, significantly higher than control (2.49 mg TE/100g). Total phenol content was highest in flaxseed meal cookies (408.92 mg GAE/100g) and lowest in control (305.24 mg GAE/100g) (Fig. 3).

Phytic acid content ranged from 245.80 mg/100g (control) to 338.80 mg/100g (sesame meal). In-vitro protein digestibility was 65.09-68.13% across cookies types, with no significant difference (Table 4).

The in-vitro protein digestibility of various meal cookies, including sesame, control, flaxseed, groundnut, and composite, ranged from 65.09% to 68.13%. No significant difference ($P \leq 0.05$) was observed among the cookie types (Table 4).

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

Types of cookies	Moisture*	Crude Protein	Crude Fat	Ash	Crude Fiber	Carbohydrate
Control	2.10±0.03	9.17±0.05	22.32±0.55	1.98±0.00	2.75±0.04	61.68±0.32
Sesame meal	1.69±0.00	12.67±0.15	25.48±0.17	2.98±0.02	3.69±0.09	53.49±0.08
Flaxseed meal	1.52±0.00	10.01±0.20	29.92±0.60	2.28±0.01	3.26±0.06	53.01±0.50
Groundnut meal	2.79±0.05	15.58±0.07	24.91±0.50	2.78±0.06	3.06±0.02	50.88±0.09
Composite meal	1.57±0.03	13.61±0.14	27.91±0.37	2.56±0.05	3.81±0.06	49.46±0.30
C.D. ($P \leq 0.05$)	0.09	0.44	1.50	0.12	0.20	0.48

Values are mean±SE of three independent determinations

* On fresh weight basis; SE=Standard error

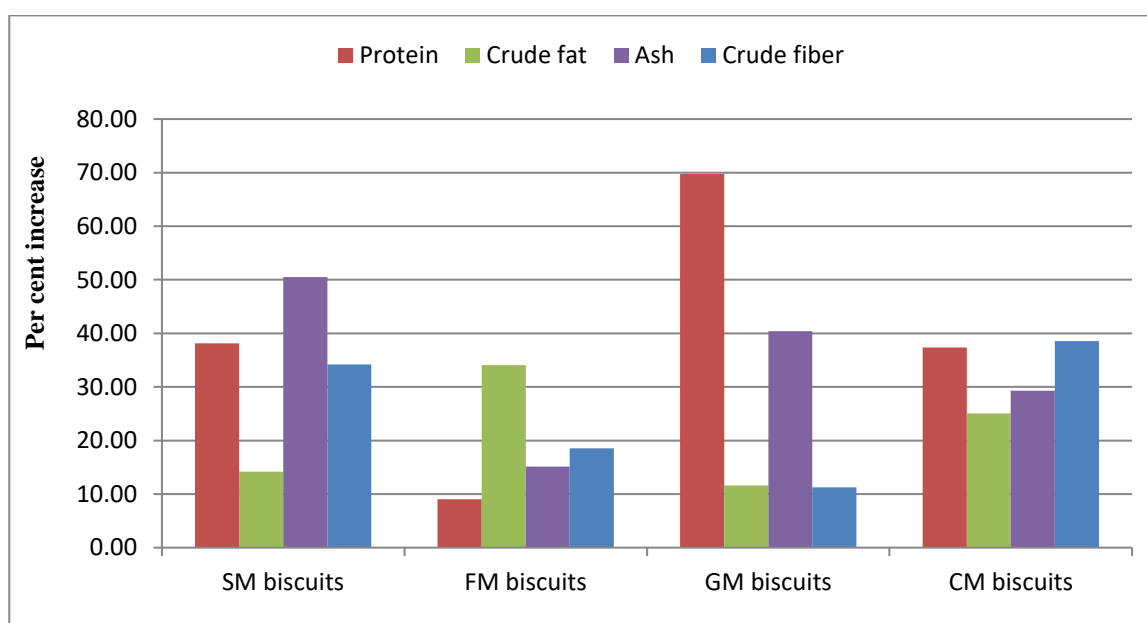


Fig. 2. Percent increase in protein, crude fat, ash, and crude fiber content of oilseed meal-based cookies (biscuits) as compared to control

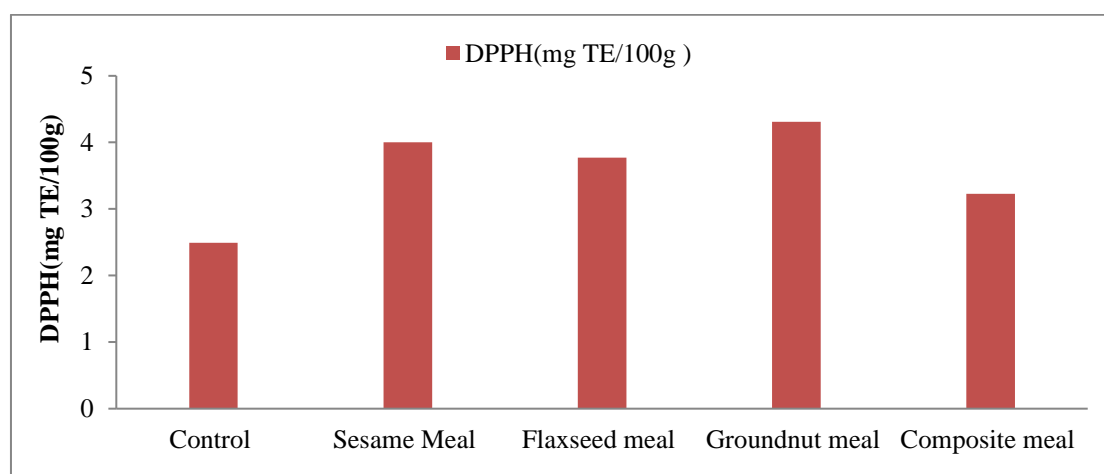


Fig. 3. Antioxidant activity of cookies incorporated with sesame, groundnut, and flaxseed meal

Values are mean \pm SE of three independent determinations

* SE=Standard error.

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

Types of cookies	TPC (mg GAE/100g)	Phytic acid(mg/100gm)	Protein digestibility (%)
Sesame meal	320.35 \pm 0.66	338.80 \pm 0.58	67.64 \pm 0.74
Flaxseed meal	408.92 \pm 0.51	286.81 \pm 0.01	67.81 \pm 0.35
Groundnut meal	362.85 \pm 0.26	275.20 \pm 0.72	67.95 \pm 0.56
Composite meal	398.95 \pm 0.68	313.63 \pm 0.38	65.09 \pm 1.35
C.D. ($P \leq 0.05$)	16.73	16.66	N/A

Values are mean \pm SE of three independent determinations

* On fresh weight basis; SE=Standard error.

3.2.2 Cake

Cakes were prepared incorporating 24% of each oilseed meal (sesame, flaxseed, groundnut, and composite) and a control cake without additions. The supplemented cakes had higher moisture (15.68-17.70%), crude fat (25.64-30.13%), crude protein (14.48-18.89%), ash (3.06-4.86%), and crude fiber (3.24-5.01%) content compared to the control (moisture 15.68%, fat 18.84%, protein 10.50%, ash 2.10%, fiber 3.24%) (Table 5).

Antioxidant activity and total phenol content were also higher in the supplemented cakes (Fig. 4). Total phenol content was determined in terms of gallic acid equivalent. Total phenol content was highest in flaxseed meal-based cake, i.e. 567.55mg GAE/100g and lowest in sesame meal cake, i.e. 300.02mg GAE/100g among oilseed meal-based cake, whereas significantly C.D. ($P \leq 0.05$) low content was found in control cake, i.e. 271.02mg GAE/100g. Phytic acid content ranged from 221.40 mg/100g (control) to 312.00 mg/100g (sesame meal cake). In-vitro protein

digestibility was lower in the supplemented cakes (72.30-80.21%) compared to the control (81.33%) (Table 6).

3.2.3 Shelf-life study of most acceptable developed products

The developed cookies selected for nutritional analysis underwent a shelf-life study. These products were stored in airtight containers at room temperature for a period of 90 days, spanning from December 2020 to February 2021. At 15-day intervals, the stored food products were evaluated for organoleptic properties and fat acidity to assess their quality over time.

3.2.4 Organoleptic evaluation

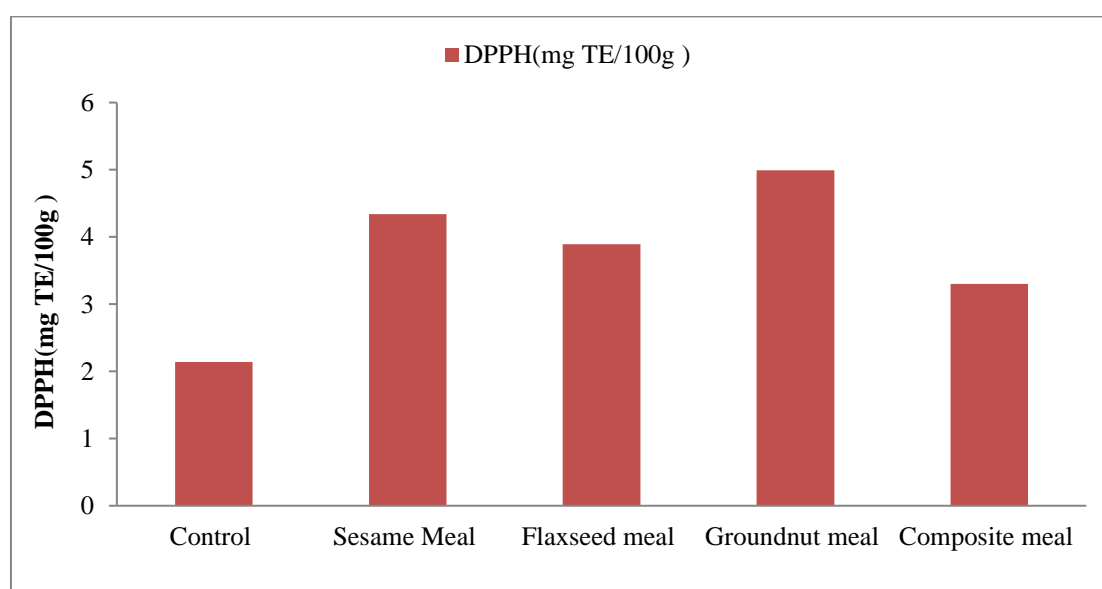
Organoleptic evaluation was done by 10 semi-trained panelists using nine-point hedonic rate scale on 0th day, 15th day, 30th day, 45th day, 60th day, 75th day, and 90th day of storage. The results obtained for organoleptic acceptability at various study are as under.

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

Types of Cake	Moisture*	Crude Protein	Crude Fat	Ash	Crude Fiber	Carbohydrate
Control	16.52±0.27	10.50±0.20	18.84±0.05	2.10±0.03	2.85±0.05	49.19±0.27
Sesame meal	17.26±0.27	15.58±0.01	28.11±0.48	4.86±0.10	4.95±0.08	29.24±0.06
Flaxseed meal	15.68±0.04	14.48±0.12	30.13±0.01	3.06±0.06	3.37±0.03	33.28±0.35
Groundnut meal	17.70±0.18	18.89±0.39	25.64±0.30	4.05±0.05	3.24±0.02	30.48±0.42
Composite meal	16.23±0.36	17.19±0.09	29.03±0.70	3.98±0.05	5.01±0.10	28.56±0.09
C.D. (P≤0.05)	0.8	0.67	1.30	0.21	0.21	0.67

Values are mean±SE of three independent determinations

* On fresh weight basis; SE=Standard error.

**Fig. 4. Antioxidant activity of cake incorporated with sesame, flaxseed, and groundnut meal**

Values are mean of three independent determinations

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

Types of Cake	TPC (mg GAE/100g)	Phytic acid (mg/100gm)	Protein digestibility (%)
Control	271.02±0.16	221.40±0.22	81.33±0.22
Sesame meal	355.76±0.34	312.00±0.19	75.57±0.33
Flaxseed meal	567.55±0.16	272.80±0.68	78.46±0.99
Groundnut meal	367.30±0.35	265.80±0.38	80.21±0.41
Composite meal	407.69±0.07	282.20±0.05	72.30±0.27
C.D. (P≤0.05)	0.77	15.03	4.30

Values are mean±SE of three independent determinations

* On fresh weight basis; SE=Standard error.

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

The mean overall acceptability scores for various cookies were 8.58, 8.36, 7.98, 7.65, 7.23, 6.83, and 6.47 on days 0, 15, 30, 45, 60, 75, and 90 of storage, respectively. No significant (P≤0.05)

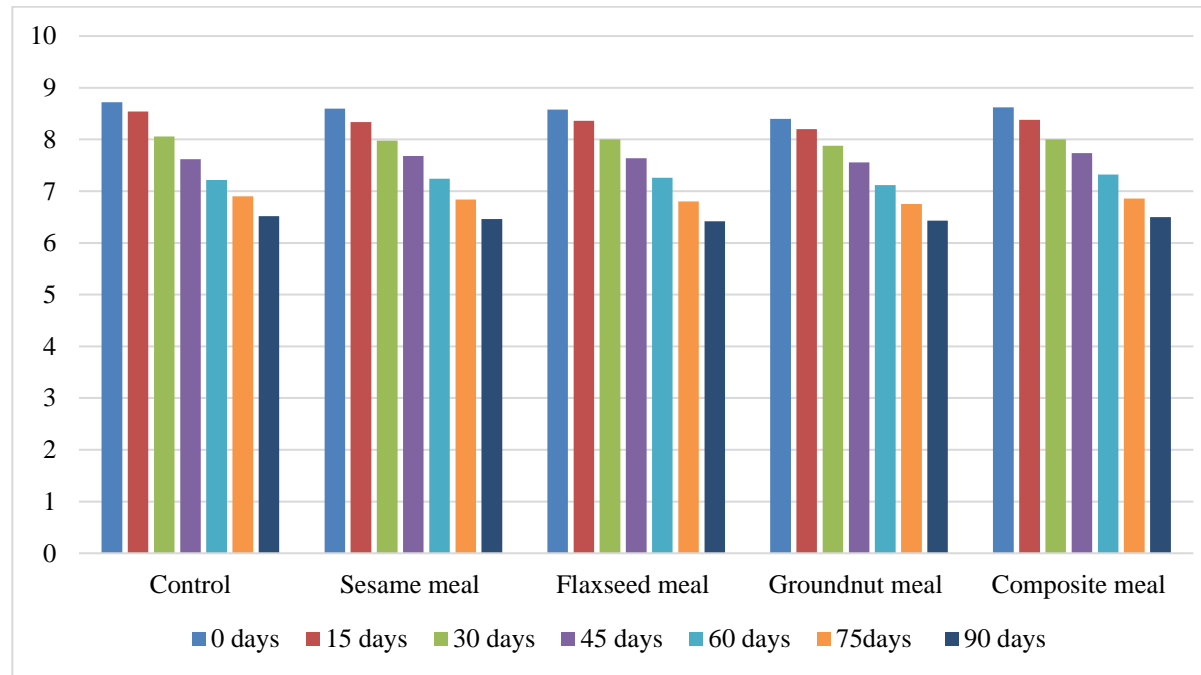


Fig. 5. Effect of storage on overall acceptability characteristic of oilseed meal-based cookies (on dry matter basis)

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

Fat Acidity	0 th day	15 th day	30 th day	45 th day	60 th day	75 th day	90 th day
Control	8.00± 0.80	43.50±0.12	63.50±1.12	92.00± 0.71	120.50±0.70	169.00±0.16	213.50±0.12
Sesame meal	26.50±0.80	49.00±1.41	76.50±0.21	108.50±0.35	127.00±0.82	200.90±0.23	264.00±0.82
Flaxseed meal	30.00± 0.00	55.50±0.12	79.50±0.70	112.80±0.50	159.80±0.22	230.00±0.19	310.50±0.07
Groundnut meal	30.00± 0.00	50.00±1.41	61.00±1.41	95.40±0.70	134.00±0.12	210.00±0.17	258.30±0.18
Composite meal	29.00±0.41	49.50±0.70	69.50±0.24	109.60±0.12	143.00±0.16	219.00±0.13	280.70±0.51
CD	Storage Period = 2.64, types of cookies=2.23, interaction between storage period × types of cookies=5.90						

Values are mean±SE of three independent determinations

** SE=Standard error.*

interaction was found among the various cookie formulations supplemented with different meals and the storage period (Fig. 5).

3.2.5 Fat acidity

Fat acidity is an indicator of biochemical changes during food products' shelf life. 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 cookies supplemented with different oilseed meals over 90 days of storage.

For cookies, fat acidity values ranged from 8.00 to 213.50 mg KOH/100g for control and 29.00 to 310.50 mg KOH/100g for composite meal on days 0 and 90, respectively (Table 7). Significant differences were observed between meal types and storage duration.

4. DISCUSSION

4.1 Cookies

The analysis of nutritional composition revealed that the moisture content of control, sesame meal, flaxseed meal, groundnut meal, and composite meal cookies was low, ranging from 1.52 to 2.79 percent. The groundnut meal cookies exhibited the highest crude protein content (18.89 percent), significantly higher ($P \leq 0.05$) than cookies developed from other meals (Fig. 2). This high protein content in the groundnut meal cookies might be attributed to the substantial amount of protein present in the groundnut meal used for its development. Similarly, the considerable protein content in sesame and flaxseed meals contributed to protein levels of 12.67 percent and 10.01 percent, respectively, in the developed cookies, exceeding the control. The control cookies contained 9.17 percent crude protein, while the supplementation of oilseed meals in the controlled recipe increased the protein content by 69.72 percent in the groundnut meal cookies, followed by 38.13 percent in the sesame meal cookies, and 37.36 percent in the composite meal cookies. The lowest percentage increase in crude protein (9.04 percent) was observed in the flaxseed meal cookies compared to the control cookies. The crude fat content was highest in the flaxseed meal cookies due to the cold-press extraction method used to obtain the flaxseed meal. The flaxseed meal cookies exhibited a significantly ($P \leq 0.05$) higher fat value (30.13 percent) among all types of meal-based cookies.

The highest percentage increase in fat content was observed in the flaxseed meal cookies (34.05 percent), followed by the composite meal cookies (25.04 percent), sesame meal cookies (14.16 percent), and groundnut meal cookies (11.60 percent). The present study revealed that the ash content of all the developed cookies was significantly ($P \leq 0.05$) different. The percentage increase in ash content of oilseed meal-based cookies over the control cookies ranged from 15.15 to 50.50 percent, with the highest increase observed in the sesame meal cookies and the lowest in the flaxseed meal cookies. Crude fiber increased by 11.27 to 38.54 percent in the supplemented cookies compared to the control cookies, which contained 2.75 percent. The highest percentage increase in crude fiber was observed for the composite meal cookies, and the lowest for the groundnut meal cookies. The findings of the present study were similar to the nutritional analysis of peanut meal cookies reported by Yadav et al. (2012). The antioxidant activity was found to be highest in the groundnut meal cookies compared to other cookies. The total phenol content was highest in the flaxseed meal cookies due to the higher amounts of SDG it contains, as reported by Toure et al. (2010). The control cookies had an antioxidant activity of 2.49 mg TE/100g and a total phenol content of 305.24 mg GAE/100g. A significant ($P \leq 0.05$) increase in total phenol content was observed with the supplementation of oilseed meals. The percentage increase in total phenol content of oilseed meal cookies compared to the control cookies was 33.97 percent for the flaxseed meal cookies, 30.70 percent for the composite meal cookies, 18.87 percent for the groundnut meal cookies, and 4.95 percent for the sesame meal cookies. The phytic acid content of cookies increased significantly ($P \leq 0.05$) with the incorporation of oilseed meals and ranged between 275.2 and 338.8 mg/100g. Statistically, no significant ($P \leq 0.05$) difference was found in the protein digestibility of cookies supplemented with different oilseed meals, with values ranging from 65.09 to 68.13 percent.

4.2 Cake

The results of the proximate composition analysis revealed significant variations ($P \leq 0.05$) in moisture content among all types of cakes incorporated with a 24 percent level, ranging from 15.68 to 17.70 percent. Among the developed cakes from selected oilseed meals, the groundnut meal cake exhibited the highest crude protein content (18.89 percent), likely due

to the high protein content (40.12 percent) present in groundnut meal. The crude protein content differed significantly ($P \leq 0.05$) among all the oilseed meal-based cakes, lying between 10.50 and 18.89g/100g. Compared to the control, the crude protein content increased by 48.38 percent, 38.00 percent, 79.90 percent, and 63.71 percent in the sesame, flaxseed, groundnut, and composite meal cakes, respectively. The data analysis revealed that the crude fat and ash content were significantly ($P \leq 0.05$) different among all types of cakes. The control cake had an ash content of 2.10 percent, while after supplementation with oilseed meals, the ash content increased by 131.42 percent in the sesame meal cake, 92.85 percent in the groundnut meal cake, 89.52 percent in the composite meal cake, and 45.71 percent in the flaxseed meal cake. The crude fiber content of all the developed cakes was significantly ($P \leq 0.05$) different, except for the flaxseed meal cake and sesame meal cake, which had similar crude fiber content. The percent increase in crude fiber of the supplemented cakes over the control cake ranged from 13.68 to 75.78 percent, with the highest increase observed in the composite meal cake and the lowest in the groundnut meal cake. The results obtained for crude fat and fiber of the developed oilseed meal cakes were almost similar to those observed by Chetana et al. (2010) in muffins supplemented with up to 40 percent flaxseed. However, the values for protein and ash were lower.

The groundnut meal-based cake exhibited significantly ($P \leq 0.05$) higher antioxidant activity compared to cakes prepared from other meals. The percent increase in total phenol content of the supplemented cakes over the control ranged from 35.52 to 109.41 percent, with the maximum increase observed in the flaxseed meal cake and the lowest in the sesame meal cake. A significant ($P \leq 0.05$) difference was observed in the in-vitro protein digestibility of the developed cakes, ranging from 72.30 to 81.33 percent. The phytic acid content was almost similar among the flaxseed meal, groundnut meal, and composite meal cakes, whereas the highest content was observed in the sesame meal cake.

The groundnut meal-based products were rich in crude protein, with 4-5 cookies meeting 17-20% of the RDA for preschoolers, and 2-3 cake pieces provided 20-30% of the RDA. Flaxseed meal cake had the highest total phenol content, while the control cake had the lowest. The phytic acid

content ranged from 183.00-353.40mg/100g across the developed products.

The experiment was planned due to lack of literature available for traditional food products based on oilseed meals and the results obtained for organoleptic acceptability were highly acceptable.

5. CONCLUSION

The present study demonstrates that products derived from oilseed meals are nutrient-dense, containing ample amounts of protein, fat, ash, crude fiber, and total phenolic compounds. The findings indicate the potential use of inexpensive and underutilized oilseed meals in the preparation of various food products for human consumption. The developed value-added products can be effectively utilized as a means of improving the nutritional status of communities by popularizing and disseminating them to combat malnutrition. Promoting these products will also contribute to the utilization of oilseed meals, which are generally discarded. Sesame meal, flaxseed meal, groundnut meal, and composite meals consisting of different meals can be used as supplements to foods consumed as part of a daily diet. Furthermore, this study provides future opportunities to develop additional varieties of products from these meals and explore the utilization of other available oilseed meals for value addition.

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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