**Original Research Article**

**Unexplored Nutritional Potential of Oilseed Meals to Combat Malnutrition**

**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.

Result: 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. The formulated products contributed significantly to the RDA of key nutrients required for growth and development in children.

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:** *Oilseed meals, Malnutrition, Nutritional potential, RDA contribution*.

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.

1. **Materials and Methods**
   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.

* 1. **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.
  1. **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.

* 1. **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.

* 1. **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). 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.

* 1. **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).

* 1. **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.

* + 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.

* + 1. **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.

* 1. **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).

1. **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%).

## 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

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%). 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).

* 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.

* + 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).

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Types of biscuit** | | **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 |
| **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 |
| **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 |
| **Composite meal** | **C1** | 8.70±0.03 | 8.50±0.15 | 8.70±0.03 | 8.70±00 | 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±00 | 8.50±0.22 | 8.51±00 | 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%).

* + 1. **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.

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%, respectivelly).

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

* 1. **Nutritional composition of developed oilseed meal-based products** 
     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).

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Types of biscuits** | **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≤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 as compared to control**

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≤0.05) was observed among the cookie types (Table 4).

Values are mean±SEof three independent determinations

\* SE=Standard error.

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

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

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

Values are mean±SE of three independent determinations

\* On fresh weight basis; SE=Standard error.

* + 1. **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≤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).

**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.

Values are mean of three independent determinations

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

**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 |

Values are mean±SE of three independent determinations

\* On fresh weight basis; SE=Standard error.

* 1. **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.

* + 1. **Organoleptic evaluation**

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

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

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

* + 1. **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.

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Fat Acidity** | **0th day** | **15th day** | **30th day** | **45th day** | **60th day** | **75th day** | **90th 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 biscuit =2.23, interaction between storage period × types of biscuit =5.90 | | | | | | |

Values are mean±SE of three independent determinations

\* SE=Standard error.

1. **Discussion**

The nutritional evaluation of developed oilseed meal-based products revealed groundnut meal products had the highest protein, ash, and moisture content, while flaxseed meal products had the highest crude fat content. Sesame meal products had the highest ash content, and flaxseed meal products had the lowest. Findings of the present study were similar for nutritional analysis of peanut meal biscuits as reported by Yadav *et al.* (2012). Composite meal products contained the highest crude fiber. Antioxidant content was similar in sesame and flaxseed meal products, with groundnut meal products containing the highest amount. Antioxidant activity was found to be highest in groundnut meal biscuits as compared to other biscuits. Total phenol content was highest in flaxseed meal biscuits because it contains SDG in higher amounts Toure *et* al. (2010). Total phenol content ranged from 241.01-567.55mg GAE/100gm, with flaxseed meal cake having the highest. % increase in total phenol content of oilseed meal in comparison of control biscuits was observed to be 33.97% in flaxseed meal biscuit, 30.70% for composite meal biscuit, 18.87 % for groundnut meal biscuit, and 4.95% for sesame meal biscuit. Phytic acid content was similar in flaxseed and groundnut meal products, while sesame meal products had the highest value. Protein digestibility was statistically similar across products, except oilseed meal cakes, with groundnut meal cake having the highest digestibility at 80.21%.

The study revealed significant percent increases in protein, fat, ash, and crude fiber content across the developed products compared to the control. Flaxseed meal cake demonstrated the highest overall increase (109.41%). 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.

1. **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.

1. **COMPETING INTERESTS**

No potential conflict of interest was reported by the authors.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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