Research Article

Journal of Meat Science
Year 2026, Vol.21 (2)

Optimization and Storage Stability of Flaxseed Flour Incorporated Chevon Nuggets Stored at 4±1°C

Hemant Pratap Singh[1], **Pramila Umaraw**[1*], **Akhilesh K Verma**[1], **V P Singh**[1] and **Ruma Devi**[1]

[1]Department of Livestock Products Technology College of Veterinary and Animal Sciences Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut- 250 110, Uttar Pradesh

***Correspondence:** <pramila1303@gmail.com>

Submission: 3 April 2026 **Acceptance:** 15 May 2026

DOI: https://doi.org/10.48165/jms.2026.21.02.07

ABSTRACT

The effect of flaxseed flour incorporation in chevon nuggets formulation was contemplated for both quality and acceptability. Chevon meat was replaced by flaxseed flour @ 2% (T1), 4% (T2) and 6% (T3) for preparing treatments that were analysed against control (C) without flaxseed flour. Results revealed significant increase in fat, dietary fibres, carbohydrate ash and overall acceptability without affecting the cooking yield and sensory attributes like colour and appearance, flavour, texture, juiciness. The most acceptable treatment (T3 with 6% flaxseed flour) and control were further evaluated for their storage stability at refrigerated conditions. The physico-chemical, antioxidant (Total phenolic content, DPPH (%) inhibition), lipid oxidation evaluation, microbial quality and sensory assessment was done at a regular interval of 5 days. During storage treatment evinced significantly better storage stability than control. Sensory evaluation revealed better acceptability of the treatment than control. Thus, it can be concluded that flax seed flour can be successfully used in chevon nuggets formulation upto 6% level with better dietary fibre content and antioxidant potential without compromising its sensory acceptability.

Keywords: Chevon nuggets; DPPH (%) inhibition; Flaxseed flour; Total phenolic content; Sensory attributes; Storage stability

INTRODUCTION

The chevon is one of the traditionally significant meat to meet contemporary global demands. Its compelling health credentials such as being lean, low in saturated fat, and rich in beneficial fats position it ideally to capitalize on the worldwide shift towards healthier meat. Moreover, its robust and growing production in Asia and Africa especially China, India ensures a stable and expanding supply. In 2023, China was the largest producer of chevon, producing approximately 2.53 million metric tons and commanding a massive 38.1% share of global production followed by India and Pakistan, which contributed 8.5% and 8.3% of the world's supply, respectively. However, the true indicator of the sector's potential lies not just in production volume, but in its market valuation and demand dynamics. Chevon being the choicest meat in India possess a strong market appeal. The sheep and goat segment is projected to be the fastest-growing portion of India's entire red meat market, with a remarkable CAGR of approximately 7.5% from 2025 to 2030. This disparity between the modest growth in production volume (~0.67% CAGR) and the explosive growth in market value (~7.5% CAGR) is critically important. It signals a powerful market shift where demand for chevon is outpacing supply, a trend that will likely lead to increased market prices, higher value realization for farmers, and greater commercial interest in the sector.

Meat nuggets are emulsion based products where the ground meat is mixed with meat extenders, fillers, seasonings, etc. and are moulded in different shapes and sizes. Modern consumers are increasingly seeking leaner meats with healthier fat profiles, specifically lower in saturated fat (SFA) and higher in polyunsaturated fat (PUFA), in line with nutritional guidelines. Chevon products naturally meets this demand, positioning it as a health-conscious choice that aligns with contemporary dietary recommendations (Wood et al. 2004). Meat naturally lacks dietary fiber, an important nutrient known for its role in reducing the risk of various lifestyle-related diseases. Adding dietary fiber to meat products can significantly improve their nutritional and functional value. Flaxseed (*Linum usitatissimum*), meaning "very useful" in Latin, is one of the most important oilseed crops used in both industrial applications and as a source of food and animal feed. Nutritionally, flaxseed contains approximately 41% fat, 20% protein, 28% total dietary fibre, 7.7% moisture, and 3.4% ash (Singh et al. 2011). Its dietary fibre content comprises both soluble and insoluble fibres, typically in a ratio ranging from 20:80 to 40:60 (Morris 2003). Thus, the present study was undertaken to explore incorporation of flaxseed powder in chevon nuggets formulation as well as contemplated its storage stability under refrigerated conditions.

MATERIALS AND METHODS

Raw materials

Fresh boneless chevon from 10–12-month-old goats was procured from a local meat market in Meerut, Uttar Pradesh. Flaxseeds, Eggs, salt, edible oil, condiments, spices and low density polyethylene (LDPE) for packaging were also purchased from local market Modipuram, Meerut. Analytical grade chemicals were obtained from standard firms.

Preparation of chevon nuggets

The chevon nuggets were prepared in the Department of Livestock Products Technology, COVAS, Meerut following methodology given by Verma et al. (2023). The formulation used in the present study have been given in Table 1. The products with different levels of flaxseed powder were evaluated for their physico-chemical qualities along with sensory evaluation. The most accepted chevon nuggets with flaxseed powder were further evaluated for its storage stability and sensory acceptability upto 10 days under refrigerated conditions in aerobic packaging.

Table 1. Formulation of chevon nuggets

Ingredients %	Control	T1	T2	T3
Meat	69.2	67.2	65.2	63.2
Oil	8.0	8.0	8.0	8.0
Salt	1.5	1.5	1.5	1.5
Hydrated Soya	3.0	3.0	3.0	3.0
Chilled Water	5.0	5.0	5.0	5.0
STPP	0.3	0.3	0.3	0.3
Spices	2.0	2.0	2.0	2.0
Condiments	3.0	3.0	3.0	3.0
Egg	5.0	5.0	5.0	5.0
Refined Wheat Flour	3	3	3	3
Flax Seed Powder	0.0	2.0	4.0	6.0
Sodium Nitrite (ppm)	120	120	120	120
Total (%)	100	100	100	100

Analytical techniques

pH and water activity

The pH of all samples was assessed by digital pH meter (Esico, Model-1012) following methodology described by Trout et al. (1992). Water activity of the samples was estimated using Novasina water activity meter.

Proximate analysis

The manual of AOAC (2000) was followed for estimation of moisture, protein, fat ash and crude fibre content of nuggets while, carbohydrate content was calculated as difference using following formula:

Carbohydrate (%) = 100 – (Moisture + Fat + Protein + Ash)

The Atwater conversion factors were implemented for calculation of Energy value of products where, energy values are given as 4.02 kcal/g for protein, 4 kcal/g for carbohydrates, and 9 kcal/g for fat.

Cooking determinants: Cooking Yield- The cooking yield of chevon nuggets was calculated using the following formula

$$\text{Cooking yield \%} = \frac{\text{weight of cooked chevon meat block}}{\text{weight of chevon meat emulsion}} \times 100$$

Cooking Loss of all the samples was calculated by

$$\text{Cooking loss \%} = \frac{\text{weight of cooked chevon meat block- weight of uncooked chevon emulsion}}{\text{weight of uncooked chevon emulsion}} \times 100$$

Antioxidant potential

Total phenolic content: The Folin–Ciocalteu colorimetric assay was adopted for estimation of total phenolic content of the samples.

1,1-diphenyl-2-picrylhydrazyl (DPPH) percent inhibition: The methodology given by Kato et al. (1998) was followed with slight modification for estimating 1,1-diphenyl-2-picrylhydrazyl radical scavenging activity of the samples using UV Vis- spectrophotometer. The DPPH radical percent inhibition was calculated by following formula: Scavenging activity (% inhibition) = 100

×100.

Where, At_0 is the initial absorbance of sample and At_{20} is measured absorbance of sample after incubation for 20 mins.

***Lipid oxidation**:* The peroxide value and TBARS values were estimated for evaluation of the lipid oxidation changes in the nuggets following methodologies given by Koniecko (1979) and Witte *et al.* (1970) respectively.

***Microbiological evaluation**:* The microbiological quality of nuggets stored under refrigerated conditions were estimated according to the APHA (1984). Under aseptic conditions serial dilutions of samples were prepared. The plate count Agar was used as a medium for enumeration of Standard Plate Count (SPC) and Psychrophilic counts. The plate for SPC were incubated at 37°C for 24-36 hours, while that for psychrophilic count were incubated at 4±1°C for 10-14 days. Colonies (30-300) were counted and expressed as log10 CFU/g.

Sensory evaluation

The product developed was evaluated for its sensory acceptability by seven semi-trained panellists, constituted from among the College faculty and PG students of the Department. Sensory evaluation was done on 9-point hedonic scale with ratings ranging from 1 (extremely poor i.e. lowest grade) to 9 (excellent i.e. highest grade). The products were assessed for quality attributes viz. colour and appearance, flavour, texture, juiciness and overall acceptability. Coded samples were providing for analysis along with potable water for rinsing of mouth in between the sample analysis.

Statistical analysis

The whole experiment was repeated thrice along with product storage. All the data was collected in duplicate for physico-chemical, cooking determinants, proximate analysis, antioxidant potential, lipid oxidation, microbial evaluation (n=6). For sensory evaluation, in each trial samples were assessed by seven panellists (n=21). Data collected was subjected to ANOVA following Snedecor and Cochran (1994) methodology using statistical tool ‘SPSS-22.0’ (SPSS, Inc, Chicago IL, USA). Level of significance between means was identified by employing Duncan’s Multiple Range Tests and homogeneity tests at 5% level ($P<0.05$)

RESULTS AND DISCUSSION

Physico-chemical quality of chevon meat nuggets

pH and water activity

Addition of flaxseed powder in the chevon nuggets formulations did not affect its pH at any level of incorporation (Table 2). This might be due to the buffering capacity of flaxseed hydrocolloids (Lorenc et al. 2022). Similarly, Bilek et al. (2009) observed no change in pH of raw beef patties prepared with addition of various levels of flaxseed powder while Novello et al. (2019) observed little effect of flaxseed flour/oil and their combination on beef patties. Incorporation of flaxseed flour at 5%, 10%, and 15% in the fish burger formulation did not significantly affect the product pH (Duman 2022).

Incorporation of flaxseed powder significantly decreased the water activity of chevon nuggets accompanied by a slight but comparable reduction in initial water activity (0.95-0.93) (Table 2). The reduction in moisture is primarily due to replacement of part of the high-moisture meat fraction with solids such as fiber, fat, and ash, consistent with findings by (Bilek et al. 2009), who reported similar effects in beef patties and emulsified meat products with flaxseed flour. Similarly, (Nurymkhan et al. 2025) observed that plant-derived polysaccharides or cereal-based extenders in meat systems reduce moisture content while increasing solids.

Proximate analysis

The proximate composition of chevon nuggets presented in Table 2 reveals that the moisture content of chevon nuggets was significantly affected with flaxseed powder addition. The moisture content decreased significantly at 4% and 6% level of incorporation. This decrease might be attributed to the replacement of high moisture meat fractions with dry flaxseed powder. Similar decrease in moisture content was also observed by Cocaro et al. (2020) and Novello et al. (2019) in beef patties. Incorporation of flaxseed powder in chevon nuggets caused a slight decrease in protein content from 16.47% in the control to 15.72% in T3. Similar decrease in protein content of beef sausage were also reported by Ghafouri-Oskuei et al. (2020) and in meat sorpotel by Singh et al. (2021). Incorporation of flaxseed powder in chevon nuggets significantly increased fat content of chevon nuggets. The increase in fat might be due to the additional lipids (mainly unsaturated fatty acids) provided by the flaxseed flour. Similarly, the ash content increased significantly with addition of flaxseed powder. The increased ash content might be attributed to flaxseed powder which is naturally rich in minerals such as calcium, magnesium, and phosphorus, which contribute to the total mineral content of the nuggets.

The carbohydrate content was significantly increased at the higher level i.e. T3 (6%) whereas, the energy value of the nuggets significantly increased with each level of flaxseed powder incorporation (Table 2). The crude fibre content of nuggets was substantially ($P<0.05$) increased in treatments 1.21% (T3) than control 0.37%. According to Shim et al. (2014) brown flaxseeds consists of about 7.7% moisture, 20% proteins, 41% fat, 3.4% ash and 28 percent dietary fibres. Our findings were in line with the reports of

Zajac et al. (2017) in liver sausages made with milled flaxseed and Valenzuela-Melendres et al. (2018) in beef patties. The moisture-to-protein (M:P) ratio also decreased from 4.07 to 3.89, although this change was not statistically significant (P>0.05), indicating a moderately denser meat matrix with a higher proportion of solids relative to water.

Cooking determinants

The cooking yield and cooking loss of the nuggets improved non significantly (P>0.05) with the flaxseed addition (Table 2). Suleman et al. (2025) also reported increase in cooking yield and lower losses with enchantment of addition of level of incorporations flaxseed in goat meat patties.

Table 2. Physico-chemical changes in flaxseed added chevon nuggets

Groups	Control	T1	T2	T3
pH	6.30±0.01	6.30±0.03	6.33±0.02	6.35±0.02
Water activity (a_W)	0.95±0.004^{b}	0.94±0.004^{ab}	0.94±0.004^{ab}	0.93±0.006^{a}
Moisture (%)	66.97±0.48^{c}	65.39±0.45^{c}	63.47±0.68^{b}	61.04±0.72^{a}
Protein (%)	16.47±0.28^{b}	16.12±0.11^{ab}	15.91±0.21^{ab}	15.72±0.28^{a}
Fat (%)	12.11±0.47^{a}	13.52±0.16^{b}	14.13±0.24^{bc}	14.62±0.25^{c}
Ash (%)	2.33±0.01^{a}	2.40±0.01^{b}	2.52±0.01^{c}	2.63±0.02^{d}
Carbohydrate (%)	1.72±0.58^{a}	1.96±0.53^{a}	3.22±0.46^{ab}	4.76±0.60^{b}
Energy (Kcal/100~~gm~~)	182.17±2.8^{a}	194.41±1.7^{b}	204.10±3.6^{c}	213.89±3.7^{d}
Crude Fiber (%)	0.37±0.02^{a}	0.58±0.03^{b}	0.72±0.04^{c}	1.21±0.04^{d}
Moisture protein ratio	4.07±0.08	4.06±0.03	3.99±0.08	3.89±0.09
Cooking yield (%)	90.94±0.51	91.90±0.66	92.47±0.81	92.51±0.93
Cooking loss (%)	9.05±0.51	8.09±0.66	7.52±0.81	7.48±0.93

Mean values bearing different superscript in a row differ significantly (P<0.05) n=6, Control=chevon nuggets without Flaxseed powder; T1= chevon nuggets with 2.0 % Flaxseed powder; T2= chevon nuggets with 4.0 % Flaxseed powder and T3= chevon nuggets with 6.0 % Flaxseed powder.

Sensory evaluation of flaxseed added chevon nuggets

Incorporation of flaxseed in chevon nuggets formulation did not affect the sensory acceptability of the nuggets (Table 3). The major attributes such as colour and appearance, flavour, juiciness and texture remained comparable among all groups indicating insignificant effect of level of incorporation. Although overall acceptability was significantly affected. The T1 was rated similar to control by panellists for overall acceptability but rated T2 significantly lower than control. This lower acceptability might be attributed to the replacement of chevon meat with flaxseed powder. Interestingly the acceptability of T3 was rated highest among all indicating better water and fat binding properties of flaxseed hydrocolloids at higher levels (Lorenc et al. 2022; Manoliu et al. 2025). Further the T3 was compared with control for its storage stability.

Table 3. Sensory evaluation of flaxseed added chevon nuggets

Groups	Control	T1	T2	T3
Colour and appearance	8.50±0.11	8.42±0.12	8.25±0.07	8.32±0.08
Flavour	8.39±0.12	8.32±0.10	8.20±0.06	8.25±0.11
Juiciness	8.28±0.10	8.32±0.10	8.19±0.07	8.39±0.11
Texture	8.32±0.27	8.25±0.20	8.17±0.27	8.21±0.26
Overall acceptability	8.32±0.10^{ab}	8.35±0.12^{ab}	8.22±0.06^{a}	8.57±0.07^{b}

Mean values bearing different superscript in a row differ significantly (P<0.05) n= (7×3=21) C=chevon nuggets without Flaxseed powder; T1= chevon nuggets with 2% Flaxseed powder; T2= chevon nuggets with 4.0 % Flaxseed powder and T3= chevon nuggets with 6 % Flaxseed powder

Storage stability of flaxseed incorporated chevon nuggets

pH and water activity

The incorporation of flaxseed powder at 6% level in chevon nuggets did not affect its pH initially but as the storage progressed the pH gradually increased by fifth day of storage in both control and T3 (Table 4). This significant increase was further elaborated by tenth day of storage. By the end of study significant difference in the pH of C and T3 was observed. The increase in pH during storage might be attributed to protein degradation, deamination, and microbial metabolism leading to the accumulation of amines (Arshad et al. 2017; Umaraw et al. 2024). The restricted increase of pH in T3 suggests better storage stability, likely due to the presence of higher TPC and DPPH inhibition activity in compression to control. The water activity of both control and T3 decreased during storage which might be attributed to the loss of moisture. Similar decreased in water activity was also observed in chicken nuggets added with *Nelumbo nucifera* powder (Verma et al. 2022). Ciobanu et al. (2025) further highlighted that fibre-enriched meat products exhibit lower water activity and improved water retention, contributing to slower spoilage reactions and reduced pH rise.

Table 4. Changes in physicochemical, and microbial quality of flaxseed added nuggets during refrigerated storage

Groups	0 day	5 days	10 days
pH			
C	6.31 ± 0.01^{a}	6.39 ± 0.01^{b}	6.53 ± 0.03^{Bc}
T3	6.34 ± 0.01^{a}	6.38 ± 0.01^{b}	6.44 ± 0.04^{Ac}
Water activity (a_W)			
C	0.943 ± 0.009^{b}	0.921 ± 0.004^{a}	0.911 ± 0.005^{a}
T3	0.933 ± 0.006^{c}	0.917 ± 0.002^{b}	0.905 ± 0.003^{a}
Standard plate counts (CFU/g)			
C	2.70 ± 0.09^{Ba}	3.61 ± 0.10^{Bb}	4.48 ± 0.12^{Bc}
T3	2.33 ± 0.11^{Aa}	2.92 ± 0.09^{Ab}	3.80 ± 0.08^{Ac}
Psychrophilic counts (CFU/g)			
C	1.97 ± 0.09^{a}	2.48 ± 0.08^{b}	2.49 ± 0.07^{b}
T3	1.76 ± 0.11^{a}	2.27 ± 0.07^{b}	2.30 ± 0.06^{b}

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly (P<0.05) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.

Total phenolic content (TPC) and 1,1-diphenyl-2-picrylhydrazyl (DPPH) percent inhibition

The incorporation of flaxseed powder significantly increased the total phenolic content of T3 which was more than 2.5 times higher than control (Fig 1a). This increase in TPC can be attributed to the higher content of phyto-active compounds in flaxseed (Zhang et al. 2023). During storage the TPC decreased significantly in both groups owing to their role in combating oxidative changes as phenolic compounds tend to donate hydrogen atoms and stabilize free radicals (Umaraw et al. 2024). Similarly, Dong et al. (2025) observed better oxidative stability of pork meatballs prepared with addition of flaxseed powder. (Figure 1)

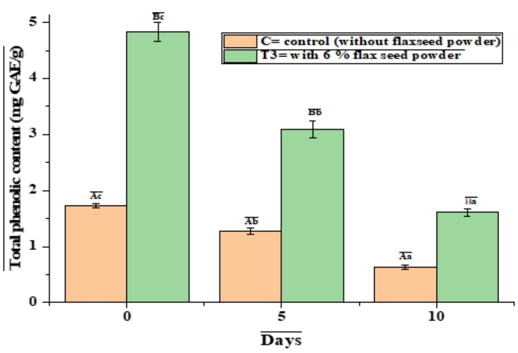

Figure 1. The total phenolic content of flaxseed powder added chevon nuggets at refrigerated storage.

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly (P<0.05) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.

The addition of flaxseed approximately doubled (P<0.05) the 1,1-diphenyl-2-picrylhydrazyl (DPPH) percent inhibition efficiency of T3 than control on initial day of analysis (Fig 1b). This improved efficiency might be correlated to the escalated TPC content of T3 which in turn increased the presence of phyto-active phenolic compounds. The major phenolic compounds in flaxseed are sinapic acid, kaempferol, quercitrin, quercitrin, and ferulic acid (Huang et al. 2024). These findings are in agreement with previous studies, where (Verma et al. 2026) reported that phenolic-rich additives in meat products significantly improve DPPH radical scavenging activity and reduce lipid oxidation during refrigerated storage. Similarly, Singh et al. (2025) observed a strong positive correlation between TPC and antioxidant activity in meat products prepared with incorporation of *Hylocereus undatus* Peel extract and Kumar et al. (2018) reported that natural phenolic compounds present in plant have potential to retard oxidative deterioration in processed meat products. (Figure 2)

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly (P<0.05) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.

Peroxide value and thiobarbituric acid reactive substances

The oxidative stability of chevon meat nuggets during storage was markedly improved by flax seed powder supplementation, as evidenced by lower lipid oxidation indices (peroxide value and thiobarbituric acid-reactive substances) in T3 compared to control (Fig. 2a & b). This indicates that flax supplementation effectively slowed both primary (PV) and secondary (TBARS) lipid oxidation during storage. A strong negative correlation was observed between TPC/DPPH and PV/TBARS, confirming that phenolic compounds and antioxidants from flax seed inhibit free radical-mediated lipid oxidation. These findings align with previous studies, Waszkowiak et al. (2014) observed reduced PV and TBARS values in meat balls added with flaxseed meals during storage and Chouikhi et al. (2023) flaxseed-derived polysaccharides improved lipid oxidative stability of beef sausages during storage. (Figure 3)

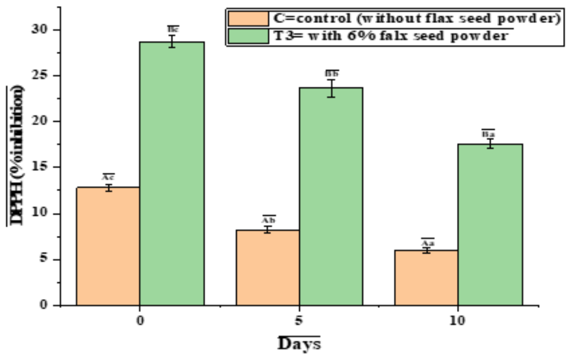

Figure 2. The 1,1-diphenyl-2-picrylhydrazyl (DPPH) percent inhibition of flaxseed powder added chevon nuggets at refrigerated storage.

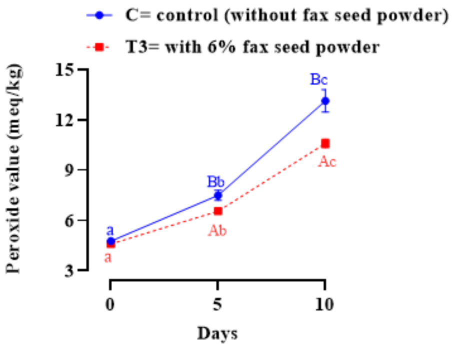

Figure 3. Changes in peroxide value during storage.

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly (P<0.05) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.(Figure 4)

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly (P<0.05) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.

Standard plate count and psychrophilic counts

The microbiological quality of chevon meat nuggets was significantly influenced by flax seed powder incorporation and storage (Table 4). Nuggets supplemented with the 6% flax (T3) exhibited lower SPC than control (C) at all storage points. During storage, SPC increased significantly in both groups although T3 evinced significantly lower counts. Similarly, Suleman et al. (2025) reported markedly lower total plate counts over 16 days of storage in mutton patties with 2–8% flaxseed powder. The psychrophilic counts in both groups remained comparable on all days studied.

Sensory evaluation

The addition of flaxseed at 6% significantly affected the colour and appearance score. The lower score of T3 might be attributed to the natural brown pigments, phenolic compounds and fiber present in flaxseed powder, which can slightly darken the meat matrix and reduce surface brightness. Similar observations were reported by (Yogesh et al. 2015) who noted that flaxseed flour decreased the lightness of meat batters due to its intrinsic pigmentation. Suleman et al. (2025) reported that flaxseed influence colour attributes through pigment interaction and increased water-binding, contributing to a slightly denser and less reflective surface appearance. Despite this, the overall colour remained highly acceptable, consistent with findings that low-to-moderate flaxseed incorporation does not significantly impair the visual quality of meat products (Zajac et al. 2017). During storage the colour scores decreased in both samples although T3 better maintained the colour and appearance that might be attributed to the better oxidative and reduced lipid oxidation.

During refrigerated storage flavour scores decreased significantly in both control and flaxseed-treated nuggets due to progressive lipid oxidation and moisture loss. However, nuggets with 6% flaxseed powder (T3) retained significantly higher flavour scores at 5 and 10 days compared to the control sample. This improved flavour stability can be attributed to the antioxidant activity of flaxseed lignans, which reduce oxidative rancidity and delay the development of off-flavours. Similar protective effects of flaxseed antioxidants during storage were reported (Li et al. 2022) who demonstrated reduced TBARS values and improved flavour stability in flaxseed-enriched meat systems.

During refrigerated storage for 10 days, texture scores gradually decreased in both control and flaxseed-treated nuggets due to protein denaturation, moisture loss, and minor fat oxidation, which are common causes of textural deterioration in meat products. However, nuggets containing 6% flaxseed powder (T3) retained significantly higher texture scores at 5 and 10 days compared to control, indicating that flaxseed's polysaccharides and fiber help retain moisture and maintain the gel matrix, thereby reducing hardness and chewiness loss during storage. These findings are consistent with recent studies showing that flaxseed addition can mitigate textural decline in meat products during storage due to its water-binding and gel-forming properties.

During refrigerated storage for 10 days, juiciness scores declined in both control and flaxseed-treated nuggets due to moisture loss, protein denaturation, and minor lipid oxidation, which are common contributors to dryness in stored meat products. However, nuggets containing 6% flaxseed powder (T3) retained significantly higher juiciness scores at 5 and 10 days compared to the control, highlighting the role of flaxseed polysaccharides in moisture retention and reducing water exudation during storage. These observations align with findings in meat patties and sausages, where flaxseed supplementation enhanced water-holding capacity and improved juiciness throughout refrigerated storage by (Ghafouri-Oskuei et al. 2022).

During refrigerated storage for 10 days, overall acceptability gradually declined in both control and flaxseed-treated nuggets due to moisture loss, protein and lipid oxidation, and textural softening, which are typical contributors to reduced sensory appeal over time. However, nuggets containing 6% flaxseed powder (T3) retained significantly higher overall acceptability scores at 5 and 10 days compared to the control, highlighting the protective role of flaxseed's natural antioxidants, polysaccharides, and fiber in preserving flavour, juiciness, and texture during storage. These findings are consistent with research showing that flaxseed supplementation can improve oxidative stability, sensory quality, and shelf-life of meat products.

Table 5. Sensory evaluation of flaxseed incorporated chevon nuggets during refrigerated storage

Groups	0 day	5 days	10 days
Colour and appearance			
C	8.35 ± 0.09^{Bc}	7.32 ± 0.17^{Ab}	6.25 ± 0.11^{Aa}
T3	8.20 ± 0.06^{Ac}	7.71 ± 0.11^{Bb}	6.66 ± 0.31^{Ba}
Flavour			
C	8.23 ± 0.07^{Bc}	7.21 ± 0.17^{Ab}	6.20 ± 0.10^{Aa}
T3	8.15 ± 0.06^{Ac}	7.66 ± 0.13^{Bb}	6.64 ± 0.07^{Ba}
Texture			
C	8.16 ± 0.10^{Ac}	7.10 ± 0.16^{Ab}	6.00 ± 0.10^{Aa}
T3	8.20 ± 0.08^{Bc}	7.60 ± 0.24^{Bb}	6.35 ± 0.10^{Ba}
Juiciness			
C	8.25 ± 0.09^{Ac}	7.32 ± 0.15^{Ab}	6.16 ± 0.08^{Aa}
T3	8.39 ± 0.12^{Bc}	7.64 ± 0.09^{Bb}	6.28 ± 0.11^{Ba}
Overall acceptability			
C	8.34 ± 0.09^{Bc}	6.82 ± 0.16^{Ab}	6.00 ± 0.11^{Aa}
T3	8.32 ± 0.27^{Ac}	7.64 ± 0.09^{Bb}	6.39 ± 0.12^{Ba}

Means values bearing capital letters (A, B, C, and D) day wise and small letters (a, b, c, d.......) group wise indicate differ significantly ($P<0.05$) n=6; C: control chevon meat nuggets without flaxseed; T3: chevon meat nuggets with 6% flaxseed powder.

ACKNOWLEDGEMENTS

The Authors are highly thankful to the University for providing the necessary facilities for carrying out the Masters Research work of the first author.

COMPETING INTERESTS

The authors declare no competing financial/non-financial interests.

ETHICS STATEMENT

Not Applicable

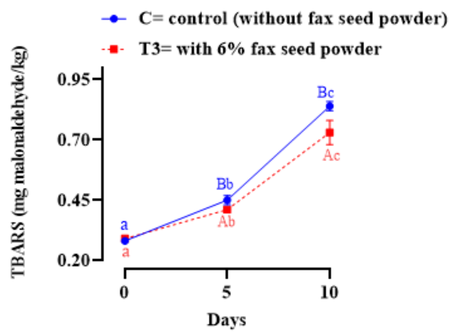

Figure 4. Changes in TBARS values during storage.

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How to Cite this Article: Singh H.P., Umaraw P., Verma A.K., Singh V.P., Devi R.. (2026). Optimization and Storage Stability of Flaxseed Flour Incorporated Chevon Nuggets Stored at 4±1°C. *J. Meat Sci.*, ***21***(2), 41-49. https://doi.org/10.48165/jms.2026.21.02.07