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Sensory Profile of Functionally Enriched Chicken Nuggets Containing Flaxseed-derived Omega-3 Fatty Acids and Betel Leaf (*Piper betel*) Extract as an Antioxidant

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ABSTRACT

The present investigation was conducted during the month of June to December of the year 2024 at the department of Livestock Products Technology, College of Veterinary Science and AH, Jabalpur to develop designer chicken meat nuggets by incorporating flaxseed flour, a rich source of omega-3 fatty acids, and betel leaf extract (BLE), a natural antioxidant, with the aim of enhancing nutritional quality and sensory acceptability while reducing dependence on synthetic preservatives. Four treatments were formulated: T_1 (control, without flaxseed flour), T_2 (10% flaxseed flour), T_3 (10% flaxseed flour+250 ppm BLE), and T_4 (10% flaxseed flour+80 ppm BHT). Nuggets were prepared following standardized protocols and evaluated for sensory attributes including colour and appearance, flavour, juiciness, texture, chewiness, gumminess, mouthcoating, and overall acceptability using an 8-point descriptive scale. The products were assessed over 16 days of refrigerated storage (4±1°C), and data were statistically analyzed at a 5% significance level ($p \leq 0.05$). Results revealed a gradual decline in all sensory attributes across treatments during storage, primarily due to oxidative changes and moisture loss. Control samples (T_1) consistently exhibited the lowest scores, particularly in flavour, juiciness, and texture. Nuggets with flaxseed flour alone (T_2) showed improved nutritional enrichment but a faster decline in flavour stability. Incorporation of BLE (T_3) and BHT (T_4) significantly ($p \leq 0.05$) improved flavour retention, juiciness, and overall acceptability compared to T_1 and T_2. Among treatments, T_3 maintained the highest sensory scores throughout storage, demonstrating the synergistic effect of flaxseed flour and BLE in enhancing product quality and consumer appeal.

KEYWORDS: Chicken nuggets, flax seeds, beetle leaf, natural antioxidant

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1. INTRODUCTION

Globally, the demand for poultry meat has been steadily rising in both developed and developing nations (Ibrahim et al., 2014). Chicken meat, whether fresh or processed, is particularly favored because it is generally free from cultural and religious restrictions and is regarded as a nutritious food with relatively low fat content. Compared to other meats, it provides a higher proportion of health-beneficial unsaturated fatty acids (De Castro et al., 2013). Levya et al., 2010 concluded that adding fish oil into the diets of laying hens can be an efficient strategy to enrich the omega-3 polyunsaturated fatty acids, including docosahexaenoic acid in eggs. Despite these advantages, processed poultry products are often criticized for their elevated levels of fat, saturated fatty acids, cholesterol, salt, and synthetic preservatives (Perez-Palacios et al., 2019). Research has increasingly linked the consumption of such products to chronic health conditions, including obesity, type 2 diabetes, cardiovascular disorders, and certain cancers (Paglarini et al., 2018). As a result, consumer awareness regarding health and nutrition has grown significantly, fueling the demand for innovative and alternative meat products (Devatkal et al., 2019). To address health concerns and reduce reliance on chemical preservatives, the use of natural preservation methods is gaining importance (Ukrainets et al., 2016). One of the major challenges in the meat industry is lipid oxidation, which compromises product quality and safety. Natural antioxidants have been extensively studied as a potential solution (Gyawali and Ibrahim, 2014). Among these, betel leaf (Piperaceae family), widely cultivated in Southeast Asia, has drawn attention for its strong antioxidant potential. This activity is attributed to bioactive compounds such as catechol, hydroxychavicol, chavibetol, allylpyrocatechol, chavibetol acetate, and allylpyrocatechol diacetate (Dasgupta et al., 2014; Rintu et al., 2015; Saini et al., 2020). Thus, the present research aims to investigate the antioxidant effectiveness of betel leaf extract in chicken meat nuggets. Meat products are rich in fat, added salts however are a poor source of complex carbohydrates such as dietary fiber (Choubey et al.,2024). Flaxseed is an alternative to marine products. It is one of the richest sources of the plant-based ω-3 fatty acid, alpha-linolenic acid (ALA). Based on the results of clinical trials, epidemiological investigations and experimental studies, ingestion of ALA has been suggested to have a positive impact on CVD. Because of its high ALA content, the use of flaxseed has been advocated to combat CVD. The purpose of the present review was to identify the known cardiovascular effects of flaxseed and ALA and, just as importantly, what is presently unknown . Incorporating flaxseed or its derivatives into meat formulations has been shown to enhance their nutritional profile (Novello et al., 2019). However, excessive inclusion can negatively impact consumer sensory acceptance, limiting its practical application (Pelser et al., 2007; Bilek and Turhan, 2009). According to literature, creating healthier meat products often requires substantial reformulation, which can result in undesirable changes to sensory characteristics. Sensory science, therefore, plays a critical role in ensuring consumer acceptability while improving nutritional value (Beriain et al., 2018). Strategies such as partial replacement of animal protein with plant-based alternatives, incorporation of probiotics, prebiotics, and symbiotics, or enrichment with vitamins, minerals, and bioactive compounds have all been explored to produce healthier meat products (Pellattiero et al., 2020). Nevertheless, consumer resistance to compromises in sensory appeal remains a key challenge (De Castro et al., 2013).

2. MATERIALS AND METHODS

The research was conducted during June to December, 2024 entitled "Development of designer chicken meat nuggets by incorporating flaxseeds rich in omega-3 fatty acids and betel leaf extract as an antioxidant" was carried out in multiple stages at the Department of Livestock Products Technology, College of Veterinary Science and Animal Husbandry, Jabalpur. This section outlines the raw material sources, additives, and methodological procedures adopted during the study.

2.1. Source of raw material

Freshly dressed chicken carcasses were obtained from licensed retail meat shops in Jabalpur. The carcasses were initially chilled at 4±1°C for 12 hours, followed by manual deboning. The separated meat was stored in a deep freezer at –18±1°C until required for product formulation. Additives and other ingredients like table salt (Tata Chemicals Ltd., Mumbai) and soybean oil (Fortune brand) were sourced from the local market. Fresh ginger and garlic were purchased from local vendors. After peeling, both were ground separately using a domestic grinder (Bajaj make) to obtain fine pastes. The condiment mixture was prepared by blending garlic and ginger paste in a 2:1 proportion. The mixture was packed in LDPE bags and stored at -18±1°C until further utilization. Spice mix was prepared in the department. Whole spices were procured from the Jabalpur market, cleaned, and oven-dried at 45±2°C for 2 hours. The dried spices were ground using a domestic grinder (Bajaj make) and sieved through a fine mesh. The powders obtained were combined in standardized proportions (Table 1) to prepare the spice mixture. The final blend was preserved in a moisture-proof PET jar for subsequent use.

2.2. Preparation of flaxseed flour

Flaxseeds were first roasted in a conventional oven pre-

Table 1: Composition of spice mix

Name of ingredients	Percentage (w/w)
Bay leaves (*Tej patta*)	03.00
Black pepper (*Kali mirch*)	10.00
Cardamom dry (*Chhoti elaichi*)	12.00
Cinnamon (*Dalchini*)	05.00
Cloves (*Laung*)	02.00
Coriander (*Dhania*)	20.00
Cumin seeds (*Jeera*)	16.00
Dry ginger powder (*Soanth*)	05.00
Fennel (*Saunf*)	03.00
Long Pepper (*Pipali*)	03.00
Mace (*Javitri*)	03.00
Nutmeg (*Jaifal*)	03.00
Red Chilli (*Lal mirch*)	15.00
Total	100.00

heated to 180°C for 5 min. The roasted seeds were then finely ground using a mixer grinder to obtain flaxseed flour, as outlined by Ahlawat et al. (2019).

2.3. Preparation of betel leaf extract

The extraction of betel leaf was carried out using a modified procedure described by Nouri and Nafchi (2014). Freshly collected leaves were shade-dried for four days and subsequently pulverized into fine powder using a domestic grinder. One hundred grams of this powdered material was dissolved in 1 L of 90% ethanol and subjected to continuous stirring on a magnetic stirrer (REMI RM-12CBL) for 24 hours at 1200 rpm. The mixture was filtered three times through Whatman filter paper (No. 42) and concentrated using a hot water bath (Yorco universal water bath) maintained at 40°C. The concentrated extract was then freeze-dried (Optics Technology freeze dryer) for 18 hours, and the resulting product was stored at -18°C until use.

2.4. Product development

Chicken meat nuggets were prepared following a modified protocol of Bhosale et al. (2011). Lean chicken meat was cut into small portions and minced using a mechanical meat mincer. The minced meat was mixed with curing ingredients such as salt, nitrite, phosphate, sugar, soybean oil, spices, condiments, and chilled water/ice, and a uniform emulsion was prepared in a bowl chopper. Four experimental groups were designed for the study: Treatment 1 (T_1: Control), Treatment 2 (T_2: Incorporated with 10% flaxseed flour), Treatment 3 (T_3: Supplemented with 10% flaxseed flour+250 ppm betel leaf extract), and Treatment 4 (T_4 – supplemented with 10% flaxseed flour+80 ppm BHT). The emulsions were thoroughly blended to ensure uniform distribution of all components and then steam-cooked for 35 minutes without pressure. After cooling to ambient temperature, the nuggets were packed in LDPE pouches, sealed using a hand sealer, placed in PET jars, and finally stored at refrigeration temperature (4±1°C) for subsequent evaluation (Table 2 and 3).

Table 2: Different treatment groups of chicken meat nuggets

Groups	Variation in chicken meat nuggets
T_1	Nuggets without flaxseed flour
T_2	Nuggets with flaxseed flour
T_3	Nuggets with flaxseed flour+betel leaf extract
T_4	Nuggets with flaxseed flour+butylated hydroxyl toluene

Table 3: Formulation used for the preparation of chicken meat nuggets in different trials

Sl. No.	Ingredients	Treatments			
		T_1	T_2	T_3	T_4
1.	Chicken meat	68.5	58.5	58.5	58.5
2.	Salt	1.7	1.7	1.7	1.7
3.	Spices	2	2	2	2
4.	Condiments	3	3	3	3
5.	Refined wheat flour	4	4	4	4
6.	Ice/chilled water	10	10	10	10
7.	Soyabean oil	10	10	10	10
8.	Flaxseed flour	0	10	10	10
9.	Sugar	0.3	0.3	0.3	0.3
10.	Phosphate	0.5	0.5	0.5	0.5
11.	Nitrite (130 ppm)	130	130	130	130
12.	BHT (80 ppm)	0	0	0	80
13.	BLE (250 ppm)	0	0	250	0
Total		100	100	100	100

2.5. Sensory evaluation

A six-member experienced panel of judges, comprising teachers and postgraduate students of C.V.Sc and A.H, Jabalpur, evaluated the samples for sensory attributes such as colour and appearance, texture, flavour, juiciness, etc., using an 8-point descriptive scale (Keeton, 1983), where 8=excellent and 1=extremely poor. The test samples were presented to the panelists after assigning the suitable codes. Water was served for rinsing the mouth between the samples for the sensory evaluation.

2.6. Statistical analysis

Data was analyzed statistically on 'SPSS-22.0' (SPSS Inc., Chicago, II USA) software package as per standard methods (Snedecor and Cochran, 1994). The average values were reported along with the standard deviation. The statistical significance was estimated at 5% level ($p \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1. Sensory scores of chicken meat nuggets- colour/ appearance scores

The colour/appearance scores of chicken meat nuggets across treatments and storage days are summarized in Table 4 with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE, and T_4=Nuggets with flaxseed flour+ BHT. Significant differences ($p \leq 0.05$) were observed within treatments over time. For all treatments, the colour/appearance scores declined gradually as storage progressed, indicating deterioration in visual quality. In the T_1 group, scores decreased from 7.53 on day 0 to 6.04 on day 16. Similar trends were noted for T_2, T_3, and T_4, with reductions from 7.46 to 5.96, 7.33 to 6.00, and 7.43 to 6.00, respectively. The decline in scores may be attributed to oxidative changes and moisture loss during storage, which can impact the surface appearance and overall visual appeal of the nuggets. At the initial stage (day 0), T_1 exhibited the highest colour/ appearance score (7.53), followed closely by T_2 (7.46), T_4 (7.43), and T_3 (7.33). However, as storage progressed, the differences among treatments narrowed, with all treatments achieving similar scores by day 16. This shows the comparative acceptability of flaxseed incorporated chicken meat nuggets, which were equally liked by the panel when compared with the control, the product prepared without flaxseed. While no treatment showed exceptional stability over time, the presence of flaxseed flour (T_2, T_3, and T_4) did not markedly alter the rate of decline compared to the control (T_1). This suggests that while additives like BLE and BHT might improve antioxidant properties, their impact on colour/appearance stability was limited in this study. In a similar study, Reddy et al. (2018) incorporated flaxseed at 0%, 3%, 6%, and 9%, and the colour scores decreased significantly as the flaxseed content increased, and this decrease was higher with 9% flaxseed flour added to chicken meat nuggets.

Table 4: Colour/ appearance scores of chicken meat nuggets

Sl. No.	Treat-ment	Storage days				
		0	4	8	12	16
1.	T_1	$7.53^{e}\pm$ 0.29	$7.21^{d}\pm$ 0.19	$6.92^{c}\pm$ 0.20	$6.42^{b}\pm$ 0.26	$6.04^{a}\pm$ 0.19
2.	T_2	$7.46^{d}\pm$ 0.33	$7.08^{c}\pm$ 0.13	$6.83^{c}\pm$ 0.16	$6.38^{b}\pm$ 0.21	$5.96^{a}\pm$ 0.29
3.	T_3	$7.33^{e}\pm$ 0.20	$7.00^{d}\pm$ 0.27	$6.73^{c}\pm$ 0.12	$6.33^{b}\pm$ 0.10	$6.00^{a}\pm$ 0.16
4.	T_4	$7.43^{e}\pm$ 0.14	$7.13^{d}\pm$ 0.14	$6.82^{c}\pm$ 0.19	$6.38^{b}\pm$ 0.26	$6.00^{a}\pm$ 0.16

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p \leq 0.05$)

3.2. Flavour scores

The flavour scores of chicken meat nuggets subjected to different treatments and evaluated over storage days are presented in Table 5 with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=nuggets with flaxseed flour+BLE, and T_4=Nuggets with flaxseed flour+ BHT. Significant variations ($p \leq 0.05$) were observed both within treatments over time and among treatments at specific storage intervals. A progressive decline in flavour scores was observed for all treatments as storage days increased. The flavour score decreased from 7.50 on day 0 to 5.97 for T_1 on day 16. Similarly, T_2 exhibited a reduction from 7.58 to 5.42, while T_3 and T_4 showed declines from 7.54 to 5.96 and 7.50 to 5.96, respectively. The relatively faster decline in T_2 compared to other treatments suggests that the inclusion of flaxseed flour alone may not provide sufficient protection against flavour degradation over time. At day 0, all treatments showed comparable flavour scores, with no significant differences observed. However, as storage progressed, T_3 and T_4 generally maintained higher scores than T_2 at comparable time points. By day 8, T_3 recorded a score of 6.67, significantly higher than T_2 (6.25). Similarly, T_4 exhibited a higher score of 6.58 compared to T_1 (6.54) and T_2 (6.25). These results suggest that the addition of BLE (T_3) and BHT (T_4) offered some protection against flavour deterioration, likely due to their antioxidant properties that minimize lipid oxidation. Fish burger with flaxseed flour showed similar scores for flavour F (0%), F (5%), F (10%)

Table 5: Flavour scores of chicken meat nuggets

Sl. No.	Treat-ment	Storage days				
		0	4	8	12	16
1.	T_1	$7.50^{c}\pm$ 0.27	$7.13^{c}\pm$ 0.21	$6.54^{ABb}\pm$ 0.19	$6.08^{a}\pm$ 0.30	$5.97^{Ba}\pm$ 0.29
2.	T_2	$7.58^{d}\pm$ 0.34	$6.83^{c}\pm$ 0.58	$6.25^{Ab}\pm$ 0.32	$5.83^{ab}\pm$ 0.30	$5.42^{Aa}\pm$ 0.41
3.	T_3	$7.54^{c}\pm$ 0.37	$7.09^{c}\pm$ 0.25	$6.67^{Bb}\pm$ 0.26	$6.08^{a}\pm$ 0.56	$5.96^{Ba}\pm$ 0.53
4.	T_4	$7.50^{c}\pm$ 0.35	$7.04^{c}\pm$ 0.29	$6.58^{ABb}\pm$ 0.30	$6.04^{a}\pm$ 0.43	$5.96^{Ba}\pm$ 0.33

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p \leq 0.05$)

and F (15%) having 8, 8, 8.5, and 7 scores respectively on a nine-point hedonic scale (Duman, 2020).

3.3. Juiciness scores

The juiciness scores of chicken meat nuggets for different treatments were analyzed during the storage period, as shown in Table 6 with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE and T_4=Nuggets with flaxseed flour+BHT. A gradual decline in juiciness was observed in all treatments as the storage duration increased. This reduction was statistically significant ($p\leq0.05$), with notable differences both across treatments and over time. For T_1, the scores decreased significantly from 6.96 on day 0 to 5.92 on day 16, showing the steepest decline among all treatments. T_2 also exhibited a reduction in scores, ranging from 7.17 on day 0 to 6.33 on day 16. Treatments T_3 and T_4 demonstrated comparatively better retention of juiciness, with scores decreasing from 7.25 to 6.50 for T_3 and from 7.17 to 6.33 for T_4. Initial juiciness scores were comparable among all treatments. However, as storage progressed, significant differences emerged. T_3 consistently retained higher juiciness scores compared to other treatments, followed by T_4 and T_2. By day 16, T_3 had the highest juiciness score of 6.50, while T_1 had the lowest at 5.92. The superiority of T_2, T_3, and T_4 over T_1 was possibly due to an increase in fat content with the addition of flaxseed. Bilek and Turhan (2009) in their study on the use of flaxseed flour as a functional ingredient in the production of beef patties reported that sensory scores were decreased by increasing the levels of flaxseed from 3 % to 9% but the values showed superiority over the control group.

3.4. Texture scores

As indicated in Table 7, with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE, and T_4=Nuggets with flaxseed flour+BHT, the texture ratings of chicken meat nuggets for various treatments were assessed. During storage, all treatments showed a decrease in texture quality, with significant ($p\leq0.05$) differences seen over time and between treatments. For all treatments, the texture scores decreased progressively with increasing storage days. In T_1, the scores declined from 7.00 on day 0 to 5.83 on day 16, marking the most substantial reduction. T_2 showed a similar trend, with scores decreasing from 7.25 on day 0 to 6.13 on day 16. Treatments T_3 and T_4 exhibited slightly better retention of texture scores over the storage period. At day 0, all treatments showed relatively high and comparable texture scores, with T_3 recording the highest score of 7.46. As storage progressed, T_3 continued to maintain better texture integrity, with scores decreasing to 6.13 by day 16. T_4 also demonstrated higher texture retention compared to T_1. T_1 without supplementation showed the lowest scores throughout storage, highlighting the role of flaxseed flour and added antioxidants in preserving texture. The texture scores of chicken meat nuggets declined significantly over the storage period, consistent with natural quality degradation. Among the treatments, T_2, T_3 and T_4 showed the highest texture stability, followed by T_1. These findings suggest that the incorporation of flaxseed and antioxidants can effectively reduce structural changes in chicken meat nuggets, enhancing texture stability during storage. Rab et al. (2019) reported the texture scores for beef sausage of control supplemented by flaxseeds (10%), 9.63 and 9.30, respectively, on a 10-point hedonic scale, which differed significantly.

Table 6: Juiciness scores of chicken meat nuggets

Sl. No.	Treatment	Storage days 0	4	8	12	16
1.	T_1	$6.96^{d}\pm$ 0.25	$6.79^{cd}\pm$ 0.25	$6.46^{bc}\pm$ 0.25	$6.13^{ab}\pm$ 0.14	$5.92^{Aa}\pm$ 0.47
2.	T_2	$7.17^{c}\pm$ 0.41	$7.04^{c}\pm$ 0.37	$6.92^{bc}\pm$ 0.47	$6.46^{ab}\pm$ 0.43	$6.33^{ABa}\pm$ 0.38
3.	T_3	$7.25^{b}\pm$ 0.35	$7.00^{ab}\pm$ 0.63	$6.96^{ab}\pm$ 0.43	$6.54^{a}\pm$ 0.49	$6.50^{Ba}\pm$ 0.35
4.	T_4	$7.17^{b}\pm$ 0.44	$7.00^{b}\pm$ 0.32	$6.96^{b}\pm$ 0.40	$6.42^{ba}\pm$ 0.26	$6.33^{ABa}\pm$ 0.41

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq0.05$)

Table 7: Texture scores of chicken meat nuggets

Sl. No.	Treatment	Storage days 0	4	8	12	16
1.	T_1	$7.00^{Ac}\pm$ 0.27	$6.75^{bc}\pm$ 0.59	$6.42^{b}\pm$ 0.34	$6.29^{a}\pm$ 0.25	$5.83^{a}\pm$ 0.49
2.	T_2	$7.25^{ABd}\pm$ 0.16	$6.96^{cd}\pm$ 0.19	$6.67^{bc}\pm$ 0.41	$6.49^{bb}\pm$ 0.31	$6.13^{a}\pm$ 0.31
3.	T_3	$7.46^{Bc}\pm$ 0.25	$7.21^{cc}\pm$ 0.25	$6.63^{b}\pm$ 0.31	$6.46^{ab}\pm$ 0.43	$6.13^{a}\pm$ 0.47
4.	T_4	$7.29^{ABb}\pm$ 0.29	$7.04^{b}\pm$ 0.40	$6.63^{a}\pm$ 0.26	$6.50^{a}\pm$ 0.32	$6.29^{a}\pm$ 0.43

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq0.05$)

3.5. Chewiness scores

The results (Table 8) with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE and T_4=Nuggets with flaxseed flour+

Table 8: Chewiness scores of chicken meat nuggets

Sl. No.	Treatment	Storage days				
		0	4	8	12	16
1.	T_1	$7.13^{b}\pm 0.14$	$6.96^{b}\pm 0.19$	$6.25^{a}\pm 0.42$	$6.08^{a}\pm 0.34$	$5.79^{a}\pm 0.62$
2.	T_2	$7.33^{c}\pm 0.26$	$7.13^{c}\pm 0.34$	$6.67^{b}\pm 0.30$	$6.38^{ab}\pm 0.41$	$6.08^{a}\pm 0.20$
3.	T_3	$7.33^{b}\pm 0.52$	$7.21^{b}\pm 0.40$	$6.67^{a}\pm 0.30$	$6.46^{a}\pm 0.29$	$6.25^{a}\pm 0.22$
4.	T_4	$7.29^{c}\pm 0.43$	$7.29^{c}\pm 0.29$	$6.71^{b}\pm 0.49$	$6.42^{ab}\pm 0.38$	$6.04^{a}\pm 0.19$

Means (Mean± SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq 0.05$)

BHT reveal significant ($p\leq 0.05$) variations in chewiness scores within treatments during storage. Chewiness scores progressively decreased over the storage period in all treatments. For T_1, the scores reduced from 7.13 on day 0 to 5.79 on day 16, reflecting the sharpest decline. In T_2, the chewiness dropped from 7.33 to 6.08, while T_3 decreased from 7.33 to 6.25 during storage. T_4, which started with relatively high scores at 7.29, ended with 6.04 on day 16, maintaining better chewiness compared to T_1. On day 0, T_2 and T_3 exhibited the highest chewiness scores (7.33), followed closely by T_4 (7.29), while T_1 had the lowest initial score (7.13). Throughout the storage period, T_2, T_3 and T_4 demonstrated better chewiness retention compared to T_1. These results suggest that the inclusion of flaxseed and antioxidants can effectively maintain the textural attributes of chicken meat nuggets during extended storage periods. However, Kumar et al. (2017) reported a chewiness of 14.04 for control and 8.54 for 8% flaxseed in mutton nuggets incorporated with hydrated flaxseed flour through instrumental texture profile analysis.

3.6. Gumminess scores

Significant differences ($p\leq 0.05$) were identified within individual treatments over time with the progress of storage in Table 9 with T_1=Nuggets without flaxseed flour, T_2= Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE and T_4=Nuggets with flaxseed flour+BHT. A gradual decline in gumminess scores was observed for all treatments as storage progressed. For T_1, scores dropped from 7.04 on day 0 to 5.83 on day 16. Similarly, T_2 experienced a reduction from 7.33 to 6.04, T_3 from 7.33 to 6.00, and T_4 from 7.38 to 6.04 over the same period. At the beginning of storage (day 0), T_4 recorded the highest gumminess score (7.38), followed closely by T_2 and T_3 (both at 7.33), while T_1 had the lowest score of 7.04. During the storage period, T_2, T_3 and T_4 comparatively maintained

Table 9: Gumminess scores of chicken meat nuggets

Sl. No.	Treatment	Storage days				
		0	4	8	12	16
1.	T_1	$7.04^{c}\pm 0.43$	$6.92^{c}\pm 0.65$	$6.54^{bc}\pm 0.19$	$6.29^{ab}\pm 0.37$	$5.83^{a}\pm 0.56$
2.	T_2	$7.33^{d}\pm 0.26$	$7.13^{cd}\pm 0.34$	$6.79^{bc}\pm 0.29$	$6.63^{b}\pm 0.41$	$6.04^{a}\pm 0.33$
3.	T_3	$7.33^{d}\pm 0.34$	$7.13^{cd}\pm 0.26$	$6.75^{bc}\pm 0.45$	$6.63^{b}\pm 0.41$	$6.00^{a}\pm 0.47$
4.	T_4	$7.38^{d}\pm 0.26$	$7.08^{cd}\pm 0.41$	$6.75^{bc}\pm 0.32$	$6.67^{b}\pm 0.41$	$6.04^{a}\pm 0.19$

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq 0.05$)

higher gumminess scores compared to T_1 which consistently exhibited the lowest gumminess scores. This could have been due to the flaxseed flour improving the gumminess score in the mentioned samples. However, Kumar et al. (2017) reported gumminess 23.56 for control and 17.59 for 8% flaxseed in mutton nuggets incorporated with hydrated flaxseed flour through instrumental texture profile analysis.

3.7. Mouth coating scores

The mouth coating properties of chicken meat nuggets were assessed over a storage period of 16 days with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE and T_4=Nuggets with flaxseed flour+BHT in Table 10. The results highlighted significant ($p\leq 0.05$) differences among treatments as well as changes over time within each group. Mouthcoating scores showed a declining trend across all treatments during storage. In T_1, the scores decreased from 7.13 on day 0 to 6.17 on day 16. A similar reduction was observed for T_2,

Table 10: Mouth coating scores of chicken meat nuggets

Sl. No.	Treatment	Storage days				
		0	4	8	12	16
1.	T_1	$7.13^{Ab}\pm 0.34$	$7.08^{b}\pm 0.54$	$6.54^{a}\pm 0.40$	$6.29^{Aa}\pm 0.25$	$6.17^{Aa}\pm 0.2$
2.	T_2	$7.67^{Bb}\pm 0.34$	$7.38^{b}\pm 0.26$	$6.71^{a}\pm 0.49$	$6.67^{ABa}\pm 0.47$	$6.25^{ABa}\pm 0.27$
3.	T_3	$7.71^{Bc}\pm 0.37$	$7.42^{c}\pm 0.26$	$7.00^{b}\pm 0.35$	$6.83^{Bab}\pm 0.20$	$6.54^{Ba}\pm 0.29$
4.	T_4	$7.71^{Bc}\pm 0.37$	$7.42^{c}\pm 0.26$	$6.88^{b}\pm 0.38$	$6.71^{ABab}\pm 0.37$	$6.33^{ABa}\pm 0.34$

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq 0.05$)

starting at 7.67 and reaching 6.25 by the end of the storage period. T_3, with an initial score of 7.71, showed a decline to 6.54, while T_4, which also started at 7.71, decreased to 6.33. At the beginning of storage (day 0), T_3 and T_4 had the highest mouthcoating scores of 7.71, followed by T_2 at 7.67, and T_1 with the lowest score of 7.13. This ranking was consistent throughout the storage period, with T_3 and T_4 maintaining relatively better scores compared to T_1 and T_2. Mouthcoating scores showed a general decline for all samples over storage, but treatments supplemented with BLE (T_3) and BHT (T_4) retained higher scores than those without antioxidants (T_1 and T_2). The most noticeable results indicated that T_3 samples recorded significantly ($p\leq0.05$) higher scores than T_1 on 0, 12 and 16 days of storage, reflecting the flaxseed and BLE effect on the product.

3.8. Overall acceptability scores

The overall acceptability scores reflected the combined influence of various sensory attributes and their decline over time (Table 11) with T_1=Nuggets without flaxseed flour, T_2=Nuggets with flaxseed flour, T_3=Nuggets with flaxseed flour+BLE and T_4=Nuggets with flaxseed flour+ BHT. Figure 1 depicts the sensory evaluation scores of the developed product on 8 point hedonic scale. For all treatments, a gradual reduction in overall acceptability scores was observed during storage. T_1 started at a score of 7.04 on day 0 and dropped to 5.75 by day 16. T_2 also showed a decline, starting at 7.33 and ending at 6.08. Tz maintained higher scores initially, with a value of 7.46 on day 0, but decreased to 6.25 by the end of the storage period. Similarly, T_4 exhibited an initial score of 7.42, which declined to 6.13 on day 16. At the beginning of storage, T_3 exhibited the highest acceptability score (7.46), followed closely by T_4 (7.42) and T_2 (7.33). T_1 had the lowest score among all treatments. Throughout the storage period, T_3 and T_4

Table 11: Overall acceptability scores of chicken meat nuggets

Sl. No.	Treat-ment	Storage days				
		0	4	8	12	16
1.	T_1	7.04^{Ac} ±0.19	6.88^{Ac} ±0.52	6.38^{Ab} ±0.38	6.08^{ab} ±0.38	5.75^{Aa} ±0.42
2.	T_2	7.33^{ABd} ±0.26	7.29^{ABd} ±0.37	6.83^{Bc} ±0.30	6.46^{b} ±0.37	6.08^{ABa} ±0.20
3.	T_3	7.46^{Bb} ±0.37	7.46^{Bb} ±0.37	7.00^{Bb} ±0.32	6.54^{a} ±0.37	6.25^{Ba} ±0.42
4.	T_4	7.42^{ABb} ±0.41	7.29^{ABb} ±0.25	6.96^{Bb} ±0.33	6.50^{a} ±0.42	6.13^{ABa} ±0.41

Means (Mean±SD, n=6) with different superscripts in upper case in a column and in lower case in a row differ significantly ($p\leq0.05$)

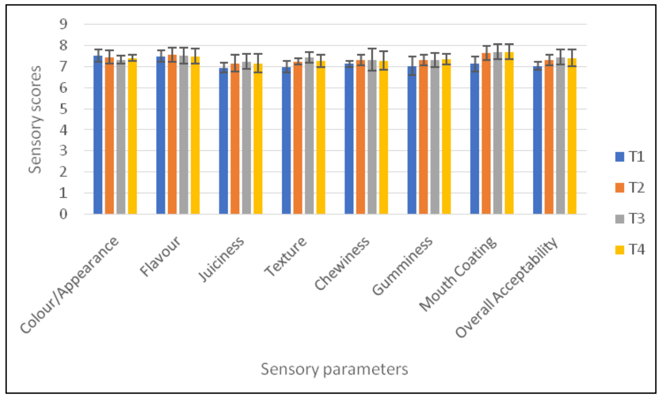

Figure 1: Sensory evaluation of the developed product on 8 point hedonic scale

consistently retained higher scores than T_1 and T_2 (Figure 1), demonstrating the effectiveness of antioxidants (BLE and BHT) in maintaining sensory quality. In maximum observations, the T_3 samples scored significantly ($p\leq0.05$) higher scores than T_1, indicating the combined effect of flaxseed and BLE on the product acceptability, where there was substantial improvement in the overall acceptability of T_3 samples. However, Bilek and Turhan (2009) in their study on the use of flaxseed flour as a functional ingredient in the production of beef patties reported that sensory scores for overall acceptability were decreased by increasing the levels of flaxseed.

4. CONCLUSION

Chicken meat nuggets across treatments showed gradual declines in all sensory scores over the 16-day storage period, with significant differences ($p\leq0.05$). No treatment prevented decline, but flaxseed formulations narrowed differences vs control, maintaining comparable acceptability. Antioxidants limited impact on colour stability but aided flavour/juiciness/texture preservation. Flaxseed-incorporated nuggets were sensorily acceptable, with T_3 optimal for storage stability. Oxidative changes and moisture loss drove deteriorations as expected; yet flaxseed improved texture/gumminess over the control group. Literature aligns variably, some report flaxseed dose-dependently lowers scores while others report otherwise.

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