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Research Article

Effect of oat flour on sensory and physico-chemical properties of chicken meatball

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Abstract

This study evaluated the effect of oats (0%, 5%, 10%, and 15%) on chicken meatball quality. The samples were stored at 4˚C for 12 days and analyzed on days 0, 4, 8, and 12. Sensory attributes (color, flavor, tenderness, juiciness, overall acceptability), physicochemical properties (proximate components, pH, cooking loss), and microbiological quality (TVC, TCC, TYMC) were assessed. Results showed that oats increased cooking yield by reducing weight loss from 26.95% to 27.76%. The 5% oats group had the most preferred color, odor, tenderness, and juiciness. The least preferred color was found in the control group. Flavor scores ranged from 3.91 to 4.8, with no significant differences, but the most preferred flavor was observed in the 10% oats group. Tenderness was highest in the 10% oats group, with scores ranging from 3.41 to 4.33. Juiciness scores ranged from 3.33 to 4.33, with no significant differences; the 5% oats group had the highest juiciness. Overall acceptability scores ranged from 3.50 to 4.16, with the highest score recorded in the 5% oats group. Dry matter content ranged from 47.05% to 50.67%, with the 5% oats group exhibiting the most preferable content. Crude protein content ranged from 19.97% to 21.71%, with significant differences observed between the control and 10% oats groups. Ether extract content ranged from 7.82% to 8.3%, with the 15% oats group having the lowest ether extract content. Ash content ranged from 1.19% to 1.35%, with significant differences across treatments. pH values of raw meatballs ranged from 5.55 to 5.69, with the 5% oats group showing the most preferable pH. Cooking loss ranged from 26.68% to 28.41%, with the most preferable cooking loss observed in the 15% oats group. TBA values ranged from 0.09 to 0.15, with no significant differences observed across treatments. Microbial counts (TVC, TCC, and TYMC) increased with storage time, with the control group showing the highest counts.

Introduction

According to the Bangladesh Economic Review (2024), the country's livestock includes 24.2 million cattle, 30.33 million goats, 3.5 million sheep, and 255.31 million chickens. The nation's economy is largely dependent on agriculture, with livestock being a key component among its four main sectors: crops, livestock, fisheries, and forestry (Baset et al., 2002). Meat, which refers to the edible flesh of animals, is a rich source of protein, iron, zinc, fatty acids, and essential vitamins (Rahman et al., 2023, Sagar et al., 2024; Sajib et al., 2023). However, fresh meat is highly perishable due to its biological composition, making it susceptible to contamination during slaughter and processing (Azad et al., 2021 and 2022; Das et al., 2022; Liza et al., 2024). As Tauhid (2015) noted, dietary fiber comprises two types: soluble fiber, which dissolves in water and acts as a prebiotic and insoluble fiber, which adds bulk and aids digestion. In modern times, changes in eating habits, driven by urbanization, smaller family units, rising incomes, and the growing number of working women, have led to an increased demand for ready-to-eat foods like canned, frozen, and convenience meals. Minced meat is a core component of meatballs, combined with spices, seasonings, and other ingredients, then cooked by frying or roasting. However, cooking can lead to liquid loss, impacting sensory quality and market value on the other hand, grinding meat exposes lipids to pro-oxidants, leading to oxidative reactions and potential quality deterioration (Asghar et al., 1991; Hashem et al., 2024). Microbial activity significantly affects meat quality, with lactic acid bacteria playing a crucial role in spoilage (Bithi et al., 2020). In Bangladesh, starch is commonly added to meatballs to improve texture and lower production costs. Key ingredients such as starch, water, and fat play critical roles in determining meatball quality. This study aims to examine the impact of oats on the proximate composition, physicochemical properties, and sensory attributes of chicken meatballs. Preservation is essential for maintaining the safety and nutritional value of meat products. Freezing is an effective method that slows spoilage while preserving meatballs in their natural state. However, the quality of frozen meatballs may vary depending on the freezing temperature. The experiment aims to evaluate the impact of refrigeration on meatballs by examining how it affects their sensory attributes, such as taste, texture, and aroma, over time. It will assess the influence of refrigeration on the nutritional content, including protein, vitamins, and minerals, as well as its effectiveness in inhibiting microbial growth to ensure food safety. Additionally, the study will analyze how refrigeration prolongs the shelf life of meatballs compared to storage at room temperature and investigate its role in retaining moisture levels, which directly affects texture and quality.

The effects of refrigeration on texture stability and firmness will also be examined to prevent undesirable changes during storage. Finally, the study will gauge consumer preferences regarding the quality and freshness of refrigerated meatballs in comparison to freshly prepared ones.

Materials and Methods

Sample Collection

Chicken meats (broiler) of 2.5 kg freshly slaughtered chicken were collected from K.R. Market‖, Bangladesh Agricultural University (BAU), Mymensingh at 10.00 a.m. The meat samples were immediately transferred to the Animal Science Laboratory.

Preparation of Jar and Other Instrument

All necessary instruments and jars or containers were cleaned with hot water and detergent powder, and then dried properly before starting the experimental activities.

Sample Preparation

A total of 2.5 kg of fresh chicken meat was prepared for meatball production. The meat was thoroughly cleaned, trimmed of fat, and ground. Spices, garam masala, salt, ice flakes, refined vegetable oil, oats, and sauce were mixed with the ground meat according to the experimental design, which included four treatment groups: T_0 (control, no flour), T_1 (5% oats), T_2 (10% oats), and T_3 (15% oats). Meatballs were shaped separately, boiled in hot water for 2-3 minutes, and excess water was drained. Finally, the meatballs were fried in hot oil until they turned reddish-brown.

Ingredients

The following ingredients were used for making meatballs. Fresh chicken meat, garlic pest, onion pest, ginger pest, meat spices, garam masala, egg, cookies crumbs, ice flakes, refined vegetable oil, refined oats.

Procedure of Meatball Preparation

The chicken meat was first cleaned thoroughly with water, and all visible fat was trimmed off using a knife. The meat was then ground using a meat grinder. Spices, including garam masala, salt, onion paste, garlic paste, ginger paste, sauce, ice flakes, refined vegetable oil, and refined oats, were mixed thoroughly with the ground meat. The mixture was divided into four parts, and meatballs weighing approximately 20-25 g each were prepared. These meatballs were boiled in hot water at 100ºC for 2-3 minutes. After boiling, the meatballs were removed from the water, and egg albumin was mixed with each type separately. Cookie crumbs were then added to each type of meatball, ensuring proper coating. Finally, the meatballs were fried in refined vegetable oil at 100ºC for 3-4 minutes. Once fried, the meatballs were removed from the oil and prepared for further analysis.

Different analytical characteristics of meatball samples

Sensory evaluation

A sensory evaluation was conducted to assess various attributes of meatball samples using a trained 8-member panel. The evaluation focused on color, smell, tenderness, juiciness, and overall acceptability, measured on a 5-point balanced semantic scale ranging from weak to strong. Panelists, consisting of department staff and students, were trained following the American Meat Science Association guidelines (AMSA, 1995). The evaluation was carried out under controlled conditions of light, temperature, and humidity in individual booths. Before the evaluation, panelists participated in orientation sessions to familiarize themselves with the intensity scale for the sensory attributes. The sensory qualities of the samples were assessed after thawing both before and after cooking, using a 5-point scoring method: 5 (excellent), 4 (very good), 3 (good), 2 (fair), and 1 (poor) as described by Rahman et al. (2012). Samples were served in petri dishes, and evaluations were conducted on days 0, 4, 8, and up to the end of refrigerated storage at 4 ± 1ºC.

Proximate Composition

Proximate composition such as dry matter, ether extract, crude protein and ash were carried out according to the methods (AOAC, 1995). All determinations were done in triplicate and the mean values were reported.

Biochemical analysis

Thiobarbituric Acid Values

Lipid oxidation was assessed in triplicate using the 2-thiobarbituric acid (TBA) method described by Schmedes and Holmer et al. (1989). Chicken meatball samples (5 g) were blended with 25 ml of 20% trichloroacetic acid solution (200g/l of tricholoroacetic acid in 135 ml/l phosphoric acid solution) in a homogenizer (IKA) for 30s. The homogenized samples were filtered with Whatman filter paper number 4 and 2 ml of the filtrate was added to 2 ml of 0.02 M aqueous TBA solution (3 g/l) in a test tube. The test tubes were incubated at 100oC for 30 min and cooled with tap water. The absorbance was measured at 532 nm using a UV-VIS spectrophotometer (UV-1200, Shimadzu, Japan). The TBARS value was expressed as mg malonaldehyde per kilogram of meatball sample.

Physico-chemical properties measurement 3 .14.1 raw pH measurement

The pH value of raw meatball was measured using pH meter from raw meatball homogenate. The homogenate was prepared by blending 5 g of meat with 10 ml distilled water.

Cooked pH measurement

The pH value of cooked meatballs was measured using pH meter from cooked meatball homogenate. The homogenate was prepared by blending 5 g of meat with 10 ml distilled water.

Microbial assessment

Microbial assessment was conducted to determine the total viable count (TVC), total coliform count (TCC), and yeast-mold count (YMC) in chicken meat samples, following ISO guidelines (ISO, 1995). For sample preparation, 10 g of chicken meat was aseptically excised and macerated with 90 mL of 0.1% peptone water to create a 1:10 dilution. Serial dilutions ranging from 10^{-2} to 10^{-6} were prepared using a whirly mixer. Plate count agar (PCA), MacConkey agar (MA), and potato dextrose agar (PDA) were used for bacterial and fungal enumeration. Media preparation involved dissolving specified quantities in distilled water, boiling, sieving, and sterilizing in an autoclave at 121°C for 30 minutes. The media were maintained at 45°C before use. For enumeration of TVC, A 0.1 mL aliquot of each tenfold dilution was spread on PCA plates in triplicate and incubated at 37°C for 24-48 hours. Plates with 30-300 colonies were counted using a colony counter, and TVC was calculated as CFU/g of chicken meat (ISO, 1995).For enumeration of TCC,A 0.1 mL aliquot of each tenfold dilution was spread on MA plates in triplicate and incubated at 37°C for 24-48 hours. Plates with 30-300 colonies were counted, and TCC was expressed as CFU/g of chicken meat (ISO, 1995). For enumeration of TYMC, A 0.1 mL aliquot of each tenfold dilution was spread on PDA plates in duplicate and incubated at 37°C for 48-72 hours. Colonies were counted using a colony counter, and TYMC was calculated as CFU/g of chicken meat (ISO, 1995).

Statistical model and analysis

The statistical model used for the experiment was a factorial design with two factors: treatments (A) and days of intervals (Data were analyzed using SAS Statistical Discovery Software (NC, USA), and the DMRT test was employed to identify significant differences among treatment means (Tauhid, 2015).

Result and Discussion

Sensory Evaluation

Color

The color scores of different treatments across day intervals are presented in Table 1, with an overall range of 3.25 to 4.91. Significant differences ($p<0.05$) were observed among the four treatments, with the most preferred color from the 15% oat group and the least preferred from the control group. Over time, the color scores ranged from 3.25 on day 12 to 4.91 on day 0, with significant differences between 0 and 12 days and slight changes observed between 8 and 12 days. The most preferred color was on day 0, while the lowest score of 2.83 was recorded across all treatments by day 12. The decline in color scores during storage was attributed to protein denaturation, especially of myofibrillar proteins affecting gel formation, as well as protein damage caused by free radicals generated during lipid oxidation and the presence of transition metals, leading to oxidized protein accumulation. This aligns with findings by Descalzo and Sancho (2008), who noted the loss of functionality in meat active peptides due to oxidation. Significantly ($p<0.05$) higher color scores were observed in the control group. The color of beef is influenced by the reversible conversion of myoglobin's redox state, which depends on oxygen availability, active enzymes, and reducing compounds present in the muscle (Tushar et al., 2023).

Flavor

The flavor scores of different treatments over time, as presented in Table 1, ranged from 3.91 to 4.8, with no significant differences ($p>0.05$) among the treatments, as indicated by the same superscripts. The most preferable flavor was observed in the 10% oats group. Flavor scores across different storage days ranged from 2.75 to 4.75, with significant differences ($p<0.05$) noted between day 0 and day 12, as well as between day 8 and day 12. The flavor was stable up to day 8 but deteriorated significantly by day 12, reflecting the impact of extended storage on quality. Flavor deterioration is a critical factor in sensory quality loss, as noted by Raghavan et al. (2007), affecting attributes like color, texture, odor, and nutritional value. Nunez and Boleman (2008) highlighted the need for cost-effective natural antioxidants to mitigate these effects while maintaining product quality and consumer satisfaction.

Tenderness

The tenderness scores of different treatments over time are summarized in Table 1, with an overall range of 3.41 to 4.33. There were no significant differences ($p>0.05$) in tenderness among the treatments, as indicated by the same superscripts. The 10% oats group had the most preferred tenderness, while the 5% oats group had the least. Across days, tenderness scores ranged from 3.91 to 4.75, with significant differences ($p<0.05$) observed between day 0, 4, 8, and 12 observations. Tenderness was highest on day 0 and day 4 and lowest by day 12, with scores reduced to 3.41 in all treatments after 12 days of storage. Moisture loss during freezing, due to ice crystals puncturing muscle cells and subsequent leakage during cooking, contributed to reduced tenderness. Repeated freezing accelerated moisture loss, resulting in a denser and drier texture. Tenderness was inversely related to the dry matter content, which increased over the storage period. These findings align with Liu et al. (2010), who noted similar trends.

Table 1. Effect of oats on sensory parameters in chicken meatballs

		Treatments					Level of significance		
Parameters	**DI**	**T_0**	**T_1**	**T_2**	**T_3**	**Mean**	**Treat**	**DI**	**T×DI**
Color	**0**	5.00±0.00	4.67±0.58	4.67±0.58	5.00±0.00	4.83a	*	**	NS
	4	5.00±0.00	4.00±0.00	5.00±0.00	4.67±0.58	4.66a			
	8	4.00±0.00	3.33±0.58	4.00±0.00	3.33±0.58	3.66b			
	12	3.00±0.00	3.00±1.00	2.66±0.58	2.67±0.58	2.83c			
	Mean	3.25a	3.75b	4.08ab	4.91ab				
Flavor	**0**	5.00±0.00	4.67±0.58	4.67±0.58	4.67±0.58	4.75a	NS	**	NS
	4	5.00±0.00	4.67±0.58	4.67±0.58	3.67±0.58	4.50a			
	8	3.67±0.58	3.67±0.58	4.00±0.00	4.00±0.00	3.83b			
	12	2.67±0.58	2.67±0.58	3.00±0.00	2.67±0.58	2.75c			
	Mean	4.08a	3.91a	4.08a	3.75a				
Tenderness	**0**	5.00±0.00	4.67±0.58	4.67±0.58	5.00±0.00	4.83a	**	**	NS

	4	4.67±0.58	4.33±0.58	3.67±0.58	4.00±1.00	4.16b			
	8	4.00±0.00	3.67±0.58	2.67±0.58	2.67±0.58	3.25c			
	12	3.67±0.58	3.00±1.00	3.00±0.00	2.00±0.00	2.91c			
	Mean	4.33a	3.91ab	3.5bc	3.41c				
Juiciness	**0**	5.00±0.00	4.67±0.58	4.67±0.58	4.67±0.58	4.75a	**	**	NS
	4	4.67±0.58	4.00±0.00	3.67±0.58	3.67±0.58	4.00b			
	8	4.00±0.00	3.67±0.58	2.67±0.58	2.67±0.58	3.25c			
	12	3.67±0.58	3.00±0.00	3.00±0.00	2.33±0.58	3.00c			
	Mean	4.33a	3.83b	3.50bc	3.33c				
Overall acceptability	**0**	4.67±0.58	4.67±0.58	4.67±0.58	4.67±0.58	4.66a	*	**	NS
	4	4.67±0.58	4.67±0.58	4.67±0.58	4.67±0.58	4.66a			
	8	4.67±0.58	4.67±0.58	4.00±1.00	2.67±0.58	4.00b			
	12	2.67±0.58	2.67±0.58	2.67±0.58	2.00±0.00	2.50c			
	Mean	4.16a	4.16a	4.00a	3.50b				

Column mean value having different superscript varies significantly at values p < 0.05. Again, mean values having same superscript in each row did not differ significantly at p > 0.05. T_0=Control group, T_1= 05% oats group, T_2=10% oat group, T_3=15% Oats group, DI=Day Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Day Intervals.

Juiciness

The juiciness scores of different treatments over time are presented in Table 1, with an overall range of 3.33 to 4.33. There were no significant differences (p>0.05) in juiciness among treatments, as indicated by the same superscripts. The 5% oats group showed the highest juiciness score, while the 15% oats group had the lowest. Across days, juiciness scores ranged from 3.00 to 4.75, with significant differences (p<0.05) observed between day 0, 4, 8, and 12 observations, as well as between day 8 and 12. Juiciness was highest on day 0 and decreased significantly by day 12, with the lowest score of 3.33 across treatments after 12 days of storage. Juiciness reduction is attributed to moisture loss during storage and cooking, as freezing and refreezing processes cause cell damage and further moisture leakage, resulting in a dense and dry texture. These findings align with the observations of Liu et al. (2010).

Overall acceptability

The overall acceptability scores of different treatments over time, as shown in Table 1, ranged from 3.50 to 4.16, with no significant differences (p>0.05) observed among treatments, as indicated by the same superscripts. Among the four treatments, the 5% oats group had the highest overall acceptability score. Across different storage intervals, the scores ranged from 2.50 to 4.66, with significant differences (p<0.05) noted between observations on the 8th and 12th days. The most preferable overall acceptability was recorded on day 0, while the lowest score of 2.50 was observed for all treatments after 12 days of storage. This decline highlights the impact of storage duration on the sensory quality and acceptability of the meatballs.

Proximate Analysis

Dry Matter

The dry matter content of different treatments over storage intervals, as shown in Table 2, ranged from 47.05% to 50.67%, with no significant differences (p>0.05) among treatments, as indicated by the same superscripts. Among the four treatments, the most preferable dry matter content was observed in the 5% oats group, while the control group had the highest dry matter content, making it less preferable. Across storage intervals, the dry matter content ranged from 47.96% to 49.08%, with significant differences (p<0.05) observed between day 0 and day 12. The lowest and most preferable dry matter content was recorded on day 0, while the highest dry matter content, 50.67%, was observed after storage. This increase in dry matter content during storage aligns with findings by Purnomo and Rahardiyan (2008), who reported a range of 56.17% to 60.32% in Indonesian traditional meatballs. Similarly, Devatkal et al. (2010) and Naveena et al. (2008) noted increased dry matter content during extended storage due to moisture loss in beef and goat meat products, even with the inclusion of natural extracts. The dry matter (DM) content increased over the storage period, likely due to reduced moisture loss, as noted by Boby et al. (2021).

Crude Protein

The crude protein (CP) content of different treatments over various storage days, as shown in Table 2, ranged from 19.97% to 21.71%. Significant differences (p<0.05) in CP content were observed between the control group and the 10% oat flour group, while no significant differences were found among the 5% and 15% oats treatments (p>0.05). The control group contained the highest amount of CP, making it the most preferable for consumers' health, while the lowest CP content was observed in the 5% oats group. Regarding the storage period, there were no significant differences (p>0.05) in CP content among the days of observation. The most preferable CP content was observed on day 4, while the least preferable was seen on day 12, with a decrease to 20.30% across all treatments by the 12th day of storage. The CP content in this study was lower than that reported for Indonesian beef meatballs, which ranged from 13.38% to 14.44%, according to Purnomo and Rahardiyan (2008). Traditional koefte meatballs have been reported to have higher protein content (25.51%) as per Ulu (2004). Similarly, pork meatballs have shown protein content ranging from 25.51% to 29.85%, as reported by Ulu (2004).

Ether Extract

The EE (Ether Extract) content of different treatments over various days is shown in Table 2. The observed EE content in different treatments ranged from 7.82% to 8.3%. Significant differences (p<0.05) were noted between the 10% oats, control, 5%, and 15% oats groups, with the 15% oats group containing the lowest amount of EE. The same superscript observed across control, 5%, and 15% oats groups indicates no significant differences (p>0.05) in EE content among these treatments. The lowest EE content suggests this product is more preferable for consumers' health. The highest EE content was observed in the 15% oats group. In terms of days, the overall EE content ranged from 8.02% to 8.46%. Significant differences (p<0.05) were noted between the 4th, 8th, and 12th days, with the most preferable EE content observed on the 4th day and the least preferable content at the 0th day. After 0 days of storage, the EE content increased to 8.56% across all treatments. Fat content in low-fat traditional Turkey koefte beef meatballs ranging from 7.9% to 8.8%, which was lower than the normal traditional koefte with a fat content of 14.70%, as reported by Ulu (2004). Verma et al. (2009) also reported a significant decrease in fat content when oats were incorporated into low-fat chicken nuggets.

Ash

The ash content of different treatments over various days is shown in Table 2. The observed ash content in different treatments ranged from 1.19% to 1.35%. Significant differences ($p<0.05$) were observed among the four treatment groups, with the 5% oats group having the lowest ash content, indicating it is more preferable for consumers' health. The highest ash content was noted in the control and 10% oats groups, which were considered less preferable. The range of ash content over different days of intervals was 1.19% to 1.39%. Significant differences ($p<0.05$) were observed between the 0th, 4th, 8th, and 12th days of observation, with significant differences between the 8th and 12th days ($p>0.05$). Ash content significantly changed with the increased storage period, with the most preferable ash content observed on the 4th day and the least preferable on the 12th day. After 12 days of storage, the highest ash content increased to 1.39% across all treatments. Similar findings were reported for Malaysian commercial beef meatballs, where ash content ranged from 1.76% to 3.40. According to Akter et al. (2009), the ash content in beef decreased, possibly due to the loss of volatile minerals during storage.

Table 2: Effects of oats on proximate components in chicken meatballs

		Treatments					Level of significance		
Parameters	**DI**	**T_0**	**T_1**	**T_2**	**T_3**	**Mean**	**Treat**	**DI**	**T×DI**
	0	52.47±0.51	46.33±0.41	44.49±0.33	53.02±0.16	49.08a			
	4	49.40±0.35	46.31±0.53	53.12±0.13	47.69±0.38	49.13a			
DM	**8**	50.36±0.36	47.05±0.15	52.50±0.41	46.18±0.18	49.02a	NS	NS	NS
	12	50.47±0.20	48.53±0.33	45.48±0.25	47.34±0.17	47.96b			
	Mean	50.67a	47.05b	48.90b	48.56c				
	0	22.55±0.22	22.82±0.15	20.62±0.24	20.03±0.19	21.50a			
	4	21.36±0.15	21.07±0.18	19.75±0.20	20.38±0.27	20.64c			
CP	**8**	21.10±0.10	22.37±0.27	19.65±0.05	20.07±0.06	20.30d	**	**	**
	12	21.84±0.13	20.86±0.11	19.86±0.17	20.65±0.05	20.80d			
	Mean	21.71a	21.28b	19.97d	20.28c				
	0	7.83±0.05	8.51±0.04	8.87±0.06	8.64±0.02	8.46a			
	4	8.39±0.05	7.76±0.05	8.54±0.02	7.42±0.05	8.02c			
EE	**8**	8.33±0.05	7.83±0.05	8.42±0.05	7.58±0.05	8.04c	**	**	**
	12	7.88±0.04	8.57±0.04	8.40±0.07	7.65±0.12	8.12b			
	Mean	8.11c	8.17b	8.56a	7.82d				
	0	1.25±0.01	1.27±0.00	1.25±0.00	1.30±0.00	1.27b			
	4	1.22±0.01	1,.13±0.02	1.16±0.01	1.25±0.00	1.19d			
Ash	**8**	1.20±0.01	1.20±0.01	1.21±0.01	1.32±0.01	1.23c	**	**	**
	12	1.36±0.01	1.34±0.01	1.34±0.01	1.37±0.01	1.35a			
	Mean	1.25b	1.23c	1.24c	1.31a				

Column mean having different superscript varies significantly at values $p<0.05$. Again, mean values having same superscript in each row did not differ significantly at $p> 0.05$. T_0=Control group, T_1= 05% oats group, T_2= 10% oats group, T_3= 15% 0ats group, DI=Day Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Day Interval

Physicochemical properties

The physicochemical properties such as raw pH, cooked pH and cooking loss were determined and the results are shown in the Table 3.

pH of raw meatball

The raw pH of different treatments over various days is shown in Table 3. The observed raw pH ranged from 5.55 to 5.69, with significant differences ($p<0.05$) observed among the four treatment groups. The data indicated a slight increase in raw pH values and a decrease in acidity values across all samples. Among these treatments, the 5% oat group exhibited the most preferable raw pH, suggesting that it is healthier for consumers compared to other treatments. The range of raw pH over different day intervals was 5.84% to 5.48%. Significant differences ($p<0.05$) were observed across these intervals, with raw pH decreasing as the storage period increased. The data showed a slight decrease in raw pH and an increase in acidity values over the 12 days of storage, likely due to the formation of free fatty acids caused by rancidity. The growth of bacteria and mold also increased with storage time, further affecting raw pH. These findings align with those of Biswas et al. (2004), who found similar results in antioxidant-treated precooked pork patties during storage, and McCarthy et al. (2001), who observed similar trends in pork patties containing BHT/BHA antioxidants during refrigerated storage.

pH of cooked meatball

The cooked pH of different treatments over various days is shown in Table 3. The observed cooked pH ranged from 6.07% to 5.94%, with no significant differences ($p>0.05$) among the four treatment groups. The data indicated a slight increase in cooked pH values and a decrease in acidity values across all samples. The range of cooked pH over different day intervals was 5.14% to 6.12%. Significant differences ($p<0.05$) were observed between the 0th and 4th day observations, while no significant differences ($p>0.05$) were found between the 0th, 4th, and 12th day observations. The most preferable cooked pH was observed on the 0th day, and the least preferable was observed on the 12th day. Similar findings were reported by Biswas et al. (2004) in antioxidant-treated precooked pork patties. Sharker et al. (2024) observed similar results, linking the pH increase in the control group to bacterial acid consumption during protein degradation.

Cooking loss

The cooking loss of different treatments at various days' intervals is shown in Table 4.3. The observed cooking loss ranged from 26.68% to 28.41%. The same superscript was observed across all treatment groups, indicating no significant differences ($p>0.05$) in cooking loss among the groups. Among the four treatments, the most preferable cooking loss was observed in the 15% oats group, suggesting that this group is more favorable for consumers based on cooking loss. The overall cooking loss ranged from 27.76% to 26.95% at different days' intervals. Significant differences ($p<0.05$) were observed between the 0th, 4th, 8th, and 12th days of observation, indicating that cooking loss decreased as the storage period increased. The least preferable cooking loss was observed on the 0th day, while the most preferable was observed on the 12th day. Cooking loss refers to the reduction in weight of meatballs during cooking, as described by Jama et al. (2008). Major components of cooking loss include thawing, dripping, and evaporation. Thawing loss occurs when fluid is lost from meatballs as a result of exudate formation following freezing and thawing, with lower losses seen after rapid freezing compared to slow freezing (Jama et al., 2008). Dripping refers to fluid loss from meatballs, while evaporation occurs from the shrinkage of muscle proteins during cooking (Yu et al., 2005).

Table 3. Effects of oats on physicochemical properties in chicken meatballs

Parameters	DI	Treatments					Level of significance		
		T_0	T_1	T_2	T_3	Mean	Treat	DI	T×DI
Raw pH	**0**	5.86±004	5.86±0.05	5.78±0.07	5.86±0.02	5.84a	*	**	**
	4	5.53±0.04	5.79±0.07	5.46±0.05	5.66±0.04	5.61b			
	8	5.62±0.02	5.69±0.09	5.45±0.03	5.43±0.04	5.55c			
	12	5.74±0.04	5.30±0.04	5.53±0.02	5.35±0.06	5.48d			
	Mean	5.69a	5.66a	5.55b	5.57b				
Cooking pH	**0**	6.10±0.04	6.13±0.02	6.11±0.04	6.14±0.04	6.12a	NS	*	NS
	4	5.87±0.05	5.93±0.05	6.07±0.06	6.15±0.12	6.00ab			
	8	6.02±0.08	5.75±0.59	5.96±0.04	6.04±0.06	5.94b			
	12	5.84±0.26	5.96±0.04	6.02±0.05	5.95±0.05	5.94b			
	Mean	5.96a	5.94a	6.04a	6.07a				
Cooking loss	**0**	28.26±0.05	26.50±0.10	29.24±0.19	27.06±0.05	27.76a	**	**	**
	4	26.37±0.05	27.29±0.05	28.02±0.05	26.13±0.04	26.95d			
	8	27.05±0.03	28.05±0.04	28.06±0.05	26.52±0.02	27.42b			
	12	25.86±0.06	27.35±0.04	28.34±0.02	27.02±0.05	27.14c			
	Mean	26.88c	27.30b	28.41a	26.68d				

Column mean having different superscript varies significantly at values $p<0.05$. Again, mean values having same superscript in each row did not differ significantly at $p> 0.05$. T_0=Control group, T_1= 05% oats group, T_2= 10% oat group, T_3= 15% 0ats group, DI=Day Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Day Interval

Biochemical properties

Thiobarbituric Acid Value

Table 4 highlights the effects of synthetic antioxidants and various levels of natural antioxidants on TBA (thiobarbituric acid) values compared to the control group. Overall, TBA levels significantly increased ($p<0.05$) with storage time, indicating a decrease in shelf life due to lipid oxidation. The observed TBA values ranged from 0.09 to 0.15 across different days, with no significant differences ($p>0.05$) between the 0th, 4th, 8th, and 12th days of observation. The malondialdehyde content, which is indicative of lipid oxidation, increased significantly over time, with the control group exhibiting a higher rate of malondialdehyde formation compared to samples treated with antioxidants. After 3 days of storage, the malondialdehyde content in the antioxidant-treated samples was significantly lower, likely due to the antioxidant activity of polyphenols, which many studies (e.g., Frankel, 1991) have shown to slow down the oxidation process in food. In terms of TBA values, the control group, without any added antioxidants, showed higher levels compared to the 5%, 10%, and 15% oats treatments. On day 12, TBA values were 0.14 for the control group, compared to 0.09, 0.11, and 0.15 for the 5%, 10%, and 15% oats treatments, respectively. These values were not significantly different ($p>0.05$) across the four treatments, but the 5%, 10%, and 15% oats groups exhibited the most preferable TBA values. This trend is consistent with other studies showing that natural antioxidants have the potential to replace synthetic antioxidants in food. For example, Racanicci et al. (2004) found that lipid oxidation increased over time in meatballs, but antioxidants like dittany and rosemary (at a concentration of 0.10%) significantly protected the product by lowering TBARS levels

Table 4: Effects of oats on Biochemical properties in chicken meatballs

Parameters	DI	Treatments					Level of significance		
		T_0	T_1	T_2	T_3	Mean	Treat	DI	T×DI
	0	0.093±0.015	0.120±0.010	0.140±0.030	0.113±0.025	0.11^{a}			
	4	0.077±0.020	0.113±0.025	0.183±0.035	0.136±0.015	0.12^{ab}			
TBARS	**8**	0.100±0.026	0.120±0.020	0.140±0.020	0.163±0.015	0.13^{ab}	**	*	NS
	12	0.117±0.030	0.160±0.010	0.123±0.025	0.153±0.030	0.14^{a}			
	Mean	0.09^{c}	0.11^{b}	0.15^{a}	0.14^{a}				

Column mean having different superscript varies significantly at values $p<0.05$. Again, mean values having same superscript in each row did not differ significantly at $p> 0.05$. T_0=Control group, T_1= 05% oats group, T_2= 10% oats group, T_3= 15% 0ats group, DI=Day Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Day Interval

Microbiological Assessment

The study examined microflora (TVC) and pathogens (Coliform, Yeast Molds) in control and treatment groups over 0, 7, and 14 days at 4ºC. Significant differences were found across treatments, intervals, and their interactions. TVC, TCC, and TYMC ranged from 4.41–5.16, 1.15–1.38, and 1.74–2.09, respectively, indicating the impact of treatment and storage time on microbial dynamics.

Total Viable Count

The study revealed that the total viable count (TVC) in the control sample was significantly higher than in oil-treated samples across all treatments. The preferable TVC was observed on day 0, with the lowest on day 14. After 14 days of refrigerated storage, TVC ranged from 4.41 to 5.16 (log10 CFU/g) across treatments and 4.55 to 4.79 across intervals. TVC increased with storage time, with the T2 group showing the lowest counts, making it the most consumer-preferred. These findings highlight the effectiveness of certain oils in reducing microbial growth in chicken meat. Spices and plant extracts exhibit antimicrobial properties.

Total coliform count

The total coliform count (TCC) in the control sample was significantly higher than in oil-treated samples across all treatments. The most preferable TCC was observed on day 0, with the lowest on day 12. After 12 days of refrigerated storage, TCC ranged from 1.15 to 1.38 (log10 CFU/g) across treatments and 1.18 to 1.31 across intervals, with counts increasing over time. The T_2 group had the lowest TCC, making it the most consumer-preferred.

Total yeast-mould count

The total yeast-mold count (TYMC) in the control sample was significantly higher than in oil-treated samples across all treatments. The most preferable TYMC was observed on day 0, with the lowest on day 12. After 12 days of refrigerated storage, TYMC ranged from 1.74 to 2.09 (log10 CFU/g) across treatments and 1.82 to 1.86 across intervals, increasing over time. The T2 group exhibited the lowest TYMC, indicating its health preference. Antibacterial action inhibited fat deterioration and bacterial metabolism. The reduced TYMC in treated meat is linked to the antifungal properties of oils. The lower TYMC in the treated meat samples may be attributed to the antifungal properties of the oils (Akhter et al., 2022).

Table 5: Effects of oats on Microbiological Assessment in chicken meatballs

Parameters	DI	Treatments					Level of significance		
		T_0	T_1	T_2	T_3	Mean	Treat	DI	T×DI
	0	4.73±0.00	4.54±0.00	4.51±0.01	4.47±0.02	4.56^b			
TVC	4	4.92±0.01	4.45±0.03	4.41±0.02	4.41±0.02	4.55^b	*	NS	**
(logCFU/g)	8	5.26±0.01	4.43±0.03	4.40±0.08	4.32±0.05	4.60^b			
	12	5.74±0.58	4.51±0.05	4.48±0.02	4.45±0.05	4.79^b			
	Mean	5.16^a	4.48^b	4.45^b	4.41^b				
	0	1.23±0.01	1.17±0.02	1.14±0.01	1.20±0.02	1.18^d			
TCC	4	1.28±0.02	1.16±0.01	1.03±0.01	1.44±0.02	1.23^c	**	**	**
(logCFU/g)	8	1.34±0.02	1.07±0.00	1.91±0.01	1.31±0.01	1.41^a			
	12	1.38±0.01	1.20±0.01	1.46±0.01	1.22±0.02	1.31^b			
	Mean	1.31^b	1.15^d	1.38^a	1.29^c				
	0	1.97±0.01	1.84±0.00	1.76±0.01	1.78±0.02	1.84^{bc}			
TYMC	4	2.05±0.01	1.76±0.01	1.75±0.02	1.73±0.04	1.82^c	**	**	**
(logCFU/g)	8	2.15±0.02	1.73±0.02	1.71±0.02	1.76±0.00	1.84^{ab}			
	12	2.19±0.01	1.75±0.03	1.75±0.01	1.74±0.00	1.86^a			
	Mean	2.09^a	1.77^b	1.74^c	1.75^c				

Column mean having different superscript varies significantly at values p<0.05. Again, mean values having same superscript in each row did not differ significantly at p> 0.05. T_0=Control group, T_1= 05% oats group, T_2= 10% oats group, T_3= 15% 0ats group, DI=Day Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Day Interval** means significant at 1% level of probability.

Conclusion

Among four treatments most preferable color, odor, tenderness, juiciness was observed at 5% oats group and less preferable color was observed from control group. Among these four treatments most preferable dry matter content was observed from 5% oats group. The lowest amount dry matter content indicates this product is most preferable. Less preferable dry matter content was observed from control group. The highest amount of dry matter content indicates this product is less preferable. The same superscript was observed at 05% and 15% oats treatments indicate there were significant difference of crude protein among these treatments. Control group contain more amount of CP than other groups. The highest amount of CP content indicates this product is most preferable for consumer's health. Less preferable CP content was observed at 10% oats group. Among four treatments most preferable raw pH was observed from controlled group. The highest amount of raw pH indicates this product is most preferable for consumers' health than other treatment groups to 5.69%. Among these four treatments most preferable cooked pH was observed from 05 % oats group. The highest amount of cooked pH indicates this product is most preferable for consumers' health than other treatment groups. Among four treatments, the 10% oats group was significantly higher than all treatments. Meatballs with oats inclusions at 5% were most acceptable.

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