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Research Article

Effect of edible oil on the quality of beef in short-term preservation

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Abstract

This study evaluated the influence of olive, mustard, sesame, and soybean oils on the quality and preservation of raw beef stored at 4±1ºC. Meat was divided into five groups: T_0 (control), T_1 (olive), T_2 (mustard), T_3 (sesame), and T_4 (soybean), with assessments on days 0, 3, 6, and 9 for physicochemical, oxidative, microbial, and sensory parameters. Oil treatments significantly impacted meat properties ($P<0.05$). pH levels were lowest in T_4 (soybean), while the control increased from 5.23 to 6.88 after 9 days ($P<0.01$). Water-holding capacity (WHC) was highest in T_3 (sesame) (93.29–94.40%), and drip loss was lowest in T_1 (olive) ($P<0.001$). Cooking loss was most favorable in T3 (26.62–27.71%). Color values were best in T_3, with L* (42.06), a* (16.81), and b* (10.52) ($P<0.01$). TBARS values were lowest in T_1 (0.20–0.56), indicating superior oxidative stability ($P<0.01$). Proximate composition showed T_2 (mustard) had the lowest dry matter (25.96–27.03%), T_1 had the highest crude protein (21.74%) and the lowest ether extract (2.47–2.65%). Ash content increased with storage, with T_4 showing the highest values (1.27–1.36%). Oil-treated samples had lower microbial counts ($P<0.05$). TVC ranged from 5.33 to 5.52 log10 CFU/g, with T_1 being the lowest. T_1 also had the lowest total coliform count (2.44–2.90 log10 CFU/g), while T_2 had the lowest yeast-mold count (2.48–2.87 log10 CFU/g). Overall, olive oil (T_1) was most effective in prolonging shelf life, reducing lipid oxidation, and microbial proliferation. Sesame oil (T_3) improved color, WHC, and cooking yield. Mustard oil (T_2) contributed to dry matter content and antimicrobial effects, while soybean oil (T_4) supported ash content and pH stability. Oil incorporation improves meat quality, shelf life, and consumer acceptability.

Introduction

According to the most recent statistics from the Department of Livestock Services (DLS) for 2023-2024, the livestock populace in Bangladesh comprises approximately 250.13 lakh cattle, 271.2 lakh goats, 39.03 lakh sheep, and 15.2 lakh buffalo, in addition to nearly 3277.78 lakh chickens and 682.6 lakh ducks. (Livestock Economy, DLS, 2024). The nation's economy is largely dependent on agriculture. Among its four main sectors—crops, livestock, fisheries, and forestry—livestock significantly contributes to the national economy (Baset et al., 2002; Rahman et al., 1997 and 2002). The livestock sector makes a substantial contribution to the nation's GDP, accounting for 1.80% of the overall GDP and 16.33% of agricultural GDP, while providing direct employment to 20% of the population and part-time employment to 50%. Meat is vital for human nutrition, offering a wide range of macro- and micronutrients (Liza et al., 2024; Asghar et al., 1991). In the fiscal year 2023-2024, meat production reached 92.25 lakh metric tons, exceeding the national demand of 76.21 lakh metric tons. Meat refers to the edible flesh of animals, which is high in protein, iron, zinc, fatty acids, and essential vitamins (Chakrabartty et al., 2024; Rahman et al., 2023). Despite its nutritional value, fresh meat is highly perishable due to its biological composition (Das et al., 2022), and contamination during slaughtering and processing is common. Microorganisms can lead to undesirable changes in meat quality, with lactic acid bacteria playing a major role in spoilage (Bithi et al., 2020). Meat spoilage generally results from two primary causes: microbial growth or chemical deterioration. Lipid oxidation, a key factor in chemical spoilage, has a significant impact on the quality of processed meat, affecting color, texture, odor, flavor, and nutritional value (Gonzalez et al., 2008; Sadakuzzaman et al., 2021 and 2024; Sagar et al., 2024). This oxidative process, which occurs in the unsaturated fatty acids of meat, not only deteriorates meat quality but can also generate harmful compounds such as lipid peroxide and malondialdehyde (MDA), which have been linked to mutagenesis and cancer in living organisms (Verma et al., 2009).To extend their freshness, meat is often processed, with cooking being a common method. However, cooking can have both positive and negative effects on meat quality (Torun et al., 2023). Preserving meat while ensuring its quality and safety stands as a critical endeavor within the food industry, and refrigeration, particularly when complemented by natural preservatives, has emerged as a highly effective methodology. Historically, refrigeration has served as a fundamental technique for prolonging the shelf life of meat; however, recent technological advancements over the past century have significantly augmented its efficacy. In Bangladesh, the adoption of meat freezing practices has surged in popularity over the last two decades, owing to its proven effectiveness in maintaining meat quality.

Marination, initially developed to enhance flavor and tenderness, has evolved to improve sensory attributes, extend shelf life, and increase product safety. Despite the rising popularity of marinated meats, there is limited research on the effects of marinating with edible oils, particularly for beef in Bangladesh. Edible oils act as natural preservatives, protecting beef from oxidative degradation and microbial contamination by sealing the surface and reducing oxygen exposure. This research explores how different oils affect the physicochemical, sensory, and microbial properties of refrigerated beef, focusing on improving oxidative stability, moisture retention, and inhibiting microbial growth to extend shelf life. So, the following objectives guided the current study's development: To examine the sensory attributes, proximate composition, biochemical changes, and microbiological quality of beef after the addition of various types of oil at different concentrations. To investigate the impact of oil on the quality and safety of raw beef during refrigerated preservation, focusing on maintaining freshness and preventing spoilage. To evaluate the effectiveness of oils in inhibiting microbial growth and extending the shelf life of raw beef during storage.

Materials and Methods

Place of Experiment

The experiment was carried out in the laboratory of the Department of Animal Science at Bangladesh Agricultural University (BAU), located in Mymensingh.

Collection of Raw materials

Two kilograms of boneless beef were purchased from Sesh Mor Market at Bangladesh Agricultural University, Mymensingh, at 10:00 a.m. The meat samples were then promptly transported to the Animal Science Laboratory.

Preparation of other instruments

The essential instruments, such as the knife and tray, underwent rigorous cleaning using hot water and detergent, followed by meticulous drying, to ensure optimal conditions prior to initiating the experimental activities.

Sample preparation

Approximately 2 kg of fresh meat was used for beef preparation. Initially, the meat was thoroughly cleaned with fresh water, and all body fat, tendons, skin, and removable connective tissues were trimmed off using a sharp knife. The boneless meat was then evenly mixed with 1% of various oils according to the experimental design. The four treatment groups included: T_0 = (Control group), T_1 = (1% Olive oil), T_2 = (1% Mustard oil), T_3 = (1% Sesame oil), and T_4 = (1% Soybean oil). Each batch of meat was then individually packed in zipper bags, with the necessary sample reserved for the experiment, while the rest was stored in the refrigerator.

Experiment Layout

The meat sample divided into 5 parts. Treatments were mixed with the 4 parts of sample. Samples were placed in zipper bags. The samples were stored at 4°C. The sample were taken from each treatment at 0, 3, 6 and 9 days respectively for different analysis

Instrumental color measurement

The instrumental color analysis of the meat was conducted using a Konica Minolta Chroma Meter (CR 410, Konica Minolta Sensing, Inc., Osaka, Japan), a Miniscan Spectro colorimeter equipped with the CIE Lab system (International Commission on Illumination), which measures L*, a*, and b* values. In this system, L* represents lightness, a* indicates redness, and b* denotes yellowness (CIELAB, 2014). The colorimeter was calibrated with a specific whiteboard before starting the measurements. Each color value was derived from the average of three readings taken from a 4–5 cm^2 area of the meat to ensure a representative evaluation of the samples. The L* value (lightness) ranges from 0 to 100, with 0 being black and 100 white, while a* and b* range from −60 to +60, where a* shifts from green (negative) to red (positive) and b* from blue (negative) to yellow (positive). All samples were placed in Petri dishes for measurement, which was performed on day 0 and repeated on the 3rd, 6th, and 9th days, continuing through the end of frozen storage at 4ºC.

Proximate Composition

The proximate composition analysis, including Dry Matter (DM), Ether Extract (EE), and Crude Protein (CP), was conducted following the standardized procedures outlined by AOAC (1995). Each measurement was performed in triplicate, and the average value was documented for accuracy.

Physicochemical properties measurement

To measure the pH of meat, first calibrate the pH meter using pH 4 and pH 7 buffer solutions. Rinse the electrode with distilled water, stabilize the reading in each buffer, and adjust to the correct values. Prepare a fresh meat sample by cutting smaller sections to expose muscle tissue, avoiding fat and connective tissue. Insert the electrode into the muscle, allow the reading to stabilize, and recorded the pH. Rinse the electrode with distilled water after use and store it per the manufacturer's instructions. Thawed 1 g samples were wrapped in absorbent cotton, placed in 1.5 ml Eppendorf tubes, and centrifuged at 10,000 RPM for 10 minutes at 4ºC. After centrifugation, the samples were weighed, and WHC (%) was calculated using the formula: WHC (%) = (Weight after centrifugation / Weight before centrifugation) × 100. To measure meat drip loss, prepare a fresh sample by trimming excess fat and connective tissue and cutting it into uniform portions. Weigh the sample to record its initial weight (W_1) using a precise scale. Place the sample in a container and refrigerate for 24 hours to allow moisture to drip out. After refrigeration, remove the sample, let it reach room temperature if needed, and weigh it again to determine the final weight (W_2). Drip loss (%) is calculated using the formula: Drip loss (%) = $[(W_1 - W_2) / W_1] \times 100$. To measure cooking loss, prepare a fresh meat sample, trimming excess fat and connective tissue, and slice it into uniform portions (5–30 g). Weigh the raw sample (W_1) using an accurate scale. Boil the meat at 70°C until it reaches the desired internal temperature, confirmed with a meat thermometer. Allow the cooked meat to rest briefly before weighing it again (W_2). Calculate cooking loss using the formula: Cooking loss (%) = $[(W_1 - W_2) / W_1] \times 100$.

Biochemical analysis

Lipid oxidation was evaluated in triplicate using the 2-thiobarbituric acid (TBA) method. Samples of beef (5 g) were blended with 25 ml of a 20% trichloroacetic acid solution (200 g/l of trichloroacetic acid in a 135 ml/l phosphoric acid solution) using a vortex mixer for 60 seconds. The homogenized mixture was then filtered through Whatman filter paper number 4, and 2 ml of the filtrate was combined with 2 ml of a 0.02 M aqueous TBA solution (3 g/l) in a test tube. The test tubes were incubated at 100°C for 30 minutes and subsequently cooled with tap water. The absorbance was measured at a wavelength of 532 nm using a UV-VIS spectrophotometer (UV-1200, Shimadzu, Japan). The TBA value was reported as mg malonaldehyde per kg of the beef sample.

Microbial assessment

Microbiological evaluation of beef samples involved preparing a 10 g sample mixed with 90 ml of sterile 0.1% peptone water to create a dilution. Serial dilutions were made, and media including Plate Count Agar (PCA), MacConkey Agar (MA), and Potato Dextrose Agar (PDA) were used to culture bacteria and yeast/mold. For Total Viable Count (TVC), Total Coliform Count (TCC), and Yeast-Mold counts, 0.1 ml of each dilution was plated and incubated at appropriate temperatures. Colony counts were determined after 24-48 hours for TVC and TCC, and 48-72 hours for yeast and mold. Results were reported as CFU/g of beef.

Statistical model and analysis

The proposed model for the planned experiment was factorial experiment with two factors A (Treatments) and B (Days of Intervals). Data were statistically analyzed using SAS Statistical Discovery software, NC, USA. DMRT test was used to determine the significance of differences among treatments means.

Results and Discussion

Instrumental color value

For the lightness (L*) of fresh beef, the T_3 treatment displayed the most desirable color, with the highest L* value of 42.06, while T_0 had the least preferred lightness at 32.45. Statistically significant differences were found in L* values across treatments, storage days, and their interaction ($P < 0.01$). For redness (a*), T_3 also showed the best result with a mean a* value of 16.81, whereas T_2 had the lowest at 12.38. Significant differences in a* values were observed across treatments, storage periods, and their interaction ($P < 0.01$). In terms of yellowness (b*), T_3 was the most preferred (mean b* value of 10.52), while T_0 had the lowest (6.19). Again, significant differences in b* values were found across treatments, storage intervals, and their interaction ($P < 0.01$). Overall, the T_3 treatment consistently exhibited higher values for L*, a*, and b* compared to T_1 and T_2, with all showing significant differences ($P < 0.01$). The color of beef is influenced by the processes that control the conversion of myoglobin redox states and this reversible reaction relies on oxygen flow, active enzymes, and reducing compounds in the muscle (Tushar et al., 2023). However, over time, all color parameters decreased, likely due to pigment and lipid oxidation, leading to non-enzymatic browning.

Table 1. Effect of different types of oil on instrumental color value (Mean ± SE) in beef at different days of intervals

Parameter	DI	Treatments						Level of significance		
		T_0	T_1	T_2	T_3	T_4	Mean	Treat.	DI	T×DI
	0	32.95±0.21	41.23±0.18	35.67±0.62	39.25±0.22	33.12±0.24	36.44^{b}			
	3	33.04±0.15	47.27±0.17	37.68±0.32	41.15±0.33	33.12±0.29	38.49^{a}			
L*	6	32.05±0.19	36.12±3.63	36.65±0.53	44.56±0.30	40.22±0.33	38.52^{a}	**	*	**
	9	31.78±0.71	34.73±4.76	39.15±0.55	43.26±0.37	40.45±0.33	37.87^{a}			
	Mean	32.45^{e}	39.83^{b}	38.04^{c}	**42.06^{a}**	36.78^{d}				
	0	16.32±0.18	14.54±0.29	13.94±0.39	15.14±0.18	15.89±0.18	15.16^{a}			
	3	11.37±0.23	11.38±0.15	14.05±0.18	13.65±0.17	15.51±0.15	13.19^{d}			
a*	6	12.52±0.14	13.31±0.32	10.72±0.13	20.21±0.18	12.25±0.13	13.80^{b}	**	**	**
	9	12.35±0.29	13.26±0.25	10.84±0.13	18.25±0.17	13.21±0.11	13.58^{c}			
	Mean	13.14^{c}	13.12^{c}	12.38^{d}	**16.81^{a}**	14.21^{b}				
	0	7.16±0.96	10.28±0.23	9.87±0.13	9.55±0.11	8.78±0.21	9.13^{a}			
	3	5.79±0.27	8.57±0.09	7.43±0.11	8.43±0.27	7.65±0.28	7.58^{b}			
b*	6	5.64±0.22	5.37±0.14	3.74±0.20	12.58±0.27	8.25±0.33	7.11^{c}	**	**	**
	9	6.18±0.37	5.23±0.23	4.21±0.11	11.51±0.44	7.20±0.17	6.88^{d}			
	Mean	6.19^{d}	7.38^{c}	6.32^{d}	**10.52^{a}**	7.97^{b}				

Same superscripts in different treatments groups and days of interval did not differ significantly, whereas different superscripts in different treatments groups and days of interval differ significantly. T_0 = (No oil), T_1 = (1% olive oil), T_2 = (1 % mustard oil), T_3 = (1% sesame oil), T_4 = (Soybean oil), DI = Day Intervals, Treat = Treatment, T×DI = Interaction of Treatment and Day Interval** means significant at 1% level of probability. L*= lightness, a* = redness, b* = yellowness.

Proximate analysis

Dry Matter

Table 2 reveals no significant differences across treatments or their interaction with storage intervals, but significant differences were observed across storage periods for dry matter (DM) content. The mean DM values ranged from 25.96 to 27.03 across all groups, with T_2 having the most desirable DM content, as lower DM is preferred. The control group (T_0) had the highest DM content, making it the least favorable. DM content increased over storage time, likely due to reduced moisture loss reported by Boby et al. (2021). The most preferred DM content was observed on day 0, and the least on day 9, though within acceptable consumer limits.

Crude Protein

Table 2 shows no significant differences among treatments or their interaction with storage time, but significant differences were observed across storage periods for crude protein (CP) content. The mean CP values ranged from 20.82% to 21.74%. Among the

Treatments, T_0 had the lowest CP content, while T_1 had the highest. CP content decreased over storage time, with the highest levels recorded on day 0 and the lowest on day 9, although this change remained within acceptable limits. Similar declines in protein content during storage were reported by Suradkar et al. (2013) for chicken nuggets containing bread crumbs.

Ether Extract

Table 2 indicates no significant differences among all treatments, days of interval, or the interaction between treatment and days of interval regarding ether extract (EE) content. The mean EE values ranged from 2.47% to 2.65%. Among the treatments, the T_0 group had the highest EE content, while T_1 exhibited the lowest, which was considered more favorable for consumer health. The T_0 group displayed less desirable EE content. Similar reductions in fat content were reported by Suradkar et al. (2013) in various meat products.

Ash

Table 2 reveals significant differences in ash content across all treatment groups and storage intervals, but no significant interaction between treatment and storage duration. The mean ash content ranged from 1.27% to 1.36%. The T_4 group had the most desirable ash content, while the control group (T_0) showed the highest, which is less favorable for consumer health. Ash content significantly increased with extended storage periods, with the lowest recorded on day 0 and the highest on day 9, though it remained within acceptable limits. After 9 days of storage, the ash content reached a maximum of 1.45% across all treatments. Akter et al. (2009) observed a reduction in ash content in beef due to loss of volatile minerals from beef during preservation.

Table 2. Effect of different types of oil on proximate parameters (Mean ± SE) in beef at different days of intervals

Parameter	DI	Treatments						Level of significance		
		T_0	T_1	T_2	T_3	T_4	Mean	Treat	DI	T×DI
	0	26.15±1.20	26.03±1.92	25.21±1.06	26.12±1.47	26.22±1.21	25.94b			
	3	26.62±1.85	26.19±1.92	25.84±1.48	26.49±1.62	26.30±1.42	26.29ab			
DM%	6	27.36±2.24	27.02±1.14	26.11±2.02	27.05±1.14	27.26±1.34	26.96ab	NS	**	NS
	9	28.03±2.90	27.83±1.11	26.67±1.20	27.56±4.28	27.88±2.27	27.60a			
	Mean	27.03^{a}	26.78^{a}	25.96^{a}	26.80^{a}	26.91^{a}				
	0	21.58±0.77	22.68±1.99	22.34±2.08	22.10±2.03	21.91±1.71	22.15^{a}			
	3	21.12±1.69	22.17±2.82	21.78±1.85	21.56±1.62	21.33±2.73	21.59^{ab}			
CP%	6	20.56±1.23	21.35±0.95	21.08±1.21	21.16±2.63	20.94±2.34	21.01^{ab}	NS	**	NS
	9	20.05±2.12	20.78±1.67	20.85±2.44	20.60±0.83	20.12±1.19	20.48^{b}			
	Mean	20.82^{a}	21.74^{a}	21.51^{a}	21.35^{a}	21.08^{a}				
	0	2.26±0.14	2.80±0.25	2.70±0.13	2.76±0.11	2.53±0.08	2.61^{a}			
	3	2.77±0.20	2.32±0.29	2.58±0.44	2.74±0.22	2.72±0.11	2.62^{a}			
EE%	6	2.77±0.14	2.48±0.29	2.28±0.44	2.63±0.45	2.49±0.33	2.53^{a}	NS	NS	NS
	9	2.80±0.15	2.58±0.29	2.33±0.44	2.45±0.45	2.61±0.43	2.56^{a}			
	Mean	2.65^{a}	2.55^{a}	2.47^{a}	2.64^{a}	2.59^{a}				
	0	1.15±0.15	1.21±0.03	1.19±0.03	1.21±0.03	1.12±0.03	1.18^{c}			
	3	1.34±0.09	1.25±0.03	1.23±0.03	1.28±0.04	1.23±0.03	1.27^{b}			
Ash%	6	1.39±0.16	1.34±0.03	1.32±0.03	1.30±0.03	1.29±0.03	1.33^{b}	**	**	NS
	9	1.56±0.27	1.39±0.03	1.45±0.41	1.44±0.13	1.42±0.14	1.45^{a}			
	Mean	1.36^{a}	1.30^{ab}	1.30^{ab}	1.31^{ab}	1.27^{b}				

Same superscripts in different treatments groups and days of interval did not differ significantly, whereas different superscripts in different treatments groups and days of interval differ significantly. T_0 = (No oil), T_1 = (1% olive oil), T_2 = (1 % mustard oil), T_3 = (1% sesame oil), T_4 = (Soybean oil), DI = Day Intervals, Treat = Treatment, T×DI = Interaction of Treatment and Day Interval. ** means significant at 1% level of probability, NS = Not significant

Physicochemical Quality

pH Value

Table 3 shows that pH values in beef treated with different oils ranged from 5.70 to 5.98, with significant differences ($P<0.001$) across treatments. The T_4 group had the lowest pH throughout storage, while the control group showed the highest increase in pH from 5.23 to 6.88 after 9 days. All treatments showed a gradual pH increase over time. Similar findings were reported by Sharker et al., (2024), with the increase in pH in the control attributed to bacterial consumption of acids during protein breakdown.

Water holding capacity

Table 3 presents the water-holding capacity (WHC) of beef combined with various oils, as well as the control group, after 9 days of refrigerated storage. Significant differences were observed among the treated batches on days 0, 3,6 and 9. The overall observed WHC ranged from 93.29 to 94.40 across different treatment levels, while the WHC values for the various intervals ranged from 91.97 to 95.33. Among the 5 treatments, the control sample exhibited a significantly lower WHC compared to the samples treated with different oils. Over the storage period, WHC gradually decreased across all treatments as the storage duration increased. The T_3 group showed the most favorable WHC value among the treatments, while the highest WHC value indicates that the product is more beneficial for consumer health. Beef liver with lower pH levels has been linked to a reduced water-holding capacity (WHC), which can lead to increased cooking loss and drip loss (Akhter et al., 2022).

Drip loss

Table 3 shows that there were significant differences in all treatments, days of interval, and the interaction between treatment and days of interval for drip loss parameter. The ranges for mean values of drip loss were 2.98 to 4.05 for different treatments. The drip loss values for different intervals ranged from 2.41 to 4.40. Among these five treatments, the most preferable drip loss value was observed from the T_1 group. The lowest amount of drip loss indicates that the product is most preferable for consumer satisfaction due to higher juiciness and quality. The drip loss values increased significantly ($p<0.001$) during storage in all treatments. Zhang et al. (2018) also found a significant increase in drip loss in pork loins with an increase in storage period.

Cooking loss

Table 3 shows that there are significant differences in days of interval but there are no significant differences in all treatments and the interaction between treatment and days of interval for cooking loss parameter. The ranges for mean values of cooking loss were 26.62 to 27.71 for different treatments. The cooking loss values for different intervals ranged from 25.28 to 29.52. Among these five treatments, the most preferable cooking loss value was observed from the T_3 group and the least preferable one is T_0. Cooking loss refers to the reduction in weight of meatballs during the cooking process (Jama et al., 2008) is the similar trend with the experiment. Major components of cooking losses are thawing, dripping and evaporation. Thawing loss refers to the loss of fluid in meatballs resulting from the formation of exudates following freezing and thawing (Jama et al., 2008) is the similar report. Such losses are lower following a rapid freezing compared with slow freezing. This is because of small crystallization formed by the rapid freezing. Drip loss is the loss of fluid from meatballs and water evaporation from the shrinkage of muscle proteins (actin and myosin) (Yu et al., 2005).

Table 3. Effect of different types of oil on physicochemical parameters (Mean ± SE) in beef at different days of intervals

Parameter	DI	Treatments						Level of significance		
		T_0	T_1	T_2	T_3	T_4	Mean	Treat.	DI	T×DI
	0	5.23±0.30	5.31±0.32	5.42±0.28	5.36±0.29	5.35±0.30	5.33^{c}			
	3	5.63±0.36	5.43±0.30	5.57±0.34	5.46±0.39	5.46±0.23	5.50^{c}			
pH	6	6.18±0.55	5.87±0.29	5.97±0.31	5.93±0.33	5.84±0.31	5.95^{b}	NS	**	NS
	9	6.88±0.33	6.25±0.31	6.21±0.29	6.31±0.34	6.15±0.34	6.36^{a}			
	Mean	5.98^{a}	5.71^{a}	5.77^{a}	5.76^{a}	5.70^{a}				
	o	96.73±0.37	95.21±1.25	94.36±0.73	95.16±1.25	95.21±0.31	95.33^{a}			
	3	93.85±1.46	94.29±1.33	94.54±1.21	95.42±0.95	95.10±1.61	94.64^{a}			
WHC	6	92.16±1.22	93.42±1.07	92.86±0.33	94.78±0.29	92.50±0.88	93.14^{b}	**	**	NS
	9	90.43±1.34	93.26±1.13	92.65±1.32	94.23±0.84	92.25±1.17	91.97^{c}			
	Mean	93.29^{b}	94.04^{ab}	93.60^{ab}	94.40^{a}	93.51^{ab}				
	0	2.86±0.31	2.13±0.28	2.45±0.28	2.36±0.29	2.26±0.27	2.41^{d}			
	3	3.54±0.31	2.81±0.35	3.30±0.28	3.27±0.24	3.21±0.26	3.22^{c}			
Drip loss%	6	4.08±0.20	3.13±0.18	3.96±0.39	3.68±0.32	3.53±0.24	3.67^{b}	**	**	**
	9	5.73±0.33	3.87±0.20	4.24±0.31	3.95±0.29	4.21±0.31	4.40^{a}			
	Mean	4.05^{a}	2.98^{c}	3.49^{b}	3.31^{b}	3.30^{b}				
	0	29.33±1.21	29.46±1.99	29.06±1.99	30.65±0.84	29.13±0.14	29.52^{a}			
	3	27.11±1.38	27.88±1.51	28.20±1.56	28.22±1.21	28.09±1.85	27.90^{b}			
Cooking loss %	6	25.69±1.25	26.62±1.09	26.67±1.73	26.50±0.87	26.73±1.15	26.44^{c}	NS	**	NS
	9	24.35±2.11	25.91±1.95	25.23±2.71	25.48±1.29	25.42±1.09	25.28^{d}			
	Mean	26.62^{a}	27.47^{a}	27.29^{a}	27.71^{a}	27.34^{a}				

Same superscripts in different treatments groups and days of interval did not differ significantly, whereas different superscripts in different treatments groups and days of interval differ significantly. T_0 = (No oil), T_1 = (1% olive oil), T_2 = (1 % mustard oil), T_3 = (1% sesame oil), T_4 = (Soybean oil), DI = Day Intervals, Treat = Treatment, T×DI = Interaction of Treatment and Day Intervals. ** means significant at 1% level of probability; *means significant at 5% level of probability, NS = Not significant.

Biochemical properties

Thiobarbituric Acid Value

Table 4 indicates significant differences in all treatments, intervals of storage, and the interaction between treatments and storage duration regarding the TBARS parameter. The mean TBARS values ranged from 0.20 to 0.56 across all groups. Among the four treatments, the T_1 group exhibited the most favorable TBARS value, with the lowest TBARS levels indicating a product that is more beneficial for consumer health. TBARS values increased significantly ($p<0.001$) during the storage period across all treatments. Similar results were observed by Chidanandaiah and Sanyal (2009) in meat patties during refrigerated storage. Yadav et al. (2018) found a significant increase in TBARS value of control and fiber enriched sausage with an increase in storage period. Similar findings were reported by Nassu et al. (2003) in goat meat sausage during refrigerated storage.

Table 4. Effect of different types of oil on biochemical parameters (Mean ± SE) in beef at different days of intervals

Parameter	DI	Treatments						Level of significance		
		T_0	T_1	T_2	T_3	T_4	Mean	Treat.	DI	T×DI
	0	0.15±0.02	0.11±0.01	0.09±0.01	0.11±0.05	0.10±0.01	0.11^{d}			
	3	0.44±0.06	0.13±0.02	0.15±0.04	0.17±0.01	0.11±0.06	0.20^{c}			
TBRS (mgmda/kg)	6	0.73±0.14	0.23±0.01	0.23±0.02	0.23±0.01	0.28±0.05	0.34^{b}	*	**	**
	9	0.91±0.11	0.34±0.09	0.42±0.10	0.38±0.02	0.36±0.02	0.48^{a}			
	Mean	0.56^{a}	0.20^{b}	0.23^{b}	0.22^{b}	0.21^{b}				

Same superscripts in different treatments groups and days of interval did not differ significantly, whereas different superscripts in different treatments groups and days of interval differ significantly T_0 = (No oil), T_1 = (1% olive oil), T_2 = (1 % mustard oil), T_3 = (1% sesame oil), T_4= (Soybean oil), DI = Day Intervals, Treat = Treatment, T×DI = Interaction and Day Intervals. ** means significant at 1% level of probability, *means significant at 5% level of probability, TBARS = Thiobarbituric acid reactive substances.

Microbiological assessment

Table 5 indicates significant differences across all treatments, storage intervals, and the interaction between treatment and storage duration for all parameters (TVC, TCC, and TYMC). The observed ranges for TVC, TCC, and TYMC were 5.33 to 5.52, 2.44 to 2.90, and 2.48 to 2.87, respectively, across all groups. The range values for the different storage intervals for TVC, TCC, and TYMC were 5.20 to 5.63, 2.32 to 2.87, and 2.40 to 2.83, respectively.

Total viable count

Table 5 shows that the total viable count (TVC) in the control sample was significantly higher than in oil-treated samples. The TVC range across all treatments was 5.33 to 5.52 log10 CFU/g, with a gradual increase over storage. The most desirable TVC was observed on day 0, and the lowest on day 9. The T_1 group, treated with oils, showed the lowest TVC, indicating better

suitability for consumer health. Oils such as cinnamon and clove have been reported to suppress spoilage microorganisms (Matan et al., 2006), reducing microbial load in treated samples.). It was reported by Babatunde and Adewumi (2015) that the plant extracts such as garlic, ginger and roselle provided antioxidant and antimicrobial benefits to raw chicken patties during cold storage.

Total coliform count

Table 5 shows that the total coliform count (TCC) in the control sample was significantly higher than in the oil-treated samples. TCC values ranged from 2.44 to 2.90 log10 CFU/g across treatments, with the lowest counts on day 9. The T_1 group, treated with oils, showed the lowest TCC, indicating better suitability for consumer health. TCC increased over storage, with lower values being more favorable. Similar findings were observed by Singh and Immanuel (2014) of raw chicken meat emulsion incorporated with clove powder, ginger and garlic paste at refrigerated storage (4±1ºC). Reddy et al. (2017) observed a significantly ($P<0.05$) lower coliform count in chicken meat patties incorporated with natural antioxidant extracts i.e., rosemary (RE) and green tea (GTE).

Total yeast-mold count

Table 5 shows that the total yeast-mold count (TYMC) was significantly higher in the control sample compared to the oil-treated samples. TYMC ranged from 2.48 to 2.87 log10 CFU/g, with the lowest count on day 0 and the highest on day 9. Over time, TYMC increased across all treatments, with the T_2 group showing the lowest counts, indicating better suitability for consumer health. The antibacterial properties of the oils inhibited fat deterioration and prevented bacteria from metabolizing fat. The lower TYMC in the treated meat samples may be attributed to the antifungal properties of the oils (Akter et al., 2022). Fernandez et al. (2005) reported on the results of a research study related to antimicrobials in beef meatballs. They noted that the presence of mold and yeasts was not detected in any cooked meatball samples.

Table 5. Effect of different types of oil on microbial parameters (Mean ± SE) in beef at different days of intervals

Parameter	DI	Treatments						Level of significance		
		T_0	T_1	T_2	T_3	T_4	Mean	Treat.	DI	T×DI
	0	5.23±0.27	5.21±0.23	5.15±0.31	5.19±0.31	5.22±0.32	5.20^{b}			
	3	5.32±0.47	5.26±0.25	5.26±0.27	5.24±0.30	5.29±0.31	5.27^{b}			
TVC (logCFU/g)	6	5.62±0.32	5.34±0.30	5.42±0.31	5.36±0.31	5.43±0.30	5.43^{ab}	NS	**	NS
	9	5.94±0.33	5.52±0.30	5.55±0.32	5.58±0.34	5.57±0.35	5.63^{a}			
	Mean	5.52^{a}	5.33^{a}	5.35^{a}	5.34^{a}	5.37^{a}				
	0	2.65±0.28	2.15±0.21	2.25±0.20	2.36±0.20	2.21±0.27	2.32^{c}			
	3	2.81±0.28	2.35±0.29	2.43±0.28	2.45±0.23	2.34±0.22	2.47^{bc}			
TCC (logCFU/g)	6	2.96±0.29	2.54±0.29	2.58±0.27	2.56±0.23	2.67±0.28	2.66^{b}	*	**	NS
	9	3.21±0.31	2.72±0.30	2.77±0.30	2.81±0.34	2.86±0.30	2.87^{a}			
	Mean	2.90^{a}	2.44^{b}	2.51^{b}	2.54^{b}	2.52^{b}				
	0	2.64±0.30	2.36±0.29	2.27±0.23	2.28±0.23	2.45±0.24	2.40^{c}			
	3	2.84±0.21	2.48±0.29	2.47±0.22	2.51±0.19	2.58±0.29	2.57^{cb}			
TYMC (logCFU/g)	6	2.92±0.30	2.77±0.30	2.58±0.23	2.61±0.20	2.74±0.28	2.72^{cb}	**	**	NS
	9	3.08±0.31	2.85±0.31	2.63±0.24	2.75±0.21	2.86±0.25	2.83^{a}			
	Mean	2.87^{a}	2.61^{b}	2.48^{b}	2.53^{b}	2.65^{ab}				

Same superscripts in different treatments groups and days of interval did not differ significantly, whereas different superscripts in different treatments groups and days of interval differ significantly. T_0 = (No oil), T_1 = (1% olive oil), T_2 = (1 % mustard oil), T_3 = (1% sesame oil), T_4 = (Soybean oil), DI = Day Intervals, Treat = Treatment, T×DI = Interaction of Treatment and Day Intervals. ** means significant at 1% level of probability. * Means significant at 5% level of probability, NS = Not significant, TVC = Total viable count, TCC = Total coliform count, TYMC =Total yeast and mold count.

Conclusion

The results showed that sensory qualities, like color, decreased with various treatment levels and over time. In contrast, DM content increased with different treatment levels and over the storage period. CP content decreased with varying treatment levels, while EE and ash content increased. pH increased and water-holding capacity decreased with the different treatment levels, with a similar trend observed as storage duration increased. Drip loss increased while cooking loss decreased across various treatment levels, showing a similar pattern as storage time extended. TBARS values, which indicate lipid oxidation, also rose with increasing treatment levels and storage time. Furthermore, microbial assessments revealed that TVC, TCC, and TYMC increased with the different treatment levels. The study concluded that beef samples can be preserved for up to 6 days using different levels of olive oil. This suggests that olive oil may provide an effective and cost-efficient solution to extend the shelf life of beef. Notably, the addition of 1% olive oil yielded better results regarding certain physicochemical properties, proximate composition, antioxidative properties, and sensory attributes compared to the control group and the samples with mustard, soybean and sesame oils. Therefore, it is recommended to use 1% olive oil for marinating beef to enhance the meat's storage duration.

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