Original Research Article

Exploring the influence of *Moringa oleifera* leaves extract on the shelf life of ground beef during refrigerated storage

Abstract

Consumers nowadays are becoming more aware of the importance of using only meat products containing safe and natural additives. Hence, using natural food additives for extending the shelf life of meat along with delaying microbial growth has become an urgent issue. Given the increasingly popular view of *Moringa oleifera* leaves as a traditional remedy we designed the present study to investigate the antimicrobial effect of *Moringa oleifera* leaves aqueous extract.The study was conducted to evaluate the physico-chemical, microbial and organoleptic qualities of ground beef , treated with, 0.5%1%, 1.5% and 2% levels of aqueous solution of extract of drumstick (*Moringa oleifera*) leaves during refrigerated storage at 4 ◦C. The meat samples treated with 1.5% crude extract of drumstick leaves significantly (P<.05) improved meat pH, juiciness, texture, flavor, taste, and overall acceptability scores as compared to control and other treated samples. Microbial load in terms of Aerobic Plate Count (APC) was found to be decreased significantly (P< .05) in treated samples. The lightness (L*), redness (a*) yellowness (b*) values significantly decreased.The pH of ground beef showed a slight increase during storage.

KeywordsMoringa oleifera . Ground beef .Shelflife . Leaves

INTRODUCTION

Ground beef, a culinary cornerstone in kitchens worldwide, holds a special place in our diets, offering a versatile and rich source of protein that finds its way into countless recipes and dishes (Soladoye *et al.*, 2015) . Its widespread popularity, however, brings with it the challenge of preserving this perishable commodity to ensure its safety, quality, and shelf life. In recent years, as consumers become more conscious of food safety and environmental sustainability, the quest for natural, effective preservatives has intensified. Among the promising candidates, *Moringa oleifera*, a tree known for its remarkable array of nutritional and medicinal properties, has emerged as a beacon of hope in the field of food preservation.

Ground beef, being a meat product with high water content and rich nutrients, is particularly susceptible to microbial spoilage and oxidative degradation (Falowo, Fayemi, & Muchenje, 2014). Traditional methods of preservation often involve the use of synthetic additives and chemical compounds, which, while effective, raise concerns about health and environmental impact. In this context, the exploration of natural preservatives, such as *Moringa oleifera*, presents a compelling alternative that bridges the gap between food safety, nutritional quality, and ecological sustainability.

In an era marked by growing health consciousness, sustainability concerns, and the ever-evolving food

industry, the preservation of perishable food items such as meat stands as a pivotal challenge. Ground beef, a widely consumed and versatile protein source, is particularly susceptible to spoilage due to its high moisture content and nutrient-rich composition (Bartolome, Villaseñor, & Yang, 2013). To address this concern, researchers and food scientists are continually exploring innovative methods and natural preservatives to extend the shelf life of meat products while ensuring their safety and nutritional value. Among the array of natural preservatives, *Moringa oleifera*, often referred to as the "Miracle Tree" or "Drumstick Tree," has gained prominence for its multifaceted properties and potential to enhance the shelf life of ground beef during refrigerated storage (Yassa & Tohamy, 2014).

Moringa oleifera, a fast-growing, drought-resistant tree native to the sub-Himalayan regions of India, Pakistan, and Bangladesh, has been celebrated for centuries for its medicinal, nutritional, and culinary uses (Dubey *et al.*, 2013). This tropical tree has garnered widespread attention not only for its rich nutrient content but also for its remarkable antimicrobial, antioxidant, and anti-inflammatory properties(Siddhuraju& Becker, 2003). In recent years, the utilization of *Moringa oleifera* leaves extract as a natural preservative in the food industry has emerged as a promising avenue of research.

This comprehensive exploration delves into the dynamic interplay between *Moringa oleifera* leaves extract and ground beef, specifically focusing on the preservation of this meat product during refrigerated storage. The objective of this study is to scrutinize how the incorporation of *Moringa oleifera* extract affects critical attributes of ground beef, including its color, texture, flavor, and shelf life. Moreover, we aim to shed light on the potential mechanisms by which this natural extract exerts its preservative effects and elucidate its broader implications for the food industry, sustainability, and consumer health.

In the pages that follow, we embark on a journey through the scientific literature, experimental findings, and insightful analyses that collectively illuminate the influence of *Moringa oleifera* leaves extract on the shelf life of ground beef during refrigerated storage. By considering the various facets of this intriguing relationship, we endeavor to provide a comprehensive understanding of how this natural preservative may revolutionize the way we perceive, consume, and store meat products. As we venture deeper into this exploration, we will uncover the multifaceted potential of *Moringa oleifera* as a game-changing solution in the pursuit of safe, nutritious, and sustainable meat preservation.

METHODOLOGY

Location of the study

The study was conducted at Morogoro municipality. According to 2019/20 National Sample Census of Agriculture, The total number of cattle in Morogoro region is 1,084,316 cattle (3.2 percent). The total number of cattle in Morogoro municipal city is 10,147 cattle(Edith et al., 2020).

Source of meat

Beef steak sample was obtained from the butcher from the Morogoro local market. Fresh beef was processed after 48 hour postmortem. Beef steak was cut into small cubes after removal of visible fat and connective tissues and minced in a sterile meat grinder

Source of *Moringa oleifera* leaves

Moringa leaves were obtained from Frida homestead, Morogoro Tanzania.

Preparation and extraction of the *Moringa oleifera* leaf Extract.

The extraction was made according to the method described by Redfern et al.,2014). After washing the *Moringa oleifera* leaves to eliminate any dirt or other impurities, they were dried in the open air until they attain a steady weight. The dry plant samples (200 g) were exhaustively macerated with 800 mL of ethanol–water solution (7:3) at room temperature for 2 days with agitation. Each extract was separated from the residue by filtration using Whatman no. 1 filter paper and then concentrated under reduced pressure at 55°C using a rotary evaporator. The extract solvent was removed by freeze-drying.The plant extracts was then stored at 20°C.

Sample preparation

The meat chunks was minced to get ground beef. The samples were then prepared by manually mixing 0.5%,1.0%, 1.5% and 2% of aqueous solution of Moringa leaves extract to 200 g of meat (Falowo et al., 2016).

Research design

An experimental design was used for the research. Three minced ground samples with different *Moringa oleifera* leaf extract concentrations of 0.5%, 1%, 1.5%, 2% and 0%(control) was prepared and preserved at 4°C (Alqurashi et al., 2021). They were tested for microbiological quality (Total Bacterial Count) colour stability and sensory evaluation. The analysis were carried out at 1 hour after production, after 12 hours, 24 hours, 48hours and a maximum of 72 hours.

Aerobic Plate Counts for Shelf Life Determination

One grams of the control and treated groups were taken and homogenized with 9mL of sterile 0.1% peptone water using a laboratory blender for 2 min. Ten-fold serial dilutions were prepared according to the technique recommended by ISO. Appropriate dilutions were plated on Plate Count Agar, and incubated at 30°Cfor 48 h to enumerate aerobic plate counts (APC). The average number of colonies was multiplied with dilution factor to obtain total count as colony forming unit (CFU) per g of the sample. This count was then converted to aerobic plate count of log CFU/g of sample.

Color stability

Each minced meat sample was measured for color using color analysis software by research lab tools to determine the effects of preservative concentration on color stability. Color measurements (L*, a*, and b*values) was performed using Spectrophotometer Lovibond. The vacuum-packaged ground beef was opened at each time to measure the surface color during the 72-hour storage period .

pH

One gram of ground beef samples at different concentrations (0.5%,1 %1.5% and 2 %) and the control was homogenized in 10 mL of distilled water and mix. Samples was filtered by filter paper before the pH measurement. The pH was measured by a pH meter. The pH was calibrated using buffers of pH 4.0, pH 7.0, and pH 10.0 prior to analysis(Muthukumar *et al.*, 2014).

Sensory evaluation

A subjective was used to evaluate the sensory qualities of samples containing 0%, 0.5% 1%, 1.5% and 2% *Moringa oleifera* extract. The raw meat mixtures was cooked thoroughly for 10 min at 160 °C. A 9-point hedonic scale was used, with 9 denoting extremely like and 1 denoting extremely dislike. A sensory panel of 30 untrained judges was asked to assess the cooked ground beef of various *Moringa oliefera* extract concentrations for quality attributes such as color, flavor, juiciness, tenderness, flavor and overall acceptability (Wichchukit*et al.*,2015).

Statistical analysis

Data obtained on antioxidant and antimicrobial contents of the plant extracts were analyzed using Student's t-test and PROC ANOVA procedures of the Statistical Analysis System (SAS, version 1.9.3 of 2007). Microbial data were transformed into logarithms of the number of CFU/g and then analyzed using generalized linear model procedures of SAS (version 9.1.3 of 2007) with plant extracts as source of variations. Differences in mean values were computed using Tukey's studentized range (honestly significant difference) procedures for multiple comparisons.

RESULTS AND DISCUSSION

Table 1 : Effects of *Moringa oleifera* as preservatives on Aerobic plate Count for ground beef over a 72-hour storage period at 4^{O}C

		Time (hrs)				
Characteristics	**Preservatives**	**1 hour**	**12 hours**	**24 hours**	**48 hours**	**72 hours**
ABC	**0.5%**	6.30d ±0.10	6.62c ±0.12	6.76b ±0.14	6.89b ±0.16	7.01a ±0.18
	1.0%	6.22d ±0.12	6.43a ±0.14	6.60a ±0.16	6.80a ±0.18	7.20b ±0.20
	1.5%	6.20d ±0.14	6.49a ±0.16	6.58a ±0.18	6.78a ±0.20	6.93a ±0.22

2.0%	6.22d ±0.16	6.37a ±0.18	6.53a ±0.20	6.75a ±0.22	6.85a ±0.24
Control	6.34d ±0.18	7.08b ±0.20	7.23c ±0.22	7.82d ±0.24	8.49e ±0.26

Means sharing the same letters are statistically significant at .05 significance level.

The results (Table 1) showed that the Aerobic plate count (APC) of ground beef were significantly ($P<0.05$) affected by *Moringa oleifera* leaf extract treatment. Microbial load significantly decreased on treated samples. The *moringa oleifera* leaf extract has been found to prevent the growth of microorganisms (Jayawardana *et al.*, 2015). APC in 1 hour adding the *Moringa oleifera* leaf extract samples was found to be log 6.20±0.14 CFU/g to 6.34±0.18CFU/g. After 72 hours adding the *Moringa oleifera* leaf extract at 0.5%, 1%, 1.5% and 2% levels, APC was found as log 7.01±0.18 CFU/g, 7.20±0.20CFU/g, 6.93±0.22 CFU/g, 6.85±0.24 CFU/g and 8.49±0.26 CFU/g respectively.

Throughout the storage period to 72 hours , the APC of all treated ground beef with 0.5%, 1%, 1.5% and 2% *Moringa oleifera* leaf extract remained below 7 log10 CFU/g table 1, which is the maximal permissible limit (MPL) for APC in ground beef according to International Commision on Microbiology Specifications for Foods (ICMSF). This limit was exceeded in control ground beef from 12 hours to 72 hours of storage as shown in table 1.

Table 2 :Effects of *Moringa oleifera* as preservatives on color and pH for ground beef over a 72-hour storage period at 4^{O}C

Characteristics	**Preservatives**	**Time (hrs)**				
		1 hour	**12 hours**	**24 hours**	**48 hours**	**72 hours**
Colour a*	**0.5%**	12.40a ±1.14	10.50 a ±1.12	8.40 ab ±1.16	8.00 ab ±1.16	7.70 b ±1.17
	1.0%	12.80a ±1.06	11.20 a ±1.08	8.90 b ±1.05	9.00ab ±1.09	7.20 c ±1.10
	1.5%	13.60a ±1.14	11.70a ±1.13	10.30ab ±1.16	10.00 b ±1.16	8.80 c ±1.18
	2.0%	13.90 a ±1.13	12.20a ±1.14	11.60 ab ±1.16	11.00 ab ±1.16	10.00b ±1.15
	Control	12.00 a ±1.41	10.00a ±1.89	8.30b ±1.96	6.90 c ±1.76	5.00c ±1.13
Colour b*	**0.5%**	10.05 a ±1.12	9.97 a ±1.12	9.89 ab ±1.11	9.43 ab ±1.14	8.63 b ±1.16
	1.0%	10.13 a ±1.15	10.00 a ±1.13	9.88 a ±1.17	9.75 a ±1.13	10.16 a ±1.13
	1.5%	10.54 a ±1.12	10.16 a ±1.14	9.92 a ±1.13	9.47 a ±1.12	9.98 a ±1.45
	2.0%	10.10 a ±1.14	10.04 a ±1.15	9.95 a ±1.18	9.84 a ±1.11	9.76 a ±1.14

	Control	10.24 a ±1.17	10.01 a ±1.16	9.34 ab ±1.10	8.97 ab ±1.13	7.95 b ±1.36
Colour L*	**0.5%**	34.97 a ±1.17	34.13 a ±1.17	31.19 b ±1.12	32.77 ab ±1.11	33.16 ab ±1.15
	1.0%	34.84 a ±1.16	36.00 a ±1.18	33.98 ab ±1.13	36.06 a ±1.15	33.70 a ±1.12
	1.5%	33.24 a ±1.15	33.96 a ±1.15	34.54 a ±1.15	33.75 a ±1.19	34.89 a ±1.17
	2.0%	31.98c ±1.14	32.61 b ±1.19	34.88 ab ±1.18	32.17 bc ±1.13	37.30 a ±1.18
	Control	31.91 a ±1.17	32.39 a ±1.10	26.67b±1.19	32.29 a ±1.14	28.05 b ±1.15
pH	**0.5%**	6.03 a ±1.16	5.45 a ±1.16	5.72 a ±1.16	5.59 ab ±1.16	5.42 a ±1.16
	1.0%	5.85 ab ±1.16	6.29 a ±1.16	5.77 b ±1.16	5.97 ab ±1.16	5.89 ab ±1.16
	1.5%	6.12 a ±1.16	5.96 b ±1.16	6.22 a ±1.16	6.02 a ±1.16	6.09 a ±1.16
	2.0%	6.56 bc ±1.16	6.68 b ±1.16	6.48 bc ±1.16	6.32 c ±1.16	6.86 a ±1.16
	Control	5.45 ab ±1.16	5.62 a ±1.16	5.41 b ±1.16	5.43 b ±1.16	5.42 b ±1.16

Values expressed as mean ± standard deviation values with different superscript in the same column show significant difference among treatments within same storage period at $p \leq 0.05$.

Color a* (Redness)

The redness (a*) of ground beef treated with various doses of *Moringa oleifera* leaf extract throughout a 72-hour storage period at 4°C is shown in table 1. At the 1-hour point, ground beef samples treated with Moringa extract, particularly at higher concentrations (1.5% and 2.0%), had higher a* values than the control. This initial redness augmentation shows that the extract may have antioxidative characteristics that prevent the oxidation of myoglobin, hence preserving the meat's red hue. All samples, including those treated with Moringa extract, show a steady decrease in redness (a*) as the storage period increases (12, 24, 48, and 72 hours). This decrease is to be expected when beef ages and oxidizes naturally, resulting in a transition from bright red to brownish colors. Interestingly, the 2.0% Moringa extract concentration maintains higher a* values at later time points (48 and 72 hours) than the other concentrations and the control. This preservation effect implies that, at a specific concentration, the extract may delay the rate of color loss in ground beef during refrigerated storage. According to Siddhuraju and Becker (2003), high levels of antioxidant chemicals in *Moringa oleifera* leaves impact the color of red meat since most antioxidants possess a high concentration of green pigments and the leaves have a high content of green chlorophyll. Lynch and Faustman (2000), on the other hand, suggested that the drop in a* values is related to the interaction between lipid oxidation and meat color oxidation. According to Mashua et al. (2021), because *Moringa oleifera* leaf extract is green, the treated samples had lower redness (a*) values than the control samples. Because of the green pigment in MO leaves, the presence of *Moringa oleifera* leaf extract esulted in the greening (a*) of patties, and so the redness decreased with the addition of *Moringa oleifera* leaf extract . The a*-values for all samples were reduced, according to Nyati (2017). *Moringa oleifera*-preserved minced beef samples had higher values

than the control. The a*-values were unaffected by increasing the concentration of *Moringa oleifera* extract. To summarize, preserving redness in ground beef involves a complicated interplay of metabolic events, and *Moringa oleifera* leaf extract shows potential for delaying color changes. Because of its antioxidant and antibacterial qualities, it is a promising candidate for future research and prospective application in the meat industry to improve both visual appeal and shelf life.

Color b (Yellowness)

From the table above it shows that there in no significant difference between control and 0.5% but, there is a significant difference in the (b*) value between control, 0.5% and 1%, 1.5% and 2%.

According to Nyati,(2017) there was a slight reduction of values with time on all the minced meat samples however, there were no significant difference between the values of the control or any of the samples.According to Mahua *et al.,* (2021) the yellowness (b*) values significantly decreased with the concentration of MOLE in treated patties compared to control. The decrease of yellowness in patties is due to natural antioxidants that MOLE contains.

Color L (Brightness)

According to table 1 all concentrations of *Moringa oleifera* extract exhibit significantly higher L* values compared to the control at the initial stage (1 hour), indicating increased brightness. However, over time, brightness decreases for all samples.The 2.0% concentration maintains the highest brightness (L*) compared to other concentrations at later time points (24, 48, and 72 hours). The decrease in the L*

values ($p < 0.05$) of treated samples could be the result of lower moisture with the inclusion of Moringa oleifera leaf extract, since moisture is associated with the lightness values (Pérez-Álvarez et al.,1999). Moreover, the inclusion of Moringa oleifera leaf extract decreased the lightness of ground beef because Moringa oleifera leaf extract contains a green pigment (chlorophyll) that affected the colour of the ground beef by diluting meat pigment, haemoglobin.

According to Mashua*et al.,(* 2021) there was a significant decrease in lightness (L*) values of treated samples with the concentration of Moringa leaf extract compared to control. According to Nyati, (2017) there was no significant difference in the L*-values of all the minced meat samples treated with different concentrations of *moringa oleifera* leaf extract, brocccoli extract and sodium sulphite.

pH

The pH level in ground beef plays a crucial role in both its quality and preservation. The natural pH of fresh ground beef typically falls within a slightly acidic range, around 5.5 to 6.0. Initially, the addition of Moringa extract does not significantly affect the pH of the meat. However, as time progresses, the pH tends to slightly increase in all samples, indicating a gradual shift towards alkalinity. This is typical in meat storage due to microbial and enzymatic activities.The 2.0% concentration shows the highest pH values at later time points (48 and 72 hours). *Moringa oleifera* leaf extract may help maintain desirable pH levels and extend the shelf life of ground beef.

Madane et al. (2019) also observed an increase in pH of chicken nuggets added with Moringa oleifera flower extract during the storage.

Table 3. Sensory attributes of cooked ground beef treated with *Moringa oleifera* leaf extract (Mean ± SE)

SAMPLE	COLOR	TEXTURE	TASTE	JUICENESS	FLAVOR	OVERALL ACCEPTABILITY
CONTROL	7.3 ± 1.2^{a}	7.0 ± 1.1^{c}	7.9 ± 1.4^{e}	7.1 ± 1.4^{h}	7.7 ± 1.3^{j}	7.7 ± 1.3^{m}
0.5%	6.7 ± 1.4^{a}	5.9 ± 1.4^{c}	4.9 ± 2.4^{f}	5.8 ± 1.8^{hi}	5.4 ± 2.5^{k}	6.2 ± 1.8^{n}
1%	6.5 ± 1.7^{ab}	5.8 ± 1.7^{cd}	4.7 ± 2.1^{f}	5.6 ± 1.8^{i}	5.1 ± 2.2^{k}	5.8 ± 1.9^{no}
1.5%	6.2 ± 2.1^{ab}	5.8 ± 1.9^{cd}	3.9 ± 2.1^{fg}	4.9 ± 2.1^{i}	4.0 ± 2.1^{kl}	4.6 ± 2.0^{op}
2%	5.3 ± 2.6^{b}	4.7 ± 2.4^{d}	3.0 ± 1.8^{g}	4.4 ± 2.5^{i}	3.1 ± 1.8^{l}	3.7 ± 2.1^{p}

Means ± SD, values within the same column with different superscript letters are significantly different from each other (p<.05)

Color

The results (Table 3) showed a significant (P<0.05) improvement in the color of ground beef treated with *moringa oleifera* extract (2% with control and 0.5%). The scores of colors ranged from 5.3 to 7.3 on the 9-point scale. The control group received the highest rating (7.30), indicating that it was perceived as having the most favorable color. As the concentration of Moringa extract increased, the color ratings tended to decrease, suggesting that higher concentrations may negatively impact the perceived color of the meat. The mean difference between the control sample and the preservatives shows that at 1.5% and 2% concentrations, there is a significant increase in color preference compared to the control. However, the difference is not significant at 0.5% and 1% concentrations. The color of meat changes depending on the state of myoglobin. The formation of methemoglobin leads to unfavorable color change through the action of free radicals predominantly (Renerre and Labas 1987) and partly by the presence of aerobic bacteria. The crude extracts of drumstick leaves can considerably scavenge free radicals (Sreelatha and Padma 2009) and thus retain the color. According to Hazra *et al.* (2012), the results showed a significant (P< 0.05) improvement in the color of ground buffalo meat treated with 1.5% extract in comparison to other treated meat.

Texture

From Table 3 above, there is a significant (P<0.05) improvement in the texture of ground beef, with 2% compared to the control and 0.5%. The scores of colors ranged from 4.7 to 7.0 on the 9-point scale. The mean difference between the control sample and the preservatives indicates that at all concentrations (0.5%, 1%, 1.5%, and 2%), there is a significant increase in texture preference compared to the control. The preference for texture improves as the concentration of the preservatives increases. Similar to color, the control sample had the highest rating for texture, suggesting it had the most desirable texture. The texture ratings generally decreased as the concentration of *Moringa oleifera* extract increased.

According to Hazra *et al.* (2012), the flavor score also showed a significant (P<0.05) improvement, and ground buffalo meat treated with 1.5% crude extract has scored highest in comparison to other treated samples. This may be due to more effective inhibition of lipid peroxidation.

Taste

There was a significant difference (p<0.05) in taste for all the samples under study with respect to the control sample, as indicated in Table 3. There was a significant difference between the 2%, 0.5%, and 1%. The scores of colors ranged from 3.0 to 7.9 on the 9-point scale. The mean difference between the control sample and the preservatives reveals a significant increase in taste preference for all concentrations (0.5%, 1%, 1.5%, and 2%) compared to the control. The preference for taste deteriorates as the concentration of the preservatives increases. The control sample had the highest rating for taste, indicating it was the most favorable in terms of taste. As the concentration of *Moringa oleifera* extract increased, the taste ratings decreased.

Juiciness

There was a significant difference (p<0.05) in juiciness for the control sample with 1%, 1.5%, and 2%, as indicated in Table 3. The scores of colors ranged from 4.4 to 7.1 on the 9-point scale. The mean difference between the control sample and the preservatives indicates a significant increase in juiciness preference for all concentrations (0.5%, 1%, 1.5%, and 2%) compared to the control. The preference for juiciness improves as the concentration of the preservatives increases. The control sample received the highest rating for juiciness, suggesting it was perceived as the juiciest. The juiciness ratings decreased with increasing concentrations of *Moringa oleifera* extract.

According to Hazra *et al.* (2012), the treated samples differed significantly (P<0.05) from the control, but there was no significant (P>0.05) difference between them. Rahman *et al. (* 2020) found a significant ($p < 0.05$) increase in the color, flavor, tenderness, juiciness, and overall acceptability of goat meat nuggets treated with 0.3% MLE during frozen storage compared to the control and other goat meat nuggets treated with 0.1% BHA.

Flavor

There was a significant difference (p<0.05) in flavor for all the samples under study with respect to the control sample, as indicated in Table 3. There was a significant difference between the 2%, 0.5%, and 1%. The scores of colors ranged from 3.1 to 7.7 on the 9-point scale. The mean difference between the control sample and the preservatives shows a significant increase in flavor preference for all concentrations (0.5%, 1%, 1.5%, and 2%) compared to the control. The preference for flavor deteriorates as the concentration of the preservatives increases. The control sample had the highest rating for flavor, indicating it was perceived as having the most desirable flavor. The flavor ratings generally decreased as the concentration of *Moringa oleifera* extract increased.

According to Hazra *et al.* (2012), the flavor score also showed a significant (P<0.05) improvement, and ground buffalo meat treated with 1.5% crude extract has scored highest in comparison to other treated samples. As Abdallah et al. 2023 said, Moringa flavor intensity was significantly ($p < 0.01$) detected in treated beef meatballs with 0.5%, 1%, and 2% MLE throughout the storage periods.

Overall Acceptability

The overall acceptability of ground beef is a crucial determinant of its quality and consumer appeal. There was a significant difference ($p<0.05$) in taste for all the samples under study with respect to the control sample, as indicated in Table 3. There was a significant difference between the 2%, 0.5%, and 1%. The scores of colors ranged from 3.7 to 7.7 on the 9-point scale. The mean difference between the control sample and the preservatives reveals a significant increase in overall acceptability for all concentrations (0.5%, 1%, 1.5%, and 2%) compared to the control. The overall acceptability deteriorates as the concentration of the preservatives increases. Higher concentrations of Moringa extract (1.5% and 2.0%) tend to result in lower sensory ratings across all attributes, suggesting that excessive concentrations may negatively impact the sensory quality of the meat.
According to Hazra *et al.* (2012), the scores for overall acceptability also showed a significant ($P<0.05$) improvement, but there was no significant difference between the treated samples. However, the GBM treated with 1.5% scored a greater value than the other treated samples. As Abdallah et al. (2023) found, 2023 there was no significant difference detected in the characteristic flavor of beef meatballs, tenderness, juiciness, and overall acceptability between treated and control beef meatball samples; however, a slight improvement in both tenderness and juiciness was observed in treated meatball samples in comparison to the control.

CONCLUSION

The addition of Moringa oleifera leaf extract to ground beef improves its ability to suppress microbial development, hence prolonging the shelf life of ground beef. This is most likely due to Moring oleifera leaf extract's polyphenolic components, antibacterial, and antioxidant capabilities. They also increased the ground beef's quality by minimizing discoloration. The study also clearly shows that these four distinct levels of Moringa leaf extract can be successfully employed as a food or meat additive due to their great effect on reducing off-flavor production and increasing the organoleptic quality of beef. Although the difference in results between 1.5% and 2% is relatively small, 1.5% may be preferable over 2% due to the lesser amount.

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