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 meat products containing safe and natural additives. Hence, using natural food additives to extend the shelf life of meat along with delaying microbial growth is important. Given the increasingly popular view of *Moringa oleifera* leaves as a traditional remedy a study was designed to investigate the antimicrobial effect of *Moringa oleifera* leaves aqueous extract on grounded meat. The study evaluated 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<0.05) 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< 0.05) in treated samples which 2% treatment was more effective. The lightness (L*), redness (a*) yellowness (b*) values significantly decrease which 2% has decrease more. The pH of ground beef showed a slight increase during storage but Moringa extract does not significantly affect the pH of the meat.

Keywords:Moringa oleifera, Ground beef, Shelf life .

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 (Ayirezang *et al.,* 2023).

The susceptibility of ground beef to microbial spoilage and oxidative deterioration is attributed to its elevated water content and nutrient-rich composition (Falowo, Fayemi, & Muchenje, 2014). The preservation techniques commonly utilized entail the utilization of synthetic chemicals and chemical components. Although the effectiveness of these treatments has been proven, there have been concerns expressed about potential health risks and environmental consequences associated with them. Within the confines of this particular approach, the analysis of natural preservatives, such as *Moringa oleifera*, offers a persuasive alternative that effectively addresses the intersection of food safety, nutritional value, and environmental sustainability according to the research conducted by Abdallah *et al.,* (2023),

In a period characterized by an increasing emphasis on health awareness, environmental considerations, and the ongoing expansion of the food sector, the preservation of perishable food products, namely meat, poses a significant and important obstacle. Ground beef, a protein source that is frequently consumed, is known for its versatility but is also prone to spoiling because of its high moisture content and nutrient-rich composition (Bartolome, Villaseñor, & Yang, 2013). In order to tackle this issue, scholars and experts in the field of food science are continuously investigating novel approaches and organic preservatives to prolong the durability of meat products, while still guaranteeing their safety and nutritional value. *Moringa oleifera,*a botanical species commonly known as the "Miracle Tree" or "Drumstick Tree," has garnered significant attention from scholars owing to its diverse array of attributes and its capacity to extend the duration of ground beef preservation under refrigerated conditions (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.

The challenges of today's food processing industry are enhancement of shelf-life and food safety for which chemical preservatives are used to prevent food spoilage due to microbial contamination or undesirable chemical changes like oxidation (Lucera *et al.,* 2012). Artificial preservatives are chemically manufactured such as those derived from benzoic acid, sodium diacetate, and potassium or calcium salts of lactic acid, etc. Most of them are expensive and pose health risks as they are said to be carcinogens and cause respiratory and digestive problems (Sharma, 2015). Given the risks of eating foods that contain chemical preservatives, antimicrobial extracts from plants or vegetables could provide natural sources of preservatives that could be used in the food business. Moringa extract has been found to be a good source of polyphenols and other phenolic compounds (Rahman *et al.*, 2020). The extracts can be mixed into meat products to improve the quality and colour stability of minced meat. 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.

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.

Material and methods

Location of the study

The study was conducted in Tanzania at Morogoro region in Morogoro municipality. According to the 2019/20 National Sample Census of Agriculture, The total number of cattle in the 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 raw materials

Beef steak sample was obtained from the butcher from the Morogoro Chief Kingalu market.

Fresh beef was processed after 48-hour postmortem. Beef steak was cut into small cubes after the removal of visible fat and connective tissues and minced in a sterile meat grinder (Sirman®, Italy; Model Buffalo TC 32) fitted with 6 mm plate.

Moringa leaves (Figure. 1) were obtained from a moringa-producing farmer in Morogoro, Tanzania.

Preparation and extraction of the *moringa oleifera* leaves extract

The *Moringa oleifera* leaves extract was prepared and extracted following the methodology outlined by Redfern et al., 2014. Initially, *Moringa oleifera* leaves, also known as mlonge, underwent a thorough washing process to eliminate dirt . Subsequently, these cleaned leaves were air-dried until they reached a consistent weight. For the extraction process, 200 grams of the dried plant samples were meticulously macerated with an ethanol–water solution (7:3) in a proportion of 800 mL. This maceration occurred at room temperature over a span of 2 days, accompanied by regular agitation.

Following the maceration, each extract was meticulously separated from the residual plant material through filtration, utilizing Whatman no. 1 filter paper. The resulting extracts were then concentrated under reduced pressure at a temperature of 55°C, employing a BÜCHI rotavapor R-205, as depicted in Figure 2. The solvent from the extracts was removed through freeze-drying, facilitated by a Labconco 700801050 freeze dryer. Ultimately, the plant extracts, now devoid of solvent, were carefully stored at a temperature of -20°C .

Figure.1 *Moringa oleifera* leaves

Figure. 2 Concentrating aqueous-ethanol mixture in a BÜCHI Rotavapor R-205

Sample preparation

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

Research design

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

Aerobic Plate Counts for Shelf Life Determination

One gram 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 6887-2:2017. Appropriate dilutions were plated on Plate Count Agar, and incubated at 30℃for 48 h to enumerate aerobic plate counts (APC). The average number of colonies was multiplied with a dilution factor to obtain the total count as colony forming unit (CFU) per g of the sample. This count was then converted to the aerobic plate count of log CFU/g of the 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 CM-700d Konica Minolta. 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 mixed. Samples were filtered by Whatman no. 1 filter paper before the pH measurement.The pH of prepared homogenates was recorded by using a digital pH meter (WTW®, Germany, Model 330i fitted with Sen Tix spelectrode) by immersing the electrode of pH meter into aliquot of the sample as per AOAC Official method 981.12. The pH was calibrated using buffers of pH 4.0, pH 7.0, and pH 10.0 before analysis(Muthukumar *et al.,* 2014).

Sensory evaluation

Consumer test was used to evaluate the sensory qualities of samples containing 0%, 0.5% 1%, 1.5%, and 2% *Moringa oleifera* extract. The raw meat mixture was boiled 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 panelists were 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

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 a source of variations. Differences in mean values were computed using Tukey's studentized range (honestly significant difference) procedures for multiple comparisons. For sensory evaluation, ph, and color statistical package for the social sciences (SPSS) software (SAS, version 1.9.3 of 2007) was used to analyse the data and two-way analysis of variance (ANOVA). For sensory evaluation data analysis, categories were assigned values from one to nine (none = one, extreme = 9). Data was subjected to analysis of variance, with treatment and panelist as the main effects. When main effects were significant at $P<.05$, treatment means were compared by using Duncan test.

RESULTS AND DISCUSSION

The results showed that the Aerobic plate count of ground beef was significantly ($P<.05$) affected by *Moringa oleifera* leaves extract treatment (Table 1). Microbial load significantly decreased on treated samples. The *moringa oleifera* leaves extract has been found to prevent the growth of microorganisms (Jayawardana *et al.,* 2015).

Table 1: Effects of *Moringa oleifera* preservative on Aerobic plate count for ground beef

Characteristics	Preservatives (Conc)	Time (hrs) 1 hour	12 hours	24 hours	48 hours	72 hours
APC	0.5%	6.30^{d} ±0.10	6.62^{c} ±0.12	6.76^{b} ±0.14	6.89^{b} ±0.16	7.39^{a} ±0.18
	1.0%	6.22^{d} ±0.12	6.43^{a} ±0.14	6.60^{a} ±0.16	6.80^{a} ±0.18	7.20^{b} ±0.20
	1.5%	6.20^{d} ±0.14	6.49^{a} ±0.16	6.58^{a} ±0.18	6.78^{a} ±0.20	6.93^{a} ±0.22
	2.0%	6.22^{d} ±0.16	6.37^{a} ±0.18	6.53^{a} ±0.20	6.75^{a} ±0.22	6.85^{a} ±0.24
	Control	6.34^{d} ±0.18	7.08^{b} ±0.20	7.23^{c} ±0.22	7.82^{d} ±0.24	8.49^{e} ±0.26

Values expressed as mean ± standard deviation. Values with different superscript in the same column show significant difference among treatments within same storage day at $p \leq .05$. Control (0%), 0.5%, 1%, 1.5% and 2%*Moringa oleifera* leaves extract. APC- Aerobic Plate count

APC in 1 hour adding the *Moringa oleifera* leaves extract samples was found to be log 6.20±0.14 CFU/g to 6.34±0.18CFU/g. After 72 hours of adding the *Moringa oleifera* leaves 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.

During the 72-hour storage period, the aerobic plate count (APC) of all ground beef samples treated with varying concentrations of *Moringa oleifera* leaves extract (0.5%, 1%, 1.5%, and 2%) consistently remained below 7 log10 CFU/g. Table 1 presents the utmost permissible limit (MPL) for aerobic plate count (APC) in ground beef as specified by the International Commision on Microbiology Specifications for Foods (ICMSF). The storage duration for control ground beef was increased from 12 hours to 72 hours, as indicated in Table 1.In the study conducted by Abdallah et al. (2023), it was observed that the aerobic plate count (APC) of beef meatballs treated with varying concentrations of MLE (0.5%, 1%, and 2%) stayed consistently below the threshold of 7 log10 CFU/g throughout the 18-day storage period. This finding is significant as it aligns with the maximum permissible limit (MPL) for APC in ground beef, as defined by the International Commission on Microbiological Specifications for Foods (ICMSF). In a similar vein, Hazra *et al.,* (2012) demonstrated a significant reduction ($p < 0.05$) in total plate counts (TPCs) in ground buffalo meat following the addition of 1.5% and 2% MLE. In the study conducted by Mashua et al. (2021), it was observed that the control samples demonstrated the highest total bacterial count of 6.63 log cfu/g on day 15. Conversely, the treated sample (T4) revealed the lowest value of 4.30 log10 cfu/g. The present study reveals that the inclusion of MOLE led to a statistically significant reduction ($p < 0.05$) in the total bacterial count observed in the patties.

The antibacterial activities of *Moringa oleifera* leaves can be attributed to the abundance of bioactive constituents, including flavonoids, saponins, tannins, and phenolic acids (Fahey, 2005). Therefore, the decreased bacterial count seen in the treated mutton patties can be attributed to these components. Moreover, the utilization of Moringa Oleifera leaves extract has been documented to lead to a decrease in the overall bacterial count during the refrigerated storage of diverse meat products, as described by Falowo *et al.,* (2016) and Najeeb *et al.,* (2015).

Table 2: Effects of *Moringa oleifera* preservative on color and pH for ground beef

Characteristics	Preservatives	Time (hrs)				
	(Conc)	1 hour	12 hours	24 hours	48 hours	72 hours
Color a*	0.5%	12.40^{a} ±1.14	10.50^{a} ±1.12	8.40^{b} ±1.16	8.00^{ab} ±1.16	7.70^{b} ±1.17
	1.0%	12.80^{a} ±1.06	11.20^{a} ±1.08	8.90^{ab} ±1.05	9.00^{ab} ±1.09	7.20^{c} ±1.10
	1.5%	13.60^{a} ±1.14	11.70^{a} ±1.13	10.30^{ab} ±1.16	10.00^{b} ±1.16	8.80^{c} ±1.18
	2.0%	13.90^{a} ±1.13	12.20^{a} ±1.14	11.60^{a} ±1.16	11.00^{ab} ±1.16	10.00^{b} ±1.15
	Control	12.00^{a} ±1.41	10.00^{a} ±1.89	8.30^{b} ±1.96	6.90^{c} ±1.76	5.00^{c} ±1.13
Color 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
Color 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%	31.98^{c} ±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	26.67^{b} ±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 superscripts in the same column show significant differences among treatments within the same storage period at $p \leq .05$

Color a* (Redness)

The redness (a*) of ground beef treated with various doses of *Moringa oleifera* leaves 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* leaves 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* leaves extract resulted in the greening (a*) of patties, and so the redness decreased with the addition of *Moringa oleifera* leaves 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. Preserving redness in ground beef involves a complicated interplay of metabolic events, and *Moringa oleifera* leaves extract shows the potential for delaying color changes. Because of its antioxidant and antibacterial qualities, it is a promising prospect for future research and application in the meat industry to improve both visual appeal and shelf life.

Color b (Yellowness)

The table above shows that there is 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 was 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 in yellowness in patties is due to the natural antioxidants that *Moringa oleifera* leaf extract 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* leaves extract since moisture is associated with the lightness values (Pérez-Álvarez *et al.,*1999). Moreover, the inclusion of *Moringa oleifera* leaves extract decreased the lightness of ground beef because *Moringa oleifera* leaves extract contains a green pigment (chlorophyll) that affected the color of the ground beef by diluting meat pigment, hemoglobin.

According to Mashua *et al.,(* 2021), there was a significant decrease in lightness (L*) values of treated samples with the concentration of Moringa leaves 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* leaves extract broccoli 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* leaves extract may help maintain desirable pH levels and extend the shelf life of ground beef.

Madane *et al.,* (2019) also observed an increase in the pH of chicken nuggets added with *Moringa oleifera* flower extract during the storage.However according to Hazra *et al.,*2012, pH of meat samples treated with 1.5% moringa crude extract were significantly (P<0.05) higher than those of other samples. Muthukumar *et al.,* 2014 observed that there was no difference (P>0.05) in pH among the control and treated groups with *moringa oleifera* leaves extract in both raw and cooked pork patties due to incorporation of antioxidants.

Table 3. Sensory attributes of cooked ground beef treated with *Moringa oleifera* leaves extract

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. 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 (Gullon *et al.,*2020) 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 color. According to Hazra *et al.* (2012), the results showed a significant (P<.05) improvement in the color of ground buffalo meat treated with 1.5% *Moringa oleifera* leaves extract in comparison to other treated meat.According to Sediek *et al.,* 2012, the highest value of color was significantly recorded with ginger extract (1.0%) these results may be due to high content of antioxidants and phenols which prevent the oxidation of hemoglobin.

Texture

The texture of ground beef showed a significant improvement with 2% *Moringa oleifera* leaves extract compared to the control and 0.5% treatment. The color scores ranged from 4.7 to 7.0. The mean difference between the control sample and the preservatives indicated a significant increase in texture preference at all concentrations (0.5%, 1%, 1.5%, and 2%) compared to the control. The preference for texture improved as the concentration of the preservatives increased. However, 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 scored highest in comparison to other treated samples. This may be due to more effective inhibition of lipid peroxidation.The results of sausage texture as presented by Sediek *et al.,* 2012, showed no significant differences were obtained between treatments and control samples.

Taste

There was a significant difference (p<0.05) in taste for all the samples under study concerning the control sample (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 taste preference 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.

According to Sediek *et al.,* 2012 taste showed the priority of ginger extract especially (1.0%). According to Hazra *et al.* (2012), the taste showed a significant ($P<0.05$) improvement, and ground buffalo meat treated with 1.5% crude extract scored highest in comparison to other treated samples.

Juiciness

There was a significant difference ($p<.05$) in juiciness for the control sample with 1%, 1.5%, and 2%, (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 ($P<.05$) from the control, but there was no significant ($P>.05$) difference between them. Rahman *et al.,* (2020) found a significant ($p<.05$) increase in the color, flavor, tenderness, juiciness, and overall acceptability of goat meat nuggets treated with 0.3% *Moringa oleifera* leaves extract during frozen storage compared to the control and other goat meat nuggets treated with 0.1% butylated hydroxyanisole (BHA).

Flavor

There was a significant difference ($p<.05$) in flavor for all the samples under study concerning 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 ($P<.05$) improvement, and ground buffalo meat treated with 1.5% crude extract scored highest in comparison to other treated samples. As Abdallah *et al.,* 2023 said, Moringa flavor intensity was significantly ($p <.01$) 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 ($p<.05$) 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 ($P<.05$) 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. AsAbdallah *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. Over all acceptance of Sausage researched by Sediek *et al.,* 2012, proved the preferability of ginger extract (1.0%) then 0.5% whereas the other treatments recorded less significant.

CONCLUSION

This study examined the antibacterial activity of *Moringa oleifera* leaves extract on ground beef. Its main goal was to evaluate the physicochemical, microbiological, and organoleptic properties of ground beef samples exposed to different concentrations of the extract. A constant 4°C temperature was employed to study refrigerated storage conditions. The study found that adding a 1.5% *moringa oleifera* leaves extract improved ground beef sample sensory characteristics. The criteria were pH, juiciness, texture, flavor, taste, and overall acceptability. This improvement was compared to the control group and other treated samples. Aerobic Plate Count (APC) showed a significant decrease in microbial load in treated samples. The medication's 2% concentration reduced microbial load more effectively. L*, a*, and b* values dropped statistically, with 2% dropping more. Ground beef had a slight pH increase throughout storage. However, Moringa extract did not significantly affect meat pH. Thus, *Moringa oleifera* leaves extract can improve beef product safety, quality, and shelf life under refrigerated storage.

RECOMMENDATIONS

- Explore the potential synergistic effects of combining *Moringa oleifera* leaves extract with other natural preservatives or packaging technologies to enhance the overall shelf life and quality of refrigerated ground beef products.
- Another study should be done using different extraction methods of *Moringa oleifera* and increasing the *Moringa oleifera* concentration.
- Collaboration with industry partners and regulatory authorities should be done to establish guidelines and standards for the incorporation of *Moringa oleifera* leaves extract in ground beef products, ensuring compliance with food safety regulations and labeling requirements.
- The preservative effect of *Moringa oleifera* should be analysed in different food products.

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