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Impact of packaging materials on quality of goat meat product (meat floss)

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Abstract. *The study investigated eco-friendly packaging materials and evaluated their effectiveness on the sensory and microbial quality of meat floss over a period of nine days' storage duration using a 3×4 factorial arrangement in completely Randomized Design (CRD). The packaging materials used were sterile containers (SC), Banana leaves (BL) and Plastic containers (PC). The storage durations were (0, 3, 6, and 9 days). Sensory attributes were colour, flavour, taste, texture and overall acceptability, evaluated every three days. Microbial counts (Total Aerobic Plate Count and Salmonella count) were also measured. The result showed that duration of storage had significant effect on the sensory attributes of meat floss (Dambun nama). All the parameters measured decreased significantly ($P<0.05$) across the days with control (0) having the best rating for taste, texture, flavour and colour, while the overall acceptability showed an unusual pattern of decrease with day 3 having the best (3.67±0.10) score. Plastic containers (PC) had the highest rating (4.0, 4.5, 4.1) for taste, texture and flavour, with no significant difference ($p>0.05$) observed across the storage durations. A slight difference ($p<0.05$) was observed for colour by day 9 across all the packaging materials. Overall acceptability also followed a similar trend. The Total Aerobic Plate Count (TAPC) increased over time across all storage materials, with the highest counts observed in plastic containers (PC). The correlation analysis showed a weak positive correlation between the sensory attributes measured. The strongest correlation was observed between flavour and taste ($r = 0.44$, $P<0.05$) while the weakest correlation was between colour and texture ($r = 0.14$, $P<0.05$). Salmonella was only detected in control (SC) on day 0, with no further detection across other storage durations or storage materials. It can be concluded that both plastic containers and banana leaves enhance the quality and storage of meat products by maintaining taste, flavour, colour and general acceptability, thus providing a balanced solution that maximizes sensory quality and minimizes microbial growth. For optimal sensory qualities and short storage duration, plastic containers should be used. Banana leaf is recommended for longer storage period due to its anti-microbial properties.*

Keywords: storage, sensory quality, packaging materials, Dambun nama, eco-friendly

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Introduction

One of the oldest domesticated animals in the world is the goat. The Fertile Crescent is where goats were initially domesticated, and from there they spread over the world (Gibson, 2016). Goats are found to be among the big five livestock species (chicken, sheep, cattle, pigs and goats) (Saleh et al., 2021). The goat is normally referred to the poor man's cow. Worldwide, domesticated goats are primarily used to provide meat, milk, fat, skin, fiber, and cashmere (Bomba et al., 2015). History has it that there are over 600 breeds of goats worldwide. Different breeds of goats are adapted to different livestock systems - from small herds of 3-5 heads on meager grazing to large intensive livestock farms, from year-round grazing to fully stable housing, with many intermediate variations between them. Among the goat breeds there are highly productive specialized, dual-triple-use and universal breeds. External differences between breeds are represented by many major and minor traits that vary in a very wide range. Goat breeds (especially dairy goats) are some of the oldest defined animal breeds for which breed standards and production records have been kept. Breeds are generally classified based on their primary use, though there are several breeds which are considered dual- or multi-purpose. These variations are categorized based on how well they serve certain functions (Bertolini et al., 2018). After domestication, goat species got scattered quickly over the world through human migrations and commercial traders (Rezaei et al., 2008). One of the main factors supporting farmers' livelihoods in arid and semi-arid areas is goat production (Mohammadi et al., 2009).

The traditional food packaging model follows a linear path, where materials are used once and discarded, contrasting with the circular economy approach, which promotes recycling and recovery. Growing concerns about packaging waste, particularly plastic, and its environmental harm have sparked interest in sustainable alternatives. Factors like policy changes, waste concerns, and resource demands are driving the development of biodegradable and compostable packaging from renewable resources (EREM, 2020). Food like rice, fish, meat, fruits and vegetable-based products are packaged using banana leaves due to their availability in the tropics and being affordable. They are recyclable, biodegradable, and have higher shelf life after processing (Rikasa and Mufeez, 2023).

Meat is the fleshy or edible part of an animal usually domesticated livestock used for food, which includes not only the muscles and fat but also the tendons and ligaments (Britannica, 2024). The quality of meat products is established in food science and technology. Packaging plays an important role in preserving the safety, quality and shelf-life of meat products, thereby protecting them from physical, chemical, and microbiological damage and danger and equally making them qualitative and safe for consumption by humans. Meat packaging is not only streamlined to wrapping or enclosing a meat product, but it also protects the meat from spoilage. Packaging must ensure safe delivery of the meat products at a minimum cost (Choi, 2014). The cost of packaging has to be affordable to its consumers. Packaging does not improve the existing quality of a product but it helps in maintaining its keeping quality (shelf life) during storage and transportation (Choi, 2014).

In order to ensure safety and meet consumer satisfaction, the current packaging materials (zip-top plastic bag, wax paper, aluminum foil, and many more) used for meat floss (a Nigerian traditional meat product) contribute to environmental degradation. This results in harm to the environment, depletion of natural resources and negative impact on public health (Vanderroost et al., 2014).

To mitigate these impacts, the use of innovations and technological preservation methods can be adopted in the packaging of meat products (Marsh et al., 2007). Packaging is vital in keeping the quality of meat products from being contaminated, which is critical for the general public's health (Vanderroost et al., 2014).

Therefore, investigating and identifying eco-friendly packaging materials for meat floss is crucial for ensuring the product's quality while promoting environmental stewardship (Robertson, 2013).

Material and methods

Description of the study area

This research was carried out at the Animal Product Processing Laboratory, Department of Animal Science, College of Agriculture and Environmental Science, Kaduna State University, Kafanchan, Kaduna Nigeria. Kafanchan is located at latitude 9° 59'N, longitude 8° 29'E and it is situated at an elevation of 733 m above sea level (World Atlas, 2018). The town has zero rainfall at the beginning and end of the year with a yearly precipitation of about 28.1 mm (1.11) on average and an average of 53.7% (Ovimaps, 2022).

Experimental design and sample preparation

The meat samples were purchased from an open market within Kafanchan metropolis. Meat samples were evaluated for qualities of meat floss (Dambun nama) under different packaging materials (banana leaves and plastic containers), with 4 storage durations (0, 3, 6, and 9 days, respectively). Four treatments were used for the study using a factorial arrangement consisting of 3×4 factors, that is 3 packaging materials and 4 storage periods in a completely randomized design (CRD).

Four (4 kg) chevon meat was used to prepare the meat product (Meat floss). The meat samples were washed, seasoned with fresh ginger (60 g), thyme (10 g), garlic (40 g), pepper (120 g), onions (220 g), salt (20 g), curry (20 g) and seasoning cubes (80 g). The meat was allowed to marinate for 30 minutes after mixing the meat together with the ingredients thereafter, cooked at a cooking temperature of 160°C for 30 minutes to enable the meat get softer for easy pounding. The meat was fried into meat floss with 100 g of cooking oil under normal frying temperature for 20 minutes; it was then allowed to cool down for 30 minutes before packaging to 4°C.

The Meat floss samples were packaged using the already sourced packaging materials (sterile container, plastic container and banana leaf) during the experiment with four samples randomly assigned to each treatment inside the already purchased packaging materials. At the end of the packing, four (4) replicates of each treatment were obtained making twelve (12) samples available with their codes on each of the packaging materials.

Packaging materials

Three different packaging materials were selected for the study. The materials were sourced from an open market within Kafanchan metropolis. The materials included sterile container, banana leaf and plastic containers. After purchasing the banana leaf, it was cut into a square shape of equal sides, then folded into a box with one side completely open in order to have a cavity. Another one was made in such a way that it could fit into the first one, that is, one box serves as the container and the other is the lid. Then a strand was removed from the banana leaf and was used to tie the two boxes together. This process was repeated until four boxes were obtained.

Storage conditions

All packaged meat samples were stored under controlled environmental conditions (e.g., refrigeration temperature of -18°C at 1.1 g of water in the air) for a period of 9 days.

Sensory evaluation

The meat was defrosted using microwave at 60°C for 5 minutes. A team of semi-trained sensory panelists (n=20) was used to evaluate the product for taste, tenderness, texture, colour, and general acceptability, respectively, using a 5-point hedonic scale (excellent: 5, very good: 4, moderately good: 3, poor: 2, very poor: 1). They were offered blind samples of the meat product. Each panelist was served with three (3) samples to score the above-mentioned parameter. They were provided with water for rinsing their mouth, and biscuits in order to avoid contamination from the taste of the previous product. Sensory evaluation was done after every three days (i.e. 0, 3. 6 and 9 days, respectively, using the method of Prince Kumar (2023).

Microbial evaluation

Meat samples were evaluated for microbial contamination using the standard microbial

procedures as described by Markey et al. (2013). The meat samples which consisted of one sample from each treatment making three samples were taken to the laboratory and evaluated for Total Aerobic Plate Count and Salmonella Count for a period of 9 days (i.e., 3×4=12) samples.

Statistical analysis

ANOVA was used to analyze data across different packaging materials using SAS 9.1 (2002) and determine significant differences in quality attributes using Duncan Multiple Range Test (DMRT).

Results and discussion

Table 1. Effect of storage duration on sensory quality of meat product (Danbun nama)

Parameters	Storage duration				P-value
	0 days	3 days	6 days	9 days	
Taste	4.57±0.10a	3.85±0.10b	3.02±0.10c	2.72±0.10c	0.0000*
Texture	4.13±0.27a	3.60±0.28a	3.53±0.2ab	2.57±0.27b	0.0009*
Flavour	3.65±0.10a	3.63±0.28b	2.73±0.10b	2.38±0.10b	0.0000*
Colour	3.62±0.11a	3.44±0.11a	2.93±0.10b	2.45±0.11c	0.0000*
Overall acceptability	3.47±0.10a	3.67±0.10a	2.66±0.10b	2.30±0.10b	0.0000*

[abc]Means with different superscripts within the same row are significantly different, *= Significant at 5 %

The results from this study showed that duration of storage had significant effect on the sensory attributes of meat floss (Dambun nama), although not much difference was observed across the storage period for the different parameters measured. The sensory attributes measured were taste, texture, colour, flavour and overall acceptability. The taste of meat floss decreased significantly (P<0.05) across the storage duration. Meat floss stored for 0 days (control) had significantly (4.57±0.10) better taste than that stored other days 3 (3.85±0.10), 6 (3.02±0.10) and 9 (2.72±0.10) days, respectively. The texture of meat floss also decreased significantly (P<0.05) with increasing storage duration. Meat floss stored for 0 days (control) had significantly (4.13±0.27) better texture than that in other storage days 3 (3.60±0.28), 6 (3.53±0.2) and 9 (2.57±0.27) days, respectively. Flavour also decreased significantly (P<0.05) with an increase in storage days. Control (0 days) had the best score (3.65±0.10) compared to those in other storage days 3 (3.63±0.28), 6 (2.73±0.10,) and 9 (2.38±0.10) days, respectively. Colour also showed the same pattern of decrease as the other parameters above, with control (0 day) having the best (3.62±0.11) colour compared to that in other storage days 3 (3.44±0.11), 6 (2.93±0.10), and 9 (2.45±0.11), respectively. The overall acceptability of meat product showed an unusual pattern of decrease (P<0.05) with 3 days' storage duration having the best (3.67±0.10) score for consumer preference compared to that in other storage days 0 (3.47±0.10), 6 (2.66±0.10), and 9 (2.30±0.10), respectively. The unusual score for consumer preference observed on day 3 may be as a result of aging of the meat product. (Wasserfall, 2019) also reported that factors such as marbling and aging influence consumer perception of the sensory quality of meat products.

The decline in sensory parameters observed in this study may be due to microbial contamination during handling and processing. Ready-to-eat (RTE) meat products like meat floss are especially a concern since these may be consumed without further cooking and are known to be good growth substrates for pathogenic microorganisms such as Listeria monocytogenes (Zhu et al., 2005), thus affecting their sensory quality. This is in line with the findings of Johnson (2017) who reported that methods used for handling and preparing meat had an impact on its quality. Appropriate handling and processing techniques are essential to maintain

meat quality and prevent contamination (Johnson, 2017). Listra et al. (2016) also reported that the nutritional and sensory qualities of meat products might alter due to microbial activity, physical alterations, or chemical changes during storage. Another reason could be the type of meat used. Nonetheless, it is known that goat meat is lower in fat than that of pigs, sheep, and cattle. This may increase its appeal to customers who are concerned with their health. Despite having this quality, it does also possess a strong odour and this will have impact on how high or low the product is regarded. According to Ikotun et al. (2021), goat meat is known for having a strong flavour and aroma, especially when it comes from mature male goats and this might influence sensory perception of consumers. Again, the storage environment, the packaging materials used and length of storage may also lead to decrease in the sensory perception by consumers. Meat is constantly changing, either chemically or physically, depending on the kind of storage environment. These alterations are the result of both environmental degradations brought on by storage and natural deterioration that happens to meat products. This is in line with the finding of Zhang (2015) who reported that meat products could undergo a variety of changes after being left for a while without being preserved properly, including changes in flavour, texture, colour, and overall appearance. Packaging materials affect the texture, colour, and appearance of chevon (Kumar et al., 2020). Meat quality characteristics like colour stability, texture, tenderness, juiciness, flavour, and shelf life can all be affected by the packaging used (Choi, 2014).

The study indicated that meat product (Danbun nama) stored for shorter durations had more perception on consumer preference in terms of sensory qualities than those stored for longer durations.

Table 2. Effect of storage material on the sensory evaluation

Parameters	Storage material			P-value
	Sterile container	Plastic container	Banana leaf	
Taste	3.56±0.09	3.55±0.08	3.50±0.08	0.8707NS
Texture	3.41±0.24	3.82±0.23	3.14±0.23	0.1251NS
Flavour	3.00±0.08b	3.33±0.09a	2.96±0.08b	0.0065*
Colour	3.25±0.09	3.09±0.09	2.99±0.08	0.1265NS
Overall acceptability	3.18±0.09	2.99±-0.09	2.90±0.08	0.0973NS

[abc]Means with different superscripts within the same row are significantly different, NS= Not significant, *= Significant at 5 %

The result obtained in this study indicated that the type of packaging material used had no significant (P<0.05) effect on the sensory parameters measured. The attributes measured included taste, texture, flavour, colour and overall acceptability. They were all similar across the packaging materials tested. The taste scores for Sterile containers (SC), Plastic containers (PC) and Banana leaves (BL) did not differ significantly (P>0/05) with scores ranging from 3.56±0.09, 3.55±0.08 and 3.50±0.08, respectively. Texture scores also had no effect on the packaging materials used. The scores included SC 3.41±0.24, PC 3.82±0.23 and BL 3.14±0.23, respectively. Flavour score differed significantly (P<0.05) with PC having the best score 3.33±0.09 compared to other packaging materials used. This could be due to the fact that modified atmosphere packaging (MAP) prolonged shelf life by reducing lipid oxidation (Chandra et al., 2020).

Packaging slows down the deterioration of meat quality, including microbial growth, discolorations, off-flavor, and vitamin loss (Fang et al., 2015). According to Kauffman (2017), the intramuscular fat level of meat, or marbling, is one of the main variables influencing its quality. Marbling is a critical factor in determining meat quality as it affects tenderness, juiciness, and flavor. Colour and Overall acceptability also did not differ significantly (P>0.05) across all the packaging materials tested. The scores included colour: SC; 3.25±0.08, PC;

3.09±0.09 and BL; 2.99±0.08, respectively. Overall acceptability scores incuded: SC; 3.18±0.09, PC; 2.99±0.09 and BL; 2.90±0.08, respectively.

Meat under preservation may be rather sensitive to the kind of substance or procedure used to preserve it, and the sensitivity of the meat and the packaging material determines how hygienic the food is. Packaging materials affect how quickly chevon oxidizes and spoils (Patel et al., 2019).

Table 3. Effects of storage duration and packaging materials on sensory evaluation of Dambun nama

Storage duration	Storage material	Sensory evaluation parameters				
		Taste	Texture	Flavour	Colour	Overall acceptability
0	A	4.45±0.17	4.00±0.47	3.45±0.18ab	3.85±0.18	3.40±0.18
	B	4.60±0.17	4.45±0.45	4.10±0.17a	3.30±0.18	3.40±0.17
	C	4.65±0.17	3.95±0.47	3.40±0.13ab	3.70±0.18	3.60±0.18
3	A	3.95±0.16	3.50±0.47	3.30±0.17b	3.55±0.17	3.85±0.18
	B	3.79±0.18	3.78±0.48	3.98±0.18a	3.47±0.19	3.71±0.19
	C	3.80±0.17	3.50±0.47	3.60±0.17ab	3.30±0.18	3.45±0.17
6	A	3.05±0.17	3.55±0.47	2.90±0.17cd	3.20±0.18	3.00±0.16
	B	3.05±0.17	4.50±0.47	2.95±0.15c	3.15±0.16	2.80±0.17
	C	2.95±0.17	2.55±0.45	2.35±0.17d	2.45±0.15	2.19±0.18
9	A	2.80±0.17	2.60±0.47	2.35±0.17d	2.45±0.18	2.45±0.17
	B	2.75±0.17	2.55±0.47	2.30±0.18d	2.45±0.18	2.05±0.18
	C	2.60±0.17	2.55±0.46	2.50±0.17cd	2.50±0.15	2.40±0.18
	P-value	0.9280^{NS}	0.5193^{NS}	0.0325*	0.0601^{NS}	0.0503^{NS}

^{abcd}Means with different superscripts within the same column are significantly different, NS= Not significant, A= control, B= Plastic container, C= Banana leaf

Table 3 shows the effects of storage duration and storage material on sensory evaluation parameters. No significant difference was observed across all the parameters measured. Taste scores were the highest on day 0, with meat stored in Banana leaf (BL) scoring 4.65, followed by Plastic containers (PC) at 4.60 and control (Sterile container, SC) at 4.45. By day 9, taste scores declined significantly to 2.75 in control (SC), 2.55 in plastic container (PC), and 2.60 in banana leaves (BL). This decline reflects the effects of oxidation and microbial spoilage, which degrade taste over time (Smith et al., 2020). It has been recorded that plastic containers can initially slow down taste deterioration by limiting exposure to air, yet their protective effects decrease over extended storage periods (Krochta, et al., 1997).

Texture scores also declined over time, starting with the highest score of 4.45 in plastic storage (PC) on day 0. By day 9, texture scores dropped to 2.55 in plastic, 2.75 in control, and 2.50 in banana leaves. This decrease in texture quality is likely due to moisture loss and muscle fiber degradation over time, resulting in tougher meat. According to Johnson (2017), moisture retention is essential for maintaining meat tenderness, and plastic packaging initially supports this better than natural materials because over time, moisture can permeate through the plastic resulting in decline in moisture retention. However, as storage time increases, the plastic's ability to retain moisture diminishes, leading to a decline in texture quality.

Flavour scores were initially the highest in plastic containers (PC) at 4.10 on day 0, compared to 3.45 in control (SC) and 3.40 in banana leaves (BL). By day 9, flavour scores decreased slightly to 2.30 (PC), and 2.35 in control (SC), showing a significant difference across.

The decline in flavour is consistent with research by Morris and Kim (2017), who reported that prolonged storage led to flavour loss due to oxidation and microbial activity. Plastic containers

provided better initial flavour preservation by limiting oxygen exposure, but this benefit reduced over time as some oxygen permeation occurs even in plastic. Colour stability also declined across storage materials. On day 0, colour scores were the highest in plastic container (PC) at 4.10, followed by control (SC) at 3.85 and banana leaves (BL) at 3.70. By day 9, colour scores dropped to 2.45 in control, 2.50 in plastic, and 2.40 in banana leaves, likely as a result of enzymatic reactions caused by either temperature or moisture levels. The more significant colour deterioration in banana leaf storage aligns with Chen et al. (2019), who found that natural materials like leaves tend to allow higher oxygen permeability, accelerating oxidative browning in meat.

Overall acceptability scores followed a similar pattern of decline, starting with control (SC) at 3.85 on day 2, Plastic container (PC) at 3.71, and banana leaves (BL) at 3.450. By day 9, acceptability scores decreased to 2.45 in control, 2.05 in plastic, and 2.40 in banana leaves, which is likely caused by moisture loss, loss of freshness or microbial growth. Anderson et al. (2021) reported that declines across sensory attributes such as taste, texture, flavour, and colour ultimately reduce consumer acceptability. This study confirms that while plastic containers initially help retain sensory qualities, prolonged storage reduces overall acceptability for all storage materials.

Table 4. Correlation among the sensory evaluation parameters

	Taste	Texture	Flavour	Colour	Overall acceptability
Taste	×	0.23*	0.44*	0.31*	0.29*
Texture		×	0.19*	0.14*	0.21*
Flavour			×	0.28*	0.24*
Colour				×	0.38*
Overall acceptability					×

*= Significant at 5%

Table 4 shows the effect of Correlation among the sensory evaluation parameters. The correlation analysis showed a weak positive correlation between the sensory attributes measured. The strongest correlation was observed between flavour and taste ($r = 0.44$, $P<0.05$) while the weakest correlation was between colour and texture ($r = 0.14$, $P<0.05$). Moderate correlation was observed between overall acceptability and texture ($r = 0.21$, $P<0.05$), texture and taste ($r = 0.23$, $P<0.05$), overall acceptability and flavour ($r = 0.24$, $P<0.05$). The positive correlations observed between the sensory attributes of meat floss indicates that sensory attributes may influence the quality of meat and meat products among panelists due to individual perception of the product. This corresponds with the finding of Zahraddeen et al. (2020) who reported that sensory attributes can be used to improve quality of meat and meat products among panelists especially of diverse cultural background. The acceptability of meat products can be improved through improvement in their sensory attributes, particularly colour, which have great influence on consumer perception (Zahraddeen et al., 2020).

Figure 1 shows the effect of storage duration and storage material on Total Aerobic Plate Count (TAPC) and Salmonella counts across different storage times and materials. The TAPC increased over time across all storage materials, with the highest counts observed in plastic containers (PC). On day 0, the TAPC was low across all materials, but by day 9, TAPC reached its peak at around 60 CFU/g in plastic container (PC). In control (SC) and banana leaves (BL), TAPC counts were lower, with the control showing a significant increase by day 6, but leveling off by day 9, and banana leaves maintaining a comparatively lower count throughout which is a result of inhibition of the microbial growth (Davidson et al., 2013).

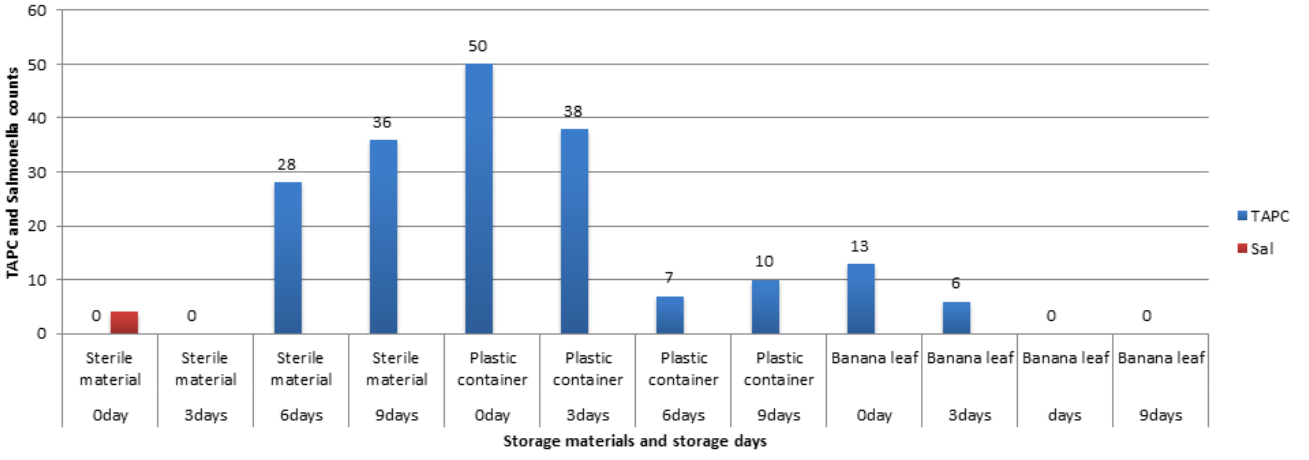

Figure 1. Effect of storage duration and storage material on Total Aerobic Plate Count (TAPC) and Salmonella counts

This increase in TAPC aligns with Lee (2020), who noted that plastic materials, while initially protective, may trap moisture and create a favorable environment for bacterial growth over extended storage periods. Banana leaves showed lower TAPC due to their natural antimicrobial properties (Choi, 2019). The latter found that banana leaf extracts inhibited bacterial growth on meat products.

Salmonella was only detected in control (SC) on day 0, with no further detection across other time points or storage materials. This may suggest that initial contamination was present but was either controlled or inhibited by storage conditions in subsequent days. The absence of Salmonella in the plastic and banana leaf storage could be due to better containment and natural antimicrobial effects, respectively, preventing Salmonella proliferation (Anderson et al., 2021). It can be concluded that: Plastic containers initially preserved the sensory qualities (taste, texture, flavour, colour, and overall acceptability) of meat better than banana leaves and control, but all sensory qualities deteriorated over time.

By day 9, microbial load, measured by Total Aerobic Plate Count (TAPC), was the highest in plastic containers, while banana leaves maintained lower counts, likely due to natural antimicrobial properties. Salmonella was only detected in control samples on day 0, with no further detection in other materials or days. For optimal sensory quality, meat should be stored in plastic containers for short durations (1-3 days) to retain taste, texture, and flavor. For longer storage, banana leaves are recommended due to their antimicrobial properties, which help to control bacterial growth. Further study on combination of plastic with natural antimicrobial treatments, such as banana leaf extract, may provide a balanced solution that maximizes sensory quality and minimizes microbial growth.

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