Asian Australas. J. Food Saf. Secur. 2026, 10(2), 92-104; https://doi.org/10.3329/aajfss.v10i2.90256

Asian-Australasian Journal of Food Safety and Security
ISSN 2523-1073 (Print) 2523-2983 (Online)
https://www.ebupress.com/journal/aajfss/

Article

Quality comparison of BLRI-developed and locally available sausages

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Received: 23 May 2026/Accepted: 02 November 2026/Published: 23 November 2026

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Abstract: Sausages are widely consumed processed meat products, yet comparative evidence on institutionally developed and commercially marketed chicken sausages in Bangladesh remains limited. This study compared the proximate composition, sensory quality, and price of chicken sausage developed at the Bangladesh Livestock Research Institute (BLRI), Savar, with two commercial brands (Brand A and Brand B) purchased from local markets in Savar, Dhaka, Bangladesh, and assessed the microbiological quality of the BLRI-developed sausage during refrigerated (up to 21 days) and frozen (up to 60 days) storage. Each product was analyzed in triplicate, and data were subjected to analysis of variance under a completely randomized design. Proximate composition differed significantly among products ($P < 0.001$). BLRI-developed sausage had the highest moisture (76.17%), crude protein (37.66%, comparable to Brand B at 37.33%) and ether extract (10.93%), and the lowest crude fiber (0.27%) and ash (3.00%). Sensory attributes did not differ significantly among products ($P > 0.05$), although BLRI-developed sausage received the highest numerical overall acceptability score (3.87 versus 3.62 and 3.25 on a five-point scale). Salmonella was not detected in any BLRI-developed sample, and total aerobic, coliform, and yeast and mold counts fluctuated without a consistent increase during storage. BLRI-developed sausage was also 35.38% cheaper than both commercial brands (BDT 168 versus BDT 260 per 340 g pack). These findings indicate that the BLRI-developed sausage offers a protein-rich, equally acceptable, and more affordable alternative to locally available products. The results support its scale-up and technology transfer to small and medium meat processors in Bangladesh, and they can guide consumers and manufacturers in improving sausage quality. Further work on shelf life and on microbiological comparison with commercial brands would strengthen these conclusions.

Keywords: chicken sausage; proximate composition; sensory evaluation; microbiological quality; price

1. Introduction

Changing lifestyles, urbanization, and increasing work-related commitments have contributed to the growing demand for convenient, ready-to-eat, and processed food products (Ameye *et al.*, 2025). Among these products, meat-based foods have gained considerable popularity because of their nutritional value, convenience, and diversity. Sausages are widely consumed processed meat products prepared from minced or ground meat, or a combination of different meat types, mixed with seasonings and other ingredients and subsequently encased in natural or artificial casings (Bazhan *et al.*, 2025). Their versatility, ease of preparation, and availability in different formulations have made them an important component of the processed meat industry (Schnettler *et al.*, 2018; Pandey *et al.*, 2023).

Sausage quality is influenced by several factors, including the type and quality of raw meat, fat content, functional ingredients, processing techniques, and storage conditions. Depending on their formulation and processing methods, sausages are broadly classified into raw, cooked, scalded, and fermented or ripened products (Carballo, 2021; Mediani *et al.*, 2022). Their composition and sensory characteristics vary considerably across regions and manufacturers because of differences in raw material availability, dietary preferences, cultural practices, production technologies, and consumer expectations (Baer and Dilger, 2014; Appiani *et al.*, 2023). Sausages are commonly manufactured using chicken, beef, chevon, and pork, with chicken sausage being particularly popular in many markets. Although specific formulations differ among manufacturers, meat, fat, water, fillers, binders, and seasonings are among the principal components used in sausage production (Pérez *et al.*, 2023; Hossain *et al.*, 2025). The proportion and functional properties of these ingredients directly influence the nutritional composition, texture, flavor, juiciness, and overall acceptability of the final product (Anyimah-Ackah, 2025).

Chicken sausage has attracted considerable consumer interest in different countries because of its versatility, relatively broad consumer acceptance, and suitability for various dietary preferences (Zaini *et al.*, 2021; Tenza *et al.*, 2026). Chicken meat is also considered a source of high-quality protein and unsaturated fatty acids, although its nutritional composition varies depending on the meat cut, fat incorporation, and processing formulation (Kononiuk and Karwowska, 2020; Das *et al.*, 2022; Mostafa *et al.*, 2025). However, the nutritional and sensory quality of chicken sausages cannot be determined solely by their meat content. The incorporation of fats, fillers, binders, additives, and seasonings, together with differences in manufacturing and cooking conditions, may substantially affect their proximate composition and organoleptic properties (Peña-Saldarriaga *et al.*, 2020; Nan *et al.*, 2025). Consequently, evaluating moisture, dry matter, crude protein, ether extract, crude fiber, and ash is important for understanding differences in the nutritional and compositional characteristics of commercially available sausage products. Sensory attributes, including appearance, flavor, tenderness, juiciness, texture, taste, and overall acceptability, are equally important indicators because they influence consumer preferences and purchasing decisions (Baer and Dilger, 2014; De Gouvêa *et al.*, 2018; Fakolade *et al.*, 2025).

Alongside nutritional and sensory considerations, microbiological safety and product affordability are important determinants of sausage quality and consumer acceptance (Carballo, 2021). The meat-processing industry faces increasing pressure to maintain hygienic production practices, control microbial contamination, and ensure product safety throughout processing, distribution, and storage (Rebezov *et al.*, 2024). Microbiological indicators, including total aerobic plate count (TAPC), coliform count, *Salmonella* detection, and total yeast and mold count, can provide useful information about the hygienic quality and microbiological stability of meat products (Mousa *et al.*, 2014; Atlabachew and Mamo, 2021). Appropriate refrigeration and freezing practices are also essential for maintaining product quality during storage. Furthermore, the growing awareness of food safety and health-related concerns has increased consumer expectations regarding the quality, safety, and affordability of processed meat products (Hashem *et al.*, 2023). Therefore, comparative assessments of nutritional composition, sensory characteristics, microbiological quality, and price can provide a broader understanding of the relative quality of sausage products available to consumers.

In Bangladesh, the availability of commercially manufactured and institutionally developed sausage products provides consumers with different choices in terms of composition, sensory characteristics, and price (Borty *et al.*, 2016). However, differences in product formulation, processing practices, nutritional composition, and quality characteristics make it difficult for consumers to assess their relative quality based on appearance or price alone (Carballo, 2021; Kassenov *et al.*, 2026). Despite the increasing availability and consumption of processed meat products, comparative information on the nutritional and sensory characteristics of institutionally developed and locally marketed sausages in Bangladesh remains limited. In particular, a systematic comparison of sausages developed by the Bangladesh Livestock Research Institute (BLRI) with commercially available products could provide useful evidence regarding their compositional quality, consumer acceptability, microbiological characteristics, and affordability.

Against this background, the present study addressed the following research question: Do BLRI-developed sausages differ significantly from locally available commercial sausage products in terms of proximate composition, sensory characteristics, and price, and what is the microbiological quality of BLRI-developed sausages during storage? It was hypothesized that differences in formulation and processing practices would result in variations in the nutritional composition and sensory attributes of the evaluated sausage products. Accordingly, this study was conducted to compare the proximate composition and sensory attributes of BLRI-developed and locally available sausages, assess the microbiological quality of BLRI-developed sausages under fresh, refrigerated, and frozen storage conditions, and evaluate their relative market prices. The findings may

help consumers make informed purchasing decisions and support manufacturers in improving sausage formulation, processing practices, product quality, and affordability.

2. Materials and Methods

2.1. Ethical approval

Ethical approval was not required for the laboratory-based analysis of sausage samples. However, the sensory evaluation involved human panelists from BLRI. Appropriate institutional permission was obtained for their participation, and the evaluation was conducted voluntarily.

2.2. Study area and sample collection

The study was conducted at the BLRI, Savar, Dhaka, Bangladesh. Three types of chicken sausages were included in the investigation: one developed by BLRI and two commercially available brands (Brand A and Brand B) collected from the local markets in Savar, Dhaka, Bangladesh (Figure 1). The BLRI-developed sausages were manufactured at the Meat Processing and Product Manufacturing Satellite Training Centre (MPPMSTC), Animal Production Research Division, BLRI.

Commercial sausage samples were purchased from local retail outlets and transported to the laboratory in insulated containers containing ice packs to maintain the cold chain during transportation. The BLRI-developed sausages were also transferred to the laboratory under appropriate storage conditions. All samples were stored under refrigerated conditions at 4 °C until further analysis. The samples were subjected to proximate composition analysis and sensory evaluation to compare their nutritional and organoleptic characteristics.

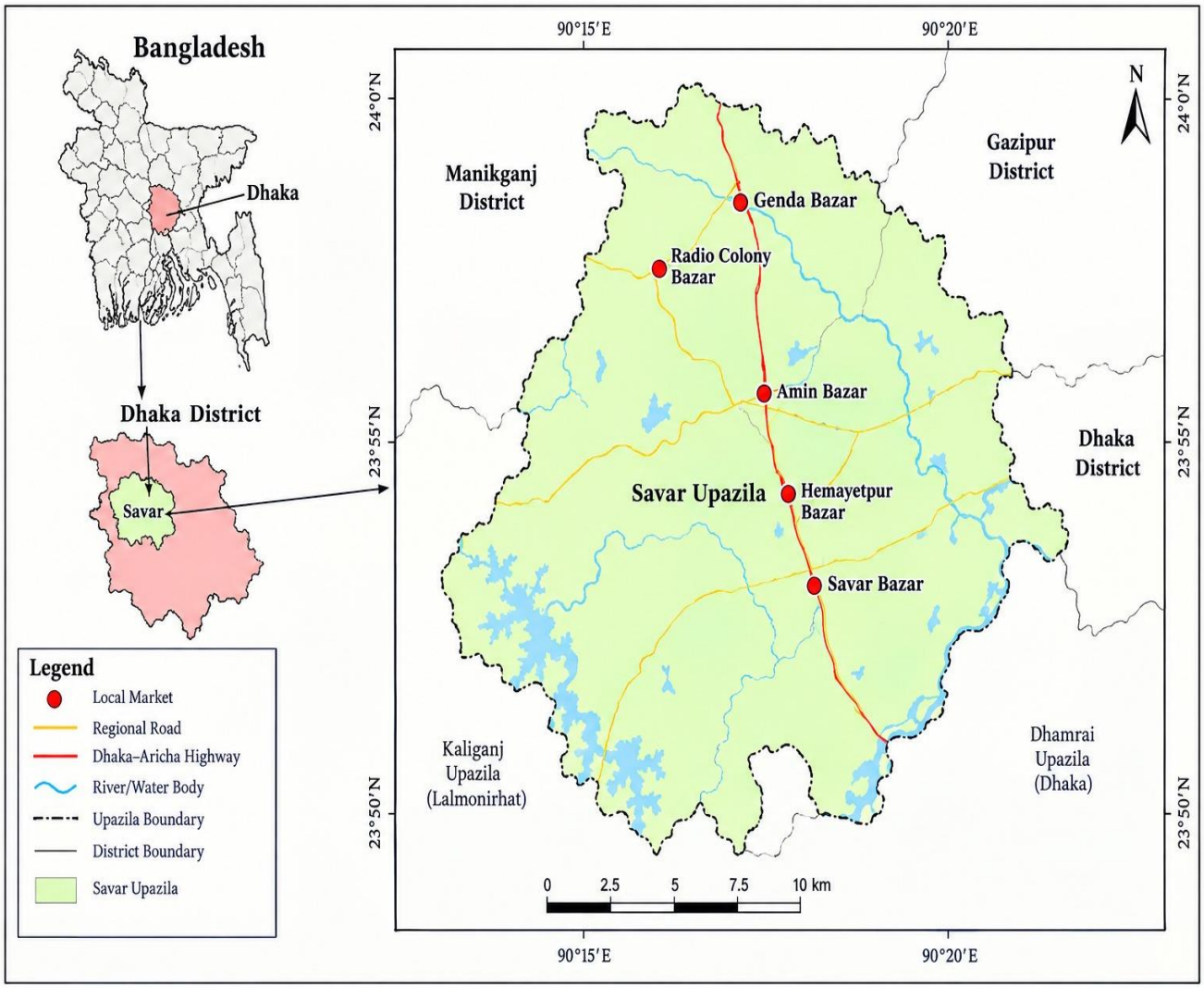

Figure 1. Sausage samples collected from local markets, Savar, Dhaka, Bangladesh.

2.3. Preparation of sausage

The BLRI-developed chicken sausages were prepared at the MPPMSTC, Animal Production Research Division, BLRI, following a standardized meat-processing procedure (Figure 2). The preparation involved raw material selection, trimming, grinding, fat emulsion preparation, chopping, filling, smoking, cooking, cooling, and packaging.

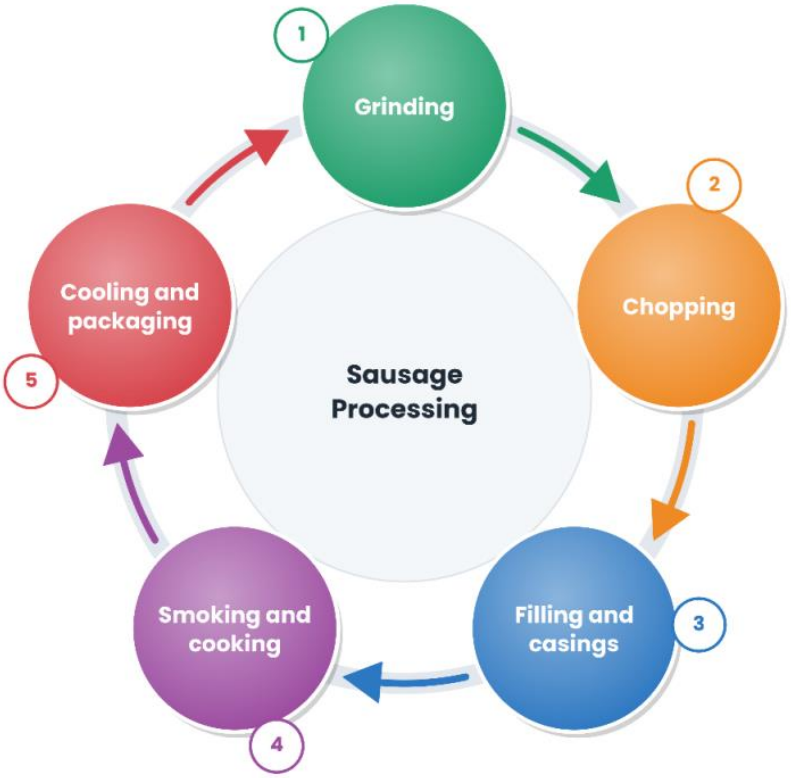

Figure 2. Flow chart for the processing of sausages.

2.3.1. Raw materials

Fresh chicken meat was collected from a local market and used as the primary raw material. The meat was carefully trimmed to remove excess fat, connective tissues, sinews, gristle, ligaments, bones, and cartilage particles. The trimmed lean meat contained less than 10% non-trimmable fat and connective tissue. Approximately 20% fat was incorporated into the formulation to improve the texture, flavor, and juiciness of the final product. Chicken fat and vegetable oil were used as fat sources. Other ingredients included soybean meal, chickpea flour, corn flour, skimmed milk, common salt, sodium nitrite, phosphate, sodium erythorbate, food color, and seasonings. The seasonings included white pepper, garlic powder, ginger powder, onion powder, and oregano powder. All ingredients were weighed before processing to ensure consistency in formulation.

2.3.2. Grinding and fat emulsion preparation

The trimmed lean chicken meat was passed through a meat grinder fitted with a 5-mm plate. The ground meat was subsequently chilled at 4 °C for 24 hours before further processing. Chicken fat was also ground using the same grinder plate. A fat emulsion was prepared by mixing sunflower oil, water, and ground chicken fat at a ratio of 6:1:6, respectively. The prepared emulsion was stored at 4 °C for 24 hours before incorporation into the sausage mixture.

2.3.3. Chopping and emulsion preparation

The ground lean meat was transferred to a mechanical bowl cutter and chopped to obtain a finely minced meat mixture. During the initial chopping stage, common salt, sodium nitrite, phosphate, sodium erythorbate, food color, and approximately one-third of the total crushed ice were gradually incorporated into the meat. Chopping was continued for approximately 6–8 minutes to facilitate the extraction of salt-soluble meat proteins, which contribute to the binding of water and stabilization of fat droplets within the meat emulsion. Subsequently, the

prepared fat emulsion, additional fat ingredients, seasonings, and the remaining two-thirds of the crushed ice were added to the mixture. Chopping was continued until a uniform and homogeneous sausage emulsion was obtained. During processing, the temperature of the meat emulsion was maintained below 12 °C to minimize excessive heat generation and maintain emulsion stability (Asyrul-Izhar *et al.*, 2021).

2.3.4. Filling and casing

The prepared sausage emulsion was transferred into a sausage-filling machine and stuffed into modified collagen casings. Vacuum filling was used to minimize the incorporation of air into the sausage mixture and reduce the formation of air pockets. The filled casings were properly sealed to maintain their shape and prevent leakage during subsequent processing.

2.3.5. Smoking and cooking

The filled sausages were subjected to smoking in a smoking chamber at 45 °C for 30 minutes. Following smoking, the sausages were cooked in a water bath maintained at 70–75 °C for approximately 20 minutes. The internal temperature of the sausages was monitored during cooking to ensure adequate heat treatment. An internal temperature of approximately 68 °C was considered the target endpoint for cooking, as specified in the original processing protocol.

2.3.6. Cooling and packaging

After cooking, the sausages were immediately immersed in cold water and cooled until their internal temperature reached approximately 3.3–4.4 °C (38–40 °F). The cooled sausages were subsequently stored at 4 °C for 24 hours to facilitate temperature stabilization before packaging. After this period, the sausages were packaged in suitable food-grade packaging materials and stored under refrigerated conditions until further analysis.

2.4. Sensory evaluation

The sensory characteristics of the three sausage products were evaluated by a panel of eight trained panelists from BLRI. A structured sensory evaluation questionnaire was used to assess seven sensory attributes: appearance, flavor, tenderness, juiciness, texture, taste, and overall acceptability. Sensory evaluation was conducted using a five-point semantic scale, where 1 represented inadequate, 2 represented acceptable, 3 represented good, 4 represented very good, and 5 represented excellent. The evaluation procedure was adapted from the American Meat Science Association (AMSA, 1995). Before evaluation, the sausage samples were fried and allowed to cool to room temperature. Each sample was cut into approximately 10-mm-thick pieces and placed in polyethylene bags labeled with randomly assigned codes to minimize potential identification bias. The coded samples were presented to the panelists with tissue paper and forks. Drinking water was provided to cleanse the palate between successive samples to minimize sensory carry-over effects.

All sensory assessments were conducted in isolated booths at BLRI to minimize external disturbances and potential influences among panelists. Each panelist independently evaluated the samples and recorded scores for the respective sensory attributes using the structured questionnaire. The resulting scores were used to compare the sensory quality and overall acceptability of the three sausage products (Marques *et al.*, 2022).

2.5. Proximate composition

The proximate composition of the three sausage products was determined following the standard analytical procedures described by the Association of Official Analytical Chemists (AOAC, 2016). The parameters analyzed included moisture, dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), and total ash. Moisture content was determined by measuring the weight loss of the samples after oven drying to a constant weight. DM content was calculated as the difference between 100% and the measured moisture percentage. CP content was determined using the Kjeldahl method by measuring total nitrogen and converting it into crude protein using an appropriate conversion factor. EE was determined through solvent extraction using a Soxhlet extraction apparatus. CF was estimated through sequential acid and alkaline digestion, followed by drying and ashing of the residue. Total ash content was determined by incinerating the samples in a muffle furnace until a constant weight was obtained. Moisture and DM contents were expressed on an as-is (fresh-weight) basis, whereas CP, EE, CF, and total ash contents were expressed on a dry-matter basis. All proximate composition analyses were conducted in triplicate, and the results were expressed as percentages (%).

2.6. Microbiological quality of BLRI-developed sausages

The microbiological quality of BLRI-developed chicken sausages was evaluated under fresh, refrigerated, and frozen storage conditions. Fresh samples were analyzed immediately after production, while refrigerated samples were evaluated after 7, 14, and 21 days of storage. Frozen samples were analyzed after 15, 30, 45, and 60 days of storage. The microbiological parameters investigated included TAPC, most probable number (MPN) of coliforms per gram, detection of Salmonella spp., and total yeast and mold count. Microbiological analyses were performed following the procedures described by Ikhlas *et al.* (2012).

For microbiological examination, representative sausage samples were aseptically collected and prepared for analysis under hygienic laboratory conditions. Appropriate sample homogenization and serial dilution procedures were applied before microbial enumeration. TAPC was determined using an appropriate general-purpose culture medium, while coliforms were enumerated using the MPN technique. *Salmonella* spp. detection was performed using an appropriate enrichment, selective isolation, and identification procedure. Total yeast and mold counts were determined using suitable fungal culture media. The results were expressed as colony-forming units per gram (CFU/g) for aerobic bacteria and yeast and mold, and as MPN/g for coliforms. Salmonella results were reported as detected or not detected.

2.7. Price comparison

The market prices of the three sausage products were recorded to compare their relative affordability. The prices and corresponding package weights were obtained for BLRI-developed sausages and the two commercially available brands. The price of each product was expressed in Bangladeshi Taka (BDT), and the package weight was recorded in grams. Price comparisons were made using the same package weight (340 g) to facilitate direct comparison among the three products.

2.8. Statistical analysis

The experimental data were organized and analyzed using the General Linear Model (GLM) procedure of SPSS software, version 17.0. Differences in proximate composition and sensory attributes among the three sausage treatments (BLRI, Brand A, and Brand B) were evaluated using analysis of variance (ANOVA) based on a completely randomized design (CRD). The results were expressed as mean values, and the standard error of the difference (SED) was calculated to assess differences between treatment means. Statistical significance was considered at $P < 0.05$, with $P < 0.001$ indicating highly significant differences. Non-significant differences were reported when $P > 0.05$.

3. Results

3.1. Proximate composition of sausages

Significant differences ($P < 0.001$) were observed among the three sausage products for all analyzed parameters, including moisture, DM, CP, EE, CF, and ash content. Moisture content was highest in BLRI-developed sausage (76.17%), followed by Brand B (68.10%) and Brand A (66.33%). Conversely, Brand A exhibited the highest DM content (33.67%), followed by Brand B (31.90%) and BLRI-developed sausage (23.83%). The crude protein content was highest in BLRI-developed sausage (37.66%), which was statistically comparable to Brand B (37.33%), whereas Brand A had a significantly lower value (32.78%). The highest EE content was recorded in BLRI-developed sausage (10.93%), followed by Brand B (7.07%) and Brand A (0.43%). In contrast, Brand A had the highest CF content (3.35%), followed by Brand B (1.13%) and BLRI-developed sausage (0.27%). Similarly, ash content was highest in Brand A (7.38%), followed by Brand B (4.45%) and BLRI-developed sausage (3.00%) (Figure 3).

3.2. Sensory quality of sausages

No statistically significant differences ($P > 0.05$) were observed among the three sausage products for any of the evaluated sensory attributes, including appearance, flavor, tenderness, juiciness, texture, taste, and overall acceptability. BLRI-developed sausage received the highest numerical scores for appearance (3.62), texture (3.62), taste (3.50), and overall acceptability (3.87). Brand B obtained the highest scores for flavor (3.62) and tenderness (3.75), while BLRI-developed sausage and Brand B shared the same juiciness score (3.50). Brand A recorded the lowest overall acceptability score (3.25), whereas Brand B and BLRI-developed sausage received scores of 3.62 and 3.87, respectively (Figure 4).

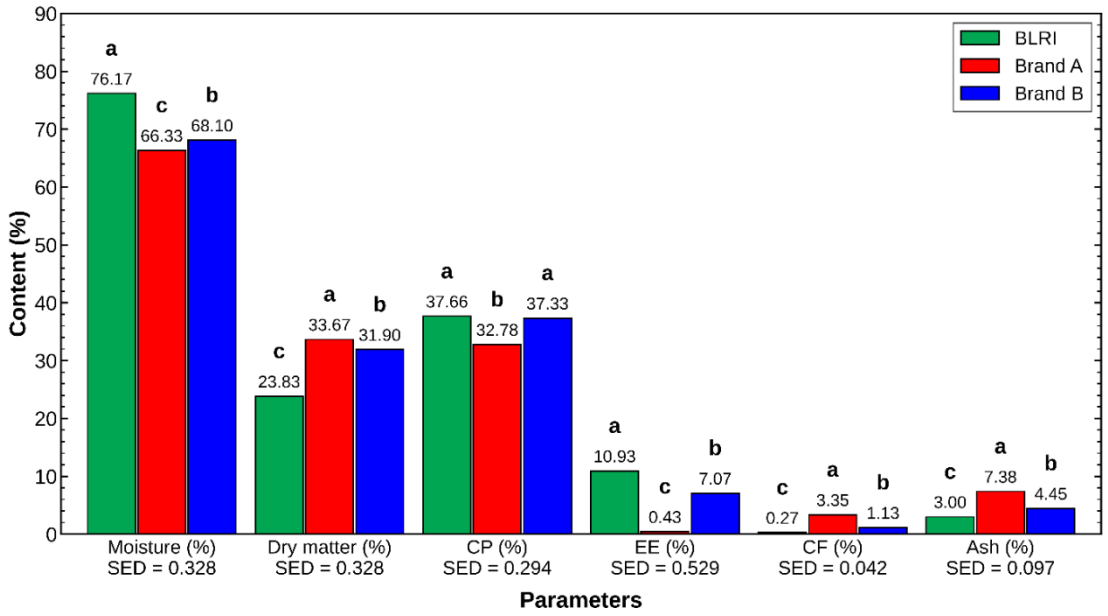

Figure 3. Proximate composition comparison between BLRI-developed and locally available sausages. Within each parameter, means sharing the same letter are not significantly different, and means with different letters differ significantly (Tukey's HSD test, P < 0.05), here, CP= crude protein, EE=ether extract, CF= crude fiber, %=percentage; SED= standard error of the difference.

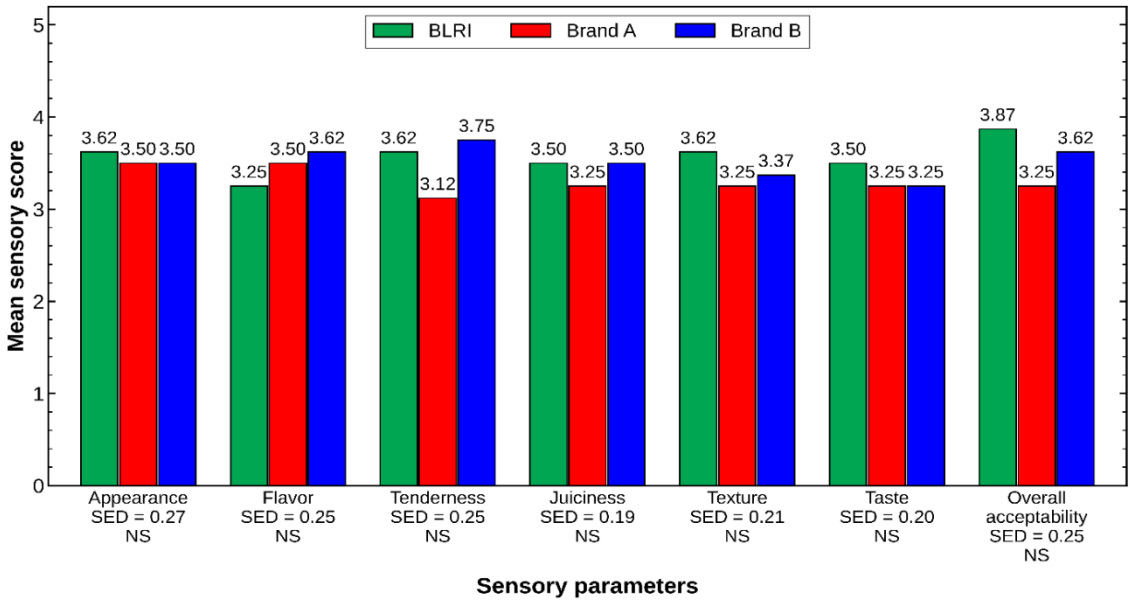

Figure 4. Sensory quality scores of BLRI-developed and commercially available sausages. Here, SED= standard error of the difference, NS=not significant.

3.3. Microbiological quality of sausages

The TAPC varied across the storage conditions and intervals, ranging from below the reported detection level to 1.7×10^4 CFU/g. Under refrigerated storage, the count decreased from 1.0×10^4 CFU/g on day 7 to 2.0×10^3 CFU/g on day 14 and was below the reported detection level on day 21. Under frozen storage, the count was 1.0×10^4 CFU/g on day 15, increased to 1.7×10^4 CFU/g on day 30, and was below the reported detection level on days 45 and 60 (Figure 5). The coliform count also showed considerable variation during storage. The fresh sample had a count of less than 3 MPN/g. Under refrigerated storage, the count was 92 MPN/g on day 7, decreased to 9.2 MPN/g on day 14, and was 23 MPN/g on day 21. Under frozen storage, the count was 460 MPN/g on day 15, decreased to less than 3 MPN/g on days 30 and 45, and increased to 23 MPN/g on day 60

(Figure 5b). *Salmonella* was not detected in any of the samples examined. The total yeast and mold count remained below 10 CFU/g in the fresh sample and throughout refrigerated storage. Similarly, counts below 10 CFU/g were recorded on most frozen-storage sampling days, except on day 30, when the count was 40 CFU/g (Figure 5c).

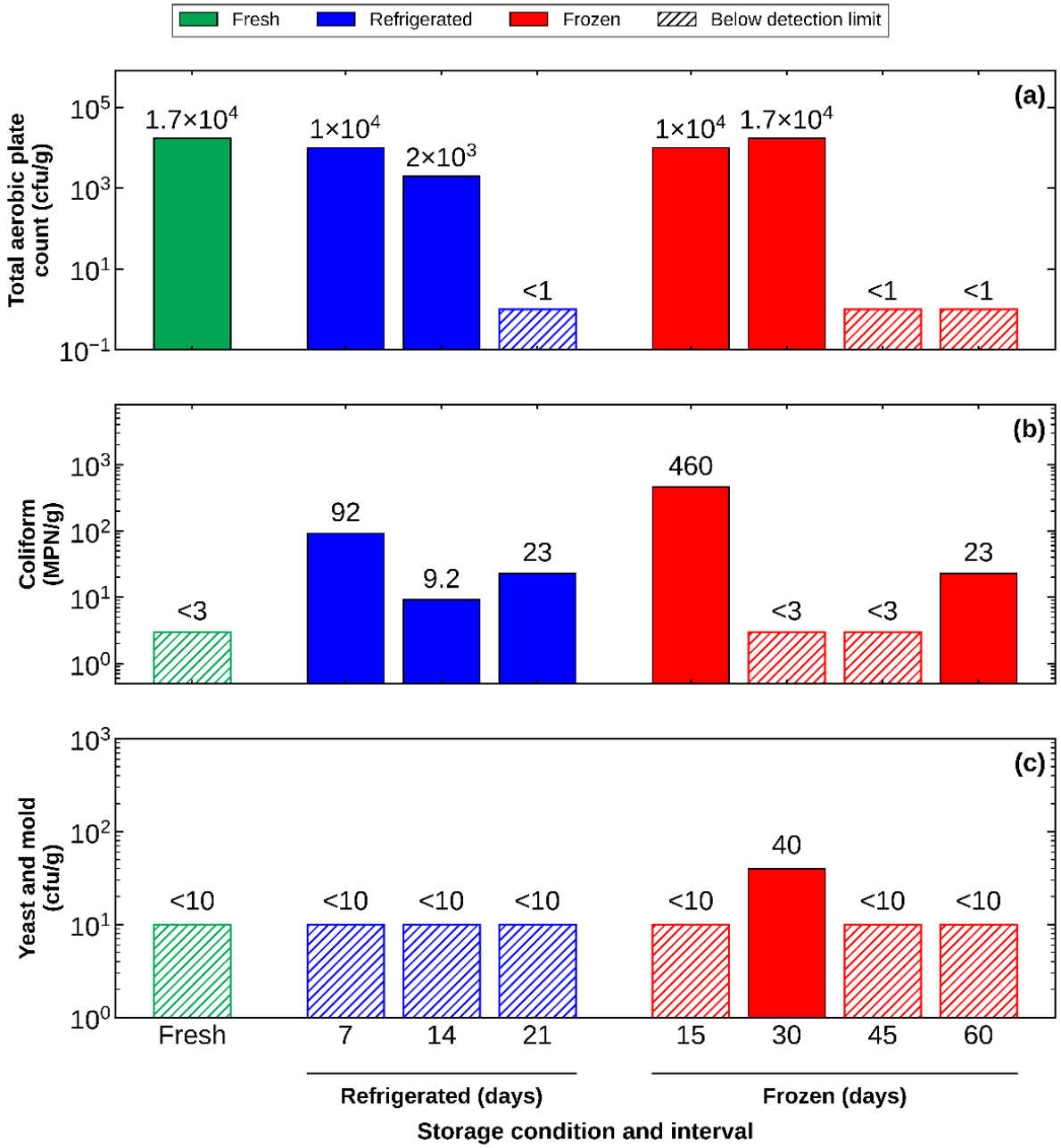

Figure 5. Changes in the microbial quality of fresh, refrigerated and frozen samples during storage, (a) total aerobic plate count (CFU/g), (b) coliform count (MPN/g) and (c) yeast and mold count (CFU/g). Hatched bars show results below the detection limit (<1 CFU/g, <3 MPN/g and <10 CFU/g, respectively). Salmonella was not detected in any sample.

3.4. Price of sausages

The BLRI-developed sausage was priced at BDT 168 per 340 g pack, whereas both Brand A and Brand B were priced at BDT 260 per 340 g pack. Thus, the BLRI-developed sausage was BDT 92 cheaper per pack than either commercial product, representing a 35.38% lower market price (Figure 6).

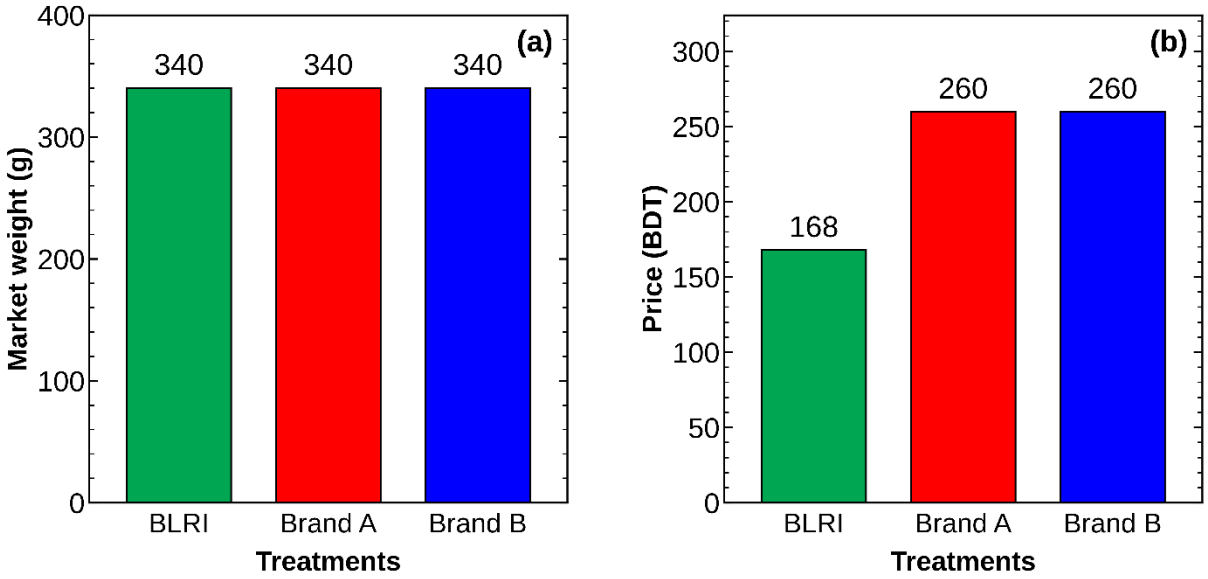

Figure 6. Comparison of (a) market weight (g) and (b) price (BDT) of the BLRI-developed sausage and two locally available commercial sausage brands (Brand A and Brand B).

4. Discussion

The differences in proximate composition among the three sausage products indicate variations in their formulation, ingredient composition, and potentially their manufacturing processes. The higher moisture content of BLRI-developed sausage (76.17%) compared with Brand A (66.33%) and Brand B (68.10%) corresponds to its lower DM content (23.83%). This inverse relationship is expected because dry matter represents the fraction of the product remaining after moisture removal. Differences in meat-to-fat ratios, water incorporation, and processing conditions may contribute to variations in moisture and dry matter content among sausage products. Lorenzo *et al.* (2011) highlighted the importance of meat and fat composition in determining the physicochemical characteristics of meat products, while Baer and Dilger (2014) discussed the influence of processing and formulation differences on product composition.

Crude protein content is an important indicator of the nutritional quality of meat products. In the present study, BLRI-developed sausage contained the highest crude protein (37.66%), although its value was statistically comparable to that of Brand B (37.33%). Brand A had a comparatively lower protein content (32.78%). These findings suggest that BLRI-developed sausage and Brand B had relatively higher protein concentrations than Brand A. The differences may be associated with variations in meat content, the incorporation of non-meat ingredients, and processing formulations. Carballo (2021) reported a positive relationship between meat content and protein concentration in sausage products.

Ether extract content also differed considerably among the evaluated products. BLRI-developed sausage had the highest EE content (10.93%), followed by Brand B (7.07%), whereas Brand A had substantially lower EE content (0.43%). These differences may reflect variations in the amount and type of fat incorporated during sausage manufacturing. Fat is an important component of sausage formulations because it contributes to flavor, juiciness, texture, and overall sensory characteristics. Therefore, the relatively higher EE content of BLRI-developed sausage may have contributed to its sensory properties, although a direct relationship cannot be established from the present results alone. Leite *et al.* (2015) reported that differences in ingredient composition and formulation strategies can influence the fat content of processed meat products.

Crude fiber content was highest in Brand A (3.35%), followed by Brand B (1.13%) and BLRI-developed sausage (0.27%). This variation may be associated with differences in the incorporation of plant-derived fillers and binding ingredients, such as soybean meal and cereal-based materials. Similarly, ash content was highest in Brand A (7.38%), whereas BLRI-developed sausage exhibited the lowest value (3.00%). Ash represents the total inorganic residue remaining after incineration and may reflect differences in mineral-containing ingredients, including salt and phosphate additives. However, ash content alone cannot identify the specific mineral composition or the quantities of individual additives present in the products. Variations in ingredient

selection and formulation may therefore explain some of the observed differences in ash content (Baer and Dilger, 2014; Leite *et al.*, 2015).

Sensory evaluation is an important approach for assessing the quality and consumer acceptability of processed meat products because attributes such as appearance, flavor, tenderness, juiciness, texture, and taste collectively influence consumers' perceptions and purchasing preferences (Fiorentini *et al.*, 2020). In the present study, no statistically significant differences were observed among the three sausage products for any of the evaluated sensory attributes ($P > 0.05$). Nevertheless, BLRI-developed sausage obtained the highest numerical score for overall acceptability (3.87), followed by Brand B (3.62) and Brand A (3.25). This numerical variation suggests that the panelists showed a relatively favorable overall response to the BLRI-developed product, although the differences were not statistically supported. The absence of significant differences indicates that, under the conditions of this evaluation, the sensory characteristics of the three products were broadly comparable (Akwetey *et al.*, 2022; Mazhangara *et al.*, 2022).

The appearance scores were relatively similar among the three products, ranging from 3.50 to 3.62. This similarity may indicate that the products had comparable visual appeal to the panelists. Appearance is commonly influenced by meat formulation, added color, processing temperature, smoking conditions, and the characteristics of the casing (Szymkowiak *et al.*, 2026). Regarding flavor and tenderness, Brand B received the highest numerical scores (3.62 and 3.75, respectively), whereas BLRI-developed sausage received scores of 3.25 and 3.62. These differences may be associated with variations in seasoning composition, fat distribution, meat protein functionality, and processing conditions. Fat content can contribute to flavor development and mouthfeel, while protein extraction and emulsion stability influence the structural properties and tenderness of processed meat products (Santhi *et al.*, 2017; Gómez *et al.*, 2020; Wijesekara and Ekaette, 2025).

The juiciness scores of BLRI-developed sausage and Brand B were identical (3.50), while Brand A received a slightly lower score (3.25). Similarly, BLRI-developed sausage obtained the highest numerical texture score (3.62), compared with Brand A (3.25) and Brand B (3.37). These variations may reflect differences in moisture retention, fat incorporation, water-binding capacity, and the structural stability of the meat emulsion. The interaction between meat proteins, water, and fat is particularly important in determining the texture and juiciness of emulsified meat products (Bostami *et al.*, 2022; Rahman *et al.*, 2025). For taste, BLRI-developed sausage obtained a score of 3.50, whereas both commercial brands received scores of 3.25. This numerical difference may be related to variations in seasoning formulations, ingredient combinations, and fat composition. However, because the differences were statistically non-significant, the results do not establish a demonstrable taste advantage for the BLRI-developed product (Han *et al.*, 2021).

Microbiological quality is an important indicator of the safety, hygienic condition, and storage stability of processed meat products. The presence and abundance of microorganisms in sausages can be influenced by the quality of raw materials, processing hygiene, heat treatment, post-processing contamination, packaging conditions, and storage temperature (Lemos *et al.*, 2024). In the present study, the TAPC varied across refrigerated and frozen storage intervals rather than showing a consistent increase over time. Although relatively higher counts were recorded on day 7 of refrigerated storage and on days 15 and 30 of frozen storage, lower counts were observed at several subsequent sampling points. Such variations may be associated with differences in microbial distribution, initial contamination levels, processing conditions, and the effects of storage temperature on microbial survival and growth (Mohammed *et al.*, 2021).

Coliform counts also fluctuated during storage, with the highest recorded value occurring on day 15 of frozen storage (460 MPN/g). Coliforms are commonly used as indicators of processing hygiene and possible post-processing contamination, although their detection does not necessarily indicate the presence of pathogenic microorganisms (Martin *et al.*, 2016). The variation in coliform counts observed in this study highlights the importance of maintaining hygienic conditions during handling, packaging, and storage. The absence of detectable *Salmonella* in all examined samples is a favorable finding because this pathogen is an important food safety concern in poultry and processed meat products (Williams *et al.*, 2020).

The total yeast and mold counts were generally below the reported detection limit, except for the sample collected on day 30 of frozen storage. The relatively low counts suggest limited detectable fungal growth under the examined conditions. Nevertheless, the detection of 40 CFU/g on day 30 indicates that fungal contamination or survival may have occurred in that sample. Proper packaging, sanitation, and temperature control remain important for limiting fungal contamination and maintaining the microbiological quality of processed meat products (Perrone *et al.*, 2019; Rodrigues *et al.*, 2026).

Price is an important consideration influencing consumers' purchasing decisions, particularly for processed meat products intended for regular household consumption (Andreyeva *et al.*, 2010). The present comparison showed that the BLRI-developed sausage was substantially less expensive than the two locally available

commercial products. At an equivalent package weight of 340 g, the BLRI product was approximately 35.38% cheaper than both commercial brands (BDT 168 versus BDT 260). The lower market price of the BLRI-developed sausage may make it a more affordable option for consumers seeking processed poultry products. Previous studies have reported that product price, nutritional value, sensory characteristics, and perceived quality can influence consumers' choices of processed meat products (Guzek *et al.*, 2020; De Araújo *et al.*, 2022). When considered alongside the proximate composition and sensory evaluation findings, the price comparison provides a useful preliminary indication of the product's market competitiveness. In particular, the sensory evaluation did not identify statistically significant differences among the three products, suggesting that the lower-priced BLRI sausage achieved comparable sensory scores under the conditions of this study.

5. Conclusions

BLRI-developed sausage showed the highest numerical sensory acceptability, the highest numerical crude protein and ether extract contents, and a lower price than the two commercial brands, although the sensory differences were not statistically significant. *Salmonella* was not detected in any sample during storage. These findings may serve as a reference for consumers and producers seeking quality sausage products.

Acknowledgments

Authors thank the Bangladesh Livestock Research Institute, Savar, Dhaka, Bangladesh for the research fund provided and also grateful to all who helped during this project.

Funding information

This study received funding from the Bangladesh Livestock Research Institute (BLRI).

Data availability statement

All relevant data are presented within the manuscript.

Generative AI statement

No generative AI was used during preparation of this article.

Authors' contributions

Biplob Kumer Roy: project management, administration, conceptualization, study design, review and editing; Sharmin Akter Tule: study design, methodology writing, lab activities, statistical analysis, manuscript preparation; Md. Mostain Billah: drafting and writing manuscript, statistical analysis, review and editing; Ahnaf Anjum Dara: writing, review and editing. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

None to declare.

Publisher's note

Ebu Press Ltd remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

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