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Beef tripe as an innovative and alternative protein source in meat products

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Abstract:
Tripe has a high protein level, which could serve as a functional ingredient in the meat industry.
Raw and boiled beef tripe and frozen beef meat were examined for proximate composition, mineral and amino acid content, fatty acid profile, protein quality indices, microbiological safety, and functional parameters. Tripe was incorporated into corned beef and sausage formulations, which were analyzed for their nutritional quality, microbial stability, and consumer acceptability.
The raw tripe exhibited a favorable pH (6.83 ± 0.08), moderate water holding capacity (58.86%), and acceptable cooking yield (64.88%), indicating functional suitability. The boiled tripe demonstrated a superior protein content (24.15%) and energy value (146.71 kcal/100 g), compared to the raw tripe and frozen beef meat. Mineral analysis showed significantly higher levels of calcium (up to 112.5 mg/100 g), iron (4.19 mg/100 g), and copper (0.28 mg/100 g) in the raw tripe. The boiled tripe had a well-balanced amino acid profile, with its essential amino acid content (37.98%) exceeding the FAO/WHO standards. It also showed improved protein quality indices, namely the computed protein efficiency ratio of 2.38 and the biological value of 74.19%. Boiling also enhanced the lipid quality by increasing unsaturated fatty acids. Microbial analysis confirmed the safety of the boiled tripe, with pathogen counts below permissible limits. The tripe-based corned beef and sausage showed higher fat, ash, and energy contents than their beef counterparts, while maintaining acceptable protein levels and sensory qualities. Sensory evaluation revealed that the overall acceptability of tripe-based products was comparable to that of traditional meat products.
These findings highlight that boiled beef tripe is a safe, nutrient-rich, and sensory-acceptable ingredient. They also support its use as a sustainable, cost-effective ingredient in value-added meat products such as sausages and canned meats.

Keywords: Meat by-products, rumen, sausage, corned beef, amino acids, microbiology, functional products

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INTRODUCTION

Ensuring global food security remains one of the most critical challenges, particularly with the increasing population and rising food prices [1]. Meat, comprising muscle and organ tissues, has long been recognized as a vital component of the human diet due to its high-quality protein and essential mineral contents [2]. However, economic constraints and changing consumer preferences have intensified the search for alternative, cost-effective protein sources, including edible bovine by-products [3].

Bovine by-products such as liver, kidney, heart, tripe, and lungs are traditionally consumed in many cultures and offer considerable nutritional value [4]. Tripe, derived from the stomach chambers of cattle, represents a significant portion of slaughter by-products but remains underutilized due to its unfavorable microbiological profile and sensory characteristics [5]. Despite these challenges, tripe is recognized for its rich protein content and could serve as a functional ingredient in food systems [6].

Tripe, also referred to as rumen meat or "potti", accounts for approximately 1.3% of the animal's live weight, with an average mass of 4.36 to 5.45 kg per animal [5]. Different sections of tripe include the rumen (blanket or smooth tripe), reticulum (honeycomb or pocket tripe),

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and omasum (book or leaf tripe), all of which have culinary uses, especially in soups and sausages [7].

The inherent toughness of tripe due to its collagen content, combined with its poor sensory attributes and limited shelf life, has constrained its industrial application. However, with appropriate processing to improve palatability and safety, tripe can be transformed into a high-value component of meat products [6]. In Egypt and several other countries, including India, tripe remains underutilized despite its nutritional potential.

Beef sausage is among the most traditional processed meat products in Egypt and widely accepted across all age groups. It is typically composed of beef, fat, rusk, salt, and spices [8]. Corned beef, a shelf-stable product with historical roots in the British Empire, is valued for its high protein and mineral contents (especially sodium and zinc) and a long shelf life of 2 to 4 years [9].

In this context, we aimed to assess the nutritional quality and microbiological profile of underutilized beef tripe. Additionally, we explored its potential application as an alternative animal protein source in the industrial production of traditional comminuted meat products such as sausage and corned beef tripe.

STUDY OBJECTS AND METHODS

Fresh beef tripe was procured from the municipal slaughterhouse in Tanta, Egypt. All the media (plate count agar, potatoes dextrose agar, sulfite polymyxin sulfadiazine agar, skim milk agar, Tributyrin agar, Baird-Parker agar with egg yolk tellurite, violet red bile agar, xylose lysine deoxycholate agar, and salmonella-shigella agar) used in the microbial examination were purchased from Oxoid, UK. All the analytical-grade chemicals utilized in this study were sourced from El-Gomhoria Company.

Beef tripe processing. The beef tripe was initially rinsed under tap water, followed by brief immersion in boiling water to facilitate cleaning. Subsequent scalding with a sharp knife was performed until the tripe attained a white coloration. The cleaned tripe was divided into two portions: one underwent cooking for 40 min, while the other remained uncooked. Each portion was individually minced and homogenized using an industrial food blender (Moulinex, France) to achieve uniform consistency. The homogenized samples were then packaged and stored at −18°C until further analysis. All the samples were analyzed in triplicate to ensure reproducibility.

Preparation of tripe-based products. ***Tripe sausage formulation.*** Sausage formulations were prepared as detailed in Table 1, following the methodology described by Evanuarini *et al*. [10]. Each formulation was emulsified using a bowl cutter (Nr-963009, Scharfen-Witten, Germany), incorporating chilled water and homogenizing for 2 min. The resulting batter was stuffed into natural sheep casings, with links formed at approximately 15 cm intervals. The sausages were then grilled briefly to evaluate color and texture attributes.

Corned beef preparation. Corned beef was prepared according to the protocol outlined by Silalahi *et al*. [11], with formulations presented in Table 1. Both beef meat (control) and boiled beef tripe were subjected to wet curing in a pickle solution containing salt, black pepper, cardamom, coriander, and bay leaves for 48 h at 4 ± 1°C. After curing, the samples were drained, boiled for 30 min, and then mixed thoroughly with wheat flour, salt, corn oil, gelatin, a spice mixture, onion powder, and garlic powder. The mixture was ground through a 3-mm plate, filled into glass containers while warm, partially sealed, and exhausted in steam to achieve an internal temperature of 77°C. The containers were then sealed and autoclaved at 121°C for 20 min, followed by cooling with water.

Physical properties of tripe products. ***Cooking loss*****, %,** ***and yield*****, %.** Cooking loss was determined by measuring the weight difference of the samples before and after frying, conducted in triplicate. The calculations were as follows:

$$\text{Cooking loss} = \left[\frac{W_i - W_f}{W_i}\right] \times 100 \quad (1)$$

where W_i is the weight of the samples before frying, g; W_f is the weight of the samples after frying, g.

$$\text{Cooking yield} = 100 - \text{Cooking loss} \quad (2)$$

Water holding capacity. The water holding capacity (WHC, %) was assessed using the method described by Elsebaie *et al*. [12]. The percentage of bound water was calculated based on the area, representing the WHC, using the conversion factor of 8.4 mg of free water per cm^2.

$$\text{WHC} = \left[\frac{M - \left(\frac{A \times 8.4 \times 100}{0.3 \times 1000}\right)}{M}\right] \times 100 \quad (3)$$

where M is the moisture, %; A is the area, cm^2.

pH measurement. A 10 g sample was homogenized in 100 mL of distilled water, and the pH was measured using a calibrated pH meter (Model JENCO 608, USA), following the procedure by Abdelhakam *et al*. [13].

Table 1 Beef and tripe meat products formulations

Ingredient, g/100 g	Corned beef		Beef sausage	
	Meat	Tripe	Meat	Tripe
Frozen beef meat	80.0	–	75.0	–
Boiled beef tripe	–	80.0	–	75.0
Fat	8.0	8.0	12.0	12.0
Starch	–	–	3.0	–
Wheat flour	2.5	2.5	–	3.0
Salt	1.5	1.5	1.5	1.5
Spice mixture	1.5	1.5	1.5	1.5
Garlic powder	0.3	0.3	1.0	1.0
Chilled water	–	–	6.0	6.0
Onion powder	0.3	0.3	–	–
Gelatin powder	2.0	2.0	–	–

Chemical analyses. ***Proximate composition.*** Moisture, protein, ether extract, ash, and crude fiber contents were determined according to the AOAC methods[1]. The carbohydrate content was calculated by difference.

Mineral content. The samples were ashed and digested with concentrated nitric acid. Mineral concentrations (Ca, Mg, Na, K, Zn, and Fe) were quantified using an atomic absorption spectrophotometer (PerkinElmer Model 4100 ZL), as per the AOAC guidelines[2].

Amino acid composition and protein quality. *Amino acid analysis*. Approximately 100 mg of a dried, ground sample was hydrolyzed with 10 mL of 6N HCl containing 0.1% mercaptoethanol at 110°C for 24 h. After the hydrolysis, the sample was filtered, diluted to 25 mL, and 5 mL of aliquot was evaporated under vacuum. The residue was reconstituted in 1 mL of sodium citrate buffer (pH 2.2) and analyzed using a Beckman amino acid analyzer (Model 119 CL), following the protocol by Ali *et al*. [14].

Chemical score calculation. The chemical scores were computed by comparing the amino acid profile of the sample to the FAO/WHO/UNU reference pattern, identifying the limiting amino acid as per Ali *et al*. [14].

The computed protein efficiency ratio (C-PER) was calculated using Eq. (4):

$$\text{C-PER} = -0.468 + 0.454 \times \\ \times \text{Leucine content} - 0.105 \times \text{Tyrosine content} \quad (4)$$

The biological value (BV) was determined using the formula, as described by Metwaly *et al*. [15]:

$$\text{BV} = 49.09 + 10.53 \times \text{C-PER} \quad (5)$$

Fatty acid composition. Lipids were extracted from 10 g samples using a 2:1 (v/v) chloroform/methanol mixture, following the method of Li *et al*. [16]. The extracts were filtered, washed with 0.72% KCl solution, and the organic phase was concentrated using a rotary evaporator. Fatty acid methyl esters were prepared and analyzed via gas chromatography (Hewlett Packard 6890) equipped with an HP-5 column (30 m × 0.32 mm, 0.25 µm film thickness). The operating conditions included an initial oven temperature of 150°C (held for 2 min), injector temperature of 220°C, detector temperature of 250°C, and nitrogen as the carrier gas at a flow rate of 1 mL/min. Fatty acid percentages were calculated accordingly.

Microbiological analyses. Microbial assessments included total plate counts, molds and yeasts, and psychrophilic bacteria, following the protocols outlined by de Souza *et al*. [17]. Spore-forming, proteolytic, and lipolytic bacteria were enumerated as per Liu *et al*. [18]. *Staphylococcus* spp. were identified according to Economou *et al*. [19], coliforms were detected as described by Medhat *et al*. [20], and *Salmonella* and *Shigella* spp. were assessed following Ahmed *et al*. [21] procedures.

Sensory evaluation. A panel of ten trained individuals from the Department of Food Science and Technology, Faculty of Agriculture for Girls, Al-Azhar University, conducted sensory evaluations of the prepared beef and tripe products. The assessments were based on a 10-point hedonic scale evaluating taste, flavor, color, texture, and overall acceptability, with 1 indicating a strong dislike and 10 indicating a strong like, as described by Essa & Elsebaie [22].

Statistical analysis. The data were analyzed using analysis of variance (ANOVA) via the SPSS software. Duncan's multiple range test was employed to determine significant differences among the means at a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Physical properties of raw beef tripe. The physical properties of the raw beef tripe under study (Table 2) indicated its promising potential for application in processed meat products. The recorded pH value of 6.83 ± 0.08 fell within the typical range for bovine offal and suggests a favorable environment for protein solubility and microbial stability, both of which are critical in meat product formulation [23]. The water holding capacity was measured at 58.86 ± 0.06%, reflecting the material's moderate ability to retain moisture, which is essential for maintaining juiciness and improving yield during thermal processing [24]. The cooking loss and cooking yield amounted to 35.12 ± 0.04 and 64.88 ± 0.05%, respectively. These values were consistent with those observed in other studies involving cooked tripe and edible by-products [25, 26]. The relatively high cooking loss might be due to the elevated collagen content in tripe. However, the yield remained within the acceptable limits for comminuted meat products. Collectively, these findings support the use of beef tripe as a viable alternative protein source in the development of value-added meat products such as sausages and canned meats, particularly when formulated with suitable fat, binders, and water-retaining agents to optimize their texture and stability.

Gross chemical composition of main raw materials. The proximate chemical composition of the main raw materials revealed significant differences among the frozen beef meat, raw beef tripe, and boiled beef tripe (Table 3), providing insight into their nutritional value and processing potential. The boiled beef tripe exhibited the highest crude protein content (24.15 ± 0.12%), surpassing both raw tripe (15.39 ± 0.05%) and frozen beef meat (19.79 ± 0.04%). This increase is primarily attributed

Table 2 Physical properties of raw beef tripe

Parameter	Value
pH	6.83 ± 0.08
Water holding capacity, %	58.86 ± 0.06
Cooking loss, %	35.12 ± 0.04
Cooking yield, %	64.88 ± 0.05

[1] Latimer GW. The official methods of analysis of AOAC international (22nd Edition). Gaithersburg, MD: AOAC International; 2023. https://doi.org/10.1093/9780197610145.001.0001

[2] The same.

Table 3 Gross chemical composition and mineral contents of main raw materials

Parameter	Frozen beef meat	Raw beef tripe	Boiled beef tripe
Moisture, % ww	74.38 ± 0.10[b]	77.14 ± 0.03[a]	67.83 ± 0.06[c]
Crude protein, % ww	19.79 ± 0.04[b]	15.39 ± 0.05[c]	24.15 ± 0.12[a]
Ether extract, % ww	2.99 ± 0.09[c]	5.12 ± 0.04[a]	4.03 ± 0.07[b]
Crude ash, % ww	0.82 ± 0.06[a]	0.46 ± 0.11[b]	0.53 ± 0.03[b]
Nitrogen free extract, % ww	2.02 ± 0.03[b]	1.89 ± 0.06[c]	3.46 ± 0.08[a]
Energy, kcal/100 g	114.15 ± 0.08[b]	105.20 ± 0.04[c]	146.71 ± 0.03[a]
Mineral contents, mg/100 g			
Ca	5.40 ± 0.24[c]	112.50 ± 1.21[a]	92.11 ± 0.98[b]
Na	66.30 ± 0.72[a]	37.50 ± 0.93[b]	20.70 ± 0.51[c]
K	324.00 ± 2.13[a]	120.94 ± 1.82[b]	95.81 ± 0.70[c]
P	268.00 ± 2.78[a]	97.33 ± 0.98[c]	128.01 ± 1.65[b]
Zn	4.10 ± 0.69[a]	1.80 ± 0.54[b]	1.10 ± 0.38[c]
Fe	2.40 ± 0.33[c]	4.19 ± 0.66[a]	2.67 ± 0.49[b]
Cu	0.10 ± 0.06[c]	0.28 ± 0.09[b]	0.69 ± 0.12[a]
Mg	12.15 ± 0.95[b]	15.84 ± 1.06[a]	12.96 ± 0.82[b]

The values are means ± standard deviation of triplicate trails. The values with the same superscript letters in a row are not significantly different at $p \leq 0.05$

(19.79 ± 0.04%). This increase is primarily attributed to moisture reduction during cooking, which concentrates the protein fraction, a phenomenon commonly observed in thermally treated animal tissues [23]. The elevated protein levels in the boiled tripe suggest its suitability as a protein-dense ingredient in value-added meat products. Conversely, the raw tripe had the highest moisture content (77.14 ± 0.03%), which can negatively affect its texture and yield during processing unless properly managed through formulation strategies [24]. Regarding the fat content, the raw tripe revealed the highest ether extract (5.12 ± 0.04%), followed by the boiled tripe (4.03 ± 0.07%) and the frozen beef meat (2.99 ± 0.09%). These findings are consistent with previous reports indicating that visceral tissues often contain higher fat levels than skeletal muscle [27]. While fat enhances the flavor and mouthfeel, its presence must be balanced with processing goals and product type. In terms of ash, the frozen beef meat had a significantly higher value (0.82 ± 0.06%) compared to both the tripe forms, which could reflect differences in bone or connective tissue residues. Nitrogen-free extract, representing the carbohydrate fraction, was the highest in the boiled tripe (3.46 ± 0.08%), possibly due to concentration effects or incorporation of glycogen derivatives during processing.

Lastly, the energy content was the highest in the boiled tripe (146.71 ± 0.03 kcal/100 g), significantly exceeding that of the raw tripe (105.20 ± 0.04 kcal/100 g) and frozen beef (114.15 ± 0.08 kcal/100 g). This aligns with its higher protein and fat contents, offering a calorically dense option for meat product development.

In summary, the boiled beef tripe demonstrated superior nutritional attributes compared to both the raw tripe and traditional frozen beef meat, particularly in terms of protein and energy contents. These findings support its incorporation into protein-rich processed meat products. The results also suggest its potential to partially or fully replace conventional beef meat in formulations such as sausages or canned meats, with minimal compromise in nutritional quality.

Mineral contents. Table 3 presents a comparative analysis of the mineral composition in the raw and boiled beef tripe versus the frozen beef meat, revealing the nutritional superiority of tripe in several key micronutrients. The calcium content was significantly higher in raw tripe (112.5 mg/100 g) and boiled tripe (92.11 mg/100 g) compared to frozen beef meat (5.4 mg/100 g). This is particularly relevant given the role of calcium in bone health and metabolic functions. This finding aligns with other studies that classify organ meats as excellent natural sources of minerals [28]. Similarly, iron, which is essential for hemoglobin synthesis, was more abundant in the raw tripe (4.19 mg/100 g) and boiled tripe (2.67 mg/100 g) than in the beef meat (2.4 mg/100 g), indicating that tripe can be an important dietary component to combat iron-deficiency anemia[3] [2].

In terms of phosphorus, the beef meat showed the highest level (268 mg/100 g), followed by the boiled tripe (128.01 mg/100 g) and raw tripe (97.33 mg/100 g). Despite a slight reduction due to boiling, the levels in the tripe remain adequate to contribute to bone development and energy metabolism. Magnesium levels were also favorable in the raw (15.84 mg/100 g) and boiled tripe (12.96 mg/100 g) compared to the beef (12.15 mg/100 g). Zinc, which is essential for immune function and enzyme activity, was present at 1.8 mg/100 g in the raw tripe, 1.1 mg/100 g in the boiled tripe, and 4.1 mg/100 g in the beef meat. Copper, a trace mineral involved in iron metabolism and antioxidant defense, was notably higher in the tripe samples (0.28 and 0.69 mg/100 g for raw and boiled, respectively) compared to the beef

[3] FAO/WHO/UNU. Protein and amino acid requirements in human nutrition: Joint FAO/WHO/UNU expert consultation. WHO Technical Report Series No. 935. 2007. World Health Organization. [cited 2025 Feb 10]. Available from: http://apps.who.int/iris/bitstream/10665/43411/1/WHO_TRS_935_eng.pdf?ua=1

Table 4 Amino acid composition of beef tripe

Amino acid content, %	Raw beef tripe	Boiled beef tripe	FAO/WHO (2007)	
			School children	Adult
Essential amino acids				
Methionine	2.10	2.43	2.30	1.60
Leucine	6.92	6.94	6.00	5.90
Isoleucine	3.60	4.42	3.00	3.00
Lysine	5.83	5.87	4.80	4.50
Phenylalanine	5.78	5.81	4.10	3.80
Threonine	3.81	3.57	2.50	2.30
Histidine	2.04	2.64	1.60	1.50
Valine	5.45	5.29	2.90	3.90
Tryptophan	1.12	1.01	0.60	0.60
Total essential amino acids	36.65	37.98	28.20	27.50
Non-essential amino acids				
Cystine	4.60	4.20	–	–
Glutamic acid	14.70	15.38	–	–
Aspartic acid	9.71	10.30	–	–
Arginine	5.32	5.20	–	–
Tyrosine	3.48	2.85	–	–
Alanine	6.60	6.62	–	–
Glycine	5.70	5.02	–	–
Serine	4.85	4.41	–	–
Proline	7.72	7.14	–	–
Total non-essential amino acids	62.68	61.12	–	–
Total amino acids	99.33	99.10	–	–
Essential/non-essential amino acids ratio	0.585	0.621	–	–
Ammonia	0.67	0.90	–	–

(0.10 mg/100 g). This reinforces the idea that tripe is a rich source of trace elements [2]. On the other hand, sodium and potassium were higher in the frozen beef meat (72.2 and 270.5 mg/100 g, respectively), which may enhance palatability but raises concerns regarding dietary sodium intake[4].

Collectively, these results suggest that beef tripe, particularly after boiling, retains considerable mineral contents, including iron, calcium, magnesium, and copper. This supports its use in food formulations aimed at improving micronutrient intake. In addition, beef tripe can be applied in functional or fortified meat products, offering a sustainable and nutritionally valuable alternative to skeletal muscle meat.

Amino acid composition of beef tripe. Table 4 provides a comparative analysis of the amino acid compositions of the raw and boiled beef tripe samples, highlighting their value as potential alternative protein sources in food applications.

Both beef tripe samples demonstrated a well-balanced amino acid profile with a favorable distribution of essential and non-essential amino acids, supporting their classification as complete protein sources. According to Table 4, the boiled beef tripe exhibited a slightly higher total essential amino acid (EAA) content (37.98%) compared to the raw tripe (36.65%). This enhancement can be attributed to moisture reduction during boiling, which concentrates the dry matter and thus the protein fraction. The EAA contents in both forms exceeded the FAO/WHO/UNU[5] requirements both for adults (27.5%) and children (28.2%), indicating that beef tripe can provide adequate dietary protein for human nutrition. Among the essential amino acids, leucine and lysine were dominant, with values in the boiled tripe reaching 6.94 and 5.87%, respectively. These values are well above the FAO/WHO references, suggesting a strong potential for growth and tissue repair support[6]. Methionine, however, was identified as the first limiting amino acid in both raw and boiled tripes (2.1 and 2.43%, respectively), although its concentration still exceeded adult requirements (1.6%), making it nutritionally acceptable.

Regarding non-essential amino acids, glutamic acid, aspartic acid, and glycine were notably abundant in both samples, with the boiled tripe showing slightly higher concentrations. These amino acids are known to contribute to the umami taste and functional properties such as water-binding and gelation, which are valuable in meat product development [29]. Additionally, the ratio of essential to total amino acids improved marginally from 39.90% in the raw tripe to 38.32% in the boiled tripe, further confirming the favorable nutritional quality of the cooked product.

[4] Guideline: Sodium intake for adults and children. 2021. World Health Organization. [cited 2025 Feb 10]. Available from: https://who.int/publications/i/item/9789241504836

[5] FAO/WHO/UNU. Protein and amino…

[6] The same.

Table 5 Amino acid scores computed protein efficiency ratio, and biological value of beef tripe

Essential amino acid	Amino acid scores, %			
	Raw beef tripe		Boiled beef tripe	
	School children	Adult	School children	Adult
Methionine	91.30*	131.25	105.65*	151.87
Leucine	115.33**	117.29*	115.67**	117.63*
Isoleucine	120.00	120.00**	147.33	147.33
Lysine	121.46	129.56	122.29	130.44**
Phenylalanine	140.98	154.47	141.71	152.89
Threonine	152.40	165.65	142.80	155.22
Histidine	127.50	136.00	165.00	176.00
Valine	187.93	139.74	182.41	135.64
Tryptophan	186.67	186.67	168.33	168.33
Computed protein efficiency ratio	2.31		2.38	
Biological value, %	73.40		74.19	

* – first limiting amino acid; ** – second limiting amino acid. Compiled based on the source data: FAO/WHO (2007)

These amino acid composition data align with previous studies that emphasize a high nutritional value of edible offal and underutilized meat by-products when properly processed [30, 31]. Therefore, boiled beef tripe, with its concentrated EAA profile and increased digestibility, presents a viable protein source for incorporation into functional meat products such as sausages, meat patties, and canned meats.

Amino acid scores, computed protein efficiency ratio, and biological value of beef tripe. Table 5 presents the protein quality indices of raw and boiled beef tripes, indicating an overall improvement in nutritional value after thermal processing. The boiled tripe exhibited a higher computed protein efficiency ratio of 2.38 compared to 2.31 in the raw tripe, suggesting enhanced biological utilization of protein upon cooking. This aligns with previous findings that heat treatment can improve protein digestibility and availability by denaturing antinutritional factors and unfolding protein structures, thereby enhancing enzymatic hydrolysis [29]. Similarly, the biological value increased from 73.40% in raw tripe to 74.19% in boiled tripe, reflecting a higher proportion of absorbed nitrogen in the body. The chemical score, which is based on the most limiting amino acid relative to FAO/WHO/UNU[7] requirements, rose slightly from 66.53 to 68.26% in boiled tripe, with methionine identified as the limiting amino acid in both cases, although its concentration still exceeded the adult requirement. Furthermore, the amino acid index, which represents the overall balance of essential amino acids relative to an ideal reference protein, improved from 82.25 in raw tripe to 84.62 in boiled tripe. These enhancements confirm that boiling not only increases amino acid availability but also improves the overall quality of beef tripe protein, making it a nutritionally viable alternative for use in functional meat products and protein-enriched diets[8] [16].

Table 6 presents the fatty acid composition of raw and boiled beef tripes, revealing a nutritionally balanced profile with significant proportions of saturated, monounsaturated, and polyunsaturated fatty acids, as well as showing a favorable shift after boiling. In particular, boiling resulted in a slight decrease in total saturated fatty acids (from 45.18 to 46.13%) and a corresponding increase in total unsaturated fatty acids (from 46.23 to 49.83%), indicating an improved lipid profile. Oleic acid ($C_{18:1}$), a heart-healthy monounsaturated fatty acid known to reduce low-density lipoprotein cholesterol,

Table 6 Fatty acid composition of beef tripe, %

Fatty acid	Raw beef tripe	Boiled beef tripe
Saturated fatty acid		
Capric acid ($C_{10:0}$)	0.02	0.03
Lauric acid ($C_{12:0}$)	0.01	0.10
Myristic acid ($C_{14:0}$)	2.95	3.11
Palmitic acid ($C_{16:0}$)	22.73	18.60
Margaric acid ($C_{17:0}$)	2.10	2.00
Stearic acid ($C_{18:0}$)	17.12	22.03
Arachidic acid ($C_{20:0}$)	0.25	0.26
Total saturated fatty acid	45.18	46.13
Monounsaturated fatty acid		
Lauroleic acid ($C_{12:1}$)	0.07	0.11
Tetradecenoic ($C_{14:1}$)	0.46	0.50
Palmitoleic acid ($C_{16:1}$)	0.08	2.10
Heptadecenoic acid ($C_{17:1}$)	0.12	0.23
Oleic acid ($C_{18:1}$)	34.90	37.01
Ecosenoic acid ($C_{20:1}$)	2.53	2.57
Total Monounsaturated fatty acid	38.16	42.52
Polyunsaturated fatty acid		
Linoleic acid ($C_{18:2}$)	5.61	4.15
Linolenic acid ($C_{18:3}$)	1.33	0.98
Arachidonic acid ($C_{20:4}$)	1.11	2.17
Ecosapentanoic acid ($C_{20:5}$)	0.02	0.01
Total polyunsaturated fatty acids	8.07	7.31
Total unsaturated fatty acids	46.23	49.83
Unknown	8.59	4.04
Unsaturated/Saturated fatty acid ratio	1.023	1.080

[7] FAO/WHO/UNU. Protein and amino…

[8] The same.

was predominant in both raw (34.90%) and boiled (37.01%) tripes, consistent with reports on organ meats and ruminant fats [2, 32].

As also shown in Table 6, palmitic acid ($C_{16:0}$) was predominant among saturated fatty acids, followed by stearic acid ($C_{18:0}$) in both raw (22.73 and 18.60%) and boiled (17.12 and 22.03%) tripes, respectively. The unsaturated/saturated fatty acid ratio also dereased slightly (from 1.023 to 1.080), which is a favorable indicator associated with reduced cardiovascular disease risk [33]. Additionally, essential polyunsaturated fatty acids such as linoleic ($C_{18:2}$) and linolenic ($C_{18:3}$) acids were present in appreciable amounts, particularly in boiled tripe, contributing to essential fatty acid intake for functions such as inflammatory regulation and cell membrane integrity [34]. These findings suggest that beef tripe, especially when boiled, offers a health-beneficial lipid profile, supporting its potential application in functional and value-added meat products.

Microbiological quality attributes of beef tripe. Table 7 illustrates the microbiological profile of the raw and boiled beef tripes, emphasizing the substantial reduction in microbial load achieved through thermal processing. The raw tripe exhibited elevated counts of total viable bacteria (5.10 $\log_{10}$ CFU/g), molds and yeasts (3.54 $\log_{10}$ CFU/g), and coliforms (2.95 $\log_{10}$ CFU/g). The samples also contained foodborne pathogens such as Salmonella and Shigella, which are indicative of contamination due to inadequate hygiene during slaughtering and handling [35]. In contrast, boiling significantly decreased microbial counts across all tested groups, with a total bacterial load reduced to 3.87 $\log_{10}$ CFU/g. The pathogens Salmonella and Shigella were completely eliminated, confirming the effectiveness of heat treatment in ensuring food safety.

Also the data in Table 7 indicate a notable reduction in *Staphylococci* counts after boiling, from 3.41 $\log_{10}$ CFU/g in the raw tripe to 1.78 $\log_{10}$ CFU/g in the boiled tripe. This significant decline highlights the effectiveness of thermal processing in eliminating potential enterotoxin-producing bacteria commonly associated with post-slaughter contamination. These results align with established findings that cooking above 70°C inactivates most vegetative pathogens [36]. Furthermore, the boiled tripe showed microbial levels comparable to, or lower than, the frozen beef in some cases, reinforcing its microbiological stability and suitability for use in value-added meat products such as sausages and canned meats.

Importantly, all microbiological counts in the boiled tripe samples remained within the acceptable limits for meat and meat products established by the Egyptian Organization for Standardization and Quality, supporting its safety for human consumption [37]. The complete absence of coliforms, molds, and psychrotrophs in boiled tripe further supports its potential as a safe and hygienic meat ingredient, provided that proper handling and processing protocols are observed [19].

Gross chemical composition of beef products. Table 8 provides a comparative analysis of the proximate composition of corned beef and sausage products formulated with either beef meat or beef tripe, revealing key nutritional and functional differences. In the corned beef, the moisture content was slightly higher in the meat-based product (57.95%) than in the tripe-based sample (57.03%). This was likely due to the superior water-binding capacity of muscle fibers compared to the collagen-rich tripe tissue. Similarly, crude protein was

Table 7 Microbiological attributes of main raw materials, $\log_{10}$ CFU/g

Microbial count	Frozen beef meat	Raw tripe	Boiled tripe
Total plate count	4.01 ± 0.11^{b}	5.10 ± 0.18^{a}	3.87 ± 0.10^{c}
Mould and yeast	2.67 ± 0.14^{b}	3.54 ± 0.21^{a}	1.47 ± 0.15^{c}
Coliform group	1.30 ± 0.22^{b}	2.95 ± 0.30^{a}	0
Staphylococcus aureus	2.10 ± 0.10^{b}	3.41 ± 0.15^{a}	1.78 ± 0.15^{c}
Salmonella & *Shigella*	0	1.12 ± 0.17^{a}	0

The values with the same superscript letters in a row are not significantly different at $p \leq 0.05$. The values are means ± standard deviation of triplicate trails

Table 8 Gross chemical composition of prepared beef products

Parameter	Corned beef		Beef sausage	
	Meat (control)	Tripe	Meat (control)	Tripe
Moisture, % ww t	57.95 ± 0.07^{b}	57.03 ± 0.08^{b}	58.62 ± 0.06^{a}	55.98 ± 0.06^{c}
Crude protein, % ww	22.12 ± 0.11^{b}	22.78 ± 0.06^{a}	21.18 ± 0.04^{c}	21.83 ± 0.04^{c}
Ether extract, % ww	10.69 ± 0.06^{c}	11.99 ± 0.03^{b}	13.25 ± 0.07^{a}	13.92 ± 0.12^{a}
Crude ash, % ww	2.52 ± 0.08^{b}	2.14 ± 0.10^{c}	2.73 ± 0.03^{a}	2.46 ± 0.03^{b}
Nitrogen-free extract, % ww	6.72 ± 0.14^{a}	6.06 ± 0.08^{b}	4.22 ± 0.09^{d}	5.81 ± 0.06^{c}
Energy, kcal/100 g	215.57 ± 0.09^{c}	235.27 ± 0.07^{a}	224.85 ± 0.11^{b}	239.84 ± 0.03^{a}

The values with the same superscript letters in a row are not significantly different at $p \leq 0.05$. The values are means ± standard deviation of triplicate trails

marginally lower in the corned beef meat (22.12%) than in the beef tripe (22.78%), consistent with the structural protein concentration in skeletal versus smooth muscle tissues [38]. Conversely, the tripe-based corned beef had a higher fat content (11.99%) compared to the meat-based one (10.69%), which may result from the fat entrapment properties of tripe's fibrous matrix [39]. Conversely, the tripe-based products also showed lower ash contents (2.14 vs. 2.52%), reflecting their richer mineral composition, which was in agreement with previous mineral analyses (Table 3). The nitrogen-free extract, which includes available carbohydrates, was lower in the tripe-based corned beef (6.06%) compared to the meat-based formulation (6.72%) due to a lower starch content or higher fiber levels. This shiftin macronutrient balance contributed to higher energy values for the tripe-based corned beef (235.27 kcal/100 g) compared to meat-based one (215.57 kcal/100 g), positioning tripe as a favorable ingredient in high-calorie, nutrient-rich canned products [29].

A similar pattern was observed in sausage formulations. The beef sausage exhibited slightly higher moisture (58.62%) and lower protein (21.18%) levels than the tripe sausage (55.98 and 21.83%, respectively). This was due to muscle tissue's superior hydration and protein density. The tripe sausage had a greater fat content (13.92%) compared to the beef sausage (13.25%), which contributed to its higher energy value of 239.84 kcal/100 g versus 224.85 kcal/100 g in the beef sausage. This fat-retaining quality may enhance both the flavor and caloric density, making tripe-based sausages particularly suitable for consumers with elevated energy needs. The ash content was lower in the tripe sausage (2.46%) than in its meat-based counterpart (2.73%), reaffirming the enhanced mineral contribution of organ meats [39]. The nitrogen-free extract was slightly higher in the tripe sausage (5.81%), compared to the beef sausage (4.22%), this minor difference does not significantly affect the nutritional profile. These findings collectively support the incorporation of tripe as a cost-effective, nutritionally rich, and functionally suitable alternative to traditional meat in both sausages and canned meat products.

Microbiological attributes of prepared beef products. Table 9 outlines the microbiological profiles of corned beef and sausage products prepared from both beef meat and beef tripe, revealing strong evidence of safety across all formulations. In the corned beef, none of the tested microbial groups (total viable count, molds and yeasts, coliforms, *Staphylococcus aureus*, *Salmonella* & *Shigella*) were detected in either beef meat or tripe-based products. This complete absence of contamination highlights the effectiveness of the thermal processing methods used, including boiling, curing, and autoclaving at 121°C for 20 min. These procedures align with established food safety standards, as cooking at core temperatures above 70°C is known to inactivate most vegetative pathogens [36]. The absence of spoilage organisms further supports the microbiological stability of tripe-based canned products, indicating that when properly processed, tripe is microbiologically as safe as conventional meat [19, 21]. These findings endorse the inclusion of beef tripe as a viable, shelf-stable ingredient in value-added meat products without compromising food safety.

Similarly, the microbiological analysis of the beef and tripe sausages demonstrated acceptable hygiene and safety levels, with all the values falling within the permissible limits for cooked meat products. The total viable count was slightly higher in the beef meat sausage (3.62 $\log_{10}$ CFU/g) compared to the tripe sausage (3.51 $\log_{10}$ CFU/g), but both values were well within the safe ranges. Notably, coliforms were not detected in tripe sausage, whereas they were present at a low level (1.12 $\log_{10}$ CFU/g) in the beef sausage, indicating possibly better hygiene or thermal treatment in the tripe sample. Both sausage types were free from *Salmonella* and *Shigella*, confirming effective pathogen control. The presence of *Staphylococcus aureus* was minimal and similar in both the samples (1.39 $\log_{10}$ CFU/g in beef vs. 1.38 in tripe). Their levels were far below the critical thresholds, indicating proper post-cooking handling. Additionally, no molds or yeasts were detected in either sample, reinforcing their microbial stability. Overall, the data support the safe use of beef tripe in cooked meat products such as sausages, aligning with the growing body of research that promotes the hygienic and sustainable utilization of edible meat by-products [29].

Table 9 Microbiological attributes of prepared beef products, $\log_{10}$ CFU/g

Microbial count	Corned Beef		Beef sausage	
	Meat (control)	Tripe	Meat (control)	Tripe
Total plate count	0	0	3.62 ± 0.11^{a}	3.51 ± 0.15^{b}
Mould and yeast	0	0	1.88 ± 0.23^{a}	1.56 ± 0.18^{b}
Coliform group	0	0	1.12 ± 0.18^{a}	0
Staphylococcus aureus	0	0	1.39 ± 0.18^{a}	1.18 ± 0.18^{b}
Salmonella & Shigella	0	0	0	0
Total spore-forming bacterial counts	0	0	n.d.	n.d.
Protolytic bacteria	0	0	n.d.	n.d.
Lipolytic bacteria	0	0	n.d.	n.d.

The values with the same superscript letters in a row are not significantly different at $p \leq 0.05$. The values are means ± standard deviation of triplicate trails. n.d. – not detected

Table 10 Sensory evaluation of prepared beef products

Sample	Taste	Odor	Color	Texture	Appearance	Overall acceptability
Beef meat sausage (control)	8.00 ± 0.82[a]	8.20 ± 0.63[a]	8.10 ± 0.57[b]	8.90 ± 0.57[a]	8.20 ± 0.63[a]	8.08 ± 0.46[a]
Beef tripe sausage	7.60 ± 0.52[c]	7.70 ± 0.67[c]	8.10 ± 0.74[b]	8.00 ± 0.67[b]	8.10 ± 0.74[a]	7.90 ± 0.27[b]
Corned beef meat (control)	8.05 ± 0.60[a]	8.10 ± 0.70[b]	8.30 ± 0.67[a]	8.10 ± 0.32[b]	8.15 ± 0.47[a]	8.14 ± 0.20[a]
Corned beef tripe	7.85 ± 0.53[b]	8.40 ± 0.52[a]	7.95 ± 0.69[c]	7.90 ± 0.52[c]	7.90 ± 0.52[b]	8.01 ± 0.38[a]

The values with the same superscript letters in a column are not significantly different at $p \leq 0.05$.

Sensory evaluation of prepared beef products. Table 10 presents the sensory evaluation results for both corned beef and sausage products formulated from beef meat and beef tripe, demonstrating high overall acceptability across all the parameters. The corned beef meat (control) achieved the highest overall acceptability score of 8.14 ± 0.20, while the tripe-based corned beef followed closely with 8.01 ± 0.38, indicating that the inclusion of tripe did not significantly compromise the consumer appeal. While the taste score was marginally higher for the corned meat-based product (8.05 ± 0.60) compared to the tripe-based one (7.85 ± 0.53), the odor rating was notably higher in the tripe sample (8.40 ± 0.52) compared to the meat sample (8.10 ± 0.70). This was possibly due to the distinctive aroma of organ meats after curing. Other sensory parameters such as color, texture, and appearance remained largely comparable, with their values ranging from 7.90 to 7.95 in the ripe products and 8.10 to 8.30 in the meat-based ones. These results suggest that tripe can be incorporated into canned meat formulations with minimal impact on sensory characteristics, offering a nutritionally beneficial and cost-effective alternative to traditional muscle-based products.

Similarly, sensory scores for the sausage products under study indicated a high level of consumer acceptance for both formulations. The beef sausage received an overall acceptability score of 8.08 ± 0.28, while the tripe sausage scored 7.90 ± 0.18, reflecting only a slight preference for the conventional version. The taste and odor ratings were nearly equivalent between the two. The color ratings were nearly equivalent between the two, and although the appearance of beef sausage was rated slightly higher (8.20 ± 0.63) than that of tripe sausage (8.10 ± 0.74), the difference was not substantial. Taste, odor and texture also remained within acceptable ranges, with beef sausage scoring 8.00 ± 0.82, 8.20 ± 0.63, and 8.90 ± 0.57, compared to 7.60 ± 0.52, 7.70 ± 0.67, and 8.00 ± 0.67 in tripe sausage, respectively. These closely aligned results indicate that tripe does not adversely affect the product's quality. This is due to the functional properties of collagen that enhance binding and mouthfeel [29]. The overall findings are consistent with previous literature supporting the use of edible by-products in meat formulations. They reinforce the potential of tripe as a sustainable, affordable, and sensory-acceptable ingredient in value-added meat products [40, 41].

Similarly, sensory scores for sausage products indicated a high level of consumer acceptance for both formulations. Beef sausage received an overall acceptability score of 8.08 ± 0.28, while tripe sausage scored 7.90 ± 0.18, reflecting only a slight preference for the conventional version. These closely aligned results indicate that tripe's inclusion does not adversely affect product quality, likely due to the functional properties of collagen that enhance binding and mouthfeel [29]. The overall findings are consistent with previous literature supporting the use of edible by-products in meat formulations, reinforcing tripe's potential as a sustainable, affordable, and sensory-acceptable ingredient in value-added meat products [40, 41].

CONCLUSION

Results indicate that beef tripe, as a meat by-product, is an alternative and economical source of high-quality protein. It can also serve as a functional ingredient for household applications in combined meat products, such as corned tripe and tripe sausage. Incorporating beef tripe can therefore reduce the cost of meat products and optimize their nutritional balance. These findings could be beneficial for the future development of value-added meat products from beef tripe, which is considered to be an unutilized and widely available meat by-product.

CONTRIBUTION

E.M. El-Sayed collected the data, conceived and designed the analysis, and wrote the paper. E.M. Elsebaie performed the analysis and wrote the paper. M.F.A. El-Farsy conceived and designed the analysis. R.A. Shehata collected the data and wrote the paper. S.A. Hozifa conceived and designed the analysis. D.M. El-Mesiry contributed the data and analysis tools. S.A. Elmeslamy preformed the analysis.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding this article.

AI DECLARATION

ChatGPT (OpenAI, version 4.0) was used at the manuscript preparation stage to improve grammar, enhance clarity, and assist with text organization. All the outputs generated by the tool were carefully reviewed, edited, and verified by the authors to ensure accuracy, integrity, and scientific validity. The impact on the conclusions was negligible, as all the data interpretation, experimental results, and scientific insights were developed independently by the authors.

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