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Influence of Cooking Techniques on the Nutritional Profile and Sensory Properties of Beef Sausages

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ABSTRACT

Background: Beef sausages are widely consumed, but their nutritional and sensory qualities vary with cooking methods. Techniques like steaming, baking, and frying can alter moisture, protein, fat, and flavor. Understanding these effects helps identify the best method to preserve nutrients and improve consumer acceptability. **Objective:** This study evaluated the effect of cooking methods on the nutritional and sensory quality of beef sausages. **Methodology:** Four groups were prepared: raw/control (A), steamed (B), oven-baked (C), and fried (D). **Results:** Moisture content was significantly higher (P≤0.05) in steamed sausages (70.90 ± 0.06%) compared to raw (69.61 ± 0.06%), fried (58.06 ± 0.02%), and oven-baked (56.17 ± 0.15%). On a dry matter basis (DMB), protein levels were 66.56 ± 0.18% (raw), 65.67 ± 0.12% (steamed), 58.06 ± 0.34% (fried), and 56.30 ± 0.43% (oven-baked). Fat was highest in steamed sausages (18.80%) followed by fried (18.21%), raw (16.02%), and oven-baked (14.81%). Ash content peaked in oven-baked sausages (9.27%), then fried (7.97%), raw (6.65%), and steamed (5.52%). Carbohydrates were greatest in oven-baked sausages (21.29%), followed by fried (12.93%), raw (11.14%), and steamed (10.58%). Calorific values (kcal/100g) were significantly higher (P≤0.05) in steamed sausages (471.91), followed by raw (453.84), oven-baked (437.01), and fried (419.09). Sensory analysis showed fried sausages scored best for color, aroma, texture, and flavor, while steamed and oven-baked sausages were rated significantly higher (P≤0.05) for palatability, mouthfeel, and overall acceptability. **Conclusion**: It is concluded that steaming was the most favorable cooking method, preserving protein content and enhancing sensory acceptance compared to oven baking and frying.

INTRODUCTION

The world's main source of animal protein is meat. Sufficient nourishment is provided by the high-protein beef product. Many studies have been conducted on expanding the variety of protein sources and optimizing the current sources, which are topics of endless interest and investigation (Asgar *et al*., 2010).

It is an edible post slaughter flash of animal's origin that is used as food for humans. These animals include buffalo, cow, goat, sheep, camel, and some wild animals' *i.e.* hog, dear and rabbit etc. including, poultry have become a main meat producing species; However, while several game animals including birds may provide a large amount of meat particularly in localized areas (Arain *et al.,* 2010; Ahmed *et al.,* 2024; Khan *et al.,* 2024; Khaliq *et al.,* 2025; Ullah *et al.,* 2024; Unar *et al.,* 2025). Heat stress can badly affect the meat composition and reproductive efficiency in animals (Khaliq *et al.,* 2025). Along with protein, meat supplies good sources of energy in shape of fat, carbohydrate, minerals (Z, Fe and selium) and B complex vitamins (B6, B12). Because of the high nutritive value meat plays a vital role in the growth and human nutrition

(Williams, 2007; Khan *et al.,* 2024; Ullah *et al.,* 2025; Shazinosh *et al.,* 2024). On average, usually muscles should comprise about 1% ash (*i.e*. phosphorous, potassium, chloride, calcium, sodium, magnesium and iron), 21% nitrogenous compounds, 1% carbohydrate, 5% lipid (predominantly proteins), and the 72% moisture cessation (hui *et al.,* 2001). Muscles differ noticeably in these components, especially because the accumulation of fat is the most influential on this variation age, sex can also affect the meat and milk composition values in animals (Khan *et al.,* 2025; Arif *et al.,* 2024).

Pakistan has great beef meat breeds potential, and it is blessed with good fattening beef animals, which are playing active part in the total meat supply within the country. The current beef production of the Pakistan is 2.155 million tons, which is 50.55 % of total meat production (Farooq, 2018). Meat of buffalo is also known as the best source of prime quality meat, which is frequently used for the manufacturing of different meat products like sausages, burgers, restructured steaks etc. The main characteristics of quality buffalo meat are good marbling, desirable texture, and water holding capacity, low connective tissue, emulsification, fragmentation index and its dark red colour. The dark red meat retains good binding properties, useful for manufacturing products (Abdul and Saghir, 2014). Sausages are cylindrical meat products usually made from ground meat, often beef, mutton, poultry, veal along with salt, spices and other flavoring agents incased by skin. Usually, sausages are formed in casing traditionally made from intestine and other synthetic material (Kandapan *et al.,* 2013*).* The product of sausages is modification of the comminuted fresh meats carried out by several treatment practices to achieve essential sensory attributes (Verbeke *et al.,* 2010). Sausages are popular meat products among several millions of consumers worldwide and as functional foods, which are designed to maintain low-fat beef meat products to increase the consumer demand of their traditional method. (Limberger *et al*., 2011). Many types of fat substitutes are used in the meat industry, one of them being dietary fibre. The production of processed meats rich in dietary fibre is now one of the most dynamically developing branches of the production of low-calorie foodstuff (Szczepaniak *et al*., 2005). Sausages are sold raw and cooked including, broiling, pan-frying and barbecuing (Sallam *et al.,* 2004; Sachindr *et al.,* 2005; Raju *et al.,* 2003). These meat products may be preserved by curing, drying, fermenting, smoking and freezing. Evidence suggest that the sausages were manufactured and famous among the ancient Greek and Roman civilizations. Currently, there are different varieties of sausages that have been produced/manufactured around the world. These are classified as; fresh, cooked, smoked, fresh smoked, dry, vegetarian, cured/aged, blood, liver and salami sausages (Zanardi *et al.,* 2010). From nutritional aspects sausages are good source of energy because of having desirable value of protein, fat, minerals, unique
appearance, taste and flavor, which are necessary for the consumers` acceptance (Marcos, 2015; Gadiyarin and Kannan 2004). Although the sausages are very popular in consumers, sausage producers still essential to isolate a quantity of several components to proper amount of production not only to achieve the perfect and enhance the quality of product, on the other hand also keep total cost (Savadkoohi *et al*., 2014; Rinaldoni *et al*., 2014).

Now this regards, usage of certain components positive effects to the health like vegetable source protein, whey protein, herbs, fibers and spices has been similarly recognized as a gradually increasing development in food production. Today, food or food components offer the physiological useful effects as well as reduce the risk of numerous degenerative diseases (Ningrum, 2014; Rinaldoni *et al*., 2014; Shahidi and Ambigaipalan, 2015). A wide variety of sausages based on varying variation in proportions, adding of flavouring agents (*i.e*. herbs, beer or vegetable powders feature descriptors (termed as "gourmet", "select" or "finest") and meat content, are procured in the markets. Many by-products are possibly valuable sources of nutrients/potentially functional ingredients, providing the opportunity to obtain value added products. In this context there is a requisite to first study the chemical composition of every by-product and its potential for future usage (Domínguez-Perles *et al*., 2010). Their optimistic effects are due to additions of either active components or removal or replacement of undesirable ingredients (Hilliam, 1998). The herbs and spices combinations have anticancer, anti- inflammatory, antioxidant properties. The cloves possess high antioxidant ability compared to that of petals, rose cinnamon, nutmeg etc. (Al-Jalay *et al.,* 1987). Use of 1% garlic juice reduces peroxide value. Whereas addition egg albumin adds moisture and protein, holding together delicate constituents
and additions of vegetables and grain fillers. Flours along with egg white powder significantly increased folding test, protein content, cooking yield, water holding capacity, lightness, fat and moisture retention, however, carbohydrate and ash content reduced than control samples (Dewi, 2012).

Based on previous literature cited regarding the importance and nutritional aspects of sausage, the present study was hypothesized to manufacture the sausages and to analyse the impact of different heat treatments on their nutritional and sensory quality.

MATERIALS AND METHODS

An experiment was conducted to prepare sausages from buffalo meat using conventional methods. Spices, cooking oil vegetables *etc.* required for sausage making and buffalo meat samples procured from butchers from local market of Tandojam (Plate No. 3.1 and 3.2). All the collected samples and raw material were brought to the laboratory of Animal Products Technology, Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agriculture University Tandojam for sausage manufacturing.

Preparation of Casings

The small intestines of goat were used as natural casings. Initially the fresh intestines were washed with tap water (three times). Then dipped in normal saline solution (0.9N CL) for 10 minutes.

Equipment/Utensils

Mincer: Mince the raw meat into small particles for easy to fill.

Filling Machine: The stuffing of sausages with help of the filler into the natural casing.

Analytical Weighing Balance: Analytical weighing balance (Adam, Model NO AAA 2502) was used for weighing beef meat sausage samples and reagents whenever required.

Refrigerator: Refrigerator (Model 9188 wanna-be-moderator, Pakistan) used to preserve beef meat sausage sample.

Hot Air Oven: Hot air oven (Memmert 854, Sachwabch W. Germany) was used for drying the glasswares and sterilization as well as determination of total solids contents in the meat samples.

Muffle Furnace: Determine ash content by the igniting of beef meat sausage through the Muffle furnace (Nevertherm Mod; L9/11/8KM, Germany).

Kjeldhal Digestion and Distillation Unit: Kjeldhal digestion unit (LABCONCO Mod 60300-01) was used to digest meat sample, and distillation was used to distillate the meat samples for determination of protein in meat.

Soxhlet Extraction Unit: Determine the beef meat sausage sample by using Soxhlet extraction unit (Lablin Melrose park, ILL).

Methods

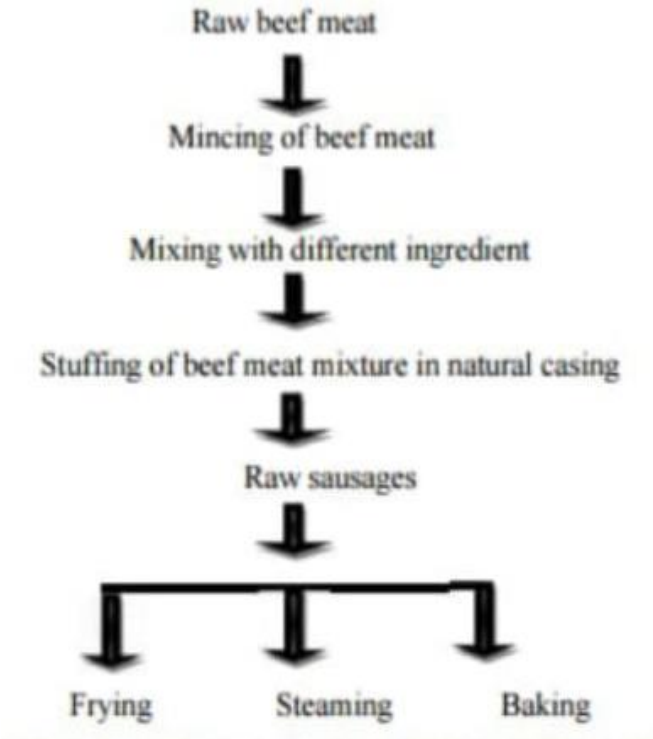
After the collection of raw materials, approximately 250g buffalo meat sample was separated for macronutrients analysis and rest of sample was used to produce beef sausages.

Preparation of Beef Sausages

In this study, six sausage batches were prepared using a modified method (Fig. 1) and divided into four groups: raw control (A), fried (B), steamed (C), and oven-baked (D). Each duplicate batch was evaluated for chemical properties, energy content, and sensory quality.

Figure 1

Flow Chart Showing Basic Methodology of Sausage Making



Analysis of Chemical Characteristics of Sausages

The raw, steam, oven and fried beef meat sausages were analyzed for

1. Moisture/Total solid (using the method of Association of Official Analytical Chemists (AOAC, 2000)

Formula: $\text{Moisture (\%)} = \frac{W2 - W1}{W2 - W3} \times 100$

Where,

W1 = weight of empty aluminium dish W2 = weight of aluminium dish + sample,
W3 = weight of aluminium dish + dried sample

2. fat (using the soxhlet Extraction Unit (Lablin Melrose park, ILL)

Formula: $\text{Fat (\%)} = \frac{W2 - W1}{W3} \times 100$

Here,
W1 = distillation flask empty weight W2 = weigh of distillation flask + fat W3 = weight of sample taken

3. (Protein using the Micro Kjeldhal digester according to the method mentioned in AOAC, (2000),

Formula:

$$\text{Nitrogen (\%)} = \frac{1.4\,(V1 - V2 \times \text{normality of HCL}}{\text{weight of meat sample taken} \times \text{volume of diluted sample}} \times 250$$

Whereas,
V1 = Titrated value, V2 = value of blank sample
Protein percentage was calculated by converting the obtained nitrogen into protein by using conversion factors (CF) i.e. 6.25.

4. Ash (using muffle furnace (Neverherm Mod; L9/11/8KM, Germany).

Formula: $\text{Ash (\%)} = \frac{W3 - W1}{W2 - W1} \times 100$

Where,
W1 = empty weight crucible W2 = Crucible + weight sample
W3 = Ashed sample weight + crucible

5. Carbohydrate contents

Formula:
Carbohydrate % = TS% - (Fat% + Protein% + Ash %)

Determination of Calorific/Nutritive Values

Calorific values of fresh and cooked like steam, fried and oven baked beef meat sausages were calculated by using energy conversion factors of major components as reported by Johnson *et al.* (1995). Like 4 for protein, 9 for fat and 4 for carbohydrates.

Formula:
Kcal (per 100g) = [(% protein) (4)] + [(% fat) (9)] + (% Carbohydrates) (4)] Where,
4 = conversion factor of protein and carbohydrate in kilocalories and 9 = conversion factor of fat in kilocalories.

Sensory Quality of beef sausages

All three cooked varieties, *i.e.* fried, steamed and oven-backed sausages were organoleptically judged by the panel of judges for the taste/flavor appearance/color body/texture, odor/smell or overall acceptability. All the sensory attributes were rated according to modified sensory evaluation proforma.

Statistical Analysis:

Analysis carried out applying computer statistical program, Student Edition of Statistix (SXW), Version 8.1 (Copyright 2005, Analytical software-USA).

RESULTS

Moisture content

The moisture content of beef sausages cooked in different ways is shown in Figure 2. On average, steamed sausages had the highest moisture (70.90 ± 0.06%), followed by raw (69.61 ± 0.11%), fried (58.06 ± 0.02%), and oven-baked (56.17 ± 0.15%). ANOVA showed clear differences ($P \leq 0.05$) among all types. The LSD test (Table 1.A) confirmed steamed sausages kept more moisture than the others. In replication 1, steamed sausages (71.68%) were higher than raw (70.58%), fried (60.08%), and oven-baked (56.59%), with the same trend in replication 2. Trial results (Table 1.B) also showed steamed sausages (71.80%) had more moisture ($P < 0.05$) than oven-baked (56.52%), fried (60.19%), and raw (70.62%), while no big effect of trial × replication was found (Table 1.C). Because of these large differences, results were also checked on a dry matter basis (DMB).

Table 1A

Interactive Influence of Type × Replication on Moisture Content of Beef Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	71.68^{a}	56.59^{d}	60.08^{c}	70.58^{b}
R2	71.65^{a}	56.55^{d}	60.09^{c}	70.57^{b}
LSD (0.05)		0.033		
S E±		0.075		

Table 1B

Interactive Influence of Type × Batch/Trial on Moisture Content of Sausages

Sausage Treatment(Type)	Trial/Batch			
	T1	T2	T3	T4
Steam	71.51^{c}	71.65^{b}	71.70^{ab}	71.80^{a}
Oven baked	56.55^{j}	56.81^{i}	56.40^{k}	56.52^{j}
Fried	60.05^{h}	60.10^{gh}	60.00^{h}	60.19^{g}
Raw/uncooked	70.75^{d}	70.55^{e}	70.42^{f}	70.62^{e}
LSD (0.05) S E±		0.1439 ±0.0636		

Table 1C

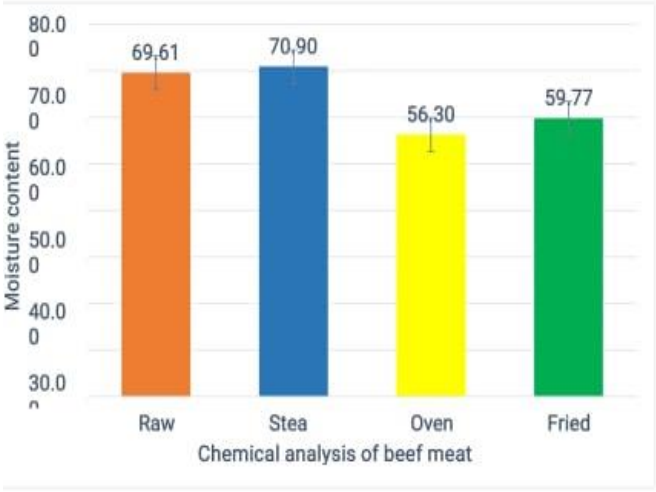
Interactive Influence of Replication × Batch/Trial on Moisture Content of Sausages

	Replication (ns)	
	R1	R2
1	64.70^{bc}	64.73^{ab}
2	64.78^{a}	64.77^{ab}
3	64.62^{c}	64.64^{c}
4	64.80^{a}	64.77^{ab}
LSD (0.05) SE±	0.033 ±0.07	

Means superscript with similar letters in column or row are non-significant ($P \leq 0.05$) from each other

Figure 2

The Average Moisture Content (%) of Beef Meat Sausages



LSD (0.05) = 0.4976, SE ± = 0.2334

Protein Content

The protein content of beef sausages under different cooking methods is shown in Figure 3. The average protein content (DMB) was highest in steamed sausages (65.67 ± 0.12%), followed by raw (66.56 ± 0.18%), fried (58.06 ± 0.34%), and oven-baked (56.30 ± 0.00%). ANOVA confirmed significant differences ($P < 0.05$) among all types. The LSD test (Table 2.A) showed protein was higher in steamed (66.00%) and raw (65.25%) sausages, while fried (58.66%) and oven-baked (55.68%) were lower. In replications, steamed sausages (65.98%, 65.92%) remained higher than fried and oven-baked but not significantly different from raw sausages (65.26%, 65.23%). Trial results (Table 2.B) also showed steamed sausages (66.32%) had more protein than oven-baked (56.73%) and fried (58.45%), but similar to raw (65.13%). No significant trial × replication effect was observed (Table 2.C).

Table 2A

Interactive Influence of Type × Replication on Protein Content of Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	65.98^{a}	55.92^{c}	58.74^{b}	65.23^{a}
R2	65.96^{a}	55.45^{c}	58.57^{b}	65.26^{a}
LSD (0.05)		0.033		
S E±		0.075		

Table 2B

Interactive Influence of Type × Batch/Trial on Protein Content of Sausages

Sausage Treatment (Type)	Trial/Batch			
	T1	T2	T3	T4
Steam	66.32^{a}	66.26 ^{a}	65.72^{ab}	65.56^{ab}
Oven baked	56.73^{e}	55.68^{e}	56.25^{e}	54.07^{f}
Fried	58.45^{d}	60.03^{c}	58.12^{d}	58.02^{d}
Raw/uncooked	65.13^{ab}	64.77^{a}	65.08^{ab}	66.01^{ab}
LSD (0.05)		1.25		
S E±		±0.55		

Table 2C

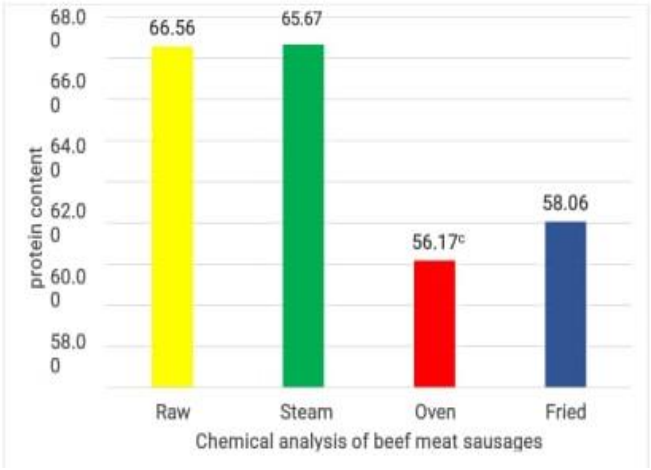
Interactive Influence of Replication × Batch/Trial on Protein Content of Sausages

Trial	Replication (ns)	
	R1	R2
1	61.90[a]	61.42[ab]
2	61.69[ab]	61.68[ab]
3	61.38[ab]	61.21[ab]
4	60.89[b]	60.94[b]
(0.05) SE±	0.88 ±0.39	

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other

Figure 3

The Average Protein Content (%DMB) of Beef Meat Sausages



LSD (0.05) = 0.5438, SE ± = 1.1592

Fat Content

The fat content of beef sausages cooked by different methods is shown in Figure 4**.** Average fat values (DMB) were highest in steamed sausages (18.80 ± 0.07%), followed by fried (18.21 ± 0.20%), raw (16.02 ± 0.04%), and oven-baked (14.81 ± 0.08%). ANOVA confirmed significant differences (P < 0.05) among all treatments. The LSD test (Table 3.A) showed steamed and fried sausages had significantly higher fat than raw and oven-baked, while steamed and raw were not different. In replications, fried sausages (20.60%, 20.48%) showed the highest fat compared to steamed (16.64%, 16.55%), raw (16.43%, 16.44%), and oven-baked (14.60%, 14.55%). Trial results (Table 3.B) revealed fried sausages (21.40%) contained more (P < 0.05) fat than steamed (16.50%), raw (16.32%), and oven-baked (14.85%), while steamed and raw remained similar. No significant trial × replication interaction was observed (Table 3.C).

Table 3A

Interactive Influence of Type × Replication on Fat Content (%DMB) of Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	16.55[b]	14.60[c]	20.48[a]	16.43[b]
R2	16.64[b]	14.50[c]	20.60[a]	16.44[a]
LSD (0.05) S E±	0.27 0.12			

Table 3B

Interactive Influence of Type × Batch/Trial on Fat Content (%DMB) of Sausages

Sausage Treatment (Type)	Trial/Batch			
	T1	T2	T3	T4
Steam	16.50[cd]	16.71[cd]	16.78[c]	16.38[d]
Oven baked	146.85[e]	15.58[ef]	14.22[f]	14.55[ef]
Fried	21.40[a]	20.30[b]	20.37[b]	20.10[b]
Raw/uncooked	16.32[d]	16.46[cd]	16.58[cd]	16.36[d]
LSD (0.05) S E±	0.39 ±0.17			

Table 3C

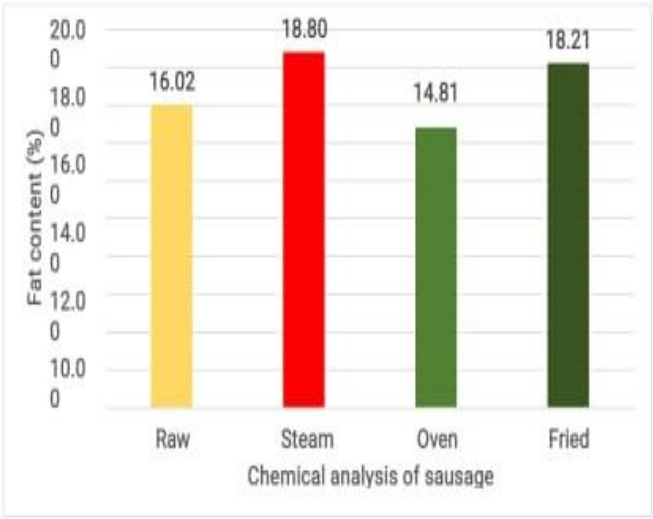
Interactive Influence of Replication × Batch/Trial on Fat Content (%DMB) of Sausages

Trial	Replication (ns)	
	R1	R2
1	17.25[a]	17.26[ab]
2	17.05[abc]	16.99[bc]
3	16.97[c]	17.01[abc]
4	16.89[c]	16.80[c]
LSD (0.05) SE±	0.27 ±0.12	

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 4

The Average Fat Content (%DMB) of Beef Meat Sausages



LSD (0.05) = 0.2586, SE ± = 0.4976

Ash Content

The ash content of beef sausages under different cooking methods is shown in Figure 5. Mean ash values (DMB) were highest in oven-baked sausages (9.27 ± 0.15%), followed by fried (7.97 ± 0.15%), raw (6.62 ± 0.13%), and steamed (5.52 ± 0.07%). ANOVA confirmed significant differences (P < 0.05) among all treatments. LSD test (Table 4.A) showed oven-baked sausages (8.48%) had significantly more ash than fried (7.86%), raw (7.18%), and steamed (6.86%). In replications, oven-baked sausages (8.25%, 8.43%) remained higher than fried (7.83%, 7.91%), steamed (6.91%, 6.81%), and raw (7.31%, 7.06%). Trial results (Table 4.B) indicated oven-baked sausages (8.98%) had higher ash than fried (7.29%), steamed (7.08%), and raw (6.98%), while raw and steamed were not significantly different. No significant trial × replication effect was observed (Table 4.C).

Table 4A

Interactive Influence of Type × Replication on Ash Content (%DMB) of Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	6.91^{d}	8.25^{a}	7.83^{b}	7.31^{c}
R2	6.81^{d}	8.43^{a}	7.91^{b}	7.06^{cd}
LSD (0.05)		0.31		
S E±		0.14		

Table 4B

Interactive Influence of Type × Batch/Trial on Ash Content (%DMB) of Sausages

Sausage Treatment (Type)	Trial/Bach			
	T1	T2	T3	T4
Steam	7.01^{gh}	6.67 ^{h}	6.68^{h}	7.08^{gh}
Oven baked	8.17^{cd}	6.68^{ab}	8.08^{cd}	8.97^{a}
Fried	8.38^{bc}	8.02^{cde}	7.77^{de}	7.29^{fg}
Raw/uncooked	7.18^{g}	7.64^{ef}	6.93^{gh}	6.98^{gh}
LSD (0.05) S E±		0.44 ±0.19		

Table 4C

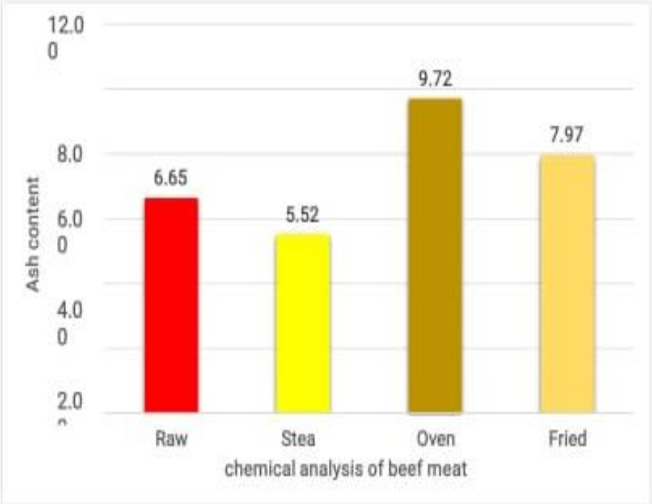
Interactive Influence of Replication × Batch/Trialon Ash Content (%DMB) of Sausages

Trial	Replication (ns)	
	R1	R2
1	7.71^{a}	7.75^{a}
2	7.66^{a}	7.75^{a}
3	7.48^{b}	7.25^{ab}
4	7.63^{a}	7.52^{b}
LSD (0.05) SE±	0.31 ±0.14	

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 5

The Average Ash Content (%DMB) of Beef Meat Sausages



LSD (0.05) = 0.2405, SE ± = 0.5126

Carbohydrate Content

The carbohydrate content of beef sausages prepared by different methods is shown in Figure 5. Mean values (DMB) were highest in oven-baked sausages (21.29 ± 0.37%), followed by fried (12.93 ± 0.51%), raw (11.14 ± 0.14%), and steamed (10.58 ± 0.13%). LSD test (Table 5.A) revealed oven-baked sausages had significantly higher carbohydrates than fried, raw, and steamed, while steamed and raw sausages were not different. In replications, oven-baked sausages (20.95%, 21.63%) remained higher than fried (13.04%, 12.83%), raw (11.03%, 11.25%), and steamed (10.59%, 10.58%). Trial analysis (Table 5.B) also showed oven-baked sausages (21.42%) had greater carbohydrate than fried (14.60%), raw (10.66%), and steamed (10.98%), while steamed and raw were similar. No significant trial × replication effect was noted (Table 5.C).

Table 5 A

Interactive Influence of Type × Replication on Carbohydrate Content (%DMB) of Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	10.59^{c}	20.95^{a}	13.04^{b}	11.03^{c}
R2	10.58^{c}	21.63^{a}	12.83^{b}	11.25^{c}
LSD (0.05)		1.05		
S E±		0.47		

Table 5B

Interactive Influence of Type × Batch/Trial on Carbohydrate Content (%DMB) of Sausages

Sausage Treatment (Type)	Trial/batch			
	T1	T2	T3	T4
Steam	10.18^{e}	10.36^{de}	10.81^{de}	10.98^{de}
Oven baked	20.05^{b}	21.05^{ab}	21.45^{ab}	22.42^{a}
Fried	11.77^{c}	11.64^{de}	13.7^{de}	14.60^{c}
Raw/uncooked	11.37^{de}	11.13^{de}	11.40^{de}	10.66^{de}
LSD (0.05) S E±		1.49 ±0.66		

Table 5C

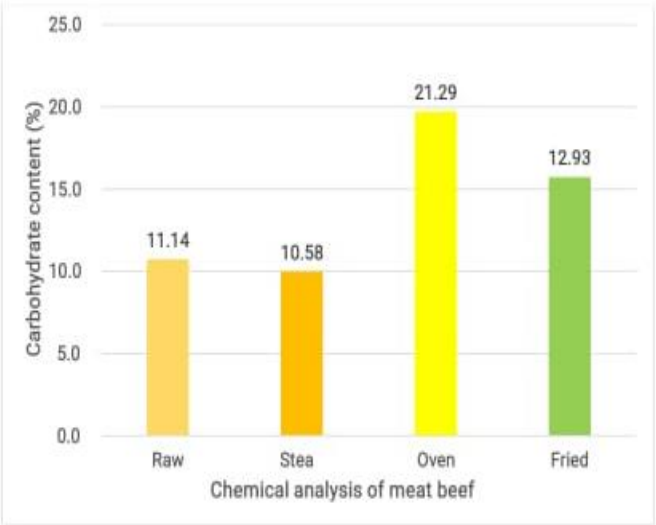
Interactive Influence of Replication × Batch/Trial on Carbohydrate Content (%DMB) of Sausages

Trial	Replication (ns)	
	R1	R2
1	13.12^{d}	13.66^{abcd}
2	13.51^{a}	13.57^{bcd}
3	14.17^{abcd}	14.52^{abc}
4	14.59^{a}	14.73^{a}
LSD (0.05) SE±	1.05 ±0.47	

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 6

The Average Carbohydrate Content (%DMB) of Beef Meat Sausages



LSD (0.05) = 0.0173, SE ± = 0.1683

Calorific/Nutritive Value

The calorific/nutritive value of beef sausages cooked by different methods is shown in Figure 7. Mean values

(DMB) were highest in steamed sausages (471.91±0.07%), followed by fried (459.20%), raw (453.48±0.04%), and oven-baked (437.01 ± 0.20%). LSD test (Table 6.A) confirmed steamed sausages had significantly higher nutritive value than fried, raw, and oven-baked, while steamed and raw were not different. In replications, steamed sausages (471.70%, 470.80%) remained higher than fried (455.14%, 455.98%), raw (453.91%, 452.97%), and oven-baked (438.90%, 438.78%). Trial analysis (Table 6.B) showed significant variation, where oven-baked sausages had lower values in trials 2 and 4 but remained consistent across others. Overall, ANOVA confirmed significant differences (P < 0.05) between cooking methods, with steamed sausages retaining the highest calorific value. No significant trial × replication effect was observed (Table 6.C).

Table 6A

Average Calorific/Nutritive Value (%DMB) of Raw, and Cooked Sausages

Replication	Sausages type (treatment)			
	Steam cooked	Oven Baked	Oil Fried	Raw
R1	471.70[a]	438.90e	455.14b[c]	453.91[d]
R2	470.80[a]	438.78[e]	455.98[b]	452.97[cd]
LSD (0.05)		0.7282		
S E±		1.6472		

Table 6B

Interactive Influence of Type × Batch/Trial on Calorific/Nutritive Value (%DMB) of Sausages

Sausage Treatment (Type)	Trial/Batch			
	T1	T2	T3	T4
Steam	449.52[efg]	477.73[a]	480.87[a]	479.50[a]
Oven baked	457.82[cd]	425.29[i]	419.54[i]	445.37[gh]
Fried	468.68[b]	466.76[b]	454.00[dfe]	447.38[fgh]
Raw/uncooked	442.16[h]	463.70[bc]	455.23[de]	452.83[def]
LSD (0.05) S E±		2.5975 6.6903		

Table 6 C

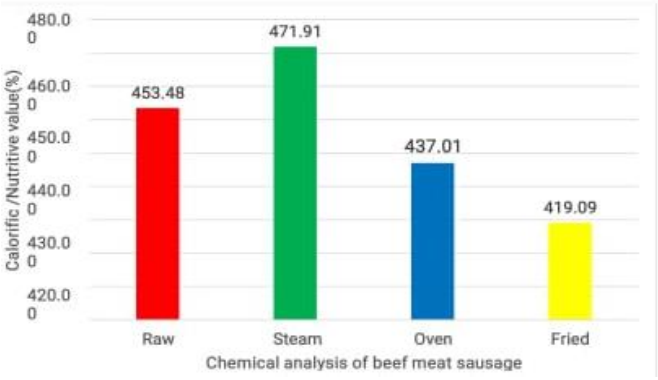
Interactive influence of Replication × batch/trial on calorific/nutritive value (%DMB) of sausages

Trial	Replication (ns)	
	R1	R2
1	455.53[d]	455.66[cd]
2	454.25[a]	453.92[a]
3	454.25[e]	456.04
4	453.94[b]	453.91[bc]
LSD (0.05) SE±	2.0913 4.7307	

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 7

The Average Nutritive Value (%DMB) of Beef Meat Sausages



LSD (0.05) = 0.5149, SE ± 1.1647

Color/ Appearance

The color/appearance of beef sausages, as judged by a sensory panel, is shown in Figure 8**.** Scores ranged from 4.00–5.00 for steamed and oven-baked sausages, and 4.00–6.00 for fried sausages. Mean scores were 4.75 ± 0.08 (steamed), 4.78 ± 0.07 (oven-baked), and 4.81 ± 0.08 (fried), with only slight differences among types. ANOVA showed significant variation (P < 0.05) based on treatment × judge interaction. LSD test (Table 7) indicated fried sausages scored highest for color/appearance from Judge 4 (5.12), but the same sausages were scored lower by Judge 3 (4.50). Overall, fried sausages were perceived as the best appearance, while variation among judges was significant.

Table 7

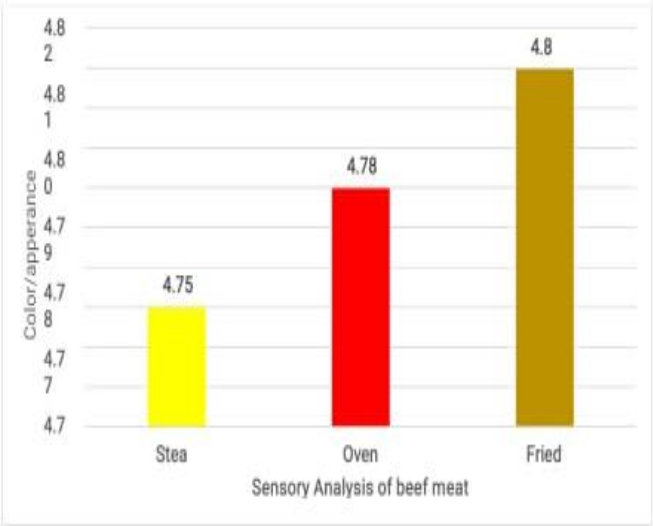
Interactive Influence of Type × Judges on Sensory Characteristics (Color/Appearance) of Sausages

Sausage Treatment (Type)	Judges			
	1	2	3	4
Steam	4.87[abc]	4.75[abc]	4.75[abc]	4.62[bc]
Oven baked	5.00[ab]	4.50[c]	4.87[abc]	4.75[abc]
Fried	4.87[abc]	4.75[abc]	4.50[abc]	5.12[a]
LSD (0.05)		0.2463		
S E±		0.4955		

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 8

Sensory Analysis (Color/Appearance) of Beef Meat Sausages



SE ± = 0.2861

Odor/ Appearance

The odor/aroma of beef sausages, as evaluated by a sensory panel, is shown in Figure 9**.** Scores ranged from 4.00–6.00 for steamed, 3.00–7.00 for oven-baked, and 4.00–7.00 for fried sausages. Mean scores were 5.37 ± 0.10 (steamed), 4.46 ± 0.25 (oven-baked), and 5.97 ± 0.12 (fried). LSD test (0.05) revealed fried sausages had significantly higher (P < 0.05) aroma scores, followed by steamed, while oven-baked scored lowest. Interactive influence of type × judges (Table 8) showed fried sausages received the highest score (6.37) from Judge 4, whereas oven-baked sausages received the lowest score (3.12) from the same judge. Overall, fried sausages were preferred for aroma, while oven-baked were least favored.

Table 8

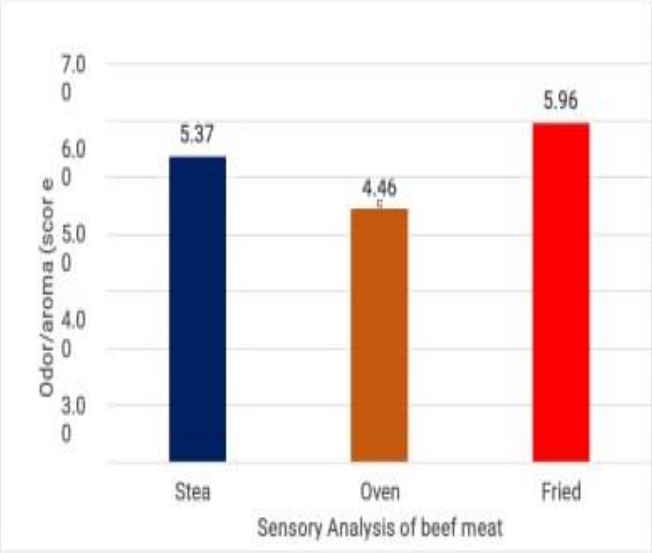
Interactive Influence of Type × Judges on Sensory Characteristics (Odor/Aroma) of Sausages

Sausage Treatment (Type)	Judge			
	1	2	3	4
Steam	5.25 ^{cd}	5.50^{cd}	5.50^{cd}	5.25^{cd}
Oven baked	5.87^{abc}	4.00^{e}	4.87^{d}	3.12^{f}
Fried	5.62^{bc}	5.62^{bc}	5.62^{ab}	6.37^{a}
LSD (0.05)		0.3644		
S E±		0.7330		

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 9

Sensory Analysis (Odor/Aroma) of Beef Meat Sausages



LSD (0.05) = 0.1477, SE ± = 0.2971

Flavor

The flavor/taste scores of beef sausages are presented in Figure 10**.** Scores ranged from 3.00–5.00 for steamed, 3.00–4.00 for oven-baked, and 3.00–4.00 for fried sausages. Mean scores were 3.47 ± 0.11 (steamed), 3.37 ± 0.09 (oven-baked), and 3.28 ± 0.09 (fried). Statistical analysis showed no significant differences (P > 0.05) among cooking methods. Similarly, the LSD test (Table 9) confirmed no significant interactive influence of type × judges on flavor scores. Overall, all sausages were rated close in taste, with steamed slightly higher but without statistical significance.

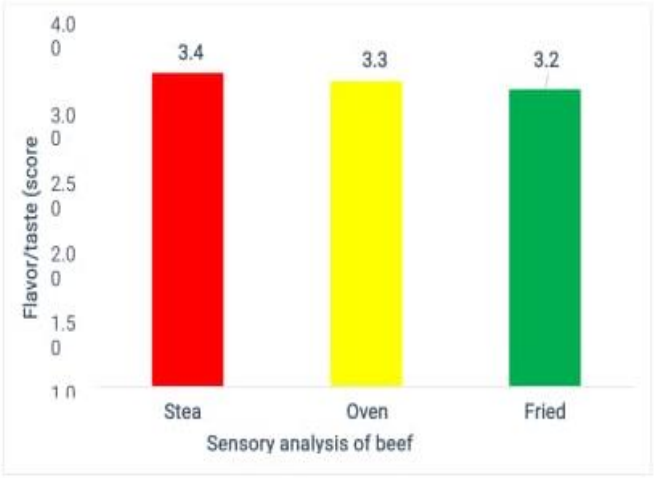
Table 9

Interactive Influence of Type × Judges on Sensory Characteristics (Flavor/Taste) of Sausages

Sausage Treatment (Type)	Judges			
	1	2	3	4
Steam	3.75	3.25	3.50	3.37
Oven baked	3.25	3.50	3.25	3.50
Fried	3.25	3.25	3.37	3.25
S E±		0.5256		

Figure 10

Sensory Analysis (Flavor/Taste) of Beef Meat Sausage



SE ± = 0.2628

Body/Texture

The sensory evaluation of body/texture of beef sausages is shown in Figure 11. Scores ranged from 1.00–7.00 for steamed, 3.00–6.00 for oven-baked, and 5.00–7.00 for fried sausages. Mean values were 5.34 ± 0.18 (steamed), 5.31 ± 0.14 (oven-baked), and 6.50 ± 0.10 (fried). LSD test (0.05) revealed fried sausages received significantly higher (P < 0.05) texture scores than steamed and oven-baked, while steamed and oven-baked did not differ significantly. Interactive effect of type × judges (Table 10) confirmed fried sausages were consistently rated superior in texture by all judges, whereas steamed and oven-baked sausages showed no significant difference. Overall, fried sausages had the best texture quality among treatments.

Table 10

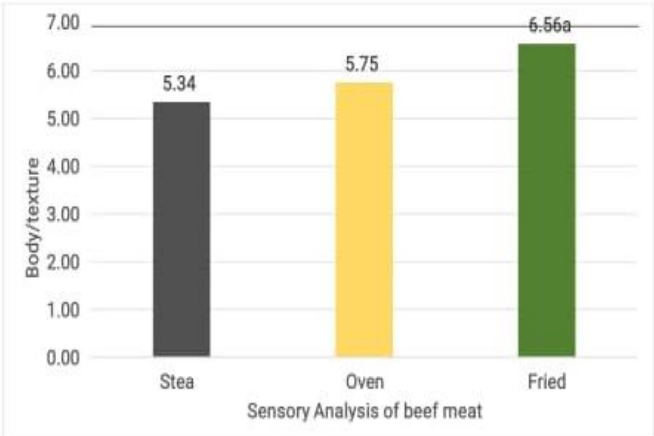
Interactive Influence of Type × Judges on Sensory Characteristics (Body/Texture) of Sausages

Sausage Treatment (Type)	Judges			
	1	2	3	4
Steam	5.12^{b}	5.62^{b}	5.12^{b}	5.12^{b}
Oven baked	5.12^{b}	5.25^{b}	5.50^{b}	5.37^{b}
Fried	6.37^{a}	6.62a	6.62^{a}	6.62^{a}
LSD (0.05)		0.3528		
S E±		0.7098		

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 11

Sensory Analysis (Body/Texture) of Beef Meat Sausages



LSD (0.05) = 0.1764, SE ± = 0.3549

Palatability

The sensory evaluation of palatability of beef sausages is presented in Figure 12**.** Scores ranged from 1.00–3.00 for steamed, 2.00–4.00 for oven-baked, and 1.00–5.00 for fried sausages. Mean values were 2.25 ± 0.12 (steamed), 2.75 ± 0.17 (oven-baked), and 1.84 ± 0.13 (fried). LSD test (0.05) showed that oven-baked sausages were significantly more palatable (P < 0.05) than steamed and fried sausages, while no significant difference (P > 0.05) was found between steamed and fried. Interactive effect of type × judges (Table 11) confirmed that oven-baked sausages were generally preferred by judges, whereas fried sausages consistently received the lowest palatability scores. Overall, oven-baked sausages were judged the most palatable.

Table 11

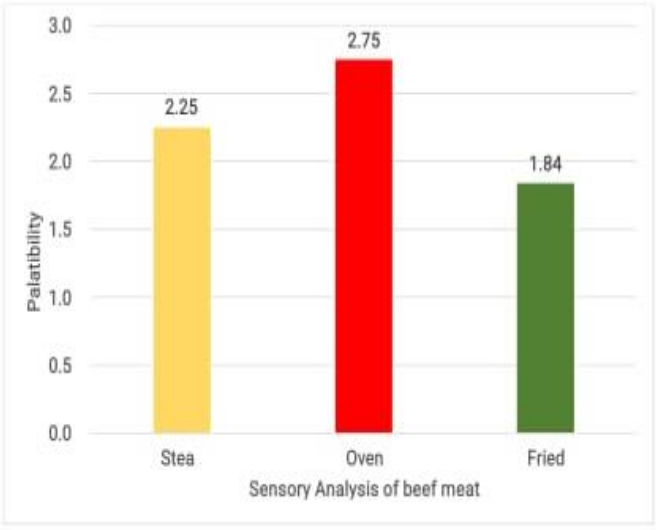
Interactive Influence of Type × Judges on Sensory Characteristics (Palatability) of Sausages

Treatment	Judges			
	1	2	3	4
Steam	2.25^{abc}	1.87^{bc}	2.62^{abc}	2.62^{abc}
Oven	2.50^{abc}	2.75^{ab}	3.00^{a}	2.75^{c}
Fried	2.00^{bc}	1.75^{c}	1.87^{bc}	1.75^{c}
SE	0.4569			
LSD (0.05)	0.9191			

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 12

Sensory Analysis (Palatability) of Beef Meat Sausages



LSD (0.05) = 0.2284, SE ± = 0.4595

Mouth Feel

The sensory evaluation of mouth feel of beef sausages is shown in Figure 13. Scores ranged from 2.00–3.00 for steamed, 2.00–4.00 for oven-baked, and 2.00–4.00 for fried sausages. Mean values were 2.34 ± 0.10 (steamed), 3.28 ± 0.12 (oven-baked), and 3.09 ± 0.12 (fried). LSD test (0.05) revealed steamed sausages had significantly lower (P ≤ 0.05) mouth feel scores compared to oven-baked and fried, while no significant difference (P ≥ 0.05) was found between oven-baked and fried sausages. Interactive effect of type × judges (Table 12) confirmed oven-baked sausages received the highest mouth feel scores from all judges, whereas steamed sausages consistently ranked lowest. Overall, oven-baked sausages provided the best mouth feel.

Table 12

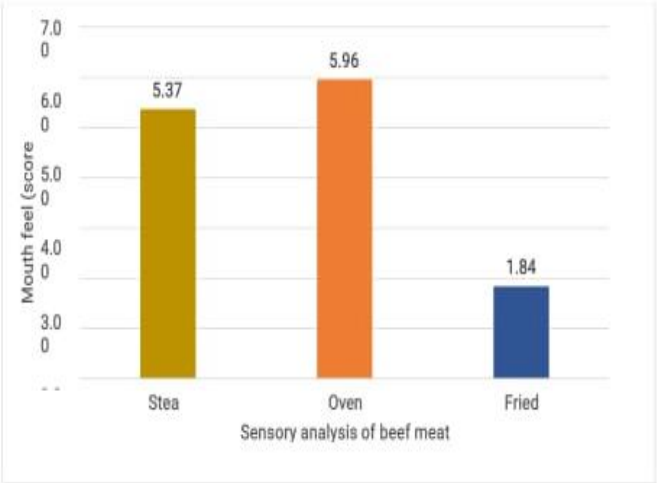
Interactive Influence of Type × Judges on Sensory Characteristics (Mouth Feel) of Sausages

Treatment	Judges			
	1	2	3	4
Steam	2.12^{g}	2.37^{fg}	2.37^{fg}	2.50^{efg}
Oven	3.12^{bcd}	2.87^{def}	3.37^{abcd}	3.75^{a}
Fried	2.25^{g}	3.00^{cde}	3.50^{abc}	3.62^{ab}
SE	0.2954			
LSD (0.05)	0.5943			

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 13

Sensory Analysis (Mouth Feel) of Beef Meat Sausages



LSD (0.05) = 0.1477, SE ± = 0.2971

Overall Acceptability

The sensory evaluation of overall acceptability of beef sausages is presented in Figure 14**.** Scores ranged from 1.00–3.00 for steamed, 2.00–3.00 for oven-baked, and 1.00 for fried sausages. Mean values were 2.00 ± 0.10 (steamed), 2.44 ± 0.09 (oven-baked), and 1.00 ± 0.01 (fried). The LSD test (0.05) revealed that oven-baked sausages were significantly (P < 0.05) more acceptable to judges compared to steamed and fried sausages. Interactive effect of type × judges (Table 13) confirmed that oven-baked sausages were consistently preferred by all judges, while fried sausages received the lowest acceptability scores. Overall, oven-baked sausages were rated highest in acceptability, followed by steamed, with fried sausages least acceptable.

Table 13

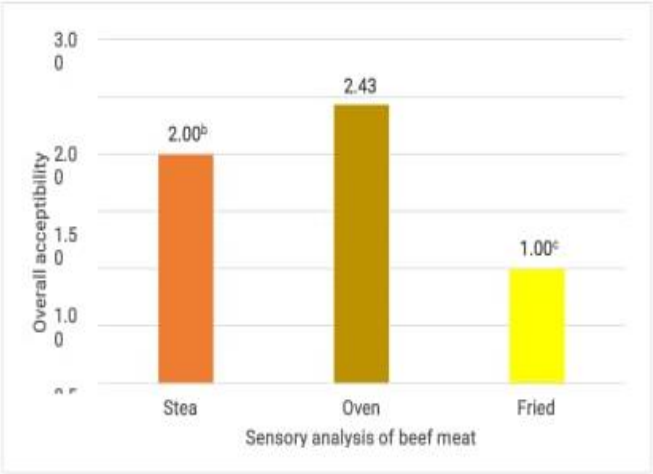
Interactive Influence of Type × Judges on Sensory Characteristics (Overall Acceptability) of Sausages

Treatment	Judges			
	1	2	3	4
Steam	1.87^{cd}	1.62^{d}	2.37^{ab}	2.12^{bc}
Oven	2.25^{abc}	2.62^{a}	2.62^{a}	2.25^{abc}
Fried	1.00^{e}	1.00^{e}	1.00^{e}	1.00^{e}
SE	0.2057			
LSD (0.05)	0.4139			

Means superscript with similar letters in column or row are non-significant (P≤0.05) from each other.

Figure 14

Sensory Analysis (Overall Acceptability) of Beef Meat Sausages



LSD (0.05) = 0.1029, SE ± = 0.2070

DISCUSSION

Sausage is chopped or ground meat that has been blended with spices and other seasonings and usually stuffed in natural or manufactured casings. Sausage making evolved as an effort to economize and preserve meat that could not be consumed fresh at slaughter. Where, the non- meat ingredients are used to impart flavor, slow the bacterial growth and increase the yield of the sausage. These include water, salt, sugar, nonfat dry milk, extenders and binders, and spices. Sausages are said to be a rich source of protein and have all essential amino acids necessary for good health and repair the body tissue also. These are available in great varieties of flavors.

The average moisture content of beef meat sausage was observed high in steamed sausages (70.90%), followed by raw (69.61%), fried (59.77%) and oven baked sausages (56.30%). These findings are in line with Serdaroglu (2003) authors found high moisture % in raw sausage (74.04% to 75.1%) than that of cooked (smoked) sausages (62.0% to 73.1%); while the current results conflict with the observations of Sheard (1998) who revealed 49.5% moisture in the raw sausage and 41.10% in cooked sausages. Contradictory results (63.43% in cooked sausage and 55.48% in fresh sausage) were also reported by Al-Shawabkeh (2009); (55.48% moisture in fresh sausages by Aghnotri (2002) and (66.7%) in fresh sausages by Aghnotri and Pal (2000) and Soltanizadeh, *et al*. (2010) (48.7%). However, the present study is supported by the results of Martin and Rogers (1993) who observed 65% and above moisture content. However, in the present study high difference in the moisture content (%) could be due to cooking patterns *i.e.* it was statistically ($P<0.05$) high in steam

cooking due to (water and steam) and drastically ($P<0.05$) reduced in oven baked and/or fried cooking due to dry heat/direct cooking compared to that of raw/uncooked sausages.

Slight increase in the average protein content of steamed cooked (65.67, % DMB) compared to that of raw sausages (66.56, %DMB) and marked reduction in protein content was examined when the raw sausages were cooked and oven baked (58.06, 56.17% DMB respectively). Relatively similar findings were observed by Dharma *et al.* 2007 (18.36%), Marcos reported that protein (18.53%) in beef sausagePresent results are also supported with the reported work of Gadiyaram, and Kannan, (2004) who found 18.53 and 18.0% for beef and goat sausages respectively and Gadiyaram (2004) found the protein (20.47%) in cooked sausages and MALICKI (2004) reported (15.94%) in steamed cooked sausages. Similarly, Martin and Rogers (1993) also reported 15.5–16.40% protein contents in beef-sausages and Yılmaz (2001) examined 16.28 to 17.53% protein content. Furthermore, current results conflict with results Meltem Serdaroğlu (2003) who examined lower level of protein *i.e.* 14.0% to 16.0%. Author also agreed with Mittal and Barbut (1994), who argued that protein levels increased on cooking pattern which could be featured due to changes in total solid contents during cooking.

The averagely high fat content of beef sausages was found in steamed sausages (18.80%DMB) followed fried, raw and oven baked (18.21, 16.02 and 14.81%DMB). These observations are matching with the results of Dharma *et al.* (2007) they reported fat content (18.36%) and Al-Shawabkeh (2009) also supported current findings who mentioned 16.7% fat in sausages. Whereas these results are disagreed with Sheard (1998) who stated higher level of fat in raw sausages and fried cooked (20.7% 19.2% respectively). According to previously reported literature (Ertaş, & Kolsarıcı, 1983; Sutton, Hand, & Newkirk, 1995; Sylvia, Claus, Marriott, & Eigel) fat content may vary between 8.94 -19.33%. It could be argued that significant variation may occur in the chemical composition of the products because of cooking methods, *i.e.* the fat content either increased or decreased depending on the relative amounts of fat and/or cooking losses during cooking conditions. Present results differed with the Martin and Rogers (1993) who carried research on low fat beef-sausages (fat content 1.0–1.1%). But as reported by Bloukas and Paneras (1993), Gadiyaram 2004 observed 7.07% fat in oven baked sausage, while Malicki (2004) found 10.41% fat in the steam sausage.

The overall mean ash content of the beef sausage was found high in oven baked (9.27%) than that of fried, raw and steam cooked sausages (7.97, 6.65 and 5.52% DMB. Respectively). These results are in line with Sheard (1998), who observed 3.12 and 4.39% ash in Raw and fried cooked sausages). Dharma *et al*. (2007) found 3.00 and Marcos reported very low level of ash content (1.33%) in sausage. Abul-Fad, (2012) observed the ash content as 6.38 to 8.91 respectively.

The average carbohydrate (%) of beef sausage in oven baked sausages existed high (9.27%) followed by fried (7.07%), raw (6.65%) and steamed (5.52). The result disagreed with Sheard (1997) who reported 17.5% and 21.7% carbohydrate content in raw and fried cooked sausages; however, these observations are matching with Al-Shawabkeh (2009) reported 3.4% and Abul-Fad examined in between 4.11 to 6.93%. Comparatively the average nutritive value of beef sausage was found high in fried sausages (471.25) followed by steamed sausage (455.56) and raw/uncooked sausages (453.44) oven baked sausages (438.84) respectively. Relatively similar

observations were reported by Arun (2010) who observed that the meat product have 501.40 to 634.50 and Abul-Fadl, (2012) found the sausages have 497.5 to 559.55 nutritive value.

Overall result regarding sensory analysis showed that the steam, fried sausages were highly liked and attractive than the oven baked sausage. The average appearance /color, odor/aroma, body/texture, flavor/taste, palatability, mouth feel overall acceptability score of steam sausage 4.75, 5.37, 5.34, 3.37, 2.25, 2.34, 2.00 respectively. The average appearance/color, odor/aroma, body/texture, flavor/taste, palatability, mouth feel overall acceptability score of fried sausage 4.81, 5.96, 3.28, 6.56, 1.84, 1.00. The average appearance/color, odor/aroma, body/texture, flavor/taste, palatability, mouth feel overall acceptability score of oven baked sausage 4.78, 4.46, 5.31, 3.37, 2.75, 3.28, 2.43 the fresh meat and poultry derived product pressure induce the color modification greatly depend on treatment (pressure time temperature) Mor Mur (2002 the sensory analysis result disagree with A. Abou-Zaid (2015) who observed odor score 9.80, flavor 9.90, texture 9.8, color 9.9, overall acceptability 9.8. The texture/body of the sausage is an essential consideration for the manufacture of sausage products and the texture/body influence user preferences to the product report that Hidayat (2017) used 5 hidonic scale the score card results were noted as appearance/color 4.67-5.04 texture 4.00-4.50 flavor 3.79-4.58, overall acceptability 0.94-1.21

CONCLUSION

It is concluded from present study that moisture content was significantly higher (P<0.05) in steamed and raw sausages compared to oven-baked and fried. Protein content (%DMB) showed negligible reduction in steamed sausages but decreased significantly in oven-baked and fried. Fat content was markedly higher (P<0.05) in fried sausages than in steamed and raw. Ash and carbohydrate contents (%DMB) increased (P<0.05) in oven-baked and fried sausages compared to steamed and raw. The highest calorific/nutritive value (P<0.05) was recorded in steamed sausages, followed by oven-baked and fried.

Authors' Contribution

Conceptualization: SF, AS
Methodology: JK, GBK
Formal analysis: FH, MAS, IA, AF
Writing review and editing: UH, MI, MUF, MM
All authors have read and agreed to the published version

REFERENCES

1. Abdolghafour, B., & Saghir, A. (2014). Buffalo: a potential animal for quality meat production-a review. *Livestock research international*, *2*(2), 19-29.
2. Abou-Zaid, A. A., Abd-Elmaguid, N. M., Abd El-Hafez, A., & Amer, M. M. (2015). The Effect of Arak Stems Extracts on Chemical Characteristics, Bacterial Activity and Sensory Evaluation of Beef Sausage Products. *Int. J. Adv. Agric. Environ. Eng*, *2*(1), 39-43. http://dx.doi.org/10.15242/IJAAEE.C0815031
3. Malicki, A. D. A. M., Jarmoluk, A. N. D. R. Z. E. J., & Brużewicz, S. Z. Y. M. O. N. (2004). Effect of sodium lactate used alone or in combination with lysozyme on the physico-chemical and microbiological properties of steamed sausage stored under the refrigeration.
4. Abul-Fadl, M. M. (2012). Nutritional and chemical evaluation of white cauliflower by-products flour and the effect of its addition on beef sausage quality. *Journal of Applied Sciences Research*, *8*(2), 693-704.
5. Agnihotri, M. K., & Pal, U. K. (2000). Quality of chevon sausages in refrigerated storage. *INTERNATIONAL JOURNAL OF ANIMAL SCIENCES*, *15*(1), 69-73.
6. Ahmed, S., Bux Kachiwal, A., Khaliq, J., Shabir Barham, G., Ahmad, T., Bilal Khan, M., ... & Ullah, E. (2024). Effect of prebiotic supplementation on the quality characteristics of rabbit meat. *Journal of Advanced Zoology*. https://doi.org/10.53555/jaz.v45i6.5071
7. Al-Jalay, B., Blank, G., Mcconnell, B., & Al-Khayat, M. (1987). Antioxidant activity of selected spices used in fermented meat sausage. *Journal of Food Protection*, *50*(1), 25-27. https://doi.org/10.4315/0362-028X-50.1.25
8. Al-Shawabkeh, A. F., Mazahreh, A. S., & Quasem, J. M. (2009). Nutritive value of seven varieties of meat products (sausage) produced in Jordan. *Pakistan Journal of Nutrition*, *8*(4), 332-334.
9. Arain, M. A., Khaskheli, M., Rajput, I. R., Rao, S., Fazlani, S. A., Devrajani, K., & Umer, M. (2010). Examination of physical properties of goat meat. *Pakistan Journal of Nutrition*, *9*(5), 422-425. https://doi.org/10.3923/pjn.2010.422.425
10. Arif, M., Kachiwal, A. B., ur Rehman, Z., Soomro, S. A., Khaliq, J., Bilal, H., ... & Ali, T. A. (2024). Studies On Influence Of Varying Age And Sex On Hematological Indices And Physiological Parameters Of Pateri Goat Breed Of Sindh. *Journal of Survey in Fisheries Sciences*, *11*(1), 108-121. http://dx.doi.org/10.53555/sfs.v11i01.3020
11. Rai, A. K., Tamang, J. P., & Palni, U. (2010). Nutritional value of lesser-known ethnic meat products of the Himalayas.
12. Asgar, M. A., Fazilah, A., Huda, N., Bhat, R., & Karim, A. A. (2010). Nonmeat protein alternatives as meat extenders and meat analogs. *Comprehensive reviews in food science and food safety*, *9*(5), 513-529. https://doi.org/10.1111/j.1541-4337.2010.00124.x
13. Dewi, M. (2012). The effects of egg white powder addition with tapioca and sago flours on physicochemical and sensory properties of duck sausage. *International Food Research Journal*. http://repository.ppnp.ac.id/id/eprint/1887
14. Dharmaveer, S., Rajkumar, V., & Mukesh, K. P. (2007). Quality and shelf-life of smoked chevon sausages packed under vacuum. *American Journal of Food Technology*, *2*(4), 238-247. https://doi.org/10.3923/ajft.2007.238.247
15. Bloukas, J. G., & Paneras, E. D. (1993). Substituting olive oil for pork backfat affects quality of low-fat frankfurters. *Journal of Food Science*, *58*(4), 705-709. https://doi.org/10.1111/j.1365-2621.1993.tb09339.x
16. Dominguez-Perles, R., Moreno, D. A., Garcia-Viguera, C., Martinez-Ballesta, M. C., Riquelme, F., & Carvajal, M. (2012). Selecting cultivars of broccoli for optimal bioactive components: the influence of saline stress. https://doi.org/10.17660/ActaHortic.2012.939.19
17. Ertaş, A. H., & Kolsarıcı, N. (1983). Salam, sosis ve sucuklarda hidroksiprolin miktarı üzerinde araştırma. *Gıda*, *8*(5). Gadiyaram, K. M., & Kannan, G. (2004). Comparison of textural properties of low-fat chevon, beef, pork, and mixed-meat sausages. *South African Journal of Animal Science*, *34*(5), 212-214.
18. Hidayat, B. T., Wea, A., & Andriati, N. (2018). Physicochemical, sensory attributes and protein profile by

SDS-PAGE of beef sausage substituted with texturized vegetable protein. *Food Research*, *2*(1), 20-31. https://doi.org/10.26656/fr.2017.2(1).106
19. Hilliam, M. (1998). The market for functional foods. *International dairy journal*, *8*(5-6), 349-353. https://doi.org/10.1016/S0958-6946(98)00057-0
20. Hui, Y. H., Nip, W. K., Rogers, R. W., & Young, O. A. (2001). Gross composition: Meat composition. *Meat Science and Applications. Eastern Hemisphere Distribution. Marcel Dekker AG. Hutgasse*, *4*, 1-19.
21. Khan, B., Soomro, J., Malhi, M., Khaliq, J., Ahmad, T., Namood, S., ... & Memon, M. (2024). Effect Of Dietary Organic Selenium Supplementation On Mass And Enzyme Activities Of Rumen Microbes Of Goat. *Journal of Survey in Fisheries Sciences*, *11*(4), 222-232. http://dx.doi.org/10.53555/sfs.v11i4.3014
22. Khan, F. A., Kachiwal, A. B., Khaliq, J., Soomro, S. A., Ahmad, T., Khan, M. B., ... & Memon, M. (2024). Effect Of Supplementation Of B-Galacto-Oligosaccharide And Probiotic Mixture On Growth Performance Of Physiologically Stressed Rabbits. *Journal of Advanced Zoology*, *45*(6). http://dx.doi.org/10.53555/jaz.v45i6.5023
23. Khan, I. U., Afzal, U., Khaliq, J., Sadia, H., Ahmad, T., Khan, S. & Khan, A. R. A. (2025). A Comparative Evaluation Of Age And Sex Related Variations In Hematological And Physiological Parameters In Lassi Breed Camels (Camelus Dromedarius). https://doi.org/10.5281/zenodo.16931250
24. Khaliq, J., Namood, S., Marri, N. U., Muhammad, A., & Memon, M. (2024). The Impact of Probiotic Supplementation on Gut Health and Immune Function in Poultry: A Clinical Trial. *Indus Journal of Animal and Plant Sciences*, *2*(1), 10-22.
25. Khaliq, J., Rahman, S. U., Shah, M., Ullah, I., Khan, S., Ahmad, T.,& Khaliq, N. (2025). Impact of Heat Stress on Reproductive Efficiency and Fertility Markers in Dairy Cows in Arid Climates. *Life Sciences and Environmental Research Journal*, *3*(01), 28-43. Limberger, V. M., Brum, F. B., Patias, L. D., Daniel, A. P., Comarela, C. G., Emanuelli, T., & Silva, L. P. D. (2011). Modified broken rice starch as fat substitute in sausages. *Food Science and Technology*, *31*, 789-792.
26. MALICKI, A., & BRUŻEWICZ, S. (2004). Porównanie trwałości mikrobiologicznej wybranych produktów mięsnych o różnym poziomie zanieczyszczenia poprodukcyjnego. *Clin Exp Med*, *13*(4), 549-553. https://doi.org/10.1590/S0101-20612011000300037
27. Martin, J. W., & Rogers, R. W. (1993). Cure levels, processing methods and meat source effects on low-fat frankfurters. *Journal of food science*, *58*(1), 59-61. https://doi.org/10.1111/j.1365-2621.1993.tb03211.x
28. Mittal, G. S., & Barbut, S. (1994). Effects of fat reduction on frankfurters' physical and sensory characteristics. *Food Research International*, *27*(5), 425-431. https://doi.org/10.1016/0963-9969(94)90236-4
29. Essien, E. (Ed.). (2003). *Sausage manufacture: Principles and practice*. Woodhead Publishing.
30. Mor-Mur, M., & Yuste, J. (2003). High pressure processing applied to cooked sausage manufacture: physical properties and sensory analysis. *Meat science*, *65*(3), 1187-1191. https://doi.org/10.1016/S0309-1740(03)00013-5
31. Soltanizadeh, N., Kadivar, M., Keramat, J., Bahrami, H., & Poorreza, F. (2010). Camel cocktail sausage and its physicochemical and sensory quality. *International Journal of Food Sciences and Nutrition*, *61*(2), 226-243. https://doi.org/10.3109/09637480903373332
32. Paneras, E. D., Bloukas, J. G., & Papadima, S. N. (1996). Effect of meat source and fat level on processing and quality characteristics of frankfurters. *LWT-Food Science and Technology*, *29*(5-6), 507-514. https://doi.org/10.1006/fstl.1996.0078
33. Raju, C. V., Shamasundar, B. A., & Udupa, K. S. (2003). The use of nisin as a preservative in fish sausage stored at ambient (28±2 C) and refrigerated (6±2 C) temperatures. *International Journal of Food Science and Technology*, *38*(2), 171-185. https://doi.org/10.1046/j.1365-2621.2003.00663.x
34. Rinaldoni, A. N., Palatnik, D. R., Zaritzky, N., & Campderros, M. E. (2014). Soft cheese-like product development enriched with soy protein concentrates. *LWT-Food science and Technology*, *55*(1), 139-147. https://doi.org/10.1016/j.lwt.2013.09.003
35. Sachindra, N. M., Sakhare, P. Z., Yashoda, K. P., & Rao, D. N. (2005). Microbial profile of buffalo sausage during processing and storage. *Food control*, *16*(1), 31-35. https://doi.org/10.1016/j.foodcont.2003.11.002
36. Sallam, K. I., Ishioroshi, M., & Samejima, K. (2004). Antioxidant and antimicrobial effects of garlic in chicken sausage. *LWT-Food Science and Technology*, *37*(8), 849-855. https://doi.org/10.1016/j.lwt.2004.04.001
37. Sallam, K. I., Ishioroshi, M., & Samejima, K. (2004). Antioxidant and antimicrobial effects of garlic in chicken sausage. *LWT-Food Science and Technology*, *37*(8), 849-855. https://doi.org/10.1016/j.lwt.2004.04.001
38. Serdaroglu, M., & Ozsumer, M. S. (2003). Effects of soy protein, whey powder and wheat gluten on quality characteristics of cooked beef sausages formulated with 5, 10 and 20% fat. *Electronic Journal of Polish Agricultural Universities*, *6*(2), 3.
39. Shahidi, F., & Ambigaipalan, P. (2015). Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects–A review. *Journal of functional foods*, *18*, 820-897. https://doi.org/10.1016/j.jff.2015.06.018
40. Sheard, P. R., Nute, G. R., & Chappell, A. G. (1998). The effect of cooking on the chemical composition of meat products with special reference to fat loss. *Meat science*, *49*(2), 175-191. https://doi.org/10.1016/S0309-1740(97)00137-X
41. Shazinosh, M. U. F., Namood, S., Marri, N. U., Khan, Z., Bismillah, A. U., & Kabir, A. (2024). Studies on concentration of some milk metabolic enzymes at different parities, stage of lactation and their correlation with composition and yield of milk in Red Sindhi Cows. *Journal of Survey in Fisheries Sciences*, *11*(4), 175-188. https://doi.org/10.53555/sfs.v11i4.2902
42. Marcos, C., Viegas, C., de Almeida, A. M., & Guerra, M. M. (2016). Portuguese traditional sausages: different types, nutritional composition, and novel trends. *Journal of Ethnic Foods*, *3*(1), 51-60. https://doi.org/10.1016/j.jef.2016.01.004
43. Sutton, D. S., Hand, L. W., & Newkirk, K. A. (1995). Reduced fat, high moisture beef frankfurters as affected by chopping temperature. *Journal of Food Science*, *60*(3), 580-582. https://doi.org/10.1111/j.1365-2621.1995.tb09831.x
44. Sylvia, S. F., Claus, J. R., Marriott, N. G., & Eigel, W. N. (1994). Low-fat, high-moisture frankfurters: Effects of temperature and water during extended mixing. *Journal of Food Science*, *59*(5), 937-940. https://doi.org/10.1111/j.1365-2621.1994.tb08162.x
45. Szczepaniak, B., Piotrowska, E., Dolata, W., & Zawirska-Wojtasiak, R. (2005). Effect of partial fat substitution with dietary fiber on sensory properties of finely comminuted sausages part I. wheat and oat fiber. *Polish journal of food and nutrition sciences*, *55*(3), 309-314.
46. Unar, S. A., Memon, A., Kalhoro, D. H., Kalhoro, W. A., Samo, F. A., Kondhar, I. A., ... & Unar, M. Z. (2025). Effect of various concentrations of pomegranate peel waste on the growth performance and nutrient digestibility of broilers. *Pure and Applied Biology (PAB)*, *14*(2), 664-674. https://dx.doi.org/10.19045/bspab.2025.140063
47. Ullah, M., Khan, F. A., Khan, M. U., Shah, S. N., Riaz, M. S.,

Solangi, N. A., & Kabir, A. (2024). Revolutionizing Livestock Management: Probiotics As Immunomodulators For Health And Productivity. *Journal of Survey in Fisheries Sciences*, *11*(3), 141-149. https://doi.org/10.53555/sfs.v11i3.2406

48. Ullah, S. A., Hassan, F., Khaliq, J., Ullah, I., Khan, S., Ahmed, S., & Saboor, A. (2025). Therapeutic Potential of Green Synthesized Zinc Oxide Nanoparticles Derived from Withania coagulans Extract against High-Fat Diet Associated Hyperlipidemia in Rat Model. *Indus Journal of Bioscience Research*, *3*(5), 547-559. http://dx.doi.org/10.70749/ijbr.v3i5.1368Verbeke
49. W., Pérez-Cueto, F. J., de Barcellos, M. D., Krystallis, A., & Grunert, K. G. (2010). European citizen and consumer attitudes and preferences regarding beef and pork. *Meat science*, *84*(2), 284-292. https://doi.org/10.1016/j.meatsci.2009.05.001
50. Williams, P. (2007). Nutritional composition of red meat. *Nutrition & Dietetics*, *64*, S113-S119. https://doi.org/10.1111/j.1747-0080.2007.00197.x
51. Yılmaz, I., Şimşek, O., & Işıklı, M. (2002). Fatty acid composition and quality characteristics of low-fat cooked saus -8ages made with beef and chicken meat, tomato juice and sunflower oil. *Meat science*, *62*(2), 253-258. https://doi.org/10.1016/S0309-1740(01)00255
52. Zanardi, E., Ghidini, S., Conter, M., & Ianieri, A. (2010). Mineral composition of Italian salami and effect of NaCl partial replacement on compositional, physico-chemical and sensory parameters. *Meat Science*, *86*(3), 742-747. https://doi.org/10.1016/j.meatsci.2010.06.015