Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v6i8.1931
Biol. Clin. Sci. Res. J., Volume 6(8), ***2025****: 1931*
Original Research Article

Effect of Meat Type on the Compositional and Functional Characteristics of Meat Sauce During Refrigerated Storage for Shelf-Life Evaluation

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(Received, 4th August 2025, Accepted 25th August 2025, Published 31th August 2025)

Abstract: *Meat sauce is a very practical food that makes preparing wholesome meals quick and simple. It eliminates the need for intricate cooking procedures by combining premium protein with deep flavors. It improves the flavor and variety of pasta, rice, and other foods while saving time for time-pressed customers. It can be readily reheated or used immediately. It is the perfect choice for contemporary lifestyles due to its long shelf life and versatility.* ***Objective:*** *This study focuses on the development, physicochemical, and functional properties, and storage stability of meat sauces made from different types of meats.* ***Methods:*** *A laboratory-based experimental study was conducted from March to July 2025. Three treatment formulations were prepared: T_1 (minced chicken), T_2 (minced beef), and T_3 (minced mutton). Meat sauces were formulated using a modified protocol from Prayitno et al. (2021). Analyses were conducted on 0, 15 and 30 days to measure variations in moisture content, ash levels, fat content, protein content, and color analysis by using a handheld spectrocolorimeter (Lovibond, LC-400) and the CIE L a*b* scale. To assess shelf life, bacterial and mold counts were regularly monitored throughout the storage period. Additionally, pH, water-holding capacity, emulsifying capacity, and antioxidant activity were also determined during the storage period. Sensory evaluations were carried out by a panel of judges using a 9-point hedonic scale to assess the meat sauce's taste, aroma, texture, and overall acceptability. The data collected from these evaluations were analyzed using Statistix 8.1 software, with a statistical significance set at $p < 0.05$.* ***Results:*** *Over a 30-day refrigerated storage period, all meat sauce samples exhibited a progressive decrease in moisture and protein content, accompanied by corresponding increases in ash and fat concentrations, likely due to moisture loss and concentration effects. Among the formulations, the T_3 sample containing minced mutton demonstrated the highest free fatty acid (FFA) content and pH values, suggesting a greater degree of lipid hydrolysis and microbial activity compared to the other variants. In contrast, the T_1 sample prepared with minced chicken showed superior emulsifying and water-holding capacities, reflecting better functional protein properties that enhance texture and stability. Sensory evaluation revealed that while T_1 was generally well-accepted by the panelists, T_2 (minced beef) achieved the highest overall acceptability scores, indicating favorable flavor and appearance attributes.* ***Conclusion:*** *The study investigates the nutritional advantages, sustainability and ease of access to consumers of using meat sauce in a variety of dishes. The sauce offers a blend of nutrients when it is incorporated into different dishes. This creative strategy promotes economic stability by sourcing meat from local shops. In addition, it fulfils the consumer demand for fresh and organic convenience meals, making it a viable choice for health-conscious individuals.*

Keywords: Meat Sauce, Storage Stability, Sensory Evaluation, Shelf Life, Refrigerated Storage, Convenience Food

[***How to Cite:*** Batool S, Shaukat A, Zahra SM, Shahid K, Khursheed S, Zahra A, Athar R, Javed S, Fazal A, Amjad K, Arbab A, Mustafa F, Batool M, Noor A. Effect of meat type on the compositional and functional characteristics of meat sauce during refrigerated storage for shelf-life evaluation. *Biol. Clin. Sci. Res. J.,* **2025;** 6(8): 1-9. doi: https://doi.org/10.54112/bcsrj.v6i8.1931]

Introduction

The most popular protein source worldwide is chicken meat, which is renowned for both its nutritional content and its adaptability in cooking. It is recommended that people of all ages consume chicken meat, especially those who are older, to prevent sarcopenia, a persistent loss of muscle mass (1). Because raising chicken involves using renewable energy sources and emitting fewer greenhouse gases into the atmosphere, the production of chicken meat is more environmentally friendly than that of red meat (2). The chicken meat was generated 117-118 million tons globally, and 17.2% of this amount was contributed by the USA, 12.5 % by Brazil, 11.4% by China, 3.9-4% by Russia, and 3.3% by India. Pakistan has been counted as the world's 11th top chicken producer with a production of 1.02 billion broilers in 2015-16 (3).
For human metabolic processes, beef is an important source of high-quality dietary proteins. According to the Food and Agriculture Organization of the United Nations, the major beef-producing nations or regions are the USA (17.1% of beef production), Europe (14.5%), Brazil (13.1%), China (8.9%), Argentina (4.0%), India (4.1%), and Australia (4.2%). The largest beef exporters were Brazil (20.1% of world beef exports), Australia (15.5%), India (14-5% including carabeef from buffalo), USA (13.1%), New Zealand (6.0%), Argentina (6%) and Canada (5.2%) in 2018/19, with the rest of the world supplying about 17-18% of exported beef (3).
Mutton ingestion is lower as compared to that of cow because of its unusual flavor and appealing chemical makeup. The Asian continent accounts for 61% of the total global production of mutton. China accounts 54% overall production of mutton in Asia. Pakistan is third in Asia in terms of the production of mutton (3).
Tomatoes (Solanum lycopersicum L.) not only belong in your pantry, they hold fourth place among the world's most widely grown food crops, and are frequently cultivated worldwide (4). Tomatoes are rich in vital phytonutrients, which includes lycopene, β-carotene, phenolic compounds, and also vitamin C, all of them plays a very important role in promoting good health (5). Tomatoes contain a large number of bioactive compounds such as vitamin C, psi-carotene and provitamin A. Tomatoes have cardio-protective, antioxidant, anti-inflammatory, anti-allergy, antibacterial, vasodilatory and antithrombotic physiological qualities (6). Salt is not a spice but a mineral. It is used to give flavor to different food products and it also acts as a preservative (7). Salt also acts as an antioxidant (8). Black pepper is often dubbed the lord of all spices (9). Oleoresins, alkaloid piperine, and essential oils are responsible for the flavor and pungency of black pepper. The major phenolic compounds present in oregano are flavonoids and phenolic acids. The most prevalent

flavonoids in oregano are flavones, flavonols, flavanones, and flavanols. The most abundant phenolic acids present in oregano are hydroxybenzoic acid and hydroxycinnamic acid derivatives (10). Bay leaves are rich in iron, manganese, calcium, vitamin C, vitamin B6, vitamin B9 and zinc. It can be used to treat numbness, spasms, migraine, ear pains and inflammation of joints. It also helps to cure indigestion, constipation, flatulence and stomach pain (11).

The study investigates the nutritional advantages, sustainability and ease of access to consumers of using meat sauce in a variety of dishes. The sauce offers a blend of nutrients when it is incorporated into different dishes. This creative strategy promotes economic stability by sourcing meat from local shops. In addition, it fulfils the consumer demand for fresh and organic convenience meals, making it a viable choice for health-conscious individuals.

The main aims and objectives of this study are:

1. Development of meat sauces using different types of meat (e.g., beef, chicken, mutton).
2. Evaluation of the compositional and functional changes in the meat sauces during refrigerated storage for shelf-life evaluation.

Methodology

Procurement of Raw Materials for Meat Sauce Preparation:

Minced meats, tomatoes, onions, garlic and spices were purchased from local and supermarkets in Lahore, Pakistan.

Preparation of Tomato Sauce:

Tomato sauce was prepared by using method of Tchonkouang *et al*., (2025) with certain modifications. After washing, shallow cuts were made using a sharp knife at the bottom of tomatoes. Then the tomatoes were blanched for 60 seconds in boiling water (100°C). After blanching, they were transferred to ice-cold water, so that their peel come off easily. After peeling, tomatoes were cut in smaller chunks. Then they were added to the pan with sauteed onion and garlic, with the addition of salt and oregano and cooked until tender (Approximately 60 minutes). When the tomatoes were fully cooked, a small amount of lemon juice was added to preserve the sauce. After that, it was blended to form a smooth sauce and stored in airtight container in refrigerator until use.

Preparation of Tomato Paste:

Tomato paste was prepared according to method of Shatta *et al*., (2017) with certain modifications. After washing and size reduction, tomatoes were blended to make puree. Then the puree was strained using a 2 mm sieve to remove seeds. Then it was transferred to pan with the addition of bay leaves and cooked for 25 minutes. After that, sugar, salt and oil were added and the mixture was cooked until it reduced to half quantity (About 20 minutes). After removing bay leaves, it was further cooked until it turned into a thick paste-like consistency (About 10 minutes). Then it was stored in airtight container until use.

Formulation of Meat Sauce:

The formulation of meat sauce was produced according to Prayitno *et al*., (2021) with certain modifications.

Table 1: Formulation of Meat Sauce

Ingredients	Chicken Sauce	Beef Sauce	Mutton Sauce
	Quantity (g)	Quantity (g)	Quantity (g)
Mince	250	250	250
Oil	30	39	38
Onion	74	74	73
Garlic	4	8	8
Tomato sauce	14	103	100
Tomato paste	30	37	37
Salt	10	10	10
Black pepper	5	5	5
Oregano	0.5	0.5	0.5
Bay leaf	1	1	1

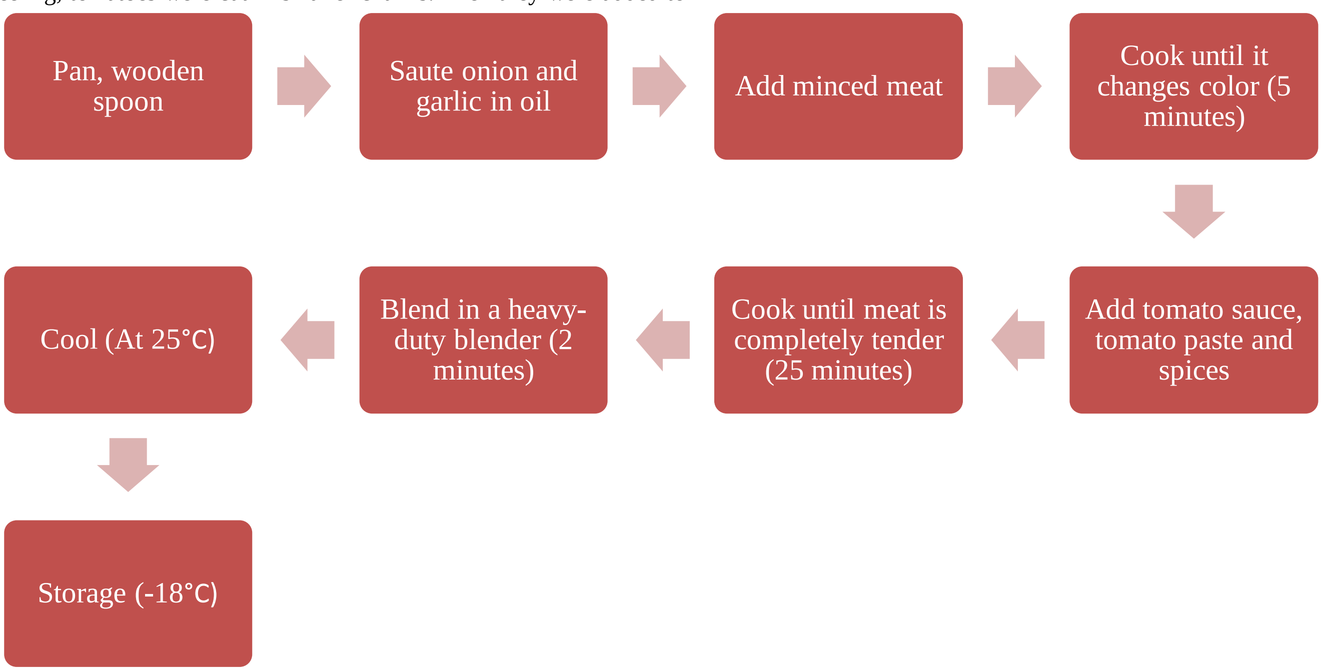

Figure 1: Flowline of Meat Sauce

Following the above flowchart, meat sauces were made using chicken, beef, and mutton minces.

Proximate Analysis of Meat Sauce

Determination of Moisture Content:

AOAC International has certified several oven methods for determining the moisture content of various food items, which were described by Imoisi *et al*. (2020). The moisture content was determined by oven drying the 10g of sample at 100°C to 105°C for 12 to 24 hours after it was weighed in a previously weighed petri plate.

$$\textbf{Moisture (\%)} = \frac{\textit{Final weight of the sample}}{\textit{Initial weight of the sample}} \times 100$$

Determination of Ash Content:

Using the AOAC International 2023 method, the amount of ash was ascertained. Before weighing, the crucibles were desiccator-cooled and dried. Weighing 1g of the sauce sample into the crucible. At 600°C, the crucible containing the samples was ignited in the muffle furnace for 3h. After the crucibles were removed from the muffle furnace, let them cool in the desiccator, and note the readings. Now the ash content is calculated as follows:

$$\textbf{Ash (\%)} = \frac{Weight\ of\ crucible\ after\ ashing - Weight\ of\ crucible\ before\ ashing}{Weight\ of\ the\ sample} \times 100$$

Determination of Fat Content:

The fat content of the sauce samples was determined using solvent extraction with a Soxhlet apparatus, as described by AOAC and Imoisi *et al.* (2020). One gram of each sample was wrapped in filter paper and placed in a Soxhlet reflux flask, which was connected to a condenser on the upper side and to a weighed oil extraction flask filled with 400 cm³ of hexane. The hexane was heated to its boiling point, causing the vapor to condense into the reflux flask and completely immerse the samples for extraction. This process continued, with the flask filling up and siphoning the extract back into the boiling solvent. The boiling, condensation, and reflux were allowed to proceed for several hours before the defatted samples were removed. The oil extract in the flask was then dried in an oven at 70°C for thirty minutes and subsequently weighed.

$$\textbf{Fat (\%)} = \frac{Weight\ of\ fat\ in\ sample}{Weight\ of\ dried\ sample} \times 100$$

Determination of Protein Content:

The crude protein content of the sauce sample was determined using the Kjeldahl method described by Imoisi *et al.* (2020). 1g of the sample was placed into a digestion flask. 10mL of nitric acid (HNO_3) was added, and the mixture was heated and filtered before being made up to a final volume of 100mL. Next, 10mL of the digest was transferred into a 500mL flask and diluted with 40 mL of distilled water. A 40% sodium hydroxide (NaOH) solution was then added, and the flask was securely stopped and connected to a 250mL conical flask. In the conical flask, 50mL of 4% boric acid was added. The mixture was heated to collect the distillate. The distillate was then titrated with 0.1N hydrochloric acid (HCl) until a faint pink color was achieved. The initial and final titration results were recorded, and the average titer value was calculated. Finally, the percentage of protein in the samples was determined based on this analysis.

$$\textbf{Wet Nitrogen (\%)} = \frac{(A-B)x1.4007}{Weight\ of\ the\ sample} \times 100$$

Where;

A = Vol (ml) Std HCl x Normality of Std HCl

B = Vol (ml) Std NaOH x Normality of Std NaOH

$$\textbf{Dry Nitrogen (\%)} = \frac{Percentage\ of\ wet\ moisture}{100 - Percentage\ of\ moisture}$$

Protein% = dry nitrogen% × 6.25 (protein nitrogen conversion factor)

Physicochemical Properties of Meat Sauce

Determination of Free Fatty Acid Contents:

Weigh 50g sauce sample and transfer it in slow speed blender. Add half teaspoon anhydrous sodium sulfate and 137ml $CHCl_3$ in it. Blend for 2 mins and filter it. Take filtrate and repeat the extraction by adding 50ml $CHCl_3$. Make volume of filtrate up to 250ml. Take 25ml diluted filtrate and 10 drops of indicator. Titrate against 0.01N alcoholic potassium hydroxide (in case of low FFA contents) or 0.1N alcoholic potassium hydroxide (in case of high FFA contents) to the end point. Note the volume of alcoholic potassium hydroxide used for titration (Modified AOAC).

$$\textbf{FFA (\%)} = \frac{\text{Normality of alkali x Volume of alkali x 28.2 x 10}}{\text{Weight of the sample}} \times 100$$

Determination of pH of Meat Sauce:

pH was determined by the method described by Young *et al.,* (2004). The probe of the convention pH meter was inserted into sauce sample at least 1 cm. The reading on the pH meter indicates the pH of the sample.

Color Analysis of Meat Sauce:

Using a handheld spectrocolorimeter (Lovibond, LC-400) and the CIE L, a, b scale, the color indices of meat sauce were ascertained using the methodology outlined by Ho and Dahri (2016). Before analysis, the apparatus was calibrated using white reference tiles. After being placed on the petri dish, the sauce sample was examined. Color characteristics including brightness (L), redness (a*), and yellowness (b*) were noted. Lightness is represented by the letter L (0º = black, 100º = white), redness and greenness by the letter a* and yellowness and blueness by the letter b*.

Functional Properties of Meat Sauce

Emulsifying Capacity of Meat Sauce:

Take 25 g sauce sample and add 100 mL 1 M NaCl. Keep the mixture overnight at 0-4°C. Blend at 13000 rpm by using high speed blender. Take 2.5 g slurry and add 37.5 mL 1 M NaCl followed by thorough mixing. Add 50 mL edible oil in it and blend at 13000 rpm. In parallel, run-down measured quantity of oil at the rate of 0.8 mL/s. Perfect emulsion will appear as a homogeneous curd. Express emulsifying capacity as the amount of oil emulsified by one gram of meat proteins (Swift *et al.,* 1961).

$$\textbf{Emulsifying Capacity} = \frac{Weight\ of\ oil\ emulsified\ (mL)}{Weight\ of\ sample\ (g)}$$

Water Holding Capacity of Meat Sauce:

Weigh 15g of sauce sample in a 50ml centrifuge tube. Add 22.5ml NaCl (0.6M) in it and stir for approximately 1 min. Allow the mixture to stand for 15 minutes at 4°C. Stir sample again and centrifuge it at 10,000 rpm and 4°C for 15 min. Measure the volume of supernatant after centrifugation to calculate water holding capacity (Trout *et al.*, 1988).

$$\textbf{WHC (\%)} = \frac{\text{(Final volume} - \text{Initial volume)}}{15} \times 100$$

Antioxidant Properties of Meat Sauce

Sample Preparation for Determination of Antioxidant Properties:

Take 5 g sample and add 50 mL ethanol in it. Now make extraction by rotating the sample in orbital shaker at 350 rpm for 1.5 hours. Filter the sample to remove any particles. After that, centrifuge the sample at 40 rpm for 20 minutes. Remove the supernatant and let it evaporate in rotary evaporator until the final volume reaches 5-6 mL (Saleh *et al.,* 2010).

DPPH Radical Scavenging Activity:

Take 125 µL extract in a test tube with 500 µL distilled water. Add 125 µL DPPH reagent. Add more distilled water to make final volume up to 3 mL. Then determine absorbance at 515 nm in UV-Vis Spectrophotometer (Saleh *et al.,* 2010).

Total Phenolic Content:

Take 110 µL sample in a test tube. Add 1.25 mL of 7% Na_2CO_3 and give stay time of 6 minutes. Add 150 µL of Folin-Ciocalteu reagent. Make final volume up to 3 mL by adding distilled water. Determine absorbance at 760 nm in a UV-Vis Spectrophotometer (Saleh *et al.,* 2010).

Microbial Analyses of Meat Sauce

Total Plate Count, Mold and Yeast Count Test:

Following the protocol outlined by Zia *et al.,* (2018) the microbiological analysis (aerobic mesophiles, yeast, and mold) was conducted with modifications. To measure the aerobic mesophiles, the conventional pour plate method was employed. Every treatment sample was serially diluted with a saline solution of 0.85%. A suitable dilution was plated onto plate count agar plates, which were then incubated for 48 hours at 35±1°C. On sample agar plates, the number of yeast and mold was counted after 120 hours of incubation at 25±1°C. Colony-forming units (CFU) were calculated by doubling the dilution factor following incubation.

Sensory Evaluation of Meat Sauce

Sensory analyses were conducted by 3 experienced and trained panelists who evaluated the foods using sensory evaluation. A 9-point hedonic scale (9 = extremely like; 1 = extremely dislike) was employed for scoring the intensities of the sensory characteristics like texture, flavor, taste, appearance and overall acceptability. Samples were served hot and placed on white plates and then were placed in random order and given to the panel for their assessment. Water and pasta were made available to the panel for the neutralization of taste and mouth rinsing between assessments. Experiments were carried out in a well-designed room (Kim, 2020).

Shelf Life of Meat Sauce

The shelf life of the meat sauce was evaluated over a storage period of 0, 15 and 30 days. The treatments involved varying storage conditions to assess their impact on product quality. To ensure comprehensive analysis, both proximate and microbial examinations were conducted at each interval. Proximate analysis included determining the moisture, ash, fat, protein, and fiber content to monitor any significant compositional changes during storage. Microbial analysis focused on identifying the growth of bacteria, yeast, and molds to ensure the safety and stability of the product over time. The findings from these analyses provided valuable insights into the product's nutritional stability, microbial safety, and overall shelf life, highlighting the effectiveness of the treatments applied.

Results & Discussion

Proximate Analysis of Meat Sauce:

The moisture content of meat sauce samples shows that the minimum mean value (7.003±0.02%) was observed in case of T_3 meat sauce samples made from minced mutton while the maximum mean value (11.480±0.01%) was observed in case of T_1 meat sauce sample made from minced chicken show that the moisture content decreases from 7.003±0.02% to 11.480±0.01% during storage period. The findings were from the research conducted on type of product similar to meat sauce (12). Their research demonstrated that during storage, the moisture content varies. Moisture content is highest at day zero and gradually decreases to 7.003±0.02% from 11.480±0.01% at day 30. Due to fluctuations in storage period and the type of packaging material used, the moisture content falls over time. The ash content of meat sauce samples shows that the minimum mean value (3.9133±0.005%) was observed in case of T_1 meat sauce samples made from minced chicken while the maximum mean value (5.8267±0.02%) was observed in case of T_3 meat sauce sample made from minced mutton show that the ash content increases from 3.9133±0.005% to 5.8267±0.02% during storage period. The results were consistent with the research conducted on a type of meat sauce. Minerals are inorganic, so they are highly unstable, which is a reason for change in their values over the storage period. Furthermore, minerals don't have the capacity to resist against deterioration, so they increase over time. The fat content of meat sauce samples shows that the minimum mean value (5.8300±0.01%) was observed in case of T_1 meat sauce samples made from minced chicken while the maximum mean value (7.7567±0.02%) was observed in case of T_3 meat sauce sample made from minced mutton show that the fat content increases from 5.8300±0.01% to 7.7567±0.02% during storage period. Studies reported a significant increase in fat content upon storage of meat products in cold storage. They attributed this to the concentrated formation of the solid components, such as fat, as the water was lost and underlines the necessity to consider the moisture dynamics when determining the compositional stability in the long-term (13). The protein content of meat sauce samples shows that the minimum mean value (18.540±0.21%) was observed in case of T_3 meat sauce samples made from minced mutton while the maximum mean value (21.150±0.18%) was observed in case of T_2 meat sauce sample made from minced beef show that the protein content decreases from 21.150±0.18% to 18.540±0.21% during storage period. Overall, the findings for every treatment indicated a constant decrease in protein content over storage. The loss in the amount of protein in the meat sauce over time could be due to the effects of the enzymatic degradation of protein molecules together with the loss of their water content in the course of extended storage. The reason behind the differences could be the initial protein content and the composition of muscle in the different meats; beef tends to be of a higher protein content in comparison to chicken or mutton (14).

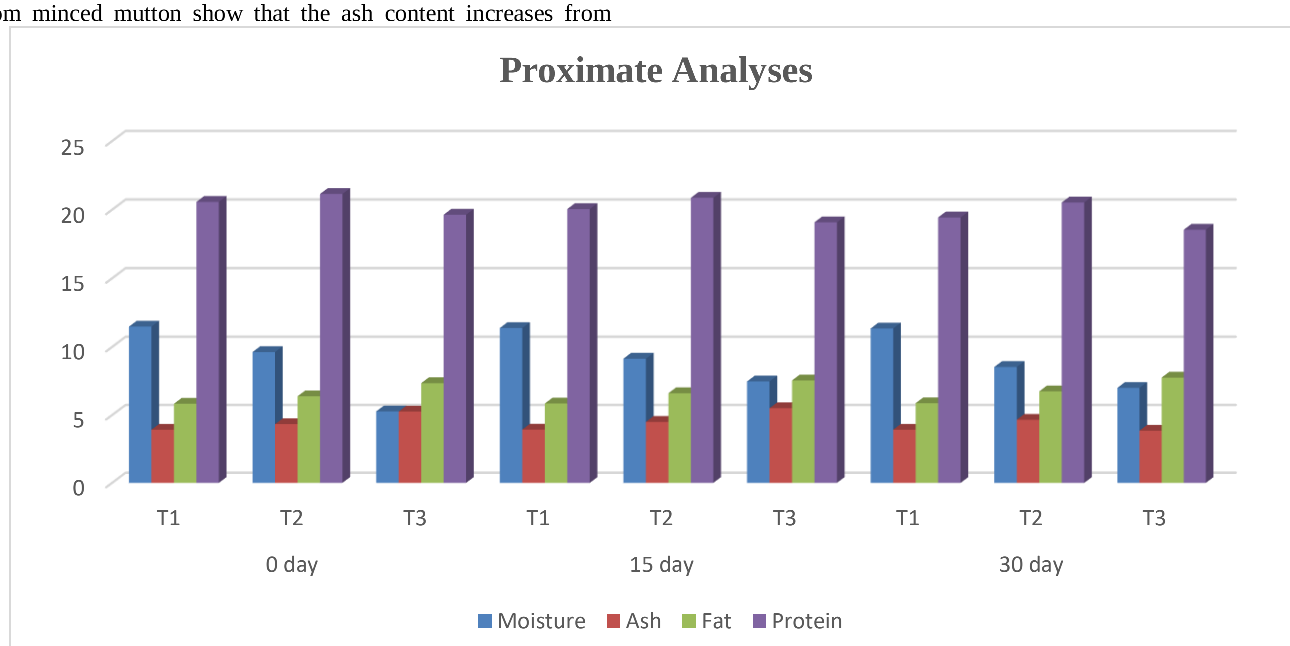

Figure 2: Present the proximate analyses of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Physicochemical Properties:

The free fatty acid content of the meat sauces shows the maximum mean value (26.083±0.03%) was observed in the meat sauce of sample (T_3) which contains minced mutton while the minimum mean value (25.377±0.01%) was observed in the meat sauce of the sample (T_1) which contains minced chicken. The difference in the FFA levels may be attributed to the difference in the lipid composition and fat metabolism of meat sauces. The raising FFA amount in mutton can be justified by the fact that mutton is more prone to lipolytic breakdown due to its unique fatty acid constituent and relatively higher fat content (15). The pH of the meat sauces shows the maximum mean value (7.9333±0.01%) was observed in the meat sauce of sample (T_3) which contains minced mutton while the minimum mean value (7.2233±0.01%) was observed in the meat sauce of the sample (T_1) which contains minced chicken. These variations in pH are likely to be caused by the intrinsic buffering capacity in the different meat varieties and their biochemical composition. Mutton normally possesses higher pH since it contains increased amount of protein and nitrogenous materials. These findings are consistent with those of Zhou *et al.* (2010) who discovered that due to the variability in the biochemical and structural composition of various meat sources, all of them share similarities in the fluctuation of the pH.

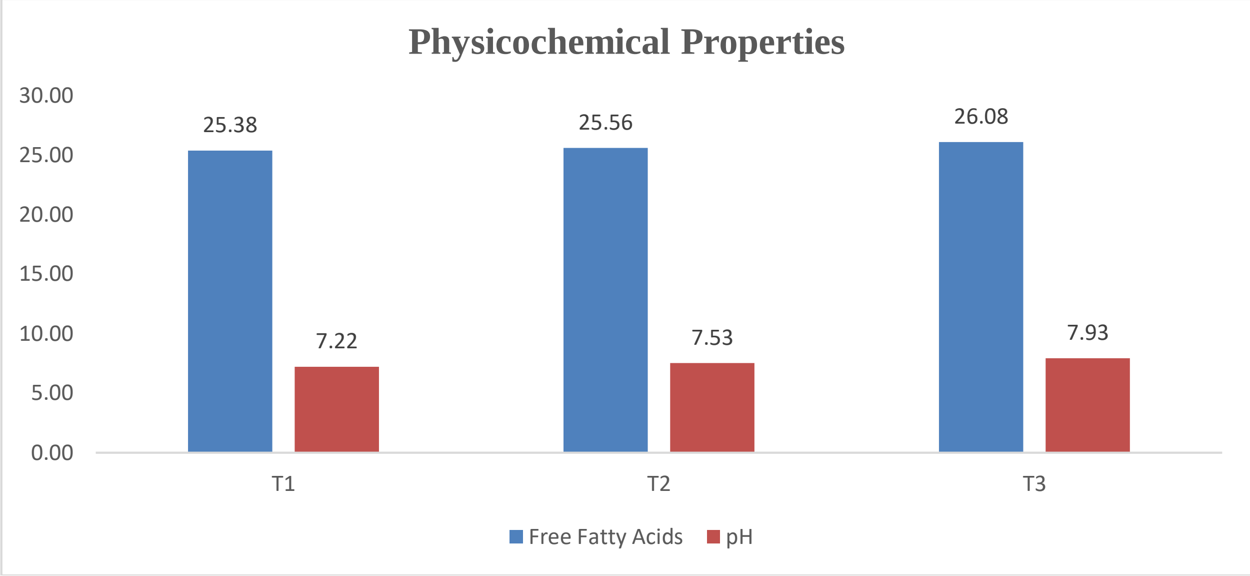

Figure 3: Present the physicochemical properties of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Color Analysis of Meat Sauce:

The results show that the L (lightness) values of samples T_1 made of minced chicken, T_2 made of minced beef and T_3 made of minced mutton were -27.667±0.57%, -26.667±0.57% and -25.667±0.57% indicating a non-significant variation in lightness among the samples. The a* (redness) values of the samples T_1 made of minced chicken, T_2 made of minced beef and T_3 made of minced mutton were 1.3667±0.05%, 1.2667±0.05% and 1.1667±0.05% indicating a non-significant difference in the red-green axis among the samples. Furthermore, the b* (yellowness) values of the samples T_1 made of minced chicken, T_2 made of minced beef, and T_3 made of minced mutton were 6.7667±0.05%, 6.6667±0.05% and 6.5667±0.05% signifying a non-significant in the yellow-blue axis among the samples. As it is represented in the graphical form in **Figure 4.** These findings demonstrate that the kind of meat used is a very significant determinant of the appearance of the meat sauces as they are being stored. Reduction and loss of pigments, or the Millard reactions, are the possibilities of the brightness and color intensity loss, particularly that of redness and yellowness (16).

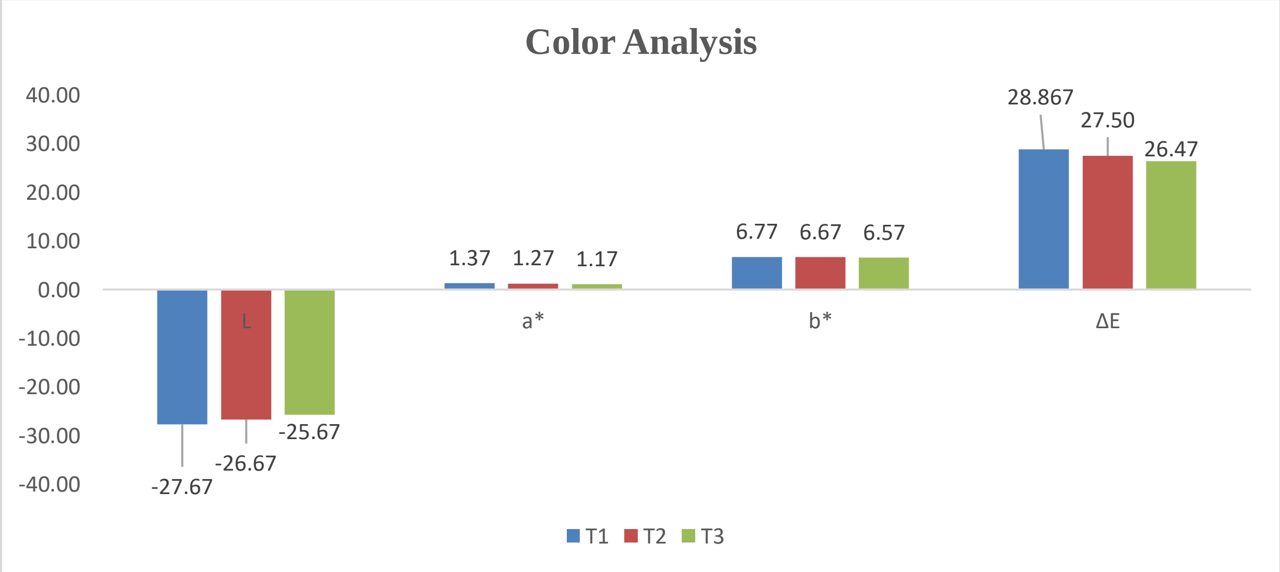

Figure 4: Present the color analysis of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Functional Properties of Meat Sauce:

The emulsifying capacity of the meat sauces shows the maximum mean value (48.167±0.35%) was observed in the meat sauce of sample (T_1), which contains minced chicken, while the minimum mean value (39.733±0.20%) was observed in the meat sauce of the sample (T_3), which contains minced mutton. Chicken mince has a superior protein-to-fat ratio and is more soluble in protein than beef and mutton and this could be the reason behind its superior emulsifying property. The muscle proteins of chicken, especially myofibrillar proteins, are characterized by their powerful emulsifying property in meat systems (17). The water holding capacity of the meat sauces shows that the maximum mean value (68.867±0.35%) was observed in the meat sauce of sample (T_1), which contains minced chicken, while the minimum mean value (48.200±0.30%) was observed in the meat sauce of the sample (T_3), which contains minced mutton. The reasons of its better WHC when used as a basis of formulation of chicken may lie in its higher solubility and more effective gel matrix trapping water molecules. Mutton can however, be poor in its ability to hold onto water because of its high connective tissue contents or lack of water-binding proteins (18).

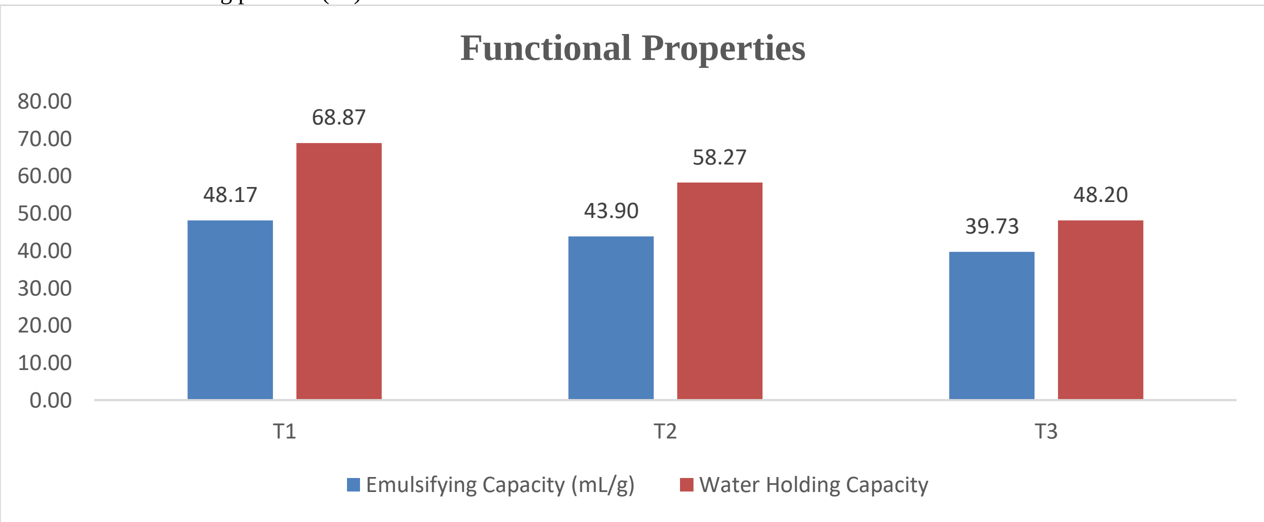

Figure 5: Present the functional properties of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Antioxidant Properties of Meat Sauce:

The DPPH of meat sauce shows the maximum mean value (97.280±0.03%) was observed in the meat sauce of the sample (T_1) which contains chicken mince while the minimum mean value (95.107±0.03%) was observed in meat sauce of the sample (T_3) which contains mutton mince. Lipid oxidation and proteolysis might produce bioactive peptides and antioxidant rich amino acids during heating and cooling of the sauce. Maillard reaction between the proteins and carbohydrates in the meat sauce produces melanoidins which have the ability to scavenge free radicals. Moreover, the gradual release of phenolic compounds into the meat sauce matrix by ingredients such as tomato paste, garlic, and spices increase antioxidant activity in it. These antioxidants present in it might become even more concentrated during storage period because of moisture loss, which cause in increases of their detectable impact (19). The TPC of meat sauce shows the maximum mean value (98.920±0.03 mgGAE/100g) was observed in the meat sauce of the sample (T_1) which contains chicken mince while the minimum mean value (97.683±0.16 mgGAE/100 g) was observed in meat sauce of the sample (T_2) which contains beef mince. Several factors which include production techniques, and storage instances might cause TPC oscillations in meat sauces. Cooking aspects which include temperature, time, and pH, they may change or break down the chemical structure of heat-sensitive phenolic compounds. These finding were consistent with the study conducted by Domínguez *et al.* (2019).

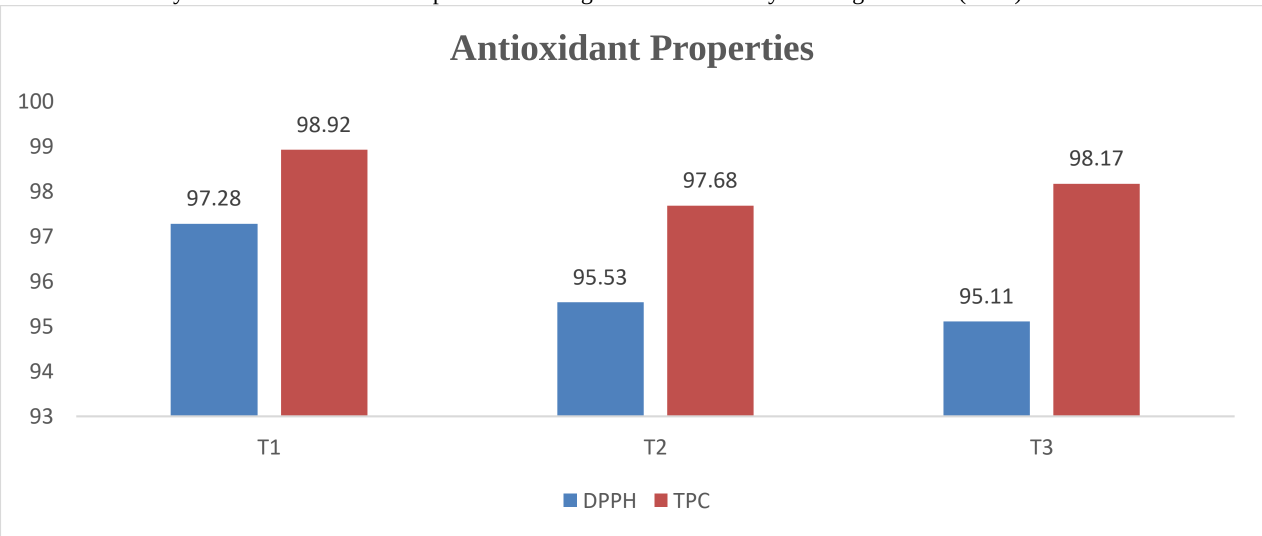

Figure 6: Present the antioxidant properties of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Microbial Analyses (TPC and Mold Count) of Meat Sauce:

TPC of meat sauce samples made from three different minced meats shows that the maximum mean value 96.333±1.15 (Log cfu/g) was observed in T_2 meat sauce sample made from beef mince, while the minimum mean value 33.667±0.70 (Log cfu/g) was observed in T_1 meat sauce sample from chicken mince. The mean values show that TPC increases from 33.667±0.70 (Log cfu/g) to 96.333±1.15 (Log cfu/g) during the storage period. Longer storage times, higher storage temperatures, greater humidity, and the particular type and efficiency of the packaging material can all influence a boost in the TPC of samples (20). The total mold and yeast count of meat sauce samples shows that the maximum mean value 49.333±1.52 (Log cfu/g) was observed in T_3 meat sauce samples made from mutton mince, while the minimum mean value 24.000±1 (Log cfu/g) was observed in T_1 meat sauce samples made from chicken mince. The mean values show that the total mold count increases from 24.000±1 to 49.333±1.52 (Log cfu/g) during the storage period.

Higher temperatures and longer storage times create ideal circumstances for microbial growth, which is directly related to the rise in the number of mold and yeast. The findings were according to the research conducted on a product similar to meat sauce Datta *et al.* (2012).

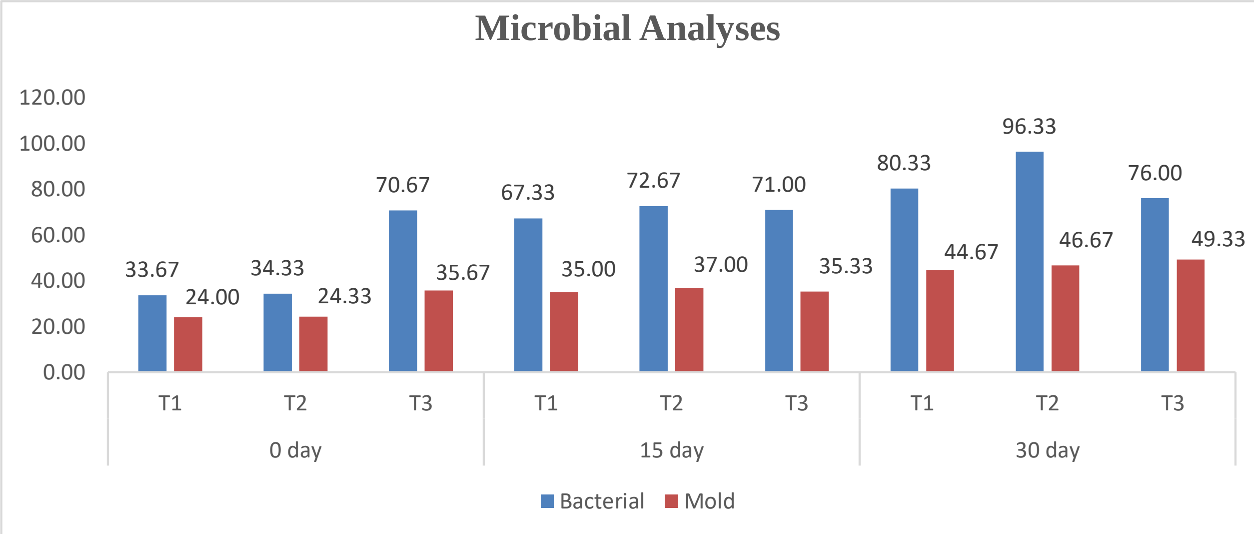

Figure 7: Present the microbial analyses of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Sensory Analyses of Meat Sauce:

The appearance score of meat sauce shows that the maximum mean value (8.3333±0.57%) was observed in the case of T_3 meat sauce sample made from mutton mince, while the minimum mean value (6.3333±0.57%) was observed in the case of T_2 meat sauce sample made from beef mince. The mean values show that the appearance score decreases from 8.3333±0.57% to 6.3333±0.57% during the storage period. The findings were according to the research conducted on meat sauce by Niimi *et al.* (2022). According to the research, storage affects the attractiveness score. The appearance score gradually drops from 8.3333±0.57% to 6.3333±0.57% after a high color score at day 0. The aroma score of meat sauce shows that the maximum mean value (8.6667±0.57%) was observed in case T_1 of the meat sauce sample made from chicken mince, while the minimum mean value (6.0000±1%) was observed in case T_2 made from beef mince. The mean values show that the aroma score decreases from 8.6667±0.57% to 6.0000±1% during the storage period. The decline in olfactory score is directly related to moisture loss, exposure to external aromas, and flavor deterioration (21). Taste score of meat sauce shows that maximum mean value (8.6667±0.57%) was observed in the case of T_1 meat sauce sample made from chicken mince, while the minimum mean value (6.3333±0.57%) was observed in the case of T2 made from beef mince. The mean values show that the taste score decreases from 8.6667±0.57% to 6.3333±0.57% during the storage period. Samples' taste ratings could drop as a result of flavor deterioration, moisture loss, or exposure to outside odors (22). The texture score of meat sauce shows that maximum mean value (8.6667±0.57%) was observed in case of T_3 meat sauce sample made from mutton mince while the minimum mean value (5.6667±1.52%) was observed in case of T_2 made from beef mince. The mean values show that the texture score decreased from 8.6667±0.57% to 5.6667±1.52% during the storage period. Microbial development, oxidation, staling, and moisture loss are all directly linked to this decline in texture score. The findings were consistent with the research conducted by Cavenaghi-Altemio *et al.* (2024). The overall acceptability score of meat sauce shows that the maximum mean value (8.6667±0.70%) was observed in case of T_3 meat sauce sample made from mutton mince while the minimum mean value (6.3333±0.57%) was observed in case of T_1 meat sauce made from chicken mince. The mean values show that the overall acceptability score decreased from 8.6667±0.70% to 6.3333±0.57% during the storage period. when samples tend to dry out with time, their texture becomes less desired and their color may fade, making them appear boring and less inviting. These changes in taste, texture, and color are likely to be the cause of the samples' overall acceptability score (23).

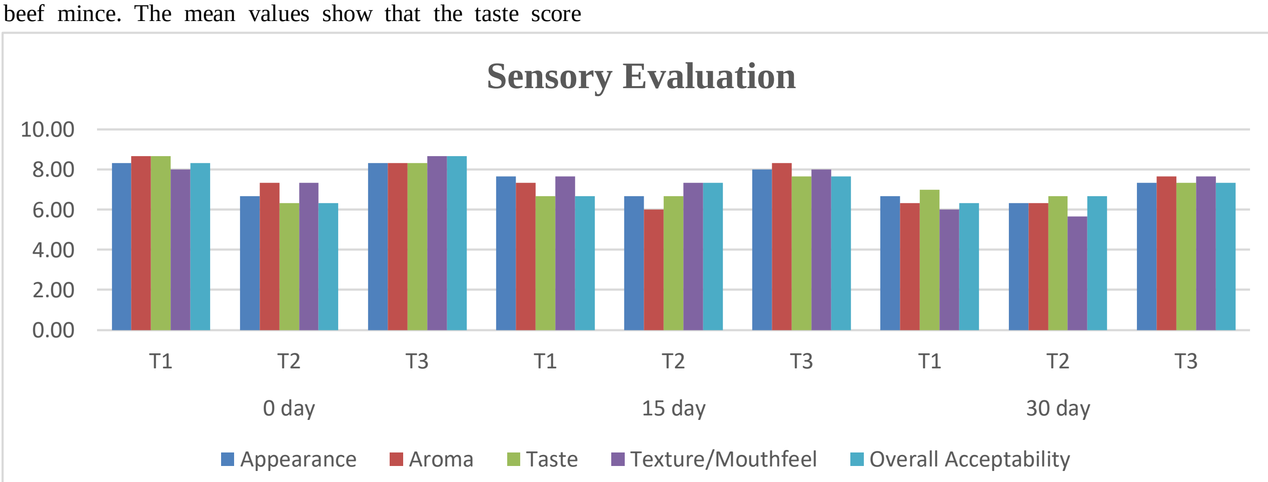

Figure 8: Present the sensory evaluation of meat sauce T_1 (minced chicken), T_2 (minced beef), T_3 (minced mutton) with storage of 0, 15, and 30 days.

Conclusion

The study comprehensively explores the development of meat sauce formulations and the determination of their physicochemical, functional and storage stability characteristics. Over a 30-day refrigerated storage period, all meat sauce samples exhibited a progressive decrease in moisture and protein content, accompanied by corresponding increases in ash and fat concentrations, likely due to moisture loss and concentration effects. Among the formulations, the T_3 sample containing minced mutton demonstrated the highest free fatty acid (FFA) content and pH values, suggesting a greater degree of lipid hydrolysis and microbial activity compared to the other variants. In contrast, the T_1 sample prepared with minced chicken showed superior emulsifying and water holding capacities, reflecting better functional protein properties that enhance texture and stability. Sensory evaluation revealed that while T_1 was generally well-accepted by the panelists, T_2 (minced beef) achieved the highest overall acceptability scores, indicating favorable flavor and appearance attributes. Overall, the study underscores the nutritional and technological benefits of meat sauces prepared from different types of meats, highlighting how meat selection significantly influences compositional quality, functional performance, and consumer perception. These findings provide valuable insights and a foundation for further research aimed at optimizing meat sauce formulations, improving shelf life, and developing innovative products tailored to diverse consumer preferences.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC-24)

Consent for publication

Approved

Funding

Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

SB, AS, SMZ

Conceived the study and contributed to study design and initial drafting of the manuscript

Assisted in data collection, literature review and manuscript editing

Contributed to data acquisition, patient evaluation and data analysis

KS, SK, AZ, RA

Performed statistical analysis and contributed to interpretation of results

Helped in methodology development, manuscript organization and proofreading

Assisted in clinical assessment and interpretation of findings

Contributed to literature search, referencing and preparation of tables

SJ, AF, KA, AA

Provided guidance in study design and critically reviewed the manuscript

Contributed to patient recruitment, data organization and analysis

Helped in manuscript writing, formatting and referencing

Provided supervision, revised the manuscript for important intellectual content

FM, MB, AN

Assisted in methodology, statistical evaluation and manuscript editing

Contributed to patient management and follow-up data collection

Final proofreading of the manuscript and approval of the final version

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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