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Effect of Hospital Food Handling Stages on the Physicochemical Quality and Microbiological Safety of Red Meat in Sudanese Hospitals

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Abstract

This study evaluated the effect of successive hospital food handling stages on the physicochemical quality and microbiological safety of red meat served in selected hospitals in Khartoum State, Sudan. Four hospitals were included, comprising two governmental hospitals and two private hospitals. Meat samples were collected at five consecutive stages of the food handling chain: raw material reception, storage, preparation, processing/cooking, and final display/service. Physicochemical analyses included moisture, crude protein, fat, ash, pH, and titratable acidity. Microbiological analyses included total viable bacterial count, yeast and mould count, total coliforms, and detection of Salmonella spp., Escherichia coli, and Staphylococcus spp. Analysis of variance (ANOVA) was performed, and the Least Significant Difference (LSD) test was used to separate means at a significance level of $P \leq 0.05$. Significant changes were observed in several physicochemical characteristics throughout the food handling chain, particularly after processing. Moisture content decreased significantly after processing, whereas the relative protein content increased, mainly as a consequence of moisture loss. Fat and ash contents showed variable changes among hospitals and handling stages, while changes were also observed in titratable acidity and pH. Thermal processing was associated with reductions in total viable bacterial and yeast and mould counts. Salmonella spp., Escherichia coli, and Staphylococcus spp. were not detected in the analyzed samples. These findings indicate that cooking is an important microbial control stage, but food safety cannot depend on cooking alone because recontamination may occur during subsequent handling, display, and service. The study highlights the importance of temperature control, prevention of cross-contamination, hygienic handling, continuous staff training, and microbiological monitoring throughout the hospital foodservice chain.

Keywords: Red meat, Hospital foodservice, Food handling chain, Food safety, Physicochemical quality, Microbiological quality, Sudan.

1. Introduction

Hospital foodservice is an important component of patient care because meals contribute to patients' nutritional requirements and may influence their satisfaction with hospital services. Foodservice quality is affected by several factors, including nutritional value, taste, food temperature, sanitation, portion size, meal timing, menu selection, and service performance (Hong & Kirk, 1995; Kim et al., 2010). Food safety is particularly important in hospitals because patients may be more vulnerable to food borne hazards than healthy populations. Consequently, hospital foodservice requires effective control from the receipt of raw materials through storage, preparation, cooking, holding, transportation, and final service. Recent evidence has emphasized the importance of food safety management systems, HACCP principles, staff training, and continuous monitoring in hospital foodservice environments (Alrasheed et al., 2021(. Food handlers are an important component of food safety because inadequate knowledge or inappropriate practices can increase the risk of contamination and cross-contamination. Abdulsalam and Alnomani (2024) emphasized the importance of assessing food safety knowledge, perceptions, and practices among hospital foodservice staff and highlighted the need for reliable food safety training and monitoring systems. Red meat is an important source of high-quality protein and minerals. However, raw meat may become contaminated during slaughter, transportation, storage, preparation, and handling. The microbial quality of meat is therefore influenced by the initial microbial load and by environmental and handling conditions throughout the food chain. Cooking is one of the most important control stages for microorganisms in meat. At the same time, heating changes meat structure and composition through protein denaturation, moisture loss, and changes in water-holding capacity. Tornberg (2005) reported that heat-induced structural changes in meat proteins are closely associated with changes in meat quality and water-holding properties. Gerber et al. (2009) also demonstrated that cooking can alter the actual nutrient composition of meat. Recent research has further confirmed that cooking conditions and endpoint temperature influence the physicochemical and microbiological characteristics of beef (Aydın et al., 2025). However, cooking does not eliminate the need for subsequent controls because cooked foods can be recontaminated through food handlers, utensils, surfaces, equipment, trays, and inappropriate holding conditions. Hospital foodservice studies have increasingly emphasized that food safety should be considered across the entire foodservice chain. Alrasheed et al. (2021) identified weaknesses in food safety knowledge and HACCP understanding among some hospital foodservice personnel, while Abdulsalam and Alnomani (2024) highlighted the importance of validated tools for evaluating food safety knowledge, perceptions, and practices. More recently, Saleh et al. (2025) emphasized comprehensive risk assessment and control measures across hospital nutrition-service food chains.

Research Gap

Despite the importance of hospital food safety, relatively limited field-based evidence is available concerning changes in the physicochemical and microbiological characteristics of meat across successive hospital food handling stages in Sudan. Previous work has addressed meat contamination and foodservice quality, but there remains a need for integrated assessment of a specific food product as it moves from receiving through storage, preparation, cooking, and final service. Furthermore, evidence comparing these stages in governmental and private hospitals in Sudan is limited. The present study therefore addresses this gap by following red meat through five consecutive food handling stages and assessing both physicochemical characteristics and microbiological indicators.

Objective of the Study

The general objective of this study was to assess the effect of hospital food handling stages on the physicochemical quality and microbiological safety of red meat served in selected hospitals in Khartoum State, Sudan.

Specific Objectives

To determine changes in moisture, crude protein, fat, ash, pH, and titratable acidity during successive food handling stages.

To determine changes in total viable bacterial and yeast and mould counts throughout the food handling chain.

To detect Salmonella spp., Escherichia coli, and Staphylococcus spp. in meat samples collected at different stages.

To compare the observed patterns among selected governmental and private hospitals.

To provide practical recommendations for improving food safety in hospital foodservice operations.

2 .Materials and Methods

2.1 Study Area

Four general hospitals were selected for the study. Two governmental hospitals were located in Omdurman City: Omdurman Teaching Hospital and Alnaow Teaching Hospital. Two private hospitals were included: Royal Care International Hospital in Khartoum City and Al-Amal National Hospital in Khartoum Bahri City.

2.2 Sampling Procedure

Red meat was selected as the food material to demonstrate the effect of hospital foodservice practices on physicochemical properties and microbial loads.

Samples were collected at five successive stages of the food handling chain:

Stage A – Raw stage: meat collected during the delivery/receiving procedure.

Stage B – Storage stage: meat collected after storage and before meal preparation.

Stage C – Preparation stage: meat collected during preparation.

Stage D – Processing stage: meat collected after cooking/thermal processing.

Stage E – Display/service stage: prepared food collected at the final stage when served to patients using a trolley or tray.

Samples were collected aseptically into sterile plastic bags and transferred directly to the laboratory in an icebox with minimum delay.

This sampling design enabled assessment of changes occurring as meat progressed through the actual hospital foodservice chain rather than under controlled laboratory processing conditions.

2.3 Physicochemical Analysis

2.3.1 Moisture and Crude Protein

Moisture and crude protein contents were determined according to AOAC methods (AOAC, 2000).

2.3.2 Fat Content

Fat content was determined using the Gerber method according to AOAC (1990).

2.3.3 pH

The pH of the meat samples was measured at ambient temperature using a glass-electrode pH meter (Hanna Instruments, Model 8521).

2.3.4 Titratable Acidity

Total titratable acidity was determined according to the method described by Board (1988).

2.4 Microbiological Analysis

Microbiological analyses included total viable bacterial count, yeast and mould count, total coliforms, and detection of Salmonella spp., E. coli, and Staphylococcus spp. The microbiological procedures were conducted according to Nickerson and Sinskey (1974) and Harrigan (1998), as specified in the original study protocol.

Salmonella spp., E. coli, and Staphylococcus spp. were not detected in the analyzed samples.

2.5 Statistical Analysis

Replicates of each sample were analyzed. Analysis of variance (ANOVA) was performed to examine significant effects among the measured parameters. The Least Significant Difference (LSD) test was used to separate means when significant differences were detected. Statistical significance was considered at $P \leq 0.05$..

3. Results and Discussion

3.1 Moisture Content (%)

Figure 1 shows the effect of the successive foodservice stages on the moisture content of meat in the selected Sudanese hospitals. Meat naturally contains a high proportion of water, although the exact moisture level varies according to animal, muscle type, and fat content. In the study, no significant differences were observed among the food handling stages before processing. However, a significant decrease in moisture content occurred after the processing stage ($P \leq 0.05$). The reduction in moisture after cooking is most plausibly related to heat-induced changes in muscle proteins and water-holding capacity. Heating causes protein denaturation and contraction of muscle structures, resulting in redistribution and loss of water. Tornberg (2005) described the relationship between thermal protein changes and

meat water-holding capacity. The study reported that the internal cooking temperature was close to 100°C for several types of meals. Such thermal conditions can produce substantial moisture loss. Gerber et al. (2009) likewise demonstrated that cooking can alter meat composition through moisture and nutrient losses. Therefore, the reduction in moisture observed after processing is consistent with the established effects of thermal treatment and represents one of the major physicochemical changes occurring during the hospital food handling chain.

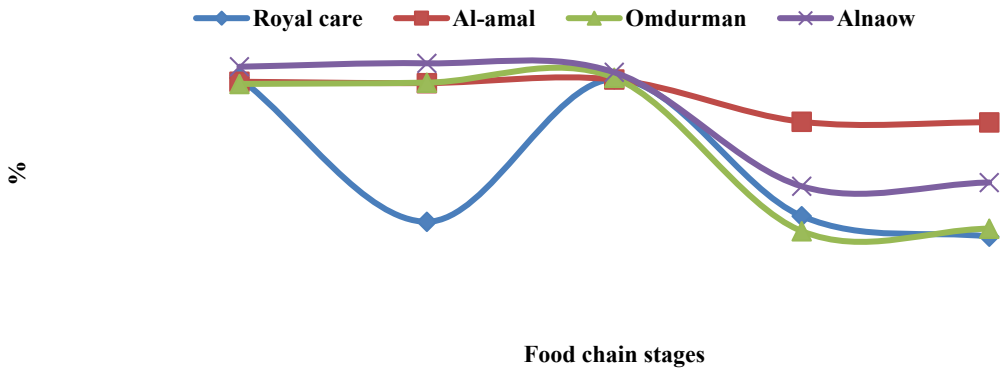


Figure 1. Effect of foodservice protocol on meat moisture content (%) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage

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3.2 Crude Protein Content (%)

Figure 2 shows the effect of foodservice stages on crude protein content. Significant differences ($P \leq 0.05$) were observed among the food handling stages, with a relative increase in protein percentage after processing. The increase in protein percentage should be interpreted as a relative concentration effect, rather than an actual increase in the absolute amount of protein. During cooking, moisture is lost from the meat, reducing the total sample mass and consequently increasing the proportion represented by protein. This interpretation is consistent with the observed decrease in moisture content. Heat-induced protein denaturation and moisture loss are well-established effects of cooking (Tornberg, 2005). Gerber et al. (2009) similarly reported that cooking changes the apparent nutrient composition of meat. The observed increase in crude protein after processing is therefore most appropriately explained by moisture loss and concentration of the remaining dry matter.

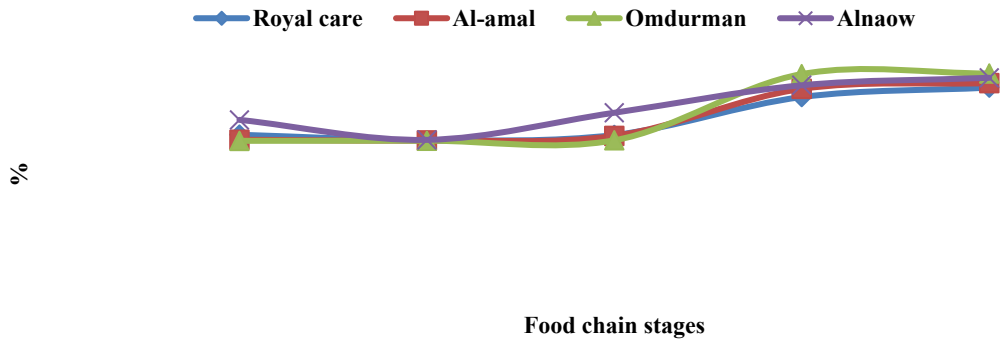


Figure 2. Effect of foodservice protocol on meat crude protein content (%) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.3 Fat Content (%)

Figure 3 presents the effect of the foodservice stages on fat content. Significant differences ($P \leq 0.05$) were observed among the food handling stages. The results showed fluctuating decreases in fat content during the food chain in most hospitals, whereas Royal Care International Hospital showed an apparent increase at the final stage. Variations in fat content can be associated with the type and cut of meat, visible fat, ingredients added during preparation, cooking conditions, and changes in moisture content. Cooking may cause actual fat losses, but the percentage of fat in the final product can also be influenced by simultaneous water loss. Gerber et al. (2009) demonstrated that cooking and fat trimming can influence the actual nutrient intake from meat. The differences observed among hospitals may therefore reflect differences in meat cuts, preparation practices, cooking procedures, and ingredient composition.

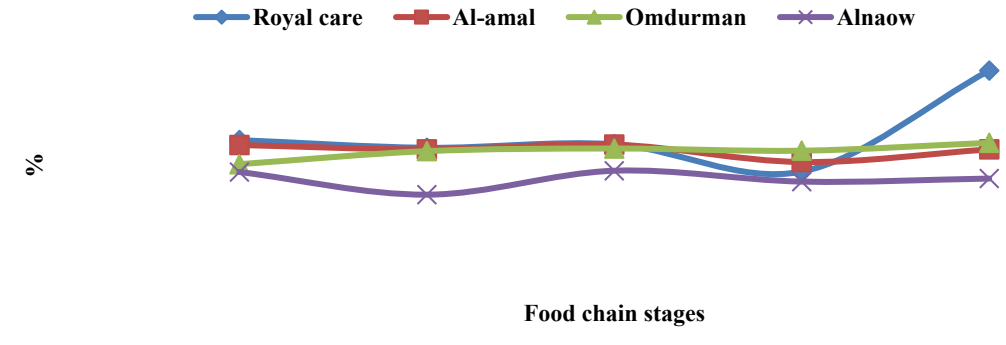


Figure 3. Effect of foodservice protocol on meat fat content (%) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.4 Ash Content (%)

Figure 4 presents the effect of the foodservice stages on ash content. Significant differences ($P \leq 0.05$) were observed among the food handling stages, with fluctuating increases in ash content across the hospitals. Ash represents the inorganic mineral fraction remaining after combustion. Changes in ash percentage can occur because of changes in moisture content and the addition of ingredients such as salt during preparation and cooking. The increase in ash content may therefore partly reflect concentration of mineral components following moisture loss and, where applicable, the addition of mineral-containing ingredients. Cooking-related changes in the relative composition of meat have been previously described (Gerber et al., 2009).

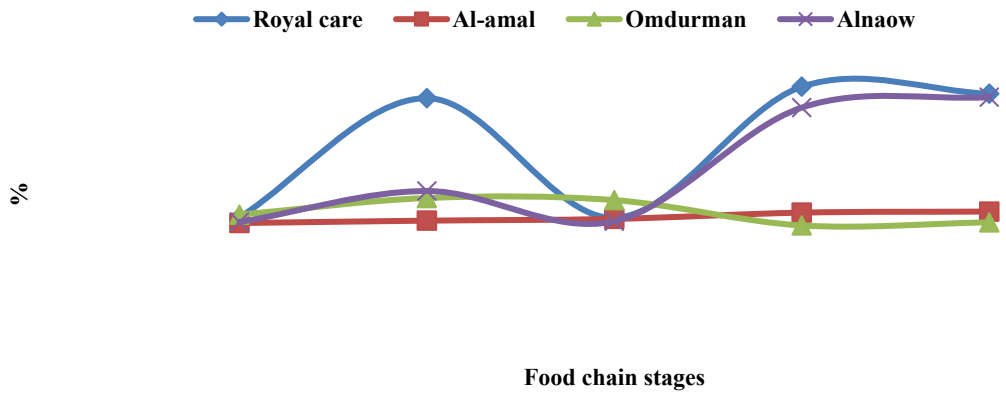


Figure 4. Effect of foodservice protocol on meat ash content (%) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.5 Titratable Acidity (%)

Figure 5 shows the effect of the foodservice stages on titratable acidity. Titratable acidity remained relatively stable throughout the food chain in most hospitals, whereas meat from Omdurman Teaching Hospital showed a tendency toward increased acidity. Significant differences ($P \leq 0.05$) were reported among the food handling stages. Changes in acidity may be associated with biochemical processes in meat and with the formation or accumulation of

acidic compounds. They may also be influenced by storage and handling conditions. The relatively stable acidity observed in most hospitals suggests that the changes during the food chain were limited for this parameter. The increase observed in Omdurman Teaching Hospital may reflect differences in storage or handling conditions.

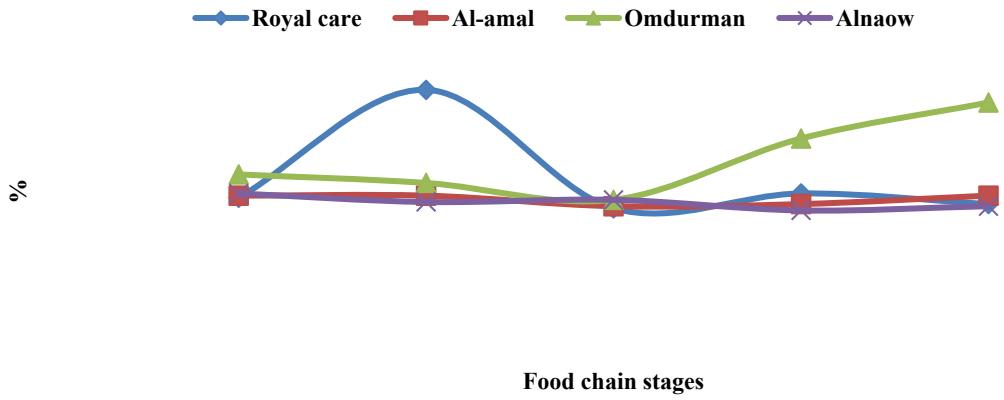


Figure 5. Effect of foodservice protocol on meat titratable acidity (%) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.6 pH Value

Figure 6 presents the effect of foodservice stages on meat pH. Meat pH is an important indicator of postmortem biochemical changes and quality. Following slaughter, glycogen metabolism and lactic acid formation contribute to a decline in muscle pH. Subsequent pH changes may depend on storage conditions, temperature, muscle characteristics, and handling. In the present study, meat pH showed a slight decrease during successive stages in most hospitals, whereas meat from Al-Amal National Hospital showed a slight increase. Significant differences ($P \leq 0.05$) were reported among the food handling stages. Changes in pH during storage and handling are consistent with the dynamic nature of meat quality. Hur et al. (2009) reported that storage conditions can influence meat quality characteristics, including pH. The differences among hospitals may therefore reflect differences in storage and food handling conditions.

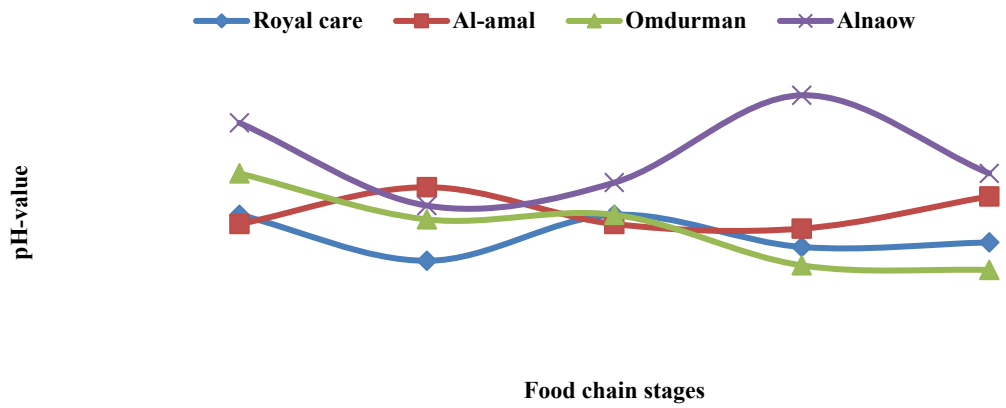


Figure 6. Effect of foodservice protocol on meat pH value in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.7 Total Viable Bacterial Count

Figure 7 presents the effect of foodservice stages on total viable bacterial count expressed as log10 CFU/g. Meat provides favorable conditions for microbial growth, and its microbial quality is influenced by the initial contamination level and subsequent handling conditions. In the present study, total viable bacterial counts generally showed fluctuating decreases throughout the food handling stages. In contrast, meat from Royal Care International Hospital showed a slight increase during the successive stages. Significant differences ($P \leq 0.05$) were observed among the food handling stages. The reduction in bacterial counts following processing is consistent with the antimicrobial effect of thermal treatment. Recent research has also emphasized the importance of cooking conditions and endpoint temperature in controlling the microbiological quality of beef. However, the increase observed at some stages in Royal Care International Hospital demonstrates that microbial control does not end with cooking. Recontamination may occur through food handlers, utensils, equipment, food-contact surfaces, or inappropriate post-cooking handling. This is particularly relevant in hospitals, where patients may be more vulnerable to foodborne infections. Recent hospital foodservice research emphasizes the need to identify and control hazards throughout the foodservice chain rather than relying exclusively on cooking (Alrasheed et al., 2021; Saleh et al., 2025).

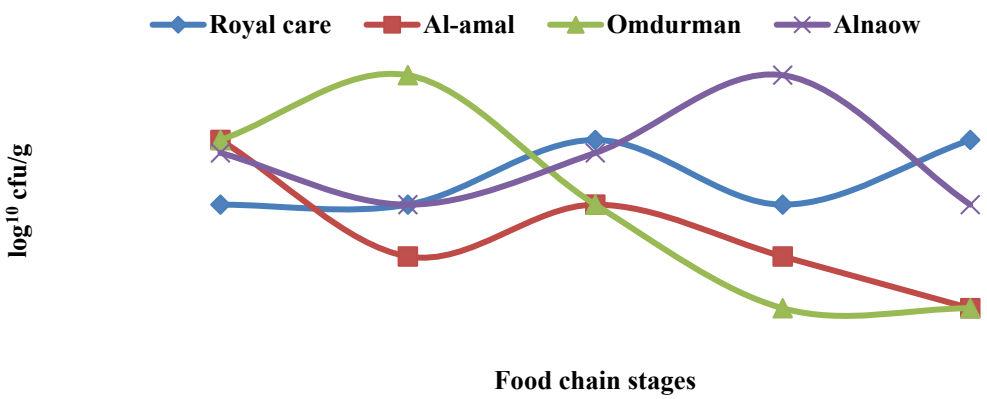


Figure 7. Effect of foodservice protocol on meat total viable bacterial count (log10 CFU/g) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.8 Yeast and Mould Count

Figure 8 presents changes in yeast and mould counts during the successive food handling stages. Yeasts and moulds are widely distributed in the environment and may reach meat through contaminated equipment, air, surfaces, and food handlers. In the present study, yeast and mould counts generally decreased significantly during the successive food handling stages. However, Alnaow Teaching Hospital showed an increase at the preparation stage followed by a significant decrease during later stages. Significant differences ($P \leq 0.05$) were observed among the food handling stages. The decrease following thermal processing is consistent with the expected effect of heating on viable microorganisms. The temporary increase at the preparation stage may have resulted from exposure to the preparation environment or contact with contaminated equipment or surfaces. The findings emphasize that hygienic preparation and post-cooking handling remain important even when microbial counts decrease during cooking.

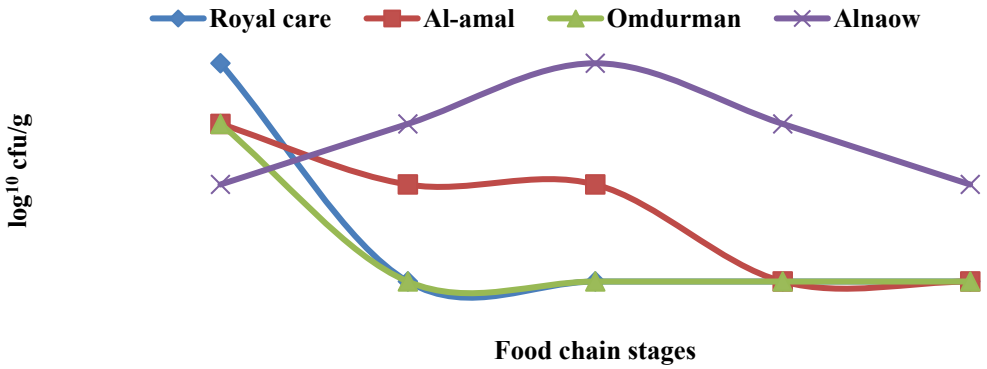


Figure 8. Effect of foodservice protocol on meat yeast and mould count (log10 CFU/g) in Sudanese hospitals.

Key: A = Raw food stage; B = Storage stage; C = Preparation stage; D = Processing stage; E = Display stage.

3.9 Detection of Salmonella spp., Escherichia coli, and Staphylococcus spp. No Salmonella spp., Escherichia coli, or Staphylococcus spp. were detected in the analyzed meat samples from the selected hospitals. The absence of these microorganisms is a favorable finding. However, it should not be interpreted as proof of complete microbiological safety of the entire hospital foodservice system. Rather, it indicates that these specific microorganisms were not detected under the sampling and analytical conditions used in this study. The absence of Salmonella and E. coli may be related to effective hygienic practices and adequate thermal processing. Nevertheless, food safety depends on controlling contamination throughout the complete food chain because pathogens may be introduced before or after cooking. The importance of comprehensive food safety management in hospitals has been emphasized by recent studies. Alrasheed et al. (2021) identified weaknesses in food safety knowledge and HACCP understanding among some hospital foodservice personnel, while Abdulsalam and Alnomani (2024) highlighted the importance of systematic assessment and training of foodservice staff. Saleh et al. (2025) further emphasized the importance of risk assessment and control measures throughout hospital foodservice chains. Thus, the microbiological findings of the present study are encouraging but should be interpreted within the limitations of the sampling design and the organisms tested.

4. Practical Recommendations for Improving Food Safety in Hospitals

Based on the findings of this study and recent evidence concerning hospital foodservice safety, the following recommendations are proposed:

Implement and strengthen HACCP-based food safety systems throughout hospital foodservice operations.

Monitor food temperatures continuously during receiving, storage, cooking, holding, transportation, and final service.

Prevent cross-contamination by separating raw and cooked meat and using appropriate utensils, equipment, and preparation surfaces.

Strengthen post-cooking controls, particularly during tray preparation, transportation, display, and service, because cooked foods may become recontaminated after thermal processing.

Provide continuous food safety training for foodservice personnel, with particular emphasis on hand hygiene, personal hygiene, cleaning and sanitation, temperature control, and prevention of cross-contamination. Training should begin at employment and be periodically repeated (Alrasheed et al., 2021; Abdulsalam & Alnomani, 2024).

Establish written standard operating procedures covering receiving, storage, preparation, cooking, holding, transportation, and service.

Conduct regular microbiological verification of high-risk foods and food-contact surfaces.

Maintain detailed records of temperatures, cleaning and sanitation, food receipt, storage, and corrective actions.

Conduct regular internal food safety audits in both governmental and private hospitals.

Strengthen management supervision and accountability to ensure that food safety procedures are consistently implemented.

These measures are particularly important in hospital environments because food is served to patients who may be more susceptible to foodborne hazards (Alrasheed et al., 2021; Saleh et al., 2025).

5. Conclusion

The present study demonstrated that successive stages of hospital food handling influence the physicochemical characteristics and microbiological quality of red meat served in selected hospitals in Khartoum State, Sudan.

The major physicochemical changes occurred after processing, particularly the significant reduction in moisture and the corresponding relative increase in crude protein concentration. Fat and ash contents showed variable patterns, while changes in titratable acidity and pH were also observed throughout the food handling chain.

Thermal processing was associated with reductions in total viable bacterial and yeast and mould counts, demonstrating the importance of cooking as a major microbial control stage. Salmonella spp., Escherichia coli, and Staphylococcus spp. were not detected in the analyzed samples.

However, the absence of these organisms in the tested samples should not be interpreted as evidence of complete microbiological safety. The findings demonstrate the importance of controlling contamination throughout the complete hospital foodservice chain, including receiving, storage, preparation, cooking, display, transportation, and service.

The study therefore recommends strengthening temperature control, prevention of cross-contamination, hygienic handling, staff training, standard operating procedures, management supervision, and microbiological verification.

The study provides field-based evidence concerning meat quality and microbiological indicators across successive hospital food handling stages in Sudan and highlights the importance of integrated food safety management in hospital foodservice systems.

Future studies should include a larger number of hospitals and samples, detailed recording of storage and cooking temperatures and durations, and broader microbiological testing to provide stronger evidence for food safety management in Sudanese hospitals.

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