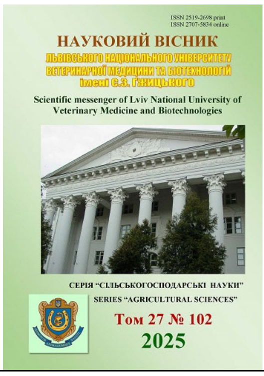

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Quality of broiler chicken meat slaughtered in compliance with halal requirements

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Ensuring the quality and safety of poultry meat is a pressing issue amid the growing global demand for halal products. This study aimed to assess the quality and safety of broiler chicken meat slaughtered using different technological approaches: in accordance with national standards (first batch) and halal standards (GSO) (second batch). The research was conducted at the accredited Dnipropetrovsk Regional State Laboratory of the State Service of Ukraine for Food Safety and Consumer Protection to evaluate the compliance of broiler chicken meat samples with physicochemical, microbiological, toxicological, and radiological indicators. The results showed that the second batch, slaughtered in accordance with halal standards, met all regulatory requirements for quality and safety. The first batch demonstrated minor deviations in certain parameters, particularly moisture content (4.5 % compared to the permissible 4 %) and tetracycline residues (0.01 IU/g), highlighting the need for stricter control over broiler chicken rearing practices, slaughtering, cooling, and storage processes. No ammonia, ammonium salts, chloramphenicol, pathogenic microorganisms, heavy metals, or radionuclides were detected in either batch, and the levels of pesticides and aflatoxins complied with the established standards. Further research should focus on investigating the long-term effects of the identified deviations on meat quality and safety, as well as optimising technological processes to ensure full compliance with halal and international standards.

Key words: *broiler chicken meat, halal slaughter, quality, safety, antibiotics, toxic substances, microbiological indicators.*

Introduction

The halal products market plays a significant role in the modern food industry, encompassing both Muslim-majority countries and the global community, which prioritises products manufactured in accordance with high standards of quality and safety. Poultry meat occupies a key position in the halal sector due to its versatility, relatively low production cost, and compliance with religious norms. Slaughter is an essential component of halal practices, and it is estimated that 84 % of poultry, 75 % of cattle, and 63 % of sheep and goats undergo halal slaughter (Riaz et al., 2021).

The global halal food market is experiencing rapid growth across all continents, particularly in Asia, the Middle East, Africa, Europe, and America. Projections indicate that by 2030, the Muslim population will reach 2.2 billion, significantly increasing the demand for halal products and stimulating market expansion in more than 50 countries (Ng et al., 2021). However, the halal segment appeals not only to Muslim consumers but also to a wider audience seeking high standards of safety and quality (Azam & Abdullah, 2020).

According to FAO estimates, poultry meat accounts for approximately 37 % of the global market. Its popularity can be attributed to the absence of major religious prohibitions, its nutritional value, and the high economic efficiency of poultry farming (Kumar et al., 2022).

Ukraine is one of the promising exporters of poultry meat, particularly to countries in the Middle East and North Africa, where demand for halal products continues to grow (Kryzhska, 2020). Domestic producers are actively adapting to international standards, obtaining certifications to access global markets. However, this process is accompanied by several challenges, including the need to comply with diverse requirements related to slaughter, processing, and transportation. Additional difficulties arise due to the complexity of standard harmonisation, which complicates the certification process and increases production costs (Ng et al., 2021).

Poultry meat contamination with antibiotic residues (Chandrakar et al., 2023), toxic elements (Edet et al., 2024), and microbiological pathogens (Wardhana et al., 2021) poses a significant risk to consumer health. Such contaminants can lead to antibiotic resistance, allergic reactions, intoxications, metabolic disturbances, and even oncological diseases (Fouad et al., 2019). Moreover, chemical contaminants formed during production, storage, and thermal processing exhibit carcinogenic potential (Lu et al., 2022), while microbiological contamination increases the risk of foodborne illnesses and infections (Klaharn et al., 2022). Consequently, ensuring the safety of poultry meat necessitates strict control at all stages of production, storage, and transportation, including compliance with international standards and the implementation of effective monitoring and risk management strategies.

Aim of the study

The objective of this study was to assess the compliance of broiler chicken meat samples, slaughtered in accordance with current national sanitary and hygienic regulations and halal standards (GSO), with a range of chemical and toxicological indicators that characterize the safety of this product.

Materials and Methods

The study was conducted at a large poultry processing facility in the Dnipropetrovsk region of Ukraine. The research focused on assessing the quality and safety of broiler chicken meat processed using different technological approaches. The first batch was processed in compliance with domestic Ukrainian standards, while the second batch was processed on a slaughtering line certified under Gulf Cooperation Council (GSO) standards, intended for export to the Kingdom of Saudi Arabia.

All laboratory analyses of the quality and safety parameters for the two batches of broiler chicken meat were conducted at the Dnipropetrovsk Regional State Laboratory of the State Service of Ukraine for Food Safety and Consumer Protection (Dnipro). The testing centre is accredited under the DSTU ISO/IEC 17025:2019 standard by the National Accreditation Agency of Ukraine (accreditation certificate No. 20192, valid from 09.06.2023 to 10.06.2028) for conducting microbiological, mycological, parasitological, ichthyopathological, radiological, and chemical-toxicological testing of products and raw materials of animal, plant, and biotechnological origin.

The quality and safety indicators of poultry meat samples were determined using the following methods. Organoleptic analysis assessed the appearance, colour, smell, texture of muscle tissue and fat, as well as the condition of the muscle cross-section and the transparency of the broth. Biochemical studies were conducted using extracts prepared at a 1:3 meat-to-water ratio. Extracts were prepared separately from red and white muscle tissues. The qualitative reaction for ammonia and ammonium salts was performed using Nessler's reagent, which forms a yellow-orange complex salt of iodide dimercurammonium.

The determination of colony-forming units of mesophilic aerobic and facultative anaerobic microorganisms (KMAFAnM), coliform bacteria (BGKP), Proteus species, Salmonella, Listeria monocytogenes, and Staphylococcus aureus was conducted using methods compliant with current regulatory standards. These methods conform to international standards such as DSTU ISO 11290 (2004).

Results

Organoleptic analysis revealed that the surface of the carcasses had a dry texture, a whitish-yellow colour with a reddish tint. The muscles, when cut, were slightly moist, pale pink in colour, and had a firm consistency. The meat's odour was specific and characteristic of fresh poultry in all samples. The evaluation of compliance with Ukrainian and halal standards (Table 1) showed that ammonia and ammonium salts were not detected in the analysed broiler chicken samples, meeting the requirements of both standards. The volatile fatty acid content was recorded at 2.6 mg KOH/g, which is acceptable and conforms to both standards. However, the moisture content released during thawing in the first batch was 4.5 %, exceeding the permissible level, whereas the second batch met the standards.

Table 1
Quality and Physico-chemical parameters

Parameter	Test Method	Meeting the requirements	
		first batch	second batch
Ammonia and ammonium salts: not permitted	DSTU 8253:2015	Not detected / Complies	Not detected / Complies
Volatile fatty acids, no more than 4.5 mg KOH/g	DSTU 8253:2015	2.6 mg KOH/g / Acceptable	2.6 mg KOH/g / Complies
Moisture released during thawing, % (no more than 4)	DSTU 3143:2013	4.5 / Does not comply	1.3 / Complies

Both batches complied with the DSTU 8253:2015 standard regarding ammonia and ammonium salts. The volatile fatty acid content was within acceptable limits in both batches. However, the moisture content in the first batch exceeded the permissible level (4.5 %), while the second batch met the requirements (1.3 %). The results of the antibiotic residue analysis are presented in Table 2.

The first batch contained tetracycline at a level of 0.01 IU/g, which does not comply with the standards. Chloramphenicol was not detected in either batch. The second batch fully complied with the regulatory requirements for both antibiotics, confirming its safety. Microbiological test results are summarised in Table 3. Both batches complied with the requirements for all tested parameters.

Table 2
Antibiotic residues

Parameter	Test Method	Meeting the requirements	
		first batch	second batch
Tetracycline, IU/g: not permitted	MV 3049-84	0.01 IU/g / Does not comply	Not detected / Complies
Chloramphenicol, mg/kg: not permitted	PV VDC DRegDL DPSS 3.2.67	Not detected / Complies	Not detected / Complies

Table 3
Microbiological parameters

Parameter	Test Method	Meeting the requirements	
		first batch	second batch
Listeria monocytogenes: not permitted	DSTU ISO 11290-1:2003	Not detected / Complies	Not detected / Complies
Aerobic mesophilic bacteria: no more than 1×10^6–1×10^7	DSTU ISO 4833:2006	$<1\times10^6$ / Acceptable	$<1\times10^4$ / Complies
Pathogenic microorganisms, incl. *Salmonella* (25 g): not permitted	ISO 6579-1:2017	Not detected / Complies	Not detected / Complies
Coliform bacteria (*E. coli*), 0.0001 g: not permitted	GOST 30518-97	Not detected / Complies	Not detected / Complies

Both batches complied with microbiological requirements. Aerobic mesophilic bacteria in the first batch were within the permissible limit, whereas the second batch demonstrated significantly better results. No pathogenic microorganisms, including *Salmonella* and coliforms, were detected. Table 4 presents the results of radionuclide and toxic element analysis.

Table 4
Radionuclides and toxic elements

Parameter	Test Method	Meeting the requirements	
		first batch	second batch
137, Bq/kg: no more than 200	PV VDC DRegDL DPSS 3.3.3	0.00 / Complies	0.00 / Complies
Sr-90, Bq/kg: no more than 20	PV VDC DRegDL DPSS 3.3.3	1.25 / Complies	1.17 / Complies
Lead, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.39	<0.01 / Complies	<0.01 / Complies
Cadmium, mg/kg: no more than 0.05	PV VDC DRegDL DPSS 3.2.39	<0.005 / Complies	<0.005 / Complies
Arsenic, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.60	<0.01 / Complies	<0.01 / Complies
Mercury, mg/kg: no more than 0.03	PV VDC DRegDL DPSS 3.2.61	<0.01 / Complies	<0.01 / Complies
Copper, mg/kg: no more than 5.0	PV VDC DRegDL DPSS 3.2.62	1.18 / Complies	1.05 / Complies
Zinc, mg/kg: no more than 70.0	PV VDC DRegDL DPSS 3.2.62	17.08 / Complies	15.00 / Complies
Alpha-HCH, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.1	<0.0008 / Complies	<0.0008 / Complies
Beta-HCH, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.1	<0.0008 / Complies	<0.0008 / Complies
Gamma-HCH, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.1	<0.0008 / Complies	<0.0008 / Complies
4,4-DDT, mg/kg: no more than 0.1	PV VDC DRegDL DPSS 3.2.1	<0.0008 / Complies	<0.0008 / Complies
Aflatoxin B1, mg/kg: no more than 0.005	PV VDC DRegDL DPSS 3.2.5	<0.0004 / Complies	<0.0004 / Complies
Nitrosamines (sum of NDMA and NDEA), mg/kg: no more than 0.002	PV VDC DRegDL DPSS 3.2.7	0.003 / Does not comply	<0.002 / Complies

The data confirm compliance of both batches with standards for radionuclides (Cs-137 and Sr-90) and toxic elements, including lead, cadmium, arsenic, mercury, copper, and zinc. Both batches also complied with pesticide limits (Alpha-, Beta-, and Gamma-HCH, 4,4-DDT) and mycotoxin levels (aflatoxin B1). However, the first batch exceeded the permissible level of nitrosamines, while the second batch met all requirements.

The findings highlight that the second batch fully complies with all regulatory standards, including physicochemical, microbiological, toxicological, antibiotic, radionuclide, and pesticide criteria. In contrast, the first batch showed minor deviations in moisture content and nitrosamine levels, indicating the need for stricter control during processing and storage. Overall, the second batch demonstrated high quality and safety for consumption.

Discussion

The identified deviations in the first batch are related to an elevated moisture content, which may indicate violations of freezing or storage conditions. This could negatively affect product quality, including organoleptic properties and shelf life (Kryzhska, 2020).

Antibiotics such as oxytetracycline, gentamicin, and ciprofloxacin are widely used in poultry farming to promote growth, prevent diseases, and treat infections. However, residues of these antibiotics in animal-derived products may pose serious health risks to consumers due to potential toxicity, microbiological effects, and the development of antibiotic resistance (Chandrakar et al., 2023; Kamouh et al., 2024). Antibiotic residues in meat may cause allergic reactions and disruptions in gut microbiota. They are also associated with the emergence of antibiotic-resistant infections, complicating treatment (Muaz et al., 2018).

The presence of tetracycline in the first batch suggests the potential use of antibiotics during poultry rearing. The routine application of antibiotics, especially without adequate regulation, may lead to residue accumulation in food products, posing health risks. Residual antibiotics in meat can contribute to antibiotic resistance and allergic reactions in humans (Muaz et al., 2018; Kamouh et al., 2024). A study by Chandrakar et al. (2023) revealed that 43.7 % of chicken meat samples contained antibiotic residues, with 17.8 % exceeding maximum residue limits (MRLs). Elevated antibiotic levels were observed in northern regions, reflecting uneven usage patterns. Thermal processing partially reduced residue levels but did not ensure complete elimination (Kamouh et al., 2024).

Excessive levels of nitrosamines in the first batch pose potential health risks due to their carcinogenic properties. Nitrosamines can form in meat products during processing or storage, especially in the presence of nitrites and nitrates (Lu et al., 2022; Xie et al., 2023). Primary strategies to reduce nitrosamine levels include optimising cooking temperatures, using antioxidants, and replacing nitrites with alternative preservatives (Xie et al., 2023).

Aflatoxins are highly toxic metabolites produced by Aspergillus fungi and are commonly found in poultry feed. Aflatoxin B1 (AFB1) represents the greatest threat due to its carcinogenic, teratogenic, and mutagenic effects (Fouad et al., 2019; Kibugu et al., 2021). Its accumulation in food products can impair vaccine effectiveness, cause intoxications, and increase cancer risks. Reducing toxicity can be achieved through the use of sorbents and feed additives.

Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are among the most toxic contaminants that can accumulate in poultry organs. This poses serious health risks, as consuming meat with elevated heavy metal levels can lead to intoxication, organ damage, and even cancer development (Hoque et al., 2023; Edet et al., 2024). Contamination may originate from water, feed, and soil, emphasising the need for stringent monitoring (Edet et al., 2024).

Caesium-137 is one of the main radionuclides persisting in the environment after industrial accidents. Its presence in animal-derived products could pose potential health risks, although current studies show low concentrations in chicken meat (Gembal et al., 2023). Monitoring radioactive contamination levels remains crucial to mitigate possible risks (Chernenko et al., 2019).

Pesticides used in agriculture can accumulate in animal tissues and enter the food chain. Residues of organophosphate and organochlorine pesticides may lead to neurotoxic, endocrine, and carcinogenic effects (Hamasalim et al., 2023; Đokić et al., 2024). Additionally, exposure to thiram can result in liver metabolism disorders, including lipid imbalances and inflammatory responses (Wang et al., 2023).

Microbial contamination of poultry meat and poultry products is a major concern. Studies indicate that most meat samples contain Salmonella, Shigella, and Escherichia coli, posing risks of infection and antibiotic resistance (Wardhana et al., 2021; Klaharn et al., 2022; Tagar & Qambrani, 2023). High levels of bacterial contamination are typically linked to inadequate hygiene during processing and storage, underscoring the need for improved sanitation practices (Salama & Chennaoui, 2024).

The findings highlight the necessity for continuous monitoring of contaminants in animal-derived products. Antibiotic resistance, nitrosamines, heavy metals, and microbiological hazards require enhanced control measures during poultry processing and storage to meet halal standards. However, this study has certain limitations, including a restricted sample size and the absence of long-term exposure data. Further research is essential to assess the long-term risks and the efficacy of strategies to mitigate hazards

Conclusion

The study results confirm that the second batch of broiler chicken meat, slaughtered in accordance with halal standards, complies with regulatory requirements for all quality and safety indicators. The first batch of poultry meat (processed using the slaughter technology adopted at the enterprise) exhibited minor deviations in certain parameters, indicating the need to strengthen control measures during production and storage to ensure compliance with international standards.

Future research should focus on investigating the long-term effects of the identified deviations on meat quality and safety, as well as optimizing technological processes to guarantee compliance with international requirements.

Conflict of interest

The authors declare that there is no conflict of interest.

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