MICROBIOLOGICAL SAFETY OF MEAT AND MEAT PRODUCTS AT THE RETAIL MARKET IN LATVIA

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Abstract
Microorganisms significantly affect the quality and safety of meat and meat products; therefore, detection of microbiological contamination is important to assess the safety of retailed products. The present study was aimed to detect microbiological contamination of raw meats and processed meat products purchased from supermarkets and farmers' markets during 2024-2025 in Latvia. Raw meat included poultry, beef, and pork, but meat products were smoked ham, smoked and boiled sausages, pâté, cutlets, and meat balls. Samples were investigated according to the International Organization of Standardization (ISO) methodology and detected microorganisms and microbial groups were the total microbial count (TVC), *Enterobacteriaceae, E. coli, Salmonella spp., Listeria* spp. and *Yersinia* spp. All purchased meat products had acceptable microbiological quality in terms of TVC, *Enterobacteriaceae* and E. coli. The highest TVC levels were recorded in raw meat samples, while the highest concentrations of *Enterobacteriaceae* were found in raw meat obtained from farmers' markets, supermarkets and retail stores. The highest levels of E. coli were found in raw meat and processed meat. Differences in microbial contamination of meat and meat product could be related to the processing and hygienic practices at the retail level. Higher microbial contamination rates for raw products at the farmer market could be explained with difficulties to provide an adequate level of hygiene at the farmer markets in comparison with supermarkets.
Keywords: food safety, food products, semi-finished products, contamination risk, microbiological contamination.

Introduction

A wide range of meat and meat products are available at supermarkets and farmers markets. These products are essential for human nutrition, as they provide essential microelements, vitamins, proteins, and other beneficial compounds for consumers' health and wellbeing. Therefore, ensuring the highest quality and safety standards for meat and meat products at the retail level is important for public health protection. To facilitate the offer of high-quality meat products at the market, food businesses work closely with farmers, regulatory authorities, and other stakeholders to provide safe food for consumption throughout the entire food chain. Food safety is a global concern that requires continuous innovation to mitigate the risks posed by pathogenic microorganisms. Foodborne pathogens remain a primary food safety issue within the European Union from farm to table strategy.

Meat is particularly susceptible to microbial growth (Sun et al., 2022), and the processing of meat products does not significantly reduce the number of microorganisms which are present if hygienic requirements are not satisfactory or processing do not target inhibition of microbial growth in foods. Since meat and meat products are rich in nutrients, microorganisms are able to colonize and proliferate rapidly making those products highly perishable. The high levels of proteins, vitamins, and minerals, combined with a nearly neutral pH, create an ideal environment for the rapid growth of various microorganisms (Fudali et al., 2021; Panea et al., 2020; Szymański et al., 2023).

The microbiota of the final product can be originated from the meat itself, as well as from spices, other ingredients, the environment, equipment, and personnel during processing. All these factors contribute to the product's microbiological quality. A lack of standardized production processes and poor manufacturing hygiene can result in microbiological contamination (Sachindra et al., 2005). The bacteria present in meat and meat products may include foodborne pathogens, opportunistic microorganisms, or commensals, which can act as reservoirs for antibiotic resistance genes or other virulence factors. Food products of animal origin are a significant source of foodborne illnesses may harbour pathogens capable of causing outbreaks and fatalities due to direct transmission from animals during primary processing steps. Foodborne zoonoses can be detected only with appropriate microbiological methods, hence interventions to eliminate these pathogens from food-producing animals or other food products could be ineffective if specific properties of pathogens are not targeted (Heredia & García, 2018). The microbiological quality of food, including meat and meat products, is crucial for consumer protection. Each producer is responsible for safety of their products placed at the retail market. The hygienic requirements for production of food for retail purposes must adhere to food legislation, specifically Regulation (EC) No. 852/2004 and Regulation (EC) No. 853/2004 which set detailed hygiene requirements for food of animal origin (European Parliament & Council, 2004).

Research indicates that meat products can be a source of pathogenic microorganisms. Studies on quality and safety aspects of meat products worldwide have identified the presence of *Listeria monocytogenes*, *Campylobacter* spp., *Salmonella* spp., coagulase-positive staphylococci, and *Escherichia coli* in meat and meat products (Halagarda & Wójciak, 2022). For instance, in Turkish sausage 'sucuk' contamination with *Listeria monocytogenes* was identified in 11.6% of tested samples (Colak et al., 2007). This pathogen

has also been isolated from smoked fermented Portuguese sausages ʻalheiraʼ, (Ferreira et al., 2006) and from ʻbiltongʼ - a popular African delicacy (Naidoo & Lindsay, 2010). Additionally, in the Lithuanian offal product ʻEars Language Rollʼ, which was available on the British market, *L. monocytogenes* levels reached 2.64 log CFU/g, exceeding the microbiological criteria set by the European Union (Gormley et al., 2010). Furthermore, the traditional Brazilian product ʻSarapatelʼ exhibited the presence of anaerobes, spore-forming bacilli, and pathogens, with *Staphylococcus aureus* levels exceeding 2.7 log CFU/g (Brasil et al., 2014). In traditional Spanish pork sausages, *Salmonella* spp. were discovered in ʻBotilloʼ and ʻAndrollaʼ sausage, while *E. coli* was detected in ʻBotilloʼ (Garcia et al., 2007; de Queiroz et al., 2013). *Staphylococcus aureus* was also isolated from another Brazilian offal-based product named ʻBuchada caprinaʼ (de Queiroz et al., 2013). The traditional Nigerian beef product ʻkilishiʼ contained both *S. aureus* and *E. coli* (Raji, 2006). Additionally, *Listeria* spp. were found in all tested samples of traditional Greek sausage (Drosinos et al., 2005).

According to the European Food Safety Authority (EFSA), foodborne zoonoses continue to pose significant public health concerns within the European Union, with salmonellosis remaining the most frequent cause of foodborne outbreaks. The highest prevalence of *Salmonella* in meat and meat products was observed in fresh poultry meat (12.6%), mechanically separated meat (MSM) (12.4%), poultry-based meat products intended for cooking (5.4%), and raw meat products, excluding those in which the production process or composition eliminates the risk of *Salmonella* contamination (0.87%). In addition, *Listeria monocytogenes* was detected in 90% of ready-to-eat meat and meat products (European Food Safety Authority & European Centre for Disease Prevention and Control, 2021).

According to Poland's Chief Sanitary Inspectorate, the national food safety authority, the most frequently reported microbiological hazard in 2022 was *Salmonella*, predominantly in poultry meat and related products (191 notifications), as well as in non-poultry meat and meat products (5 notifications). Notably, the number of *Salmonella* notifications in poultry meat and its derivatives showed a decreasing trend, dropping from 273 cases in 2020 to 263 in 2021, and further to 191 in 2022 (Chief Sanitary Inspectorate, 2022).

Meat and meat products may contain microbiological contamination and become contaminated with pathogenic microorganisms of public health significance; hence the aim of the present study was to detect microbiological contamination of meat and meat products available at the retail market in Latvia.

Materials and Methods

Collection of samples

The study was conducted from October, 2024 to February, 2025 in the region of Zemgale, Latvia. Samples of meat and meat products were collected from various retail outlets, including four supermarket chains, as well as butcher shops and farmer market in Jelgava. A total of 73 samples were selected for analysis, including cold-smoked products (n=7), hot-smoked products (n=9), pâtés (n=8), raw meat (n=18), boiled meat products (n=13), semi-finished products (n=7), boiled-smoked products (n=6), and dry-cured products (n=4).

The majority of the selected products (60 samples) was produced locally or imported by various companies and private entrepreneurs from Lithuania (8 samples), Poland (3 samples), and Estonia (2 samples). Of out these, 32 samples were packaged in protective packaging, such as vacuum or polymer packaging with hermetic sealing. All products were purchased from retail outlets within their shelf-life period.

For the remaining 41 products sold by weight, the customer assistant weighed them into a single-use, food-grade plastic bag at the customer's request. Among those samples, 21 were purchased from supermarkets. Additionally, 20 samples were obtained from grocery and farmers markets. Before purchasing, the adherence to shelf-life, storage temperature and storage condition were checked.

All the samples were transported to the laboratory according to storage conditions indicated on the product package or according to labels were available at the retail outlets for customers. The microbiological investigations were initiated immediately after delivering of products to the laboratory.

The research was conducted at the laboratories of the Institute of Food Hygiene and Environmental Health at the Faculty of Veterinary Medicine of Latvia University of Life Sciences and Technologies. The meat product samples were analysed for total microbial counts (TVC), as well as for the presence of hygiene indicators (*Enterobacteriaceae* and *Escherichia coli*) and pathogens (*Salmonella* spp., *L. monocytogenes*, *S. aureus* and *Y. enterocolitica*).

Preparation of samples and microbiological investigations

Detection of quantitative microbiological contamination

For microbiological analysis, the tested meat products were prepared according to ISO 6887-2:2017 (ISO, 2017a). A 10 g portion of each product sample was placed in 90 mL of sterile buffered peptone water (BPW; Biolife Italiana Srl, Italy) and homogenized for 1 minute. The initial suspension was then used to prepare decimal dilutions in BPW. Plate Count Agar (PCA) was used for the enumeration of the TVC in accordance with ISO 4833-1:2013 (ISO, 2013). A 1 mL aliquot of the diluted suspension was inoculated onto Plate Count Agar (PCA) and incubated at 30 °C for 72 hours. For the detection of *Enterobacteriaceae*, the sample suspension was plated onto Violet Red Bile Glucose (VRBG) agar and incubated at 37 °C for 24 hours, in accordance with ISO 21528-2:2017 (ISO, 2017b). Typical colonies of violet red colour with

diameter of 1-3 mm were considered as *Enterobacteriaceae*.

Escherichia coli was identified following the ISO 16649-1:2018 (ISO, 2018). A loopful of the diluted sample was streaked onto Chromogenic Coliform Agar (CCA) and incubated at 36 ±2 °C for 24 hours. Blue or purple colonies were considered presumptive *E. coli*, while pink colonies were recorded as other coliforms.

The isolation and identification of *Staphylococcus aureus* were performed according to ISO 6888-3:2003 (ISO, 2003). Ten-fold serial dilutions of the sample suspension were inoculated onto Baird-Parker agar (Biolife, Italy) and incubated aerobically at 37 ±1 °C for 18 to 24 hours. Colonies presumptive for *S. aureus* were identified by their characteristic appearance: black center surrounded by clear haloes.

Qualitative detection of foodborne pathogens

The presence of *Yersinia* spp. in meat and meat products was assessed using both direct plating and cold enrichment methods, following ISO 10273:2017 (ISO, 2017c). Samples were prepared in Peptone Mannitol Bile Salt Broth (PMB), and the sample suspensions were inoculated onto Cefsulodin-Irgasan-Novobiocin (CIN) agar. For direct plating, a 10 µL of the inoculated PMB suspension was spread onto the surface of CIN agar and incubated aerobically at 30 °C for 24–48 hours. For cold enrichment, PMB suspensions were incubated at 4 °C for one, two, and three weeks. After each enrichment interval, CIN agar plates were inoculated. If no presumptive colonies were observed after the first or second week, a 0.25% KOH alkaline treatment was applied to reduce background microbiota. Colonies exhibiting small dark red centers surrounded by clear, colorless zones on CIN agar were considered as presumptive for *Yersinia*. Preliminary confirmatory tests included screeding for urease activity using Christensen's urea agar.

Listeria monocytogenes was detected in accordance with ISO 11290-1:2017-07 guidelines (ISO, 2017d), which include pre-enrichment, selective enrichment, and plating onto selective agar media. For pre-enrichment, 25 g of the sample was transferred into Half-Fraser Broth (Oxoid, UK) and incubated at 30 °C for 24 hours. Subsequently, 0.1 mL of the pre-enriched culture was transferred into 9 ml of Fraser Broth (Oxoid, UK) and incubated at 37°C for 48 hours. Samples that turned black after incubation (indicator of esculin hydrolysis) were considered presumptive for Listeria. These samples were streaked onto selective agars: ALOA (Agar Listeria according to Ottaviani and Agosti; Biolife, Italy) and PALCAM Agar (Biolife, Italy) followed by incubation at 37 °C for 24–48 hours. Colonies of typical morphology for Listeria were subcultured onto Columbia Blood Agar to assess β-haemolysis for further confirmation.

The presence of *Salmonella* spp. was determined according to ISO 6579-1:2017 guidelines (ISO, 2017e). Initially, samples were pre-enriched in buffered peptone water at 37 °C for 18–24 hours. Following pre-enrichment, the sample suspensions were selectively enriched in Müller-Kauffmann Tetrathionate-Novobiocin (MKTTn) broth (Oxoid, UK) at 37 °C for 24 hours.

After enrichment, aliquots were streaked onto Xylose Lysine Deoxycholate (XLD) agar and incubated at 37 °C for 24 hours. Colonies with typical Salmonella morphology were selected for further identification. Confirmation of microbial species was conducted using matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS; Vitek MS, Biomerieux, Marcy l'Etoile, France).

Data analysis

The microbiological results were expressed in log CFU/g. For microbiological contamination with the TVC, *Enterobacteriaceae* and *E. coli*, the mean and standard deviation were calculated.

Results and Discussion

The enumeration of aerobic mesophilic micro-organisms in meats is considered as one of the key microbiological indicators of its quality and hygiene. The presence of those microorganisms in high counts reflects favorable conditions for microbial growth and proliferation in a product (Kebede & Getu, 2023). In the present study, TVC, *E. coli*, and *Enterobacteriaceae* were detected in categories of tested meat products. Microbial counts varied depending on the type of product and the manufacturer. The highest levels of bacterial contamination were observed in raw meat samples, where TVC reached 5.5 ± 0.46 log CFU/g. In contrast, the lowest levels were recorded in dry-cured products with TVC values of 3.7 ± 0.5 log CFU/g.

A high number of aerobic colonies (5–6 log CFU/g) may indicate that food is potentially hazardous due to violations during storage, processing, or hygiene practices. Although TVC is not a direct food safety indicator, it plays an important role in assessing the hygienic conditions under which food is produced, processed, and stored (Chukuezi, 2010).

Based on our findings, the average TVC in raw meat was of 5.5 ± 0.46 log CFU/g, which is the upper limit of the acceptable range. However, considering the standard deviation, it is likely that some samples exceeded the 6.0 log CFU/g threshold, suggesting that the regulatory or HACCP-based microbial contamination limits may have been partially exceeded. This highlights the need for improved monitoring of storage conditions and hygiene during raw meat processing.

The highest *E. coli* levels were observed in raw meat (0.7 ± 0.7 log CFU/g) and semi-finished products (0.4 ± 0.5 log CFU/g). The lowest levels were found in hot-smoked products (0.07 ± 0.21 log CFU/g), whereas *E. coli* was not detected in dry-cured products and pâtés.

The average values and standard deviations indicate a high variability of contamination between samples. Although the levels of *E. coli* were not elevated, its presence indicate fecal contamination, which may result from violations of hygiene during production,

packaging or retail. Contributing factors may include handling meat with bare hands, lack of protective clothing, or contact with money during service, all of which can significantly increase the risk of contamination of meat products (Grace et al., 2019).

Regarding *Enterobacteriaceae*, the highest concentration was found in raw meat (1.9 ± 0.8 log CFU/g), while the lowest was detected in hot-smoked products (0.1 ± 0.31 log CFU/g). The results are summarized in Table 1.

Table 1
Microbiological contamination of meat and meat products

Product Type	***No. of samples***	***Microbiological criteria***		
		TVC	***Escherichia coli***	***Enterobacteriaceae***
		Mean log CFU/g (mean ± SD)		
Cold smoked products	7	5.14 ± 0.39	0.2 ± 0.2	1.2 ± 0.4
Dry-cured products	4	3.7 ± 0.5	0	0.4 ± 0.7
Hot smoked products	9	4.8 ± 0.7	0.07 ± 0.21	0.1 ± 0.31
Cooked-smoked products	6	5.0 ± 0.35	0.2 ± 0.4	0.7 ± 0.7
Cooked sausages	13	4.1 ± 1.8	0.2 ± 0.4	0.5 ± 0.8
Raw meat	18	5.5 ± 0.46	0.7 ± 0.7	1.9 ± 0.8
Semi-finished products	7	4.6 ± 1.9	0.4 ± 0.5	1.1 ± 0.9
Pâtés	8	5.4 ± 0.28	0	0.9 ± 0.4
Total	73			

The microbiological analysis of meat products to detect the presence of pathogenic microorganisms yielded the following results. Among the 73 tested samples, no *Salmonella spp*. was detected, which complies with the requirements set forth in Commission Regulation (EC) No 2073/2005, indicating that the sanitary condition of the examined products is satisfactory (European Commission, 2005). However, certain samples tested positive for other pathogens, namely *Yersinia enterocolitica* (16 % of the samples), *Staphylococcus aureus* (12 %), and *Listeria monocytogenes* (6 %). Across all retail outlets examined, the highest contamination rates were found in raw meats and semi-finished products.

Despite the presence of these pathogens, their levels did not exceed the permissible limits established by European legislation (European Commission, 2005) in most cases. The results are presented in Table 2.

Table 2
Foodborne Pathogens in Meat and Meat Products

Product Type	***No. of Samples***	***Foodborne pathogen***		
		Staphylococcus aureus	***Yersinia enterocolitica***	***Listeria monocytogenes***
		No. of positive samples (%)		
Cold smoked products	7	0 (0)	0 (0)	0 (0)
Dry-cured products	4	0 (0)	1 (25)	1 (25)
Hot smoked products	9	1 (11)	0 (0)	0 (0)
Cooked-smoked products	6	1 (17)	2 (33.3)	1 (17)
Cooked sausages	13	0 (0)	0 (0)	0 (0)
Raw meat	18	4 (22)	2 (11.1)	1 (5.6)
Semi-finished products	7	2 (29)	4 (57.1)	0 (0)
Pâtés	8	1 (14)	0 (0)	0 (0)
Total	73	12%	16%	6%

A microbiological assessment of various meat and meat products collected from different retail sources revealed notable variations in contamination levels depending on the type of product and type of retail outlet. The analysis targeted key pathogenic microorganisms (*S. aureus*, *Y. enterocolitica*, *L. monocytogenes*), as well as general hygiene indicators such as total viable counts (TVC), *E. coli*, and *Enterobacteriaceae*.

Among the tested categories, semi-finished products obtained from supermarkets exhibited the highest levels of pathogenic contamination, with *S. aureus* and *Y. enterocolitica* detected in 28.5% and 42.8% of samples, respectively. Raw meat samples also showed

a concerning level of microbial presence in all types of retail outlets. In supermarkets, *Y. enterocolitica* was found in 16.6% of raw meat samples, while the prevalence of 5.5% for *S. aureus*, *Y. enterocolitica*, and *L. monocytogenes* were identified for both retail stores and farmer markets for raw meat. Cooked-smoked products from supermarkets were similarly contaminated by all three pathogens (16.6%). In contrast, no pathogenic bacteria were detected in cooked sausages or cold smoked products from any outlet type.

Dry-cured products purchased from supermarkets were contaminated with *Y. enterocolitica* and *L. monocytogenes* (25% for each pathogen) while 25% of pâtés samples from supermarkets contained *S. aureus*. Regarding general microbiological indicators, the highest TVC counts were recorded in raw meat from farmer markets (6.4 ± 1.97 log CFU/g), followed by supermarket samples (5.4 ± 0.38 log CFU/g) and retail stores (5.8 ± 0.2 log CFU/g). Raw meat also exhibited the highest levels of *E. coli* and *Enterobacteriaceae*, with concentrations reaching 0.8 ± 0.6 and 3.1 ± 1.4 log CFU/g, respectively, particularly in samples purchased from retail stores and farmers' markets. Cooked sausages and pâtés demonstrated significantly lower total viable counts (TVC) compared to raw meat and semi-finished products, indicating better microbiological stability. In contrast, dry-cured and hot-smoked products showed reduced levels of hygiene indicator bacteria, such as *Enterobacteriaceae* and *Escherichia coli*, especially in samples obtained from supermarkets, suggesting better compliance with storage and handling standards. The findings of the present underscore the importance of retail outlet type because it may influence microbial quality and safety of meat products. Microbial contamination was associated with semi-finished and raw meat products, pointing to the need for more stringent hygiene monitoring and processing control for these product categories.

The present study results demonstrated that contamination levels varied significantly depending on the product type, storage conditions, and the place of purchase.

The highest levels of microbiological contamination were observed in samples of raw meat and semi-finished products purchased from farmer markets. In those samples increased TVC, *E. coli*, and *Enterobacteriaceae* were found, indicating poor hygiene practices, lack of temperature control, and unsanitary handling conditions.

Similar findings were reported by (De Oliveira et al., 2011), who documented high contamination levels in meat products sold at traditional markets, largely due to the absence of packaging and inadequate sanitary conditions.

In contrast, products purchased from supermarkets generally met microbiological safety requirements. However, several cases of contamination were found in semi-finished products, suggesting that issues may originate from the production level, rather than the retail environment.

Retail stores exhibited moderate contamination levels, particularly in terms of TVC and *E. coli*, highlighting the need for improved storage and hygiene control.

Furthermore, the presence of foodborne pathogens such as *S. aureus*, *Y. enterocolitica* and *L. monocytogenes* was confirmed from 5.5% to 16.6% of tested samples, mainly in raw meat and semi-finished products.

These results are consistent with the observations of (Buncic & Sofos, 2015), who emphasized that meat remains a key reservoir of foodborne pathogens, especially when hygiene is compromised.

Conclusions

1. The findings of this study underline the importance of a comprehensive and preventive approach to microbiological safety across all stages of the food chain - from production to final consumption.
2. Strengthening implementation of HACCP-based procedures, standardizing storage conditions, and training of personnel remain essential strategies for reducing foodborne risks.

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