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RESEARCH ARTICLE

Prevalence and Risk Assessment of *Listeria monocytogenes* in Retail Meat and Meat Products from the Anatolian Side of Istanbul

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ABSTRACT

Listeria monocytogenes is a foodborne pathogen. This study aimed to detect *L. monocytogenes* in meat and meat products, identify the serotypes that may be pathogenic, and assess the risk of infection from foods. A total of 300 samples were collected under aseptic conditions from retail outlets in Istanbul and analyzed. According to the results, a total of 83 *Listeria* spp. suspected isolates were identified, of which 8% (24/300) were confirmed as *L. monocytogenes*. *Listeria* spp. isolates were subjected to verification using the Vitek 2 system, with 24 (28.9%) isolates identified as *L. monocytogenes*, 44 (53%) isolates identified as *L. innocua*, 5 (6%) isolates as *L. grayi*, 6 (7.2%) isolates as *L. welshimeri*, and 4 (4.8%) isolates as *Listeria* spp. The total distribution of *L. monocytogenes* isolates according to serotypes was as follows: 10 (41.6%) 1/2a, 3 (12.5%) 1/2b, 1 (4.8%) 1/2c, 5 (20.8%) 3a, 4 (19%) 3c, and 1 (4.8%) 4b serotypes. Quantitative risk assessment was conducted, revealing that 98 minced meat and chopped meat, each weighing 0.3 kg/day, 7 fermented sausages, 1 salami, and 1 sausage product could be contaminated with *L. monocytogenes*. Finally, cross-contamination is likely to play a critical role in the transmission of *L. monocytogenes*. It is concluded that there is a need to implement effective food safety management approaches. Measures at all stages of the meat supply chain, from slaughter to retailing, transportation, and cooking, are essential for reducing the burden of exposure to this risk for consumers, thereby enhancing public health.
Keywords: *Listeria monocytogenes*, Meat and meat products, Serotypes, Risk assessment, Istanbul

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İstanbul'un Anadolu Yakasında Perakende Satışa Sunulan Et ve Et Ürünlerinde *Listeria monocytogenes* Prevalansı ile Risk Değerlendirme

ÖZ

Listeria monocytogenes, gıda kaynaklı bir patojendir. Çalışmada, *L. monocytogenes*'in et ve et ürünlerinde tespiti ve ürün tiplerine göre dağılımı, patojen özelliği taşıyabilecek serotiplerin tespiti ile gıdalarda enfeksiyonun ortaya çıkma riskinin ortaya konulması amaçlanmıştır. İstanbul'daki perakende satış noktalarından, aseptik koşullarda alınan 300 adet numune analiz edilmiştir. Test sonuçlarına göre toplam 83 adet *Listeria* spp. şüpheli izolat belirlenerek bunların 8% (24/300) *L. monocytogenes* olarak saptanmıştır. *Listeria* spp. izolatları Vitek 2 sistemi kullanılarak doğrulama işlemine tabii tutulup 24 (%28,9) adet izolat *L. monocytogenes*, 44 (%53) adet izolat *L. innocua*, 5 (%6) adet izolat *L. grayi*, 6 (%7,2) adet izolat *L. welshimeri* ve 4 (%4,8) adet izolat ise *Listeria* spp. olarak identifiye edilmiştir. *L. monocytogenes* izolatlarının serotiplere göre toplam dağılımı; 10 (%41,6) adet 1/2a, 3 (%12,5) adet 1/2b, 1 (%4,8) adet 1/2c, 5 (%20,8) adet 3a, 4 (%19) adet 3c ve 1 (%4,8) adet 4b serotipi şeklindedir. Nicel risk değerlendirmesi sonucunda; günlük 0,3 kg'lık 98 adet kıyma ve parça et , 7 adet sucuk, 1 adet salam ve 1 adet sosis ürününün *L. monocytogenes* ile kontamine olabileceği ortaya konulmuştur. Sonuç olarak, *L. monocytogenes* bulaşmasında çapraz kontaminasyonun önemli bir yere sahip olduğu öngörülmekte ve söz konusu risk ile tüketicilerin maruz kalma yükünü azaltmak için kırmızı et ve et ürünlerinin kesim, işleme, perakende ile taşıma ve pişirme dahil tüketici seviyesinin tüm basamaklarında etkili gıda güvenliği yönetimi yaklaşımları ve tedbirlerini uygulama ihtiyacının halk sağlığı açısından önemli olduğu kanaatine varılmıştır.
Anahtar Kelimeler: *Listeria monocytogenes*, Et ve et ürünleri, Serotiplendirme, Risk değerlendirme, İstanbul

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INTRODUCTION

Since *Listeria monocytogenes (L. monocytogenes)* serotypes are ubiquitous, it has been reported that animal foods can be contaminated with *L. monocytogenes* during the production, processing, and storage stages of food from farm to table (Çiftçioğlu, 1992; Coban et al., 2019). Animal foods are of great importance in human nutrition because they contain protein with high biological value, primarily exogenous amino acids that the body cannot synthesize, as well as mineral substances such as Fe, P, Zn, Cu, and vitamins such as Vitamin B12 (Uğur et al., 2001). It has been reported that meat and meat products, milk and dairy products, and seafood cause sporadic and epidemic cases of listeriosis (Rocourt et al., 2003). It is reported that listeriosis is one of the infections that cause the highest number of deaths because the agent survives in the facilities where foods such as meat and milk are produced, contaminates the products during the production stages and causes severe infections in susceptible people in the risk group who consume these contaminated foods (Jemmi and Stephan 2006; Matle et al 2020)).

Listeriosis is defined as a disease that causes severe infections such as meningitis, encephalitis, abortion, septicemia, and even death in humans as a result of consuming foods contaminated with *L. monocytogenes*. *L. monocytogenes*, characterized as an intracellular pathogen, is frequently reported to pose a risk to newborns, pregnant women, the elderly, and individuals with compromised immune systems. The disease has 5 different forms in humans: acute septic form, Central Nervous System (CNS) form, glandular form, local form, and chronic septic form, and is essential due to its high mortality rate (20-30%) (Ramaswamy et al., 2007). It is reported that the incubation period of the disease ranges from 1 to 70 days, and the disease can persist for days or even years (Raybourne et al., 2003).

Studies on foodborne epidemics in Europe have revealed the presence of *L. monocytogenes* and that it poses a public health risk. Since 2009, important information on the degree of risk related to the microorganism in question has been obtained. In European countries, 2,519 cases of listeriosis were reported in 2016, 2,497 in 2017, 2,570 in 2018, 2,652 in 2019, and 1,931 in 2020. In this context, it is reported that listeriosis is most common in Germany, France, and Spain. It is stated that 72.5% of the disease is seen in individuals aged 65 and over and that men are more likely to be infected than women (ECDC, 2023). In this context, the European Food Safety Authority (EFSA) established commissions in previous years to set regulations (EFSA, 2012), which were subsequently published. In the United States of America (USA), it was reported that 361 people were infected with this disease between 2016 and 2021, and 47 of them died (CDC, 2021). Moreover, several researchers reported the *L. monocytogenes* prevalence, such as 0.2% (Gözütok and Aydin, 2022), 1.52% (Büyükünal et al., 2016), 8.75% (Şanlibaba et al., 2020), 11.6% (Colak et al., 2007), 12.8% (Sahin et al., 2020), 17% (Uludağ et al., 2023), 24% (Atasever and Atasever, 2014), and 41.9% (Arslan and Baytur, 2019) in Türkiye.

In studies on *L. monocytogenes*, 13 serotypes that cause infection in humans and animals have been identified, with serotypes 1/2a, 1/2b, and 4b being particularly frequent. Although 4b serotype is reported to cause the most disease in humans, 1/2a serotype is the most common in foods (Zhang et al., 2007). The distribution of serotypes causing the disease is reported as 4b in 57%, 1/2a in 26%, 1/2b in 13%, and others in 3% (CDC, 2014). Considering the different sensitivities of *L. monocytogenes* serotypes to technological processes such as heat and pH, it is essential to determine the distribution of pathogenic serotypes, particularly in meat and meat products (Buncic et al., 2001).

Accurate detection of pathogenic bacterial serotypes is crucial for maintaining human health and controlling infections, particularly within the context of food safety and risk analysis. However, there have been limited evaluations of these different serotypes in previous years (Rebuffo-Scheer et al., 2007). Nevertheless, it is stated that studies on the subject are increasing (Garre et al., 2020; Yang and Yoon, 2022).

To date, there have been a limited number of risk analysis studies conducted in Türkiye regarding food safety, the distribution of *L. monocytogenes* serotypes, and public health. According to the Turkish Food Codex Regulation on Microbiological Criteria, ready-to-eat meat and meat products should not contain *L. monocytogenes* in 25 g of the food. Still, there is no such criterion in raw meat and minced meat (Turkish Food Codex, 2011).

This study aimed to determine the prevalence and distribution of *L. monocytogenes* in meat and meat products sold from the Anatolian side of Istanbul, detect serotypes that may pose a foodborne pathogen, identify animal foods at risk of carrying infectious serotypes, and assess the risk of infection from foods consumed in Istanbul.

MATERIALS and METHODS

Supply of samples

In this study, samples were taken from retail outlets, including butcher shops and grocery stores, located in the districts of the Asian Side of Istanbul. 50 samples of raw meat (minced meat and chopped meat) and technologically processed meat products (sausage, salami, and fermented sausage) were collected under aseptic conditions every month for a period of 6 months. A total of 300 meat products were brought to the laboratory as soon as possible in thermoboxes (+4°C) and analyzed by maintaining the cold chain.

Isolation and Identification

The method recommended by the United States Department of Agriculture (USDA) and Food Safety and Inspection Service (FSIS) was used for the isolation and identification of *L. monocytogenes* (Dever et al., 1993).

Each collected food sample was aseptically weighed to 25 grams, minced with a sterile scalpel, and transferred into sterile sample bags. Leftover food samples were stored in a deep freezer (Arçelik, Türkiye) (-18℃) until the analysis was completed. 225 ml of Listeria Enrichment Broth (Oxoid, CM 0862, Basingstoke, UK) was added to the sampling bags containing 25 grams of each sample. Homogenization was achieved with a stomacher device (Thermo Fisher Scientific, USA) for 2 min. The pre-enrichment process was then completed by incubating the sample in an incubator (Memmert, Germany) for 24 hours at 30℃. Selective enrichment was then performed by adding 0.1 mL of homogenate to tubes containing 10 mL of Fraser Broth Base (Oxoid, CM 0895), to which Fraser Supplement (Oxoid, SR 0156) was added, and incubating at 35℃ for 24 hours. The cultures obtained after selective enrichment were inoculated using the scratch plate method on Oxford Listeria Selective Agar (Oxoid, CM 0856) supplemented with Listeria Selective Supplement (Oxoid, SR 0140) and then poured into sterile petri dishes. Plates were incubated at 35℃ for 24-48 hours. Colonies measuring 2-3 mm in diameter, displaying a brownish black halo and sunken center, were considered presumptive for *Listeria* spp. From the suspicious colonies obtained, 1-5 pieces were selected and inoculated onto Blood Agar (Oxoid, CM 0055) medium to obtain a pure culture by streaking, allowing single colonies to form. The cultures were then incubated at 37℃ for 24 hours. Suspected colonies were then pure cultured on blood agar and tested for Gram staining, oxidase activity, and catalase production. Then β-Hemolysis and Christe Atkins Munch Peterson (CAMP) identification tests were performed for species differentiation (McLauchlin and Rees, 2009).

Verification and Serotyping

Isolates obtained through cultural methods and biochemical tests were identified using the Automated Identification System (VITEK 2 Compact) (Biomerieux, 2014; Crowley et al., 2012). Subsequently, the isolates obtained during the isolation and identification stages of *L. monocytogenes* were serotyped using antisera with specific agglutination to each species antigen of *Listeria* spp. (Denka Seiken, 1995).

Risk Assessment

Within the framework of an analytical cross-sectional study, it was calculated according to the Principles and Guidelines for the Conduct of Microbiological Risk Assessment published by the Codex Alimentarius Commission and ISO 31010: 2019 adapted and calculated according to the standards (CAC, 2014; IEC 31010:2019, 2019; Lyon et al., 2021).

The population of Türkiye was 85,279,553 as of 2022, and the population of Istanbul was 15,907,951 in 2022, with 35.30% of the population (5,616,577 people) living on the Asian side (TUİK, 2022). In this context, according to TUIK data, per capita consumption of large animal meat is 12.99 kg (General Directory of Meat and Milk Board, 2021). The number of risky samples has been calculated in the following steps, taking into account OECD-FAO (2022) and Turkish Meat Industry and Producers Association (2022) data. In the first stage, considering the Asian side of Istanbul, where the samples were collected, the population of this region was divided by the total population of Türkiye, and the Population Cross-Sectional Ratio (PCR) was calculated using the formula given below.

$$PCR = \frac{\text{Population of Istanbul's Anatolian Region}}{\text{Population of Türkiye}} \times 100$$

In the second stage, the Total Daily Consumption (TDC) amounts of raw red meat products (minced meat and chopped meat) and technologically processed meat products (sausage, salami and fermented sausage) used in the study and to be risk assessed were determined by dividing the annual consumption amounts in Türkiye by the total number of days using the formula given below.

$$TDC = \frac{\text{Annual consumption in Türkiye}}{\text{Day}}$$

In the next step, the consumption rate (CRR) of raw red meat products (minced meat and chopped meat) and technologically processed meat products (sausage, salami and fermented sausage) in the cross-sectional area to be risk assessed was found by dividing the total daily consumption (TDC) of these products in Türkiye by 100 and multiplying by the population cross-sectional ratio (PCR).

$$CRR = \frac{TDC}{100} \times PCR$$

The number of samples that may pose a risk in the cross-sectional area to be risk assessed (RA) was calculated by dividing the consumption rate of the cross-sectional area (CRR) by the standard weight (0.3 kg) of the sample used in the study.

$$RA = \frac{CRR}{0{,}3\ \text{kg}}$$

In another step, the isolated pathogen ratio (PR), which should be used for risk assessment, will be calculated. This rate is calculated by dividing the

number of pathogen isolates detected in the study by the total number of samples studied and then multiplying by 100, as shown in the formula below.

$$PR=\frac{\text{Rate of İsolates Detected}}{\text{Total Number of Samples Studied}}\times 100$$

In the last step, the number of risky pathogen samples in the cross-sectional area (RPNS) will be found. For this calculation, the number of samples that may pose a risk in the cross-sectional area to be risk-assessed (RA) was calculated by multiplying the proportion of pathogens isolated (PR) and then dividing by 100.

$$RPNS=\frac{RA\times PR}{100}$$

RESULTS

A total of 83 (27.6%) of the 300 samples analyzed in our study were suspected *Listeria* spp. and 24 (8%) of the strains *were L. monocytogenes* (Table 1).

Table 1. Distribution of detected *Listeria* spp. and *L. monocytogenes* according to samples.

Sample	n	*Listeria* spp. (n)	*L. monocytogenes* (n)
Minced meat	80	36 (45%)	12 (15%)
Piece of meat	80	26 (33%)	7 (8.8%)
Sausage	50	8 (16%)	2 (4%)
Salami	50	7 (14%)	1 (2%)
Fermented sausage	40	6 (15%)	2 (5%)
Total	**300**	**83 (%27,6)**	**24 (%8)**

The 83 *Listeria* spp. suspected samples obtained by cultural and biochemical test results were subjected to confirmation using the VITEK 2 system and 24 (28.9%) of these isolates were identified as *L. monocytogenes*, 44 (53%) *L. innocua*, 5 (6%) *L. grayi*, 6 (7.2%) *L. welshimeri,* and 4 (4.8%) *Listeria* spp. (Table 2). In this study, the isolates obtained using the cultural method, biochemical test, and VITEK 2 system were tested with Denka Seiken antisera at the time of this research. Of the 24 *L. monocytogenes* isolates obtained in total, 10 (41.6%) were 1/2a, 3 (12.5%) were 1/2b, 1 (4.8%) were 1/2c, 5 (20.8%) were 3a, 4 (19%) were 3c, and 1 (4.8%) were 4b serotypes (Table 3). When analyzed separately by sample type; Of the 12 isolates obtained from minced meat products, 5 were serotype 1/2a, 3 were serotype 1/2b, 2 were serotype 3c and 2 were serotype 3a, and of the 7 isolates obtained from meat samples, 3 were serotype 1/2a, 2 were serotype 3a, 1 was serotype 1/2c and 1 was serotype 3c, Of the 2 isolates obtained from sausage products, 1 was serotype 1/2a and the other was serotype 3a, 1 isolate obtained from salami samples was serotype 3c and finally, of the 2 isolates from fermented sausage products, 1 was serotype 4b and the other was serotype 1/2a (Table 4).

The results of the risk assessment calculations revealed that 820 out of 160 minced meat and meat cut samples (0.3 kg) collected from districts in the Anatolian side of Istanbul could be considered risky, based on the consumption rate calculation for the region. In the present study, the pathogen isolation count (19) in the minced meat and meat products identified, as well as the total number of samples studied (160), resulted in a pathogen rate of 11.9%. The final calculation identified 98 minced meat and chopped meat, with a combined weight of 0.3 kg, that could pose a potential risk (RPNS). In line with these results, it was determined that 98 minced meats and chopped meat, with a weight of 0.3 kg per day, could be contaminated with *L. monocytogenes*. The 40 samples of fermented sausage, 50 samples of salami, and 50 samples of sausage collected, with a total weight of 0.3 kg, indicate that the number of products that could be considered risky

Table 2. *Listeria* species detected according to sample types.

Sample	n_1	*L. monocytogenes*	*L. innocua*	*L. grayi*	*L. welshimeri*	*Listeria* spp.
Minced meat	36	12 (33.3%)	18 (50%)	2 (5.5%)	2 (5.5%)	2 (5.5%)
Piece of meat	26	7 (26.9%)	14 (53.4%)	2 (7.7%)	2 (7.7%)	1 (3.8%)
Sausage	8	2 (25%)	5 (62.5%)	-	1 (12.5%)	-
Salami	7	1 (14.3%)	4 (57.1%)	-	1 (14.3%)	1 (14.3%)
Fermented sausage	6	2 (33.3%)	3 (50%)	1 (16.7%)	-	-
Total	**83**	**24 (%28,9)**	**44 (%53)**	**5 (%6)**	**6 (%7,2)**	**4 (%4,8)**

n_1:Number of *Listeria* spp. suspected samples detected.

Table 3. Total distribution of *Listeria monocytogenes* isolates according to serotypes.

Number of *L. monocytogenes* isolates	1/2a	1/2b	1/2c	3a	3c	4b
24	10 (41.6%)	3 (12.5%)	1 (4.8%)	5 (20.8%)	4 (19%)	1 (4.8%)

Table 4. Serotyping results obtained according to sample types.

Sample	n	Serotype	n_1	O antigen	H antigen
Minced meat	12	1/2a	5	I/II, I	A, AB
		1/2b	3	I/II, I	A, AB, C
		3c	2	I/II, IV	AB, D
		3a	2	I/II, IV	A, AB
Piece of meat	7	1/2a	3	I/II, I	A, AB
		3a	2	I/II, IV	A, AB
		1/2c	1	I/II, I	AB, D
		3c	1	I/II, IV	AB, D
Sausage	2	1/2a	1	I/II, I	A, AB
		3a	1	I/II, IV	A, AB
Salami	1	3c	1	I/II, IV	AB, D
Fermented sausage	2	4b	1	V/VI, VI	A, AB, C
		1/2a	1	I/II, I	A, AB

n: Number of *Listeria monocytogenes* isolates obtained, n_1: Number of serotypes obtained.

based on the region's consumption rate is 133 (fermented sausage), 52 (salami), and 34 (sausage). The number of pathogen isolates found in the samples obtained in the present study and the pathogen rates based on the total number of samples studied were 5 (fermented sausage), 2 (salami), and 4 (sausage), respectively. The quantity of fermented sausage, salami, and sausage products that could potentially pose a risk, at a quantity of 0.3 kg, was found to be 7 (fermented sausage), 1 (salami), and 1 (sausage) according to our final calculations (RPNS). It was determined that, based on the available data, 7 pieces of fermented sausage, 1 piece of salami, and 1 piece of sausage, with a combined weight of 0.3 kg, could be contaminated with *Listeria monocytogenes* daily.

DISCUSSION

In Türkiye, various studies have been conducted on raw red meat (including minced meat and chopped meat) and technologically processed meat products (such as sausages, salami, and fermented sausages). Similar to the results of our study, Büyükünal et al. (2016) determined the incidence of *L. monocytogenes* to be 1.52% in 132 sausage samples collected from various provinces in Türkiye. They reported that the difference between their results and ours may be related to production techniques, post-production contamination, storage conditions, and inadequate personal hygiene. Şanlibaba et al. (2020) in Ankara determined that 25% of 80 meat samples collected from butcher shops and markets were *Listeria* spp. and 8.75% were *L. monocytogenes*. Similarly, Uludağ et al. (2023) in a study conducted in Istanbul, 17% *L. monocytogenes* in minced meat samples obtained from butchers in 9 different regions; Çiftçioğlu (1992) in a study conducted in Istanbul, 100 sausage samples were taken and 11% *Listeria* spp, 2% *L. monocytogenes*, 8% *L. innocua* and 1% *L. seeligeri*; in a study conducted in Afyon, the incidence of *Listeria* spp. in sausage samples was found to be 9% and it was concluded that *L. monocytogenes* could be eliminated especially in heat-treated meat products. The presence of *Listeria* was attributed to contamination that occurred after this process (Sırıken et al., 2006).

In a study conducted in Bolu, 41.9% *L. monocytogenes*, 43.5% *L. innocua*, 9.7% *L. grayi* and 3.2% *L. welshimeri* were detected in 62 minced meat samples collected from butchers and markets and the difference between the results was attributed to various factors such as isolation methods, type of food sample, season, geographical location and packaging, transportation and storage conditions (Arslan and Baytur, 2019). In another study, 300 sausage samples collected from markets in Istanbul were examined. *Listeria* spp. and *L. monocytogenes* were detected in 21% and 11.6% of them, respectively. The differences in the results obtained were attributed to several factors, including geographical region, animal breeding methods, slaughtering processes, food production and storage conditions (especially temperature control), isolation methods, and medium selection (Colak et al., 2007). In a study conducted in Ankara, 15.8% of *L. monocytogenes*, 21.6% of *L. innocua*, 7.5% of *L. welshimeri*, and 1.6% of *L. grayi* were found in 120 raw meat samples collected from markets and butchers. *L. grayi*, and depending on the reason for the difference between the results, the importance of the source of the meat, country, slaughter conditions, isolation and identification methods, retail workplace hygiene, number of samples and from which part of the animal the sample meat was obtained was emphasized (Kocaman and Sarımehmetoğlu, 2017). Finally, in a study conducted on minced meat samples collected from butchers, delicatessens and markets in Erzurum, the incidence of *L. monocytogenes* was determined to be 24%. It was thought that this high incidence may pose a significant potential risk to public health if minced meat is consumed raw or without adequate heat treatment and cross-contamination occurs (Atasever and Atasever, 2014).

Several studies have been conducted in Türkiye with lower incidence rates than those found in this study. Within the framework of the Eastern Region of Türkiye, 180 minced meat samples obtained from butchers and markets were examined and 28.8% *Listeria* spp., 7.2% *L. monocytogenes*, 15.5% *L. innocua*,

6.1% *L. welshimeri* incidences were determined, suggesting that the difference may be due to differences in food processing environment, human activity, fattening farm management, sampling and isolation methods (Kalender, 2012). In a study conducted in Istanbul, a total of 255 raw red meat and minced meat samples were examined, and *Listeria* spp. was detected at a rate of 8.6%. *L. monocytogenes* was not detected, and it was concluded that differences between studies may be related to production techniques, contamination due to production processes, storage conditions, and inadequate personal hygiene (Bingol et al., 2013). Another study reported the incidence of *L. monocytogenes* as 4,7% and 8% in a total of 691 raw meat and meat product (sausage) samples obtained from retail outlets, respectively (Kahraman and Aydin, 2009). Moreover, *L. monocytogenes* was not found in 80 sausage samples (fermented) in Diyarbakır, which was attributed to the bacteriocins produced by *Lactobacillus*, the predominant bacterium in sausage following the ripening period and acidification. The use of garlic during the production phase may inhibit the growth of *Listeria*.

L. monocytogenes serotypes 1/2a, 1/2b, 1/2c, and 4b are responsible for most human listeriosis; moreover, these serotypes can be recovered from food, environmental samples, and patients. Additionally, serotypes 4a and 4c are rarely associated with epidemics (Coban et al., 2019). Based on serogrouping, most isolates obtained from meat and meat product samples belonged to serogroups associated with human listeriosis, indicating a potential public health risk.

When various studies were examined, Sahin et al. (2020) reported that 55%, 25%, 15%, and 5% of the 20 *L. monocytogenes* isolates obtained from red meat products were serotypes 1/2c, 1/2a, 4b, and 1/2b, respectively. In another study, it was reported that of the 8 *L. monocytogenes* isolates obtained from red meat originating from Samsun province, 3 were serotype 1/2a, 3 were serotype 1/2b, and 3 were serotype 4c (Özkiraz and Gücükoğlu, 2018). Cetinkaya et al. (2014) determined that the most common *L. monocytogenes* serotype in red meat was 1/2a-3a. Matle et al. (2020) conducted a study in South Africa and determined *L. monocytogenes* isolates; In raw meat products, 47.5% were 1/2a-3a, 5.1% were 1/2c-3c, 10.2% were 1/2b-3b-7, 13.6% were 4b-4d-4e and 18.6% were 4a-4c serotypes, while 39% of processed raw meat products, 6% were 1/2a-3a, 2% were 1/2c-3c, 14.1% were 1/2b-3b-7, 33.6% were 4b-4d-4e and 10.7% were 4a-4c serotypes. More than 80% of the *L. monocytogenes* isolates in the present study were identified as epidemiologically important serotypes. They reported that this situation reveals a potential for causing listeriosis in humans and that the emergence of these virulent isolates, belonging to important serotypes 1/2a-3a, 1/2c-3c, and 4b-4d-4e, in meat and meat products is a matter of public health concern. Chen et al. (2019), in another study on meat and meat products, 458 isolates of *L. monocytogenes* isolates, 45% were found to be 1/2a-3a, 26.9% were found to be 1/2c-3c, 4.8% were found to be 4b-4e-4d, 23.3% were found to be 1/2b-3b-7 serotypes, they did not find serotypes 4a or 4c in any isolate, they concluded that serotypes 4b, 1/2b and 1/2a were predominant in human listeriosis cases, which suggests that these isolates may be pathogenic to consumers.

In line with the findings obtained within the scope of this research, a quantitative risk assessment was conducted using scientific data. Accordingly, the population cross-sectional rate (PCR), total daily consumption amount (TDC), cross-sectional regional consumption rate (CRR), number of risky samples (RA), isolated pathogen rate (PR), and finally, the number of risky pathogen samples (RPNS) were determined for the Asian side of Istanbul. Based on the quantitative risk assessment, 98 units of minced meat and meat products (0.3 kg/day) were estimated to be potentially contaminated with *L. monocytogenes*. Similarly, 7 fermented sausage, 1 salami, and 1 sausage product of the same weight may carry contamination risk. It is especially important in terms of the contamination rate of raw red meat products (minced meat and chopped meat) with *L. monocytogenes*, given that there are no microbiological criteria for the presence of *L. monocytogenes* in these products in Türkiye (Turkish Food Codex, 2011). *L. monocytogenes* in our country is a disease that causes serious infections in humans due to meningitis, encephalitis, abortion, septicemia, and a high mortality rate (20-30%), mainly in newborns (Gandhi and Chikindas, 2007). Considering that it may pose a risk for pregnant women, the elderly and immunocompromised people, it has been revealed that this situation is important in terms of taking precautions.

CONCLUSION

Raw meat products are considered the most risky food group in terms of *L. monocytogenes* contamination. Technologically processed salami, sausage, and fermented sausage samples containing various additives are less exposed to contamination. In this respect, it is crucial not to consume raw or undercooked meat and meat products, as this can pose significant public health risks. The occurrence of *L. monocytogenes* in raw meat products underscores its potential as a significant public health concern, due to its psychrotrophic nature, ability to proliferate at low temperatures, broad pH tolerance, and high pathogenicity in contaminated products. In this respect, it is recommended that hygiene and sanitation rules should be followed in food production facilities, butcher shops and retail establishments, hazard analysis and identification of critical control points, good manufacturing practices and good hygiene practices should be integrated and monitored, existing standard production procedures should be improved

and personnel should be trained on these issues. Potential *L. monocytogenes* contamination in retail establishments and butcher shops may be caused by cross-contamination of personnel, tools, and equipment from meat grinders and slicing machines used for delicatessen products. On the other hand, the presence of serotypes 1/2a and 4b, which are most common in human listeriosis outbreaks, poses a public health hazard. In this context, consumers should be educated about the risks associated with raw meat and meat products. In conclusion, it is emphasized that cross-contamination plays a crucial role in the transmission of *L. monocytogenes*, underscoring the need to implement effective food safety management approaches. Measures at all steps of slaughter, processing, retail, and consumer level (transportation and cooking) of meat and meat products to reduce this risk and reduce the burden of exposure of consumers.

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