Arch Lebensmittelhyg 74,
109–119 (2023)
DOI 10.53194/0003-925X-74-109

ISSN 0003-925X

Korrespondenzadresse:
didemkankaya@isparta.edu.tr

[1]) Department of Food Processing, Gelendost Vocational School, Isparta University of Applied Sciences, 32900, Isparta, Turkey; [2]) Faculty of Engineering, Department of Food Engineering, Süleyman Demirel University, 32260, Isparta, Turkey

Safety assessment of Lactobacilli isolated from foods of animal origin

Sicherheitsbewertung von aus Lebensmitteln tierischen Ursprungs isolierten Laktobazillen

Didem Akpınar Kankaya[1]), Banu Özden Tuncer[2]), Yasin Tuncer[2])

Summary

In this study, lactobacilli strains that were isolated from different foods of animal origin were identified at the species level and investigated for antibiotic resistance, virulence factors, biofilm, and biogenic amine production characteristics. According to the results of the 16S rDNA sequence analysis, thirty isolates were identified as 22 *Lactiplantibacillus plantarum,* three *Lacticaseibacillus paracasei* subsp. *tolerans,* two *Latilactobacillus sakei* subsp. *sakei,* one *Lacticaseibacillus rhamnosus,* one *Limosilactobacillus fermentum,* and one *Lactilactobacillus curvatus.* By disk diffusion test, all strains were found to be resistant to at least one antibiotic. Most of the strains were found resistant to vancomycin (90%), followed by cefoxitin (86.67%) and norfloxacin (66.67%). The only $vanX$ gene (93.33%, 28/30) was detected in strains, but no other antibiotic resistance genes were detected in any of the strains. PCR findings revealed the presence of the *acm* (3/30, 10%) and $efaA_{fs}$ (1/30, 3.33%) genes in strains, but other virulence factor genes were not detected in any of the strains. The biofilm production genes were not found in any of the isolates. Only the tyrosine decarboxylase gene *tdc* was found in *Lactilactobacillus curvatus* DYB17, which dexarcoxylates tyrosine.

Keywords: Lactobacilli, antibiotic resistance, virulence factor, biofilm, biogenic amine

Journal of Food Safety and Food Quality 74, Heft 4 (2023), Seiten 101–128

Introduction

Lactic acid bacteria (LAB) are industrially important bacteria known for their fermentative properties as well as their positive effects on nutrition and health (Badr et al., 2005). Certain lactobacilli belonging to the LAB family are used as starters or beneficial cultures in traditional applications and are employed as probiotics to help human health. The nomenclature of the genus *Lactobacillus* was revised in 2020 and *Lactobacillus plantarum, Lactobacillus paracasei* subsp. *tolerans, Lactobacillus sakei* subsp. *sakei, Lactobacillus rhamnosus, Lactobacillus fermentum* and *Lactobacillus curvatus* were renamed as *Lactiplantibacillus plantarum, Lacticaseibacillus paracasei* subsp. *tolerans, Latilactobacillus sakei* subsp. *sakei, Lacticaseibacillus rhamnosus, Limosilactobacillus fermentum, Latilactobacillus curvatus* respectvly (Zheng et al., 2020). However, in the article, the term *Lactobacillus* in the old nomenclature was used for convenience in specifying the strains. Several *Lactobacillus* species have been given 'generally recognized as safe' (GRAS) status and are considered safe for human and animal consumption (Todorov et al., 2017). However, lactobacilli can also cause some infections such as endocarditis, bacteremia, and abscesses (Slover and Danziger, 2008). Moreover, there is a risk that these bacteria may act as reservoirs for the spread of antibiotic resistance genes to other bacteria (Mathur and Singh, 2005; Bernardeau et al., 2006; Courvalin, 2006a). Bacteria can show intrinsic or acquired resistance to the main groups of antibiotics used clinically (Davies and Davies, 2010; Fraqueza, 2015). In addition to medical treatment, antibiotics are also used in livestock and agricultural production (Nisha, 2008; Dugassa and Shukuri, 2017). This has led to an increase in the incidence of resistant strains (Ammor et al., 2007). Previous studies show that beneficial and common bacterial populations play a role in the transfer of antibiotic resistance to pathogenic and opportunistic pathogenic bacteria (Levy and Marshall, 2004; Salyers et al., 2004). Glycopeptide group antibiotics, which act by modifying the antibiotic target, are mainly used in the treatment of infections caused by Gram-positive bacteria (Kristich et al., 2014). Lactobacilli are inherently resistant to vancomycin, which works by interfering with the production of peptidoglycan precursors, which are necessary for the formation of the bacterial cell wall (Eliopoulos and Gold, 2001; Courvalin, 2006b; Goldstein et al., 2015). Compared to enterococci, although lactobacilli lack *vanA*, *vanB*, and *vanC* genes (Klein et al., 2000), some strains of lactobacilli have the *vanX* gene encoding D-ala-D-ala dipeptidase, which is essential for cell wall synthesis (Liu et al., 2009). For this reason, their survival even with the use of antibiotics strengthens the use of these bacteria for probiotic purposes (Das et al., 2020). However, there is a risk that probiotic bacteria with transferable antibiotic resistance genes may act as reservoirs for transferring these resistance genes to other bacteria. The emergence of vancomycin-resistant strains has been a cause for concern, especially since vancomycin is used as a last resort in the treatment of infections caused by multi-resistant Gram-positive bacteria (Garcia-Migura et al., 2007; Fisher and Philips, 2009).

The presence of virulence factors increases the likelihood that bacteria will cause disease. The virulence factors of LAB, especially of enterococci, have been well researched. However, the long history of safe use of non-enterococcal LAB and their low virulence potential make it difficult to find virulence factors for these bacteria (Franz et al., 2010). Even if the presence of virulence factors does not necessarily result in clinical infections, commensal bacteria that contain virulence factors may mediate the spread of virulence genes to other bacteria (Eaton and Gasson, 2001; Comerlato et al., 2013; Jimenez et al., 2013). Despite the fact that lactobacilli are generally recognized as safe, it is important to investigate the virulence factors they have due to their potential applications in food products (Eaton and Gasson, 2001).

Biofilm formation is a dynamic process that is affected by various environmental parameters such as bacterial strain, surface properties, pH, nutrient concentration, and temperature (Donlan, 2002). Biofilm production allows bacteria to adapt to harsh environmental conditions (Zhang et al., 2013) and also protects them from antibiotics and enzymes (Lewis, 2001). Biofilm formation is seen as a positive feature for probiotic microorganisms to adhere to surfaces and create various health effects (Lepargneur and Rousseau, 2002). On the other hand, biofilm production is accepted as a potential danger in the food industry, as it enables bacteria to be resistant to adverse conditions and causes bacterial contamination in foods (Kumar and Anand, 1998). Biogenic amines are naturally produced by plants, animals, and microorganisms (Shalaby, 1996) and play a role in the fulfillment of various activities of the cell (Medina et al., 2003). However, consumption of foods containing high amounts of biogenic amines leads to toxic results (Shalaby, 1996). The presence of biogenic amines in foods is an indicator of undesirable microbial activity. High biogenic amine levels in foods are considered an indication of faulty production or food spoilage (Linares et al., 2011).

The European Food Safety Authority (EFSA) has adopted a general approach to the safety assessment of microorganisms used in food and feed and has included a group of microorganisms in the "Qualified Presumption of Safety" (QPS) application (EFSA, 2005). In order to prevent the transmission of antibiotic resistance genes to pathogenic or other commensal bacteria, it is not desirable to have antibiotic resistance genes in starter or protective cultures, according to QPS conditions (EFSA, 2012). It is also desirable that these strains do not have other virulence factors and biogenic amine production characteristics (EFSA, 2011). For this reason, in this study, antibiotic resistance profiles, antibiotic resistance genes, virulence factors, biofilm and biogenic amine production properties of lactobacilli strains isolated from foods of animal origin were investigated.

Material and methods

Bacteria and growth conditions

A total of 30 isolates obtained from the Süleyman Demirel University Bacterial Genetic Laboratory culture collection were used in this study. These isolates were previously isolated from different foods of animal origin such as traditional Turkish cheeses, raw red meat, red meat products (sucuk and pastırma), raw chicken meat and sea fish. Isolates were randomly picked from vancomycin-containing (4 µg/mL) enterococcosel agar (BBL, Becton Dickinson and Company, Spark, USA) during the isolation of vancomycin-resistant enterococci from food samples of animal origin according to Robredo et al. (2000). Thirty isolates were identified as Gram-positive bacilli were stored at

–32°C by adding 20% sterile glycerol. Isolates were grown in de Man Rogosa Sharpe (MRS, Biokar, France) broth at 37°C for 18 h before analysis.

Identification of isolates

Genomic DNA samples were extracted from isolates using a combination of the methods of Cancilla et al. (1992) and Abed (2013). Briefly, 0.5 mL of overnight cultures were centrifuged (15394 xg for 5 min) in 2 mL Eppendorf tubes, and cell pellets were dissolved in 0.5 mL of lysis buffer. Tubes were incubated in a water bath at 37°C for 60 min. Then, 2 µL of proteinase K (50 mg/mL) was added to the tubes and incubated at 37°C for 15 min. Following incubation, 30 µL of 10% (w/v) sodium dodecyl sulfate was added to the tubes and incubated for 5 minutes at 80°C. Then 0.7 mL of phenol-chloroform (1:10, v/v) was added to the cell suspensions and the tubes were centrifuged (15394 xg for 5 min) and this step was repeated two times. The upper phase was taken into new sterile tubes, 0.7 mL of 2-propanol was added, and the tubes were centrifuged (15394 xg for 5 min). The nucleic acid pellet was also extracted using 1 mL of 70% ethanol and centrifuged (15394 xg for 5 min). The precipitates were dissolved in 50 µL of Tris-EDTA buffer (pH 8.0) and stored at –20°C. The presence of the obtained genomic DNA samples was checked in gels prepared with a 0.7% (w/v) agarose ratio.

The universal bacterial primers pA and pE‘ were used in the amplification of the 16S rDNA region of the isolates by PCR (Edwards et al., 1989). Amplified products were analyzed in a 1% (w/v) agarose gel. DNA sequence analysis of PCR products was carried out by BM Labosis (Ankara, Turkey). The 16S rDNA sequence similarity of the samples was determined using the BLAST program of the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool (BLAST) algorithm.

Antibiotic susceptibility

The antibiotic susceptibility of isolates was determined using the disk diffusion test. The test was performed on Mueller Hinton agar (LAB M, Lancashire, United Kingdom) plates using 18 commercial antibiotic disks: ampicillin (10 µg), erythromycin (15 µg), gentamicin (10 µg and 120 µg), kanamycin (30 µg), clindamycin (2 µg), chloramphenicol (30 µg), norfloxacin (10 µg), ofloxacin (5 µg), penicillin G (10 U), rifampin (5 µg), cephalothin (30 µg), cefoxitin (30 µg), ciprofloxacin (5 µg), streptomycin (10 µg and 300 µg), tetracycline (30 µg), vancomycin (30 µg) (Oxoid Ltd., UK). Strains were classified as resistant, intermediary, or susceptible according to Charteris et al. (1998) and CLSI (2016) guidelines.

Minimum inhibitory concentration (MIC)

The minimum inhibitory concentration (MIC) of isolates against vancomycin was tested using E-test strips (Liofilchem, Italy) according to the method recommended by the manufacturer. *Enterococcus faecalis* ATCC 29212 (*van*$^-$) and *E. faecium* ATCC 51559 (*vanA*$^+$) strains were used as controls in the MIC test.

Antibiotic resistance genes

Erythromycin *(ermA, ermB, ermC),* tetracycline *(tetK, tetL, tetM, tetO, tetS),* vancomycin *(vanA, vanB, vanC1, vanC2, vanC3, vanD, vanE, vanG, vanX)* and aminoglycoside *(aph(3’)-IIIa, ant(4’)-Ia, ant(6’)-Ia, aac(6’)-Ie-aph(2’’)-Ia, aph(2’’)-Ib, aph(2’’)Ic, aph(2’’)-Id)* resistance genes in isolates were investigated by PCR using specific primer pairs and protocols indicated by previous researchers (Dutka Malen et al., 1995; Lemcke and Bülte, 2000; Vakulenko et al., 2003; Depardieu et al., 2004; Ouoba et al., 2008; Liu et al. 2009; Niu et al., 2016). *E. faecium* ATCC 51559 *(vanA*$^+$*), E. faecalis* ATCC 51299 *(aph(3’)-IIIa*$^+$*, aac(6’)-Ie-aph(2’’)-Ia*$^+$*, ant(6’)-Ia*$^+$*, vanB*$^+$*), E. gallinarum* DYE45 *(ermA*$^+$*, ermB*$^+$*), E. casseliflavus* DYE26 *(tetS*$^+$*, vanC2*$^+$*, vanC3*$^+$*), E. gallinarum* DYE22 *(vanC1*$^+$*, vanD*$^+$*)* (Akpınar Kankaya and Tuncer, 2020), *E. faecium* FYE41 *(ermC*$^+$*, tetM*$^+$*, tetL*$^+$*)* (Demirgül and Tuncer, 2017), *E. faecium* MSE53.1 *(ant(4’)-Ia*$^+$*, aph(2’’)-Ib*$^+$*, aph(2’’)Ic*$^+$*)* (Yalçın et al., 2023) were used as positive controls in the experiments.

Hemolytic and gelatinase activities

For the detection of hemolytic activity, the overnight cultures grown in MRS broth were transferred to blood agar (5% v/v) medium (Liofilchem) with the sterile loop and plates kept at 37°C for 48 hours of incubation. At the end of the incubation period, the formation of a clear zone around the colonies was evaluated as beta (β) hemolytic, the formation of a fuzzy greenish zone was considered alpha (α) hemolytic, and the absence of a zone was considered a gamma (γ) hemolytic reaction (Cariolato et al., 2008). In the hemolytic activity test, β-hemolytic *Staphylococcus aureus* ATCC 25923 was used as a control strain.

For the detection of gelatinase activity, overnight cultures were spread on Todd-Hewitt agar medium (Liofilchem) containing 3% gelatine (Merck, Germany) and incubated at 37°C for 24 hours. After the incubation period, the Petri dishes were kept in a refrigerator at 4°C for 5 hours. At the end of the period, the formation of an opaque zone around the colonies was accepted as a positive result (Eaton and Gasson, 2001). The *E. faecalis* NYE7 strain was used as a positive control in the gelatinase test (Inoğlu and Tuncer, 2013).

Detection of virulence factors

For the detection of virulence genes in isolates, gelatinase *(gelE),* cell wall adhesins *(efaA*$_{fm}$*, efaA*$_{fs}$*),* sex pheromones *(cpd, cob, ccf, cad),* collagen binding protein *(ace, acm),* aggregation protein *(agg),* cytolysin *(cylM, cylB, cylA)* and hyaluronidase *(hyl)* encoding genes were investigated by PCR (Eaton and Gasson, 2001; Vankerckhoven et al., 2004; Reviriego et al., 2005; Camargo et al., 2006; Belgacem et al., 2010). The *E. faecalis* ATCC 29212 *(gelE*$^+$*, efaA*$_{fs}$$^+$*, cpd*$^+$*, cob*$^+$*, ccf*$^+$*, cad*$^+$*, ace*$^+$*, acm*$^+$*, cylB*$^+$*, cylA*$^+$*)* was used as a positive control strain (Kasap and Tuncer, 2019).

Detection of biofilm production genes

The existence of genes involved in the production of extracellular surface protein *(esp*$_{fm}$*, esp*$_{fs}$*),* endocarditis and biofilm-associated pili *(ebpA, ebpB, ebpC),* and D-alanine lipotaichoic acid *(dltA)* in isolates was investigated according to Reviriego et al. (2005), Nallapareddy et al. (2006), and Fabretti et al. (2006).

Detection of biogenic amine production and amino acid decarboxylase genes

For the detection of the biogenic amine production of the isolates, basal medium containing lysine, tyrosine, ornithine, or histidine (Merck) precursor amino acids with a final concentration of 1% was used (Bover-Cid and Holzapfel 1999). The presence of histidine *(hdc),* lysine *(ldc),* ornithine *(odc)* and tyrosine *(tdc)* decarboxylase genes in isolates was investigated using the primers given by De Las Rivas et al. (2006).

Journal of Food Safety and Food Quality 74, Heft 4 (2023), Seiten 101–128

Results and discussion

Identification of isolates

According to 16S rDNA gene sequence analysis, 30 isolates were identified to be *Lactiplantibacillus plantarum* (22), *Lacticaseibacillus paracasei* subsp. *tolerans* (3), *Latilactobacillus sakei* subsp. *sakei* (2), *Lacticaseibacillus rhamnosus* (1), *Limosilactobacillus fermentum* (1), and *Lactilactobacillus curvatus* (1). LAB are used as starter cultures in the production of many fermented foods due to their fermentation abilities.

The metabolites produced by LAB not only provide the desired taste, aroma, and textural properties to fermented products, but also contribute to extending the shelf life of the products (Rattanachaikunsopon and Phumkhachorn, 2010). Previous studies have shown that lactobacilli can be isolated in many fermented foods (Liu et al., 2009; Nawaz et al., 2011; Kumar and Kumar, 2015; Yüceer and Özden Tuncer, 2015; Eid et al., 2016; Sharma et al., 2016; Kakelar et al., 2019). Similar to our results, Dos Santos et al. (2015) reported that vancomycin-resistant *L. rhamnosus* and *L. plantarum* strains were isolated from Coalho cheese in Brazil. Pavli et al. (2016) found that lactobacilli isolated from traditional dairy products in Greece also include vancomycin-resistant *L. plantarum, L. pentosus, L. paraplantarum, L. sakei,* and *L. brevis.* Sharma et al. (2016) identified vancomycin-resistant *L. rhamnosus, L. acidophilus, L. fermentum,* and *L. plantarum* strains from commercial probiotic and pharmaceutical products.

Antibiotic susceptibility

The antibiotic resistance profiles of the isolates are given in Table 1. It was found that 90% (27/30) of the isolates had multidrug resistance. Similar to our results previous studies indicated that multidrug resistance was observed in *Lactobacillus* isolates (Kumar and Kumar, 2015; Anisimova and Yarullina, 2019). Considering that the examined isolates are food isolates, this situation may pose a serious threat to public health. Resistance to vancomycin (90.0%, 27/30), cefoxitin (86.67%, 26/30) and norfloxacin (66.67%, 20/30) was found to be most common among the isolates. Isolates were found to be resistant to other antibiotics used in this study at different rates. Antibiotic susceptibility and resistance rates of isolates were given in Table 2.

TABLE 1: *Antibiotic resistance profile, antibiotic resistance genes, hemolytic and gelatinase activities, virulence genes, biofilm formation genes, biogenic amine production and decarboxylase genes in isolates.*

Strain	Isolation material	Antibiotic resistance profile[a]	Antibiotic resistance genes	Hemolytic / gelatinase activities	Virulence genes	Biofilm formation genes	Biogenic amine production/ decarboxylase genes
Lactiplantibacillus plantarum DYB1	Lamb meat	AMP, RD, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB2	Goat meat	NOR, KF, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB3	Lamb meat	NOR, RD, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB5	Butter	NOR, OFX, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB6	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB7	White cheese	NOR, KF, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB8	Yoruk cheese	NOR, KF, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB9	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB10	Tulum cheese	NOR, OFX, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB12	Çökelek cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB15	Lamb meat	OFX	*vanX*	α / -	-	-	-
Lactiplantibacillus plantarum DYB16	Chicken breast meat	NOR, P, KF, FOX, CIP, VA	*vanX*	γ / -	-	-	-
Lactiplantibacillus plantarum DYB18	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB19	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB20	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB23	Otlu (herby) cheese	NOR, OFX, P, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB24	Tulum cheese	NOR, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB25	Tulum cheese	NOR, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB26	Sucuk	FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB27	Sucuk	NOR, OFX, P, KF, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB28	Sucuk	NOR, OFX, P, FOX, VA	*vanX*	weak α / -	-	-	-
Lactiplantibacillus plantarum DYB30	Sucuk	VA	*vanX*	weak α / -	-	-	-
Lacticaseibacillus rhamnosus DYB4	Kasar cheese	CN, K, FOX, S, VA	*vanX*	weak α / -	*acm*	-	-
Limosilactobacillus fermentum DYB11	Pastırma	K, NOR, FOX, CIP, S, VA	-	weak α / -	-	-	-
Lacticaseibacillus paracasei subsp. *tolerans* DYB13	Çökelek cheese	FOX, VA	*vanX*	weak α / -	-	-	-
Lacticaseibacillus paracasei subsp. *tolerans* DYB14	Ezine cheese	FOX, VA	*vanX*	weak α / -	*acm*, *efaA*$_{fs}$	-	-
Lacticaseibacillus paracasei subsp. *tolerans* DYB29	Ezine cheese	K, FOX, VA	-	weak α / -	-	-	-
Lactilactobacillus curvatus DYB17	Red mullet (*Mullus barbatus*)	CN, K, NOR, OFX, RD, CIP, S, VA	*vanX*	weak α / -	*acm*	-	Tyramine / *tdc*
Latilactobacillus sakei subsp. *sakei* DYB21	Chicken breast meat	FOX	*vanX*	α / -	-	-	-
Latilactobacillus sakei subsp. *sakei* DYB22	Chicken breast meat	OFX, FOX	*vanX*	weak α / -	-	-	-

[a]AMP: Ampicillin, CN: Gentamicin (10 µg), K: Kanamycin, NOR: Norfloxacin, OFX: Ofloxacin, P: Penicillin, RD: Rifampin, KF: Cephalothin, FOX: Cefoxitin, CIP: Ciprofloxacin, S: Streptomycin (10 µg), VA: Vancomycin

TABLE 2: *Antibiotic susceptibility and resistance (%) of vancomycin-resistant lactobacilli isolates.*

					Interpretative zone diameters (mm) [d]		
Antibiotic	Concentration µg/disk	Sensitive	Intermediary	Resistance	R	I	S
Ampicillin[a]	10	96.67	0	3.33	≤12	13-15	≥16
Cefoxitin[a]	30	6.67	6.67	86.67	≤14	15-17	≥18
Cephalothin[a]	30	73.33	10	16.67	≤14	15-17	≥18
Chloramphenicol[a]	30	100.0	0	0	≤13	14-17	≥18
Ciprofloxacin[a]	5	40	50	10	≤13	14-18	≥19
Clindamycin[a]	2	100.0	0	0	≤8	9-11	≥12
Erythromycin[a]	15	96.67	3.33	0	≤13	14-17	≥18
Gentamicin (low-level)[a]	10	93.33	0	6.67	≤12	-	≥13
Gentamicin (high-level)[b]	120	100.0	0	0	6	7-9	≥10
Kanamycin[a]	30	73.33	13.33	13.33	≤13	14-17	≥18
Norfloxacin[a]	10	13.33	20	66.67	≤13	14-18	≥19
Ofloxacin[a]	5	16.67	56.67	26.67	≤13	14-18	≥19
Penicillin G[a]	10[c]	46.67	40	13.33	≤19	20-27	≥28
Rifampin[a]	5	90	0	10	≤14	15-17	≥18
Streptomycin (low-level)[a]	10	80	10	10	≤11	12-14	≥15
Streptomycin (high-level)[b]	300	100.0	0	0	6	7-9	≥10
Tetracycline[a]	30	100.0	0	0	≤14	15-18	≥19
Vancomycin[a]	30	10	0	90	≤14	15-16	≥17

[a]Charteris et al. (1998); [b]CLSI (2016) Performance Standards for Antimicrobial Susceptibility Testing 26th Information Supplement. [c]Penicillin G 10 U/disk; [d]R: resistant, I: intermediary, S: susceptible

The glycopeptide antibiotic vancomycin acts by inhibiting the synthesis of peptidoglycan, which provides mechanical stability to the cell wall. Vancomycin is used in the treatment of infections caused by Gram-positive bacteria with multiple antibiotic resistance and is very important in clinical applications (Kristich et al., 2014). For this reason, the presence of transferrable vancomycin resistance genes in lactobacilli used for commercial purposes is the main concern due to the possibility of transferring antibiotic resistance genes to pathogenic bacteria (Bernardeau et al. 2008). On the other hand, it has been reported that some *Lactobacillus* species are naturally resistant to vancomycin (Gueimonde et al., 2013). Different researchers stated that the *Lactobacillus* isolates they examined were highly resistant to vancomycin (Yüceer and Özden Tuncer, 2015; Sharma et al., 2016; Anisimova and Yarullina, 2019; Saif and Sakr, 2020). The data that 90% of the lactobacilli isolates examined in this study were resistant to vancomycin is similar to the previous data. The MIC values of all isolates were found to be > 256 µg/mL for vancomycin. The data obtained in this study shows similarities with the studies conducted by different researchers (Dos Santos et al., 2015; Georgieva et al., 2015; Pavli et al., 2016). In a study examining the antimicrobial activity and antibiotic susceptibility of *Lactobacillus* isolates collected from different ecological niches, it was reported that 10 of 23 *Lactobacillus* isolates were resistant to vancomycin (> 256 µg/mL) (Georgieva et al., 2015). Dos Santos et al. (2015) reported that *L. plantarum* and *L. rhamnosus* isolates (except *L. plantarum* EM270), which they examined, showed high resistance to vancomycin (MIC >256 µg/mL). Pavli et al. (2016) found that the vancomycin MIC values of *Lactobacillus* isolates that they isolated from traditional fermented products of Greece were >256 µg/mL (except *L. lactis* T4 with an MIC of 32 µg/mL and *L. brevis* T47 with an MIC of 64 µg/mL). Although all isolates were found to be resistant to vancomycin according to the MIC results, *Lactiplantibacillus plantarum* DYB15, *Latilactobacillus sakei* subsp. *sakei* DYB21, and *Latilactobacillus sakei* subsp. *sakei* DYB22 strains were determined sensitive to vancomycin by the antibiotic disk diffusion test. A 10% very major error was found when disk diffusion results and MIC values of the isolates were compared. This means that these three strains were found to be false-susceptible in the disk diffusion test. The very major error rate of isolates was found to be higher than acceptable error rates (3%) according to CLSI guidelines (CLSI, 2016). The results of antibiotic susceptibility tests showed that the vancomycin susceptibility of lactobacilli isolates should be examined according to the MIC method. Similarly, very major errors were reported for the antibiotic disk diffusion test for vancomycin (Akpınar Kankaya and Tuncer, 2020) and high-level of gentamicin and streptomycin (Özdemir and Tuncer, 2020).

Another peptidoglycan inhibitor is β-lactam group of antibiotics (Pandey and Cascella, 2021). In this study, 46.67% and 96.67% of the isolates were found to be susceptible to penicillin G and ampicillin, respectively. Similar to our results, previous studies have shown that lactobacilli are sensitive to penicillin G (Bacha et al., 2010; Yüceer and Özden Tuncer, 2015; Talib et al., 2019) and ampicillin (Sharma et al., 2016; Anisimova and Yarullina, 2019; Talib et al., 2019). Beta-lactams are broad-spectrum antibiotics used for clinical purposes. Compared to other classes, beta-lactam antibiotics are generally safe and well tolerated (Chiriac et al., 2017). For this reason, resistance to this group of antibiotics is a concern for public health.

Since the ribosome is responsible for the synthesis of all cell proteins, it is an important target for antibiotics. Many antibacterial agents prevent cell development by affecting ribosome functions (Wilson, 2014; Lin et al., 2018). Due to the low permeability of the cell surface to aminoglycosides, lactobacilli are usually intrinsically resistant to low-level aminoglycosides, which act by disrupting the protein synthesis of the cell (Liu et al., 2009; Sharma et al., 2016; Anisimova and Yarullina, 2019). Disk difusion test results showed that a low rate of isolates were found to be resistant to kanamycin (13.33%), low-level streptomycin (10%), and low-level gentamicin (6.67%). Contrary to our results, high rates of aminoglycoside resistance have been reported in previous studies (Yüceer and Özden Tuncer, 2015; Sharma et al., 2016; Anisimova and Yarullina, 2019). However, all (100%) of the isolates examined in our study were found to be susceptible to high-level gentamicin and streptomycin, as well as 73.33% of isolates were found to be sensitive to kanamycin. Lactobacilli do not usually cause infections. However, they can cause various infections in immunocompromised individuals. Because of the synergistic effect, the use of aminoglycosides together with β-lactams is generally recommended in the treatment of these infections (Slover and Danziger, 2008; Grazioli-Gauthier et al., 2022). Moreover, aminoglycosides have an important role in the treatment of infections caused by pathogenic bacteria that threaten human life. Therefore, the spread of high-level aminoglycoside resistance in bacteria leads to difficulties in the treatment of bacterial infections (Jaimee and Halami, 2016; Sparo et al., 2018). The fact that a high-level aminoglycoside resistance can be encoded on mobile genetic elements raises concerns due to the possibility of transmission of resistance genes from commensal bacteria to pathogenic bacteria (Özdemir and Tuncer, 2020; Yalçın et al., 2023). The use of clinically important antibiotics for growth-promoting purposes in animals is prohibited in most countries (Jaimee and Halami, 2016; Sparo et al., 2018). However, aminoglycoside antibiotics are recommended for use as therapeutic and protective agents in farm animals due to their effects against Gram-positive and Gram-negative bacteria (Jaimee and Halami, 2016). High-level aminoglycoside resistance is associated with transferable aminoglycoside-modifying enzymes (AMEs) genes (Niu et al., 2016; Özdemir and Tuncer, 2020). Therefore, the sensitivity of isolates to high-level aminoglycosides is important for the safety of the strains.

Antibiotics, members of the macrolide group, target the bacterial ribosome and also inhibit protein synthesis (Vázquez-Laslop and Mankin, 2018). It was determined that 96.67% of the isolates were susceptible to the macrolide group antibiotic erythromycin. Similar to our results, lactobacilli from fermented milk products and traditional fermented foods were found to be sensitive to erythromycin in previous studies (Liu et al., 2009; Turchi et al., 2013; Yadav et al., 2016; Saif and Sakr, 2020).

Quinolones inhibit DNA replication by binding to type II topoisomerases (DNA gyrase and DNA topoisomerase IV), which are responsible for DNA supercoiling (Kristich et al., 2014). In this study, 66.67% (/30), 26.67% (/30) and 10% (3/30) of isolates were found to be resistant to norfloxacin, ofloxacin and ciprofloxacin, respectively. Similarly, the presence of lactobacilli resistant to norfloxacin, ofloxacin, and ciprofloxacin has been reported by Sharma et al. (2016) and Anisimova and Yarullina (2019). Yüceer and Özden Tuncer (2015) reported that all of the lactobacilli isolated from fermented Turkish sausages were resistant to ofloxacin and 83.33% to norfloxacin.

Journal of Food Safety and Food Quality 74, Heft 4 (2023), Seiten 101–128

All isolates tested in the study were found susceptible to chloramphenicol, which is in agreement with the results obtained in previous studies (Liu et al., 2009; Turchi et al., 2013; Sharma et al., 2016; Anisimova and Yarullina, 2019). All of the strains examined in this study were found to be sensitive to tetracycline and clindamycin, and 90% to rifampin. Previous studies have shown that lactobacilli are generally sensitive to tetracycline and clindamycin, which act by inhibiting protein synthesis (Sharma et al., 2016; Anisimova and Yarullina, 2019; Talib et al., 2019). Cefoxitin is another antimicrobial to which lactobacilli are generally considered resistant. Cell wall impermeability is probably the main mechanism of resistance to cefoxitin (Delgado et al. 2007). The lactobacilli examined were generally resistant (86.67%) against cefoxitin. At the same time, 73.33% of the isolates were found to be susceptible to cephalothin. Similarly, Sharma et al. (2016) stated that 90% of the isolates they examined were susceptible to cephalothin.

Antibiotic resistance genes

Today, the spread of antibiotic resistance among pathogenic bacteria poses a global risk to public health. The use of antibiotics outside of clinical practice not only promotes the development of antibiotic resistance in bacteria, but may also lead to the spread of resistant pathogenic bacteria, which may compromise the efficacy of antibiotic therapy. The high intake of LAB, which contain transferable antibiotic resistance genes, into the body through foods raises the risk that these bacteria could act as a reservoir for the spread of resistance genes to other bacteria (Rozman et al., 2020). Of the resistance genes tested in this study, only *vanX* could be detected among the isolates (Table 1). The presence of the *vanX* gene was detected in all isolates, except *Limosilactobacillus fermentum* DYB11 and *Lacticaseibacillus paracasei* subsp. *tolerans* DYB29. Similar to our results, previous studies indicated that the *vanX* gene is commonly observed among *Lactobacillus* isolates (Guo et al., 2017; Anisimova and Yarullina, 2019). It is thought that vancomycin resistance is provided by a different mechanism in *Limosilactobacillus fermentum* DYB11 and *Lacticaseibacillus paracasei* subsp. *tolerans* DYB29 strains with phenotypically vancomycin-resistant detected but no *vanX* gene found. Similarly, Toomey et al. (2010), Zhang et al. (2013), and Shao et al. (2015) did not detect the presence of vancomycin resistance genes in phenotypically vancomycin-resistant *Lactobacillus* isolates. Even if the isolates are resistant to antibiotics, they may not contain antibiotic resistance genes. This may be due to the presence of natural antibiotic resistance in isolates, biofilm formation, mutations or changes in membrane structure, or the presence of resistance genes in isolates that could not be detected by the methods used in the study (Zhang et al., 2013).

Erythromycin, tetracycline, gentamicin, and streptomycin resistance genes were not detected in any of the isolates by PCR. These results confirm the disk diffusion test results. According to antibiotic disk diffusion results, all of the isolates were found to be sensitive to erythromycin (except for intermediate resistant *Lactiplantibacillus plantarum* DYB7), tetracycline, high-level gentamicin, and high-level streptomycin. Conversely to our results, it was reported that erythromycin (Ammor et al., 2008; Comunian et al., 2010; Mayrhofer et al., 2010; Nawaz et al., 2011; Gueimonde et al., 2013; De Souza et al., 2019; Arellano et al., 2020), tetracycline (Comunian et al., 2010; Mayrhofer et al., 2010; Nawaz et al., 2011; Gueimonde et al., 2013; Arellano et al., 2020), gentamicin (Shao et al., 2015; De Souza et al., 2019; Arellano et al., 2020) and streptomycin (Shao et al., 2015; De Souza et al., 2019; Arellano et al., 2020) resistance genes were previously detected in *Lactobacillus* isolates. It is important for the safety of isolates that they do not include antibiotic resistance genes that may be transferred to other organisms.

Hemolytic and gelatinase activities

As a result of the hemolytic activity test, it was determined that 27 (90%) of the isolates showed weak α-hemolytic activity, two (6.67%) showed α-hemolytic activity and one (3.33%) γ-hemolytic activity. β-hemolytic activity was not detected in any of our isolates (Table 1). *Lactobacillus* isolates were shown to be absent of β-hemolytic activity in a number of investigations (Saelim et al., 2017; Abouloifa et al., 2020; Banwo et al., 2021), which is in agreement with our results. Since hemolytic activity is an important virulence factor that threatens human health, isolates to be used as starter cultures or for probiotic purposes should not show beta-hemolytic activity (Semedo et al., 2003).

Gelatinase activity was not detected in any of the isolates (Table 1). This result is consistent with the findings for *Lactobacillus* isolates of other researchers (Aarti and Khusro et al., 2019; Mami et al., 2019; Abouloifa et al., 2020; Saif and Sakr, 2020; Banwo et al., 2021). As stated by the Food and Agriculture Organization (FAO) and EFSA, no strains with hemolytic/gelatinase activity are allowed to be used in food production (FAO, 2006; EFSA, 2012).

Detection of virulence factors

Virulence factors are effector molecules that increase the disease-causing effect of microorganisms. Except for some *L. rhamnosus* strains, which are opportunistic pathogens, *Lactobacillus* species are not considered pathogenic for humans (EFSA, 2007). Despite the general acceptance of lactobacilli as safe, it is important to investigate the virulence factors of lactobacilli due to their potential applications in food products because these genes are usually plasmid encoded and there is a risk of transmission to intestinal pathogens (Eaton and Gasson, 2001). In this study, the acm gene was detected in three (10%) and $efaA_{fs}$ in one (3.33%) of the isolates. The gelatinase *(gelE)*, cell wall adhesion $(efaA_{fm})$, sex pheromones *(cpd, cob, ccf, cad)*, collagen-binding protein *(ace)*, aggregation protein *(agg)*, cytolysin *(cylM, cylB, cylA)*, hyaluronidase *(hyl)* genes were found in none of the isolates (Table 1). Previous study on the virulence factor genes in *Lactobacillus* has found that isolates either do not have any virulence factor genes or have a low rate of them, which is consistent with our findings (Dos Santos et al. 2015; Sanchart et al., 2016; Li et al., 2017; Saelim et al., 2017; Arellano et al., 2020). The collagen-binding proteins Ace and Acm are encoded by the *ace* and *acm* genes, respectively (Rich et al., 1999; Nallapareddy et al., 2008). Collagen-binding proteins, which play an important role in colonization, are effective on endocarditis in previous studies (Nallapareddy et al., 2008; Singh et al., 2010). It has also been reported that ace proteins facilitate binding to collagen during infections (Girish and Kemparaju, 2007). Efa is an important colonization factor (Kafil et al., 2016), and it also plays an important role in biofilm formation (Kafil et al., 2016; Beomidehagh et al., 2018; Narenji et al., 2020). In particular, $efaA_{fs}$ has been reported to play a pathological role in animal models (Eaton and Gasson, 2001). Similar to our results, the

presence of the *ace* gene in one *L. rhamnosus* and three *L. plantarum* strains isolated from artisanal Coalho cheeses was reported by Dos Santos et al. (2015). De Moraes et al. (2017) detected the *efaA* in the *L. mucosae* CNPC009 strain isolated from goat milk. Furthermore, Motahari et al. (2017) indicated that both the *ace* and $efaA_{fs}$ genes were found in the *L. pentosus* 22C strain isolated from Iranian traditional yogurt. According to the results of this study, gelatinase activity was not found in any of the isolates. This was in line with the fact that the *gelE* gene was not found in the isolates. In the same way, the lack of *cylA, cylB,* and *cylM* genes in isolates and the absence of hemolytic activity in isolates support one another.

Detection of biofilm production genes

The presence of biofilm production associated genes encoding extracellular surface protein *(esp_{fm}, esp_{fs})*, endocarditis and biofilm-associated pili *(ebpA, ebpB, ebpC)*, and D-alanine lipotaichoic acid *(dltA)* was not detected in isolates (Table 1). Similar to the data obtained in our study, some researchers reported that the *Lactobacillus* isolates did not have the *esp* gene (Jeronymo-Ceneviva et al., 2014; Todorov et al., 2017; De Souza et al., 2019). Biofilm-associated pili (Ebp) are among the virulence factors that play an important role in biofilm formation and endocarditis development in *E. faecalis* (Nallapareddy et al., 2006). Similar to the data obtained in our study, Landeta et al. (2013) reported that the *ebpA* gene was not found in *L. paracasei, L. plantarum,* and *L. sakei* strains, isolated from dry-cured sausages. Teichoic acids are molecules found in the cell-wall of Gram-positive bacteria. Commonly, it consists of variable-length polyglycerol phosphate or polyribitol phosphate chains substituted by glycosyl residues, D-alanyl esters, or both. Studies on dlt mutants show that D-alanyl ester reduction of teichoic acid affects various phenotypes in Gram-positive bacteria, especially biofilm production (Walter et al., 2007). The dlt operon has been extensively studied in enterococci isolates (Fabretti et al., 2006; Wang et al., 2015). However, there are limited studies on the presence and effects of the *dltA* gene in *Lactobacillus* isolates. Along with that, it has been reported that d-alanylation of teichoic acid is an important cell function for the survival of *L. reuteri* in acidic environments and other adverse stomach conditions (Walter et al., 2007). The biofilm formed by lactobacilli has been mostly studied in terms of the survival of probiotic bacteria and interaction with the host. Some researchers state that biofilm formation of starter cultures is a positive feature, as it will prevent the adhesion of pathogens and spoilage bacteria by providing colonization of starter cultures (Leriche and Carpentier, 2000; Lebeer et al., 2007). However, biofilm formation is undesirable because of the potential problems it creates in the food industry, and biofilm-forming isolates are more resistant to antimicrobials (Radovanovic et al., 2020). In studies conducted by different researchers, biofilm production has been reported in lactobacilli (Landeta et al., 2013; Zhang et al., 2013; Sun et al., 2020).

Detection of biogenic amine production and amino acid decarboxylase genes

Phenotypic decarboxylase activity tests indicated that only the *Lactilactobacillus curvatus* DYB17 strain decarboxylated tyrosine, but other strains did not decarboxylate any of the precursor amino acids used in this study. These results showed 100% corelation with the PCR results (Table 1). The tyrosine decarboxylase gene *tdc* was detected only in the *Lactilactobacillus curvatus* DYB17 strain. The amino acid decarboxylase genes *tdc, hdc, odc,* or *ldc* were not detected in any of the other strains. Similar to our results, De Moraes et al. (2017) reported that the *tdc* gene was detected only in the *L. mucosae* CNPC009 strain among three *L. mucosae* isolates. Previously, biogenic amine production was not detected in *Lactobacillus* species isolated from food samples (Lee et al., 2011; Zhang et al., 2012; Yüceer and Özden Tuncer, 2015; Sanchart et al., 2016; Arellano et al., 2020). On the other hand, the presence of biogenic amin producer *Lactobacillus* strains was detected in wine (Bonnin-Jusserand et al., 2012), sausage (Pircher et al., 2007; Moracanin et al., 2015) and cheese (Pircher et al., 2007; Diaz et al., 2016). Biogenic amine production is associated with food fermentation (Shiling et al., 2015) and causes serious health problems if consumed in high amounts (Arellano et al., 2020). Except for *Lactilactobacillus curvatus* DYB17, all isolates were found to be safe in terms of biogenic amine production.

Conclusion

The isolates were found to be susceptible to most of the clinically important antibiotics. Only the *vanX* gene was detected in isolates, and none of the isolates contained transferrable antibiotic resistance genes examined in this study. When disk diffusion results and MIC values of the isolates were compared, a 10% very major error was found. The results of this study showed that the disk diffusion test should be supported by the MIC test in the investigation of vancomycin resistance in lactobacilli. As a result of the analysis in which the safety evaluation of isolates was performed, it was determined that they had a generally low-risk profile. These results are an advantage in terms of consumer health. Isolates that are shown to be safe for human consumption in future research may then be studied for their technological and probiotic capabilities to assess their use in the food industry.

Funding

This study was supported by the Scientific Research Fund of Isparta University of Applied Sciences with project no. 2020-BTAP1-0079.

Conflict of interest

The authors declare no conflicts of interest.

ORCID

Didem Akpınar Kankaya: 0000-0002-1091-6210
Banu Özden Tuncer: 0000-0001-9678-4441
Yasin Tuncer: 0000-0002-2075-5027

References

Aarti C, Khusro, A (2019): Functional and technological properties of exopolysaccharide producing autochthonous Lactobacillus plantarum strain AAS3 from dry fish based fermented food. LWT - Food Sci Technol 114:108387.

Journal of Food Safety and Food Quality 74, Heft 4 (2023), Seiten 101–128

Abed TA (2013): Evaluation of methods for the extraction and purification of DNA of cultured Lactobacillus colony isolated from dairy products. Int J Appl Microbiol Biotechnol Res 1:20-25.

Abouloifa H, Rokni Y, Bellaouchi R, Ghabbour N, Karboune S, Brasca M, Ben Salah R, Chihib NE, Saalaoui E, Asehraou A (2020): Characterization of probiotic properties of antifungal Lactobacillus strains isolated from traditional fermenting green olives. Probiotics Antimicrob Proteins 12(2):683-696.

Akpınar Kankaya D, Tuncer Y (2020): Antibiotic resistance in vancomycin-resistant lactic acid bacteria (VRLAB) isolated from foods of animal origin. J Food Process Pres 44(6):e14468.

Ammor MS, Flórez AB, Mayo B (2007): Antibiotic resistance in non-enterococcal lactic acid bacteria and bifidobacteria. Food Microbiol 24(6):559-570.

Ammor MS, Flórez AB, Van Hoek AH, Clara G, Aarts HJ, Margolles A, Mayo B (2008): Molecular characterization of intrinsic and acquired antibiotic resistance in lactic acid bacteria and bifidobacteria. J Mol Microbiol Biotechnol 14(1-3):6-15.

Anisimova EA, Yarullina, DR (2019): Antibiotic resistance of Lactobacillus strains. Curr Microbiol 76(12):1407-1416.

Arellano K, Vazquez J, Park H, Lim J, Ji Y, Kang HJ, Cho D, Jeong HW, Holzapfel WH (2020): Safety evaluation and whole-genome annotation of Lactobacillus plantarum strains from different sources with special focus on isolates from green tea. Probiotics Antimicrob Proteins 12(3):1057-1070.

Bacha K, Mehari T, Ashenafi M (2010): Antimicrobial susceptibility patterns of lab isolated from Wakalim, a traditional Ethiopian fermented sausage. J Food Safety 30(1):213-223.

Badr S, Karem A, Hussein H, El-Hadedy D (2005): Characterization of nisin produced by Lactococcus lactis. Int J Agric Biol 7(3):499-503.

Banwo K, Alonge Z, Sanni AI (2021): Binding capacities and antioxidant activities of Lactobacillus plantarum and Pichia kudriavzevii against cadmium and lead toxicities. Biol Trace Elem Res 199(2):779-791.

Belgacem ZB, Abriouel H, Omar NB, Lucas R, Martínez-Canamero M, Gálvez A, Manai M (2010): Antimicrobial activity, safety aspects, and some technological properties of bacteriocinogenic Enterococcus faecium from artisanal Tunisian fermented meat. Food Control 21(4):462-470.

Beomidehagh M, Rezaee MA, Ganbarov K, Jafari F, Hasani A, Alizadeh N, Tanomand A, Kafil HS (2018): Effect of acidic and alkali shocks on expression of efaA gene in Enterococcus faecalis, isolated from root canal infection. Cell Mol Biol 64(13):1-5.

Bernardeau M, Guguen M, Vernoux JP (2006): Beneficial lactobacilli in food and feed: long-term use, biodiversity and proposals for specific and realistic safety assessments. FEMS Microbiol Rev 30(4):487-513.

Bernardeau M, Vernoux JP, Henri-Dubernet S, Guéguen M (2008): Safety assessment of dairy microorganisms: the Lactobacillus genus. Int J Food Microbiol 126(3):278-285.

Bonnin-Jusserand M, Grandvalet C, Rieu A, Weidmann S, Alexandre H (2012): Tyrosine-containing peptides are precursors of tyramine produced by Lactobacillus plantarum strain IR BL0076 isolated from wine. BMC Microbiol 12(1):1-11.

Bover-Cid S, Holzapfel WH (1999): Improved screening procedure for biogenic amine production by lactic acid bacteria. Int J Food Microbiol 53(1):33-41.

Camargo ILBC, Gilmore MS, Darini ALC (2006): Multilocus sequence typing and analysis of putative virulence factors in vancomycin-resistant and vancomycin-sensitive Enterococcus faecium isolates from Brazil. Clin Microbiol Infect 12(11):1123-1130.

Cancilla MR, Powell IB, Hillier AJ, Davidson BE (1992): Rapid genomic fingerprinting of Lactococcus lactis strains by arbitrarily primed polymerase chain reaction with 32P and fluorescent labels. Appl Environ Microb 58(5):1772-1775.

Cariolato D, Andrighetto C, Lombardi A (2008): Occurrence of virulence factors and antibiotic resistances in Enterococcus faecalis and Enterococcus faecium collected from dairy and human samples in North Italy. Food Control 19(9):886-892.

Charteris WP, Kelly PM, Morelli L, Collins JK (1998): Antibiotic susceptibility of potentially probiotic Lactobacillus species. J Food Protect 61(12):1636-1643.

Chiriac AM, Rerkpattanapipat T, Bousquet PJ, Molinari N, Demoly P (2017): Optimal step doses for drug provocation tests to prove beta-lactam hypersensitivity. Allergy 72(4):552-561.

CLSI, Clinical and Laboratory Standards Institute (2016): Performance standards for antimicrobial disk susceptibility tests; twenty-six informational supplement. M100-S26, Wayne, PA: Clinical & Laboratory Standards Institute.

Comerlato CB, Resende MCCD, Caierão J, d'Azevedo PA (2013): Presence of virulence factors in Enterococcus faecalis and Enterococcus faecium susceptible and resistant to vancomycin. Mem I Oswaldo Cruz 108:590-595.

Comunian R, Daga E, Dupré I, Paba A, Devirgiliis C, Piccioni, V., Perozzi G, Zonenschain D, Rebecchi A, Morelli L, De Lorentiis A, Giraffa, G (2010): Susceptibility to tetracycline and erythromycin of Lactobacillus paracasei strains isolated from traditional Italian fermented foods. Int J Food Microbiol 138(1-2):151-156.

Courvalin P (2006a): Antibiotic resistance: the pros and cons of probiotics. Digest Liver Dis 38:261-265.

Courvalin P (2006b): Vancomycin resistance in gram-positive cocci. Clin Infect Dis 42(1):25-34.

Das DJ, Shankar A, Johnson JB, Thomas S (2020): Critical insights into antibiotic resistance transferability in probiotic Lactobacillus. Nutrition 69:110567.

Davies J, Davies D (2010): Origins and evolution of antibiotic resistance. Microbiol Mol Biol R 74(3):417-433.

De Las Rivas B, Marcobal A, Carrascosa AV, Munoz R (2006): PCR detection of foodborne bacteria producing the biogenic amines histamine, tyramine, putrescine, and cadaverine. J Food Protect 69(10):2509-2514.

De Moraes GMD, de Abreu LR, do Egito AS, Salles HO, da Silva LMF, Nero LA, Todorov SD, Dos Santos, KMO (2017): Functional properties of Lactobacillus mucosae strains isolated from Brazilian goat milk. Probiotics Antimicrob Proteins 9(3):235-245.

De Souza BMS, Borgonovi TF, Casarotti SN, Todorov SD, Penna ALB (2019): Lactobacillus casei and Lactobacillus fermentum strains isolated from mozzarella cheese: probiotic potential, safety, acidifying kinetic parameters and viability under gastrointestinal tract conditions. Probiotics Antimicrob Proteins 11(2):382-396.

Delgado S, O'Sullivan, E, Fitzgerald G, Mayo, B (2007): Subtractive screening for probiotic properties of Lactobacillus species from the human gastrointestinal tract in the search for new probiotics. J Food Sci 72(8):310-315.

Demirgül F, Tuncer Y (2017): Detection of antibiotic resistance and resistance genes in enterococci isolated from sucuk, a traditional Turkish dry-fermented sausage. Korean J Food Sci Anim Resour 37(5): 670-681.

Depardieu F, Perichon B, Courvalin P (2004): Detection of the van alphabet and identification of enterococci and staphylococci at the species level by multiplex PCR. J Clin Microbiol 42(12):5857-5860.

Diaz M, Del Rio B, Sanchez-Llana E, Ladero V, Redruello B, Fernández M, Martin C, Alvarez MA (2016): Histamine-producing Lactobacillus parabuchneri strains isolated from grated cheese can form biofilms on stainless steel. Food Microbiol 59:85-91.

Donlan RM (2002): Biofilms: microbial life on surfaces. Emerg Infect Dis 8(9):881.

Dos Santos KMO, Vieira ADS, Buriti FCA, do Nascimento JCF, de Melo MES, Bruno LM, Borges MF, Rocha CRC, Lopes ACS, Franco BDGM, Todorov SD (2015): Artisanal Coalho cheeses as source of beneficial Lactobacillus plantarum and Lactobacillus rhamnosus strains. Dairy Sci Technol 95(2):209-230.

Dugassa J, Shukuri N (2017): Review on antibiotic resistance and its mechanism of development. J Health Med Nurs, 1(3):1-17.

Dutka-Malen S, Evers S, Courvalin P (1995): Detection of glycopeptide resistance genotypes and identification to the species level of clinically relevant enterococci by PCR. J Clin Microbiol 33(1):24-27.

Eaton TJ, Gasson, MJ (2001): Molecular screening of Enterococcus virulence determinants and potential for genetic exchange between food and medical isolates. Appl Environ Microb 67(4):1628-1635.

Edwards U, Rogall T, Blöcker H, Emde M, Böttger EC (1989): Isolation and direct complete nucleotide determination of

entire genes. Characterization of a gene coding for 16S ribosomal RNA. Nucleic Acids Res 17(19):7843-7853.

Eid R, Jakee JE, Rashidy A, Asfour H, Omara S, Kandil MM, Mahmood Z, Hahne J, Seida, AA (2016): Potential antimicrobial activities of probiotic Lactobacillus strains isolated from raw milk. J Probiotics Health 4(2):138.

Eliopoulos GM, Gold HS (2001): Vancomycin-resistant enterococci: mechanisms and clinical observations. Clin Infect Dis 33(2):210-219.

European Food Safety Authority (EFSA) (2012): EFSA Panel on Additives and Products or Substances used in Animal Feed (FEEDAP). Guidance on the assessment of bacterial susceptibility to antimicrobials of human and veterinary importance. EFSA Journal 10(6):10, 2740.

European Food Safety Authority (EFSA) (2011): EFSA Panel on Biological Hazards (BIOHAZ); Scientific opinion on risk based control of biogenic amine formation in fermented foods. EFSA Journal 9(10):93, 2393.

European Food Safety Authority (EFSA) (2007): Introduction of a Qualified Presumption of Safety (QPS) approach for assessment of selected microorganisms referred to EFSA-Opinion of the Scientific Committee. EFSA Journal 5(12):587.

European Food Safety Authority (EFSA) (2005): The EFSA's 2nd Scientific Colloquium Report-Qps. EFSA Supporting Publications 2(2):109E.

Fabretti F, Theilacker C, Baldassarri L, Kaczynski Z, Kropec A, Holst O, Huebner J (2006): Alanine esters of enterococcal lipoteichoic acid play a role in biofilm formation and resistance to antimicrobial peptides. Infect Immun 74(7):4164-4171.

Fisher K, Phillips C (2009): The ecology, epidemiology and virulence of Enterococcus. Microbiology 155(6):1749-1757.

Food and Agriculture Organization (FAO) (2006): Probiotic in Food: Health and Nutrition Properties and Guidelines for Evaluation; FAO Food Nutrition Paper; FAO: Roma, Italy, Volume 85, 56p.

Franz CMAP, Cho GS, Holzapfel WH, Gálvez A (2010): Safety of Lactic Acid Bacteria. In: Mozzi F, Raya RR, Vignolo GM (Eds.), Biotechnology of Lactic Acid Bacteria Novel Applications. Wiley-Blackwell, 341-361.

Fraqueza MJ (2015): Antibiotic resistance of lactic acid bacteria isolated from dry-fermented sausages. Int J Food Microbiol 212:76-88.

Garcia-Migura L, Liebana E, Jensen LB (2007): Transposon characterization of vancomycin-resistant Enterococcus faecium (VREF) and dissemination of resistance associated with transferable plasmids. J Antimicrob Chemoth 60(2):263-268.

Georgieva R, Yocheva L, Tserovska L, Zhelezova G, Stefanova N, Atanasova A, Danguleva A, Ivanova G, Karapetkov N, Rumyan N, Karaivanova, E (2015): Antimicrobial activity and antibiotic susceptibility of Lactobacillus and Bifidobacterium spp. intended for use as starter and probiotic cultures. Biotechnol Biotechnol Equip 29(1):84-91.

Girish KS, Kemparaju K (2007): The magic glue hyaluronan and its eraser hyaluronidase: a biological overview. Life Sci 80(21):1921-1943.

Goldstein EJ, Tyrrell KL, Citron DM (2015): Lactobacillus species: taxonomic complexity and controversial susceptibilities. Clin Infect Dis 60(2):98-107.

Grazioli-Gauthier L, Rigamonti E, Leo LA, Lucchinic GM, Priore EL, Bernascon, E (2022): Lactobacillus jensenii mitral valve endocarditis: Case report, literature review and new perspectives. IDCases 27:e01401.

Gueimonde M, Sánchez BG, de los Reyes-Gavilán C, Margolles A (2013): Antibiotic resistance in probiotic bacteria. Front Microbiol 4:202.

Guo H, Pan L, Li L, Lu J, Kwok L, Menghe B, Zhang H, Zhang W (2017): Characterization of antibiotic resistance genes from Lactobacillus isolated from traditional dairy products. J Food Sci 82(3):724-730.

Inoğlu ZN, Tuncer Y (2013): Safety assessment of Enterococcus faecium and E nterococcus faecalis strains isolated from Turkish Tulum Cheese. J Food Safety 33(3):369-377.

Jaimee G, Halami PM (2016): High level aminoglycoside resistance in Enterococcus, Pediococcus and Lactobacillus species from farm animals and commercial meat products. Ann Microbiol 66(1):101-110.

Jeronymo-Ceneviva AB, de Paula AT, Silva LF, Todorov SD, Franco BDGM, Penna ALB (2014): Probiotic properties of lactic acid bacteria isolated from water-buffalo mozzarella cheese. Probiotics Antimicrob Proteins 6(3):141-156.

Jiménez E, Ladero V, Chico I, Maldonado-Barragán A, López M, Martín V, Fernández L, Fernández M, Álvarez MA, Torres C, Rodríguez JM (2013): Antibiotic resistance, virulence determinants and production of biogenic amines among enterococci from ovine, feline, canine, porcine and human milk. BMC Microbiol 13(1):1-12.

Kafil HS, Mobarez AM, Moghadam MF, sadat Hashemi Z, Yousefi M (2016): Gentamicin induces efaA expression and biofilm formation in Enterococcus faecalis. Microb Pathogenesis 92:30-35.

Kakelar HM, Barzegari A, Hanifian S, Barar J, Omidi Y (2019): Isolation and molecular identification of Lactobacillus with probiotic potential from abomasums driven rennet. Food Chem 272:709-714.

Kasap M, Tuncer Y, (2019): Fermente sucuktan izole edilen mundtisin KS üreticisi Enterococcus mundtii YB6.30 suşunun teknolojik özellikleri ve güvenlik değerlendirmesi. The Journal of Food 44(5):866-880.

Klein G, Hallmann C, Casas IA, Abad J, Louwers J, Reuter G (2000): Exclusion of *vanA*, *vanB* and vanC type glycopeptide resistance in strains of Lactobacillus reuteri and Lactobacillus rhamnosus used as probiotics by polymerase chain reaction and hybridization methods. J Appl Microbiol 89(5):815-824.

Kristich CJ, Rice LB, Arias CA (2014): Enterococcal Infection-Treatment and Antibiotic Resistance, In: Gilmore MS, Clewell DB, Ike Y, Shankar N (Eds.) Enterococci: From Commensals to Leading Causes of Drug Resistant Infection. Massachusetts Eye and Ear Infirmary, Boston, [Internet].

Kumar A, Kumar D (2015): Characterization of Lactobacillus isolated from dairy samples for probiotic properties. Anaerobe 33:117-123.

Kumar CG, Anand SK (1998): Significance of microbial biofilms in food industry: a review. Int J Food Microbiol 42(1-2):9-27.

Landeta G, Curiel JA, Carrascosa AV, Muñoz R, De Las Rivas B (2013): Technological and safety properties of lactic acid bacteria isolated from Spanish dry-cured sausages. Meat Sci 95(2):272-280.

Lebeer S, Verhoeven TL, Perea Vélez M, Vanderleyden J, De Keersmaecker SC (2007): Impact of environmental and genetic factors on biofilm formation by the probiotic strain Lactobacillus rhamnosus GG. Appl Environ Microb 73(21):6768-6775.

Lee H, Yoon H, Ji Y, Kim H, Park H, Lee, J, Shin H, Holzapfel W (2011): Functional properties of Lactobacillus strains isolated from kimchi. Int J Food Microbiol 145(1):155-161.

Lemcke R, Bülte M (2000): Occurrence of the vancomycin-resistant genes *vanA*, *vanB*, vanC1, vanC2 and vanC3 in Enterococcus strains isolated from poultry and pork. Int J Food Microbiol 60(2-3):185-194.

Lepargneur JP, Rousseau V (2002): Protective role of the Doderlein flora. J Gynecol Obst Bio R 31(5):485-494.

Leriche V, Carpentier B (2000): Limitation of adhesion and growth of Listeria monocytogenes on stainless steel surfaces by Staphylococcus sciuri biofilms. J Appl Microbiol 88(4):594-605.

Levy SB, Marshall B (2004): Antibacterial resistance worldwide: causes, challenges and responses. Nat Med 10(12):122-129.

Lewis K (2001): Riddle of biofilm resistance. Antimicrob Agents Ch 45(4):999-1007.

Li B, Jin D, Etareri Evivie S, Li N, Yan F, Zhao L, Liu F, Huo G (2017): Safety assessment of Lactobacillus helveticus KLDS1. 8701 based on whole genome sequencing and oral toxicity studies. Toxins 9(10):301.

Lin J, Zhou D, Steitz TA, Polikanov YS, Gagnon MG (2018): Ribosome-targeting antibiotics: modes of action, mechanisms of resistance, and implications for drug design. Annu Rev Biochem 87:451-478.

Linares DM, Martín M, Ladero V, Alvarez MA, Fernández M (2011): Biogenic amines in dairy products. Crit Rev Food Sci 51(7):691-703.

Liu C, Zhang ZY, Dong K, Yuan JP, Guo XK (2009): Antibiotic resistance of probiotic strains of lactic acid bacteria isolated from marketed foods and drugs, Biomed Environ Sci 22:401-412.

Mami A, Kheloufi A, Djelilate M, Kihal M, Mansouri LM (2019): Probiotic properties of Lactobacillus plantarum iso-

Journal of Food Safety and Food Quality 74, Heft 4 (2023), Seiten 101–128

lated from raw goat milk in the Northwestern Region of Algeria. Livest Res Rural Dev 31(7).

Mathur S, Singh R (2005): Antibiotic resistance in food lactic acid bacteria-A review. Int J Food Microbiol 105(3):281-295.

Mayrhofer S, Van Hoek AH, Mair C, Huys G, Aarts HJ, Kneifel W, Domig KJ (2010): Antibiotic susceptibility of members of the Lactobacillus acidophilus group using broth microdilution and molecular identification of their resistance determinants. Int J Food Microbiol 144(1):81-87.

Medina MÁ, Urdiales JL, Rodríguez-Caso C, Ramírez FJ, Sánchez-Jiménez F (2003): Biogenic amines and polyamines: similar biochemistry for different physiological missions and biomedical applications. Crit Rev Biochem Mol 38(1):23-59.

Moracanin SV, Stefanovic S, Radicevic T, Borovic B, Djukic D (2015): Production of biogenic amines by lactic acid bacteria isolated from Uzicka sausages. Procedia Food Sci 5:308-311.

Motahari P, Mirdamadi S, Kianirad M (2017): Safety evaluation and antimicrobial properties of Lactobacillus pentosus 22°C isolated from traditional yogurt. J Food Meas Charact 11(3):972-978.

Nallapareddy SR, Singh KV, Okhuysen PC, Murray BE (2008): A functional collagen adhesin gene, acm, in clinical isolates of Enterococcus faecium correlates with the recent success of this emerging nosocomial pathogen. Infect Immun 76(9):4110-4119.

Nallapareddy SR, Singh KV, Sillanpää J, Garsin DA, Höök M, Erlandsen SL, Murray BE (2006): Endocarditis and biofilm-associated pili of Enterococcus faecalis. J Clin Invest 116(10):2799-2807.

Narenji H, Teymournejad O, Rezaee MA, Taghizadeh S, Mehramuz B, Aghazadeh M, Asgharzadeh M, Madhi M, Gholizadeh P, Ganbarov K, Yousefi M, Pakravan A, Dal T, Ahmadi R, Kafil, HS (2020): Antisense peptide nucleic acids againstftsZ andefaA genes inhibit growth and biofilm formation of Enterococcus faecalis. Microb Pathogenesis 139:103907.

Nawaz M, Wang J, Zhou A, Ma C, Wu X, Moore JE, Millar BC, Xu J (2011): Characterization and transfer of antibiotic resistance in lactic acid bacteria from fermented food products. Curr Microbiol 62(3):1081-1089.

Niu H, Yu H, Hu T, Tian G, Zhang L, Guo X, Hu H, Wang, Z. (2016): The prevalence of aminoglycoside-modifying enzyme and virulence genes among enterococci with high-level aminoglycoside resistance in Inner Mongolia, China. Braz J Microbiol 47:691-696.

Nisha AR (2008): Antibiotic residues-a global health hazard. Vet World 1(12):375.

Ouoba LII, Lei V, Jensen LB (2008): Resistance of potential probiotic lactic acid bacteria and bifidobacteria of African and European origin to antimicrobials: determination and transferability of the resistance genes to other bacteria. Int J Food Microbiol 121(2):217-224.

Özdemir R, Tuncer Y (2020): Detection of antibiotic resistance profiles and aminoglycoside-modifying enzyme (AME) genes in high-level aminoglycoside-resistant (HLAR) enterococci isolated from raw milk and traditional cheeses in Turkey. Mol Biol Rep 47(3):1703-1712.

Pandey N, Cascella M (2021): Beta lactam antibiotics. StatPearls Publishing, Treasure Island, [Internet], PMID: 31424895.

Pavli FG, Argyri AA, Papadopoulou OS, Nychas GJE, Chorianopoulos NG (2016): Probiotic potential of lactic acid bacteria from traditional fermented dairy and meat products: Assessment by in vitro tests and molecular characterization. J Prob Health 4(3).

Pircher A, Bauer F, Paulsen P (2007): Formation of cadaverine, histamine, putrescine and tyramine by bacteria isolated from meat, fermented sausages and cheeses. Eur Food Res Technol 226(1):225-231.

Radovanovic RS, Savic NR, Ranin L, Smitran A, Opavski NV, Tepavcevic AM, Ranin J, Gajic, I. (2020): Biofilm production and antimicrobial resistance of clinical and food isolates of Pseudomonas spp. Curr Microbiol 77(12):4045-4052.

Rattanachaikunsopon P, Phumkhachorn P (2010): Lactic acid bacteria: their antimicrobial compounds and their uses in food production. Ann Biol Res 1(4):218-228.

Reviriego C, Eaton T, Martín R, Jiménez E, Fernández L, Gasson MJ, Rodríguez JM (2005): Screening of virulence determinants in Enterococcus faecium strains isolated from breast milk. J Hum Lact 21(2):131-137.

Rich C, Favre-Bonte S, Sapena F, Joly B, Forestier C (1999): Characterization of enteroaggregative Escherichia coli isolates. FEMS Microbiol Lett 173(1):55-61.

Robredo, B, Singh, KV, Baquero, F, Murray, BE, Torres, C (2000): Vancomycin-resistant enterococci isolated from animal and food. Int J Food Microbiol 54:197-204.

Rozman V, Lorbeg PM, Accetto T, Matijašić BB (2020): Characterization of antimicrobial resistance in lactobacilli and bifidobacteria used as probiotics or starter cultures based on integration of phenotypic and in silico data. Int J Food Microbiol 314:108388.

Saelim K, Jampaphaeng K, Maneerat S (2017): Functional properties of Lactobacillus plantarum S0/7 isolated fermented stinky bean (Sa Taw Dong) and its use as a starter culture. J Funct Foods 38:370-377.

Saif FAA, Sakr EA (2020): Characterization and bioactivities of exopolysaccharide produced from probiotic Lactobacillus plantarum 47FE and Lactobacillus pentosus 68FE. Bioact Carbohydr Diet Fibre 24:100231.

Salyers AA, Gupta A, Wang Y (2004): Human intestinal bacteria as reservoirs for antibiotic resistance genes. Trends Microbiol 12(9):412-416.

Sanchart C, Rattanaporn O, Haltrich D, Phukpattaranont P, Maneerat S (2016): Technological and safety properties of newly isolated GABA-producing Lactobacillus futsaii strains. J Appl Microbiol 121(3):734-745.

Semedo T, Almeida Santos M, Martins P, Silva Lopes MF, Figueiredo Marques JJ, Tenreiro R, Barreto Crespo MT (2003): Comparative study using type strains and clinical and food isolates to examine hemolytic activity and occurrence of the cyl operon in enterococci. J Clin Microbiol 41(6):2569-2576.

Shalaby AR (1996): Significance of biogenic amines to food safety and human health. Food Res Int 29(7):675-690.

Shao Y, Zhang W, Guo H, Pan L, Zhang H, Sun T (2015): Comparative studies on antibiotic resistance in Lactobacillus casei and Lactobacillus plantarum. Food Control 50:250-258.

Sharma P, Tomar SK, Sangwan V, Goswami P, Singh R (2016): Antibiotic resistance of Lactobacillus sp. isolated from commercial probiotic preparations. J Food Safety 36(1):38-51.

Shiling L, Caihong J, Xinglian X, Chengjian X, Kaixiong L, Ruihua S (2015): Improved screening procedure for biogenic amine production by lactic acid bacteria and Enterobacteria. Czech J Food Sci 33(1):19-26.

Singh KV, Nallapareddy SR, Sillanpää J, Murray BE (2010): Importance of the collagen adhesin ace in pathogenesis and protection against Enterococcus faecalis experimental endocarditis. Plos Pathog 6(1):e1000716.

Slover CM, Danziger L (2008): Lactobacillus: a review. Clin Microbiol Newsl 30(4):23-27.

Sparo M, Delpech G, García Allende N (2018): Impact on public health of the spread of high-level resistance to gentamicin and vancomycin in enterococci. Front Microbiol 9:3073.

Sun L, Zhang Y, Guo X, Zhang L, Zhang W, Man C, Jiang Y (2020): Characterization and transcriptomic basis of biofilm formation by Lactobacillus plantarum J26 isolated from traditional fermented dairy products. LWT-Food Sci Technol 125:109333.

Talib N, Mohamad NE, Yeap SK, Hussin Y, Aziz MNM, Masarudin MJ, Sharifuddin AA, Hui, YW, Ho CL, Alitheen NB (2019): Isolation and characterization of Lactobacillus spp. from kefir samples in Malaysia. Molecules 24(14):2606.

Todorov SD, Perin LM, Carneiro BM, Rahal P, Holzapfel W, Nero LA (2017): Safety of Lactobacillus plantarum ST8Sh and its bacteriocin. Probiotics Antimicrob Proteins 9(3):334-344.

Toomey N, Bolton D, Fanning S (2010): Characterisation and transferability of antibiotic resistance genes from lactic acid bacteria isolated from Irish pork and beef abattoirs. Res Microbiol 161(2):127-135.

Turchi B, Mancini S, Fratini F, Pedonese F, Nuvoloni R, Bertelloni F, Ebani VV, Cerri D (2013): Preliminary evaluation of probiotic potential of Lactobacillus plantarum strains isolated from Italian food products. World J Microb Biot 29(10):1913-1922.

Vakulenko SB, Donabedian SM, Voskresenskiy AM, Zervos MJ, Lerner SA, Chow JW (2003): Multiplex PCR for detection of aminoglycoside resistance genes in enterococci. Antimicrob Agents Ch 47(4):1423-1426.

Vankerckhoven V, Van Autgaerden T, Vael C, Lammens C, Chapelle S, Rossi R, Jabes D, Goossens, H. (2004): Development of a multiplex PCR for the detection of asa1, gelE, cylA, esp, and hyl genes in enterococci and survey for virulence determinants among European hospital isolates of Enterococcus faecium. J Clin Microbiol 42(10):4473-4479.

Vázquez-Laslop N, Mankin AS (2018): How macrolide antibiotics work. Trends Biochem Sci 43(9):668-684.

Walter J, Loach DM, Alqumber M, Rockel C, Hermann C, Pfitzenmaier M, Tannock GW (2007): D-alanyl ester depletion of teichoic acids in Lactobacillus reuteri 100-23 results in impaired colonization of the mouse gastrointestinal tract. Environ Microbiol 9(7):1750-1760.

Wang S, Liu K, Seneviratne CJ, Li X, Cheung GSP, Jin L, Chu CH, Zhang C (2015): Lipoteichoic acid from an Enterococcus faecalis clinical strain promotes TNF-α expression through the NF-κB and p38 MAPK signaling pathways in differentiated THP-1 macrophages. Biomed Rep 3(5):697-702.

Wilson DN (2014): Ribosome-targeting antibiotics and mechanisms of bacterial resistance. Nat Rev Microbiol 12(1):35-48.

Yadav R, Puniya AK, Shukla P (2016): Probiotic properties of Lactobacillus plantarum RYPR1 from an indigenous fermented beverage Raabadi. Front Microbiol 7:1683.

Yalçın M, Özden Tuncer B, Akpınar Kankaya D, Tuncer Y (2023): Presence of genes encoding aminoglycoside-modifying enzyme (AME) and virulence factors in highlevel aminoglycoside-resistant (HLAR) Enterococcus strains isolated from retail chicken meat in Turkey. J Hellenic Vet Med Soc 10.12681/jhvms.30850 (in press).

Yüceer Ö, Özden Tuncer B (2015): Determination of antibiotic resistance and biogenic amine production of lactic acid bacteria isolated from fermented Turkish sausage (Sucuk). J Food Safety 35(2):276-285.

Zhang H, Xie L, Zhang W, Zhou W, Su J, Liu J (2013): The association of biofilm formation with antibiotic resistance in lactic acid bacteria from fermented foods. J Food Safety 33(2):114-120.

Zhang ZY, Liu C, Zhu YZ, Wei YX, Tian F, Zhao GP, Guo XK (2012): Safety assessment of Lactobacillus plantarum JDM1 based on the complete genome. Int J Food Microbiol 153(1-2):166-170.

Zheng J, Wittouck S, Salvetti E, Franz CMAP, Harris HMB, Mattarelli P, O'Toole PW, Pot B, Vandamme P, Walter J, Watanabe K, Wuyts S, Felis GE, Gänzle MG, Lebeer S (2020): A taxonomic note on the genus Lactobacillus: Description of 23 novel genera, emended description of the genus Lactobacillus Beijerinck 1901, and union of Lactobacillaceae and Leuconostocaceae. Int J Syst Evol Microbiol 70:2782-2858.

Address of corresponding author:
Didem Akpınar Kankaya
Department of Food Processing
Gelendost Vocational School
Isparta University of Applied Sciences
32900, Isparta
Turkey
didemkankaya@isparta.edu.tr