meat technology
Founder and publisher: Institute of Meat Hygiene and Technology, Belgrade

UDK: 614.97(497.11) ; 637.513.12 ; 636.5'64.065
ID: 254360332

Original scientific paper

Pigs and cattle slaughter process hygiene in a large-scale and a small-scale abattoir: A report from one county in Serbia

Boris Mrdovic[1], Mladen Raseta[1], Ivana Brankovic-Lazic[1], Milan Milijasevic[1], Branislav Baltic[1], Ivan Nastasijevic[1]

A b s t r a c t: Microbiological data on hygiene indicators are important for assessment of hygiene levels in abattoirs and control of carcass contamination. Risk categorization of slaughterhouses should be based on a process hygiene output through the use of indicator organisms – Total Viable Counts (TVC), Enterobacteriaceae counts (EC) and Salmonella spp. – monitored on carcasses. The level of TVC indicates the overall hygiene in abattoirs (equipment, tools, workers), while the presence of EC on carcasses can indicate fecal contamination which can occur during slaughter/dressing. Detection of Salmonella spp. indicates the presence of pathogens, with potential origin from the farm. The aim of this study was to assess the slaughter process hygiene in abattoirs of different sizes and throughputs, a large- and a small-scale abattoir, and to analyze differences in process hygiene levels based on implementation of their self-control plans, throughout a period of five years for cattle and six years for pigs. In the large-scale abattoir, TVC levels were slightly higher on cattle carcasses than on pig carcasses, but were always within the regulatory satisfactory or acceptable ranges. In the small-scale abattoir, low counts of EC were observed on cattle and pig carcasses, with slightly higher levels on cattle carcasses, but the counts were always within the regulatory satisfactory range. Higher TVC levels on both cattle and pig carcasses were observed in the large-scale abattoir versus the small-scale abattoir, but both abattoirs still showed process hygiene levels within the regulatory satisfactory or acceptable range. Salmonella was recovered only from two pig carcasses in the large-scale abattoir. The study revealed that TVC levels differed more on pig carcasses, while EC levels differed more on cattle carcasses. Process hygiene levels in both abattoirs were always in the allowed regulatory range and also were similar to the hygiene levels in other, developed European countries.

Keywords: *abattoir, process hygiene, Total Viable Count, Enterobacteriaceae, Salmonella.*

Introduction

An abattoir is a place where animals are humanely killed, under the supervision of authorized/official veterinarian, in order to provide meat for human consumption. During slaughter, many processing steps can contribute to cross-contamination of carcasses with the microorganisms originating from animal hide/skin, utensils and equipment, food-contact surfaces, workers and, most importantly, from the gastro-intestinal tract (*Veterinary Directorate*, 2007). Evisceration is the phase that contributes most to the finding of bacteria on the surface of the carcasses, especially because after skinning, at the slaughter line there is no longer any primary treatment phase that could reduce the number of bacteria (*Raseta et al*., 2015).

The implementation of Good Manufacturing Practice (GMP), Hazard Analysis and Critical Control Points (HACCP) and various interventions such as physical interventions (hygienic de-hiding, scalding/singeing/polishing, evisceration) and chemical interventions (carcass decontamination) (*Antic*, 2010) by slaughter and meat processing facilities play a large role in enhancing the safety of meat products (*Bohaychuk et al*., 2011). Such interventions can lead to significant decrease of microbial numbers on carcasses. However, the physical methods cannot be substituted and/or replaced simply by chemical interventions, but rather must be supplemented with multiple decontamination procedures which have additional biocidal effect and therefore increase the level of microbial reductions. Additionally, contamination from the environment can also be significant during primary processing at abattoirs (*Australian Meat Processor Corporation*, 2013).

From the standpoint of food spoilage and foodborne disease, enteric bacteria are of great concern because they are frequently encountered in red meat production. Although various foods can

[1]*Institute of Meat Hygiene and Technology, Kacanskog 13, 11000 Belgrade, Republic of Serbia.*

Corresponding author: Ivan Nastasijevic, *ivan.nastasijevic@inmes.rs*

serve as vehicles of foodborne illness, meat and meat products remain important sources of human infections with a variety of foodborne pathogens, i.e. *Salmonella spp*., *Campylobacter jejuni/coli*, *Yersinia enterocolitica*, human pathogenic Verotoxigenic *Escherichia coli*, and *Listeria monocytogenes* (*Nørrung et al*., 2009). Foodborne disease provoked due to the presence of pathogenic bacteria in the food usually manifests itself in episodes of gastro-intestinal disease (diarrhea, vomiting, etc.) (*Nørrung et al*., 2009).

The intestines of animals contain large numbers of microorganisms, e.g. *E. coli* levels are usually greater than 10^5 cfu g^{-1}, and amongst these microorganisms can be found foodborne pathogens such as *E. coli* O157, *Salmonella* and *Campylobacter* (*Australian Meat Processor Corporation*, 2013). The important meat hygiene indicators are *Enterobacteriaceae* (EC) and Total Viable Counts (TVC). The deep muscle tissues of healthy, slaughtered livestock contain few, if any, microorganisms (*Veterinary Directorate*, 2007). However, their exterior surfaces (hide, hair, skin) are naturally contaminated with a variety of microorganisms, as well as their gastro-intestinal tracts. The most common order of event anticipating foodborne diseases involves the existence of a primary source, e.g. healthy animals intended for meat production, which can intermittently fecally shed the pathogens that can be further spread in the process of primary production (on-farm), processing (in abattoir and meat processing), as well as handling by consumers (*Nørrung and Buncic*, 2008).

Regulation (EC) No. 2073/2005 and the Regulation on the general and specific food hygiene requirements at any stage of production, processing and trade (*Serbia*, 2010) require the obligatory control of TVC and EC, which are defined as hygiene indicators in slaughter processes. *Martelli et al*. (2017) stated that TVC are defined as indicators of the overall slaughter hygiene (equipment, tools, workers, environment), while EC are recognized as indicators of fecal contamination on carcasses and in abattoirs. *Salmonella* is the second most commonly reported zoonotic gastro-intestinal pathogen in the European Union (*EFSA*, 2016), and a significant proportion of the cases is linked to the consumption of contaminated pork (*Martelli et al*., 2017). *Salmonella* is regularly found in the intestines of humans and animals, and by fecal shedding it can also reach the environment. Many *Salmonella* serovars which are closely related to foodborne outbreaks, e.g. *S.* Typhimurium, *S.* Enteritidis, *S.* Newport, and *S.* Heidelberg, have reservoirs in farm animals (*Andino*, 2015). The most common primary reservoirs for *S.* Typhimurium are pigs, cattle and poultry (*Nørrung et al*., 2009). Pork is especially important because pigs are one of the main meat-producing species that can asymptomatically carry *Salmonella*, periodically shedding the bacteria through feces (*Martelli et al*., 2017).

It has been estimated that approximately 1% of *Salmonella* infections in humans are caused by the consumption of contaminated pork or processed foods derived from pork in the United States (*Guo*, 2011), and 0.02 % in the EU (*EFSA*, 2016). On the other hand, the average percentage of all positive cattle carcasses contaminated with *Salmonella* in the EU along the meat chain (pre-harvest/on-farm, harvest/slaughter and post-harvest/meat-processing), during 2008 and 2009 was 0.2% (EFSA, 2013). The most commonly isolated *Salmonella* serovars originating from cattle carcasses were *S.* Typhimurium and *S.* Dublin. According to EFSA report from 2015, the overall herd prevalence was 12.4% and 2.1%, for pigs and cattle, respectively, while *Salmonella* was detected in 1.7% and 0.2% of pork and cattle meat samples, respectively (*EFSA*, 2016).

In addition, the main reservoir of *E. coli* O157 is cattle, which can shed the pathogen fecally, and therefore, this alimentary pathogen can subsequently contaminate the foods originating from cattle, most commonly, meat. Direct fecal contamination of carcass with pathogens originating from penetrated intestines during evisceration (leakage from guts onto the meat) is relatively rare in modern slaughterhouses, while microbiological contamination from hides (direct contact, knife, equipment, air) is a crucial and relatively common event (*Antic et al*., 2010; *Koohmaraie et al*., 2005). In Serbia, *Nastasijevic et al*. (2008) found that the prevalence of *E. coli* on the skin of slaughtered cattle was 28.2%, while *Blagojevic et al*. (2011) found that the prevalence was 52 to 64%. Under conditions of simulated direct skin-meat contact, this transfer amounts to 0.5% of TVC and 2% of EC from the numbers on cattle skins (*Antic et al*., 2010). However, despite this low transfer rate, the high level of bacterial contamination of the skin, as well as the regularity of bacterial transfer to the body during skin removal, indicate that the risk of bacterial contamination of the carcass from the skin is very significant (*Nastasijevic et al*., 2016).

According to the 1989 regulation on the conditions that must be fulfilled by abattoirs and meat processing establishments (*SFRJ*, 1989) and until 2011, abattoirs in Serbia were divided by structure, technical equipment, capacity, work and veterinary inspection organization into: (i) large-scale abattoirs (industrial abattoirs), (ii) small-scale abattoirs, and (iii) community abattoirs. However, meat

produced in small abattoirs can have a significant influence on consumers taking into consideration the level of their exposure to the meat delivered by these abattoirs, based on the market share. One of the best examples is in the UK, where 51% of abattoirs are small-scale, accounting for 22.7% of the meat market share (*UK*, 2008).

Changes to the Serbian Rulebook on Veterinary--Sanitary Requirements, and general and special conditions of hygiene of food of animal origin (*Serbia*, 2011) and its harmonization with EU law (*EC*, 2004) on the hygiene of foodstuffs of animal origin, did not recognize differences between large- and small-scale abattoirs. In fact, the terms *large-scale abattoirs* and *small-scale abattoirs* has been used to describe production volume, the number of employees, the craft of financial assets and the annual profit. For example, small-scale UK abattoirs have a maximum of 50 employees, while large establishments have a minimum of 250 employees (*UK*, 2008). No matter whether the abattoir is small-scale or large-scale, it must satisfy specific conditions related to the construction methods, technical/technological equipment, veterinary/sanitary conditions, working methods, hygiene level and workers' training. The aim of this research was: a) to determine if there are any differences regarding process hygiene level at slaughter between selected large- and small-scale abattoirs in one Serbian county, and b) to assess to which extent those abattoirs achieved satisfactory level of the slaughter process hygiene.

Materials and methods

The study encompassed one small-scale and one large-scale (industrial) abattoir in one county in Serbia, regularly inspected by the competent authority (veterinary inspection). Abattoirs that were the object of this research had different production capacities. The industrial abattoir had a daily production capacity of 700 pig carcasses and 70 cattle carcasses. Daily capacity of the small-scale abattoir was 90 pig carcasses and 30 cattle carcasses. Altogether, 1180 wet-dry swabs were collected in the large- and small-scale abattoirs during a five year period (2012–2016) for cattle carcasses and during a six year period (2011–2016) for pig carcasses. Therefore, swab (sample) collection took place throughout 2011 and until 2016. Samples were taken in accordance with the local regulation on the general and specific food hygiene requirements at any stage of production, processing and trade (*Serbia*, 2010). A random sampling strategy was followed, which means that swabs were regularly collected once per month. The sampling was based on standard Serbian-ISO harmonized methods (*ISO*, 2009). The sampling was also in line with the self-control plans developed by HACCP teams in both abattoirs and was regularly approved by the veterinary inspector in charge. The number of samples by year was not the same for large- and small-scale abattoirs, due to observed differences in their self-control plans. Therefore, the sampling frequency varied for large-and small-scale abattoirs depending on the year during the period 2011–2016. The sampling of cattle and pig carcasses was conducted by an authorized person in both abattoirs and testing was performed by an external laboratory accredited in accordance with ISO 17025 (*ISO*, 2005) for TVC, EC and *Salmonella* detection and enumeration. TVC and EC detection was performed according to ISO 4833 (*ISO*, 2003) and ISO 21528–2 (*ISO*, 2004), respectively. The interpretation of results was carried out according to EU Regulation 2073/2005 (*EC*, 2005). Detection of *Salmonella* spp. was carried out according to ISO 6579 (*ISO*, 2002), and results were recorded as *Salmonella* presence or absence (*EC*, 2005).

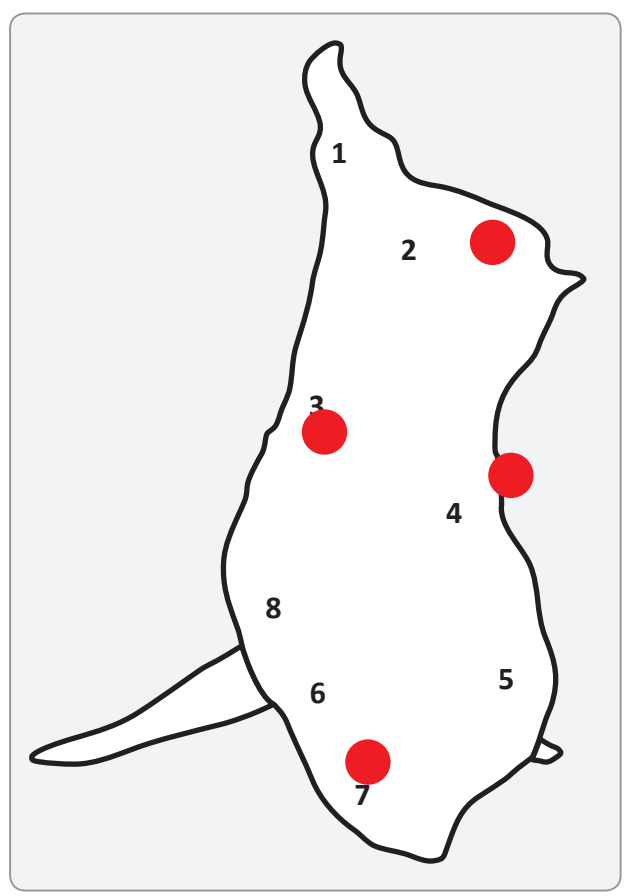

Figure 1. Sampling sites on pig carcass

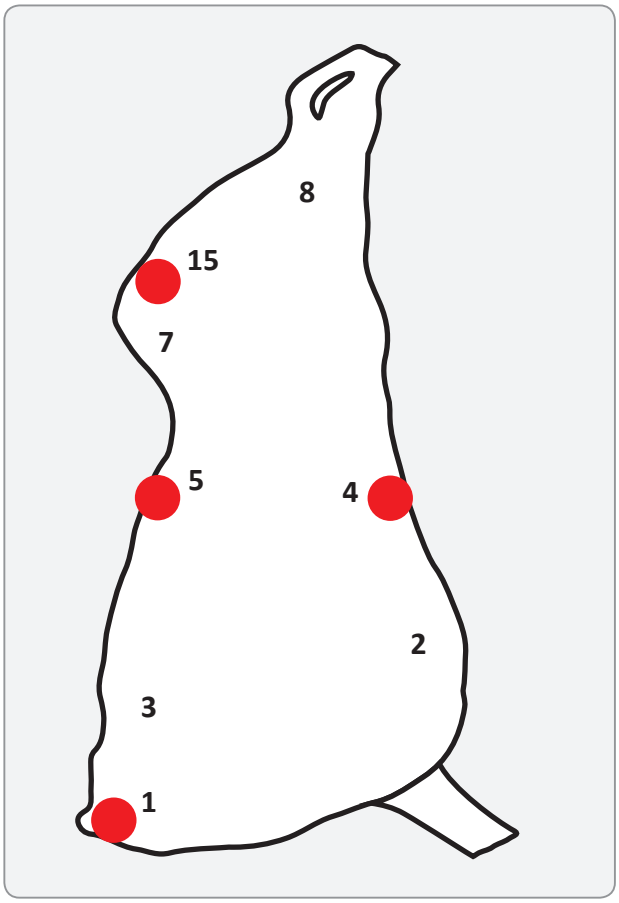

Figure 2. Sampling sites on cattle carcass

Swabs were collected in each abattoir at regular time intervals during this study. During each sampling session, swabs were taken from five cattle and/or five pig carcasses randomly selected at the end of slaughter line, after the final wash but before chilling. The swabs were taken at four sites on each carcass, e.g. pig carcasses (rump, belly, back and jaw; Figure 1) and cattle carcass (rump, belly, thorax and neck; Figure 2) following the recommendation of the harmonized national standard (*ISO*, 2009; it has to be taken into consideration that this version of the standard was used during the time when this study was conducted, from 2011–2016).

Sterile, pre-moistened sponges were used to swab four adjacent areas (Figure 1) covering a total area of 400 cm^2 (100 cm^2 per each area) on one half of each chosen carcass. *Salmonella* was recovered from sponges used to swab the corresponding half of each carcass, from a 400 cm^2 area. In total, 1180 carcasses were examined from 2011–2016. Altogether, 640 carcasses (cattle n=270, pig n=370) were swabbed in the industrial, large-scale abattoir, while 540 carcasses (n=cattle 340, pig n=200) were swabbed in the small-scale abattoir.

The obtained microbial results/data were analyzed using Microsoft Office Excel 2007. Firstly, the average logarithm value of TVC and EC for each carcass was calculated (based on previously estimated log values for each of four corresponding sites on each carcass), and then the average daily logarithm was defined. The average daily logarithm of *Salmonella spp.* was not calculated, taking into account the regulatory requirement defining only the absence or presence of *Salmonella spp*.

Results

Overall, in the period from 2012 to 2016 for cattle carcasses and 2011 to 2016 for pig carcasses, TVC counts ranged from 1.17–2.33 log cfu cm^{-1} and from 1.34–3.10 log cfu cm^{-1}, for cattle and pig carcasses, respectively (Tables 1 and 2). The EC levels varied from 0.01–0.37 log cfu cm^{-1} and 0.11–0.82 log cfu cm^{-1}, for cattle and pig carcasses, respectively (Tables 1 and 2).

Table 1. The level of cattle carcass contamination in a large-scale and a small-scale abattoir, 2012–2016 (n=610)

		2012		2013		2014		2015		2016	
		A	B	A	B	A	B	A	B	A	B
n		85	55	50	75	35	85	55	50	75	35
%		31.48	16.18	18.52	22.06	12.96	31.48	16.18	18.52	22.06	12.96
TVC – log cfu cm^{-1} ($\bar{x}$±SD)		0.60±0.26	0.24±0.15	1.12±0.10	0.82±0.19	1.63±0.11	1.43±0.17	2.16±0.21	1.99±0.14	2.85±0.25	2.57±0.23
EC – log cfu cm^{-1} ($\bar{x}$±SD)		0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.01±0.04	0.00±0.00	0.17±0.04	0.11±0.12	0.97±0.66	0.84±0.38
***Salmonella* spp.**	*n*	0	0	0	0	0	0	0	0	0	0
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Legend: A – large-scale abattoir; B – small-scale abattoir, n – number of carcasses

Table 2. The level of pig carcass contamination in a large-scale and a small-scale abattoir, 2011–2016 (n=570)

		2011		2012		2013		2014		2015		2016	
		A	B	A	B	A	B	A	B	A	B	A	B
n		35	5	55	20	50	35	90	50	80	35	60	55
%		9.46	2.50	14.86	10.00	13.51	17.50	24.32	25.00	21.62	17.50	16.22	27.50
TVC – log cfu cm^{-1} ($\bar{x}$±SD)		0.39±0.18	0.00±0.00	1.15±0.12	0.47±0.33	1.44±0.07	1.01±0.18	1.94±0.27	1.60±0.25	2.63±0.17	2.26±0.14	3.40±0.28	3.06±0.39
EC – log cfu cm^{-1} ($\bar{x}$±SD)		0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.37±0.14	0.89±0.71	1.30±0.55	0.06±0.10
***Salmonella* spp.**	n	0	0	0	0	0	0	0	0	2	0	0	0
	%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00

Legend: A – large-scale abattoir; B – small-scale abattoir, n – number of carcasses

Total Viable Counts

In the large-scale abattoir, TVC were isolated from all cattle carcasses (n=300; 100%) and from all pig carcasses (n=370, 100%). Mean TVC values for cattle carcasses were within the satisfactory range (<2.8 log cfu cm^{-1}) in 75% (n=225) of tested cattle carcasses, while in 25% (n=75) of tested carcasses, TVC levels were within the acceptable range, between 2.8–4.0 log cfu cm^{-1}. The established TVC levels on pig carcasses were within the satisfactory range (<3.3 log cfu cm^{-1}) in 74.33% (n=275) of tested carcasses, while in 25.67% (n=95) of tested pig carcasses, the TVC levels were within the acceptable range, between 3.3 and 4.3 log cfu cm^{-1}. In the small abattoir, TVC were isolated from all cattle carcasses (n=300; 100%), with levels within the satisfactory range. Further, TVC were isolated from all tested pig carcasses (n=200, 100%), but again, all of them were within the satisfactory range. Apparently higher TVC levels were observed in the large-scale abattoir versus the small-scale abattoir, but both abattoirs still showed process hygiene levels within the satisfactory range (Table 3).

Enterobacteriaceae Counts

In the large-scale abattoir, EC were isolated from 165 (55%) cattle carcasses, while on 135 carcasses, the EC levels were below the detection limit; EC values were always within the satisfactory range, below 1.2 log cfu cm^{-1}. On 230 (62.16%) of pig carcasses, the EC levels were below the detection limit, while on 140 (37.84%) of pig carcasses, the detected EC levels were within the satisfactory range (<1.3 log cfu cm^{-1}). In the small abattoir, low counts of EC were also determined. EC were confirmed on 85 (28.33%) of the cattle carcasses and 90 (45%) of the pig carcasses. In both cases, cattle and pig carcasses, the observed EC levels were always within the satisfactory range as defined by the legislation (*EC*, 2005; *Serbia*, 2010).

Salmonella species

The presence of *Salmonella* spp. was detected only on two pig carcasses originating from the large-scale, industrial abattoir.

Table 3. Summary view of cattle and pig carcass contamination in a large-scale and a small-scale abattoir, 2011–2016 (n=1180).

	TVC – log cfu cm^{-1} ($\bar{x}$±SD)		**EC – log cfu cm^{-1} ($\bar{x}$±SD)**		***Salmonella spp. detected***	
	Cattle	Pig	Cattle	Pig	Cattle	Pig
A	(n=270)	(n=370)	(n=270)	(n=370)	(n=270)	(n=370)
	1.53±0.98	1.99±1.01	0.20±0.49	0.30±0.62	0	2*
B	(n=340)	(n=200)	(n=340)	(n=200)	(n=340)	(n=200)
	1.40±0.97	1.86±1.10	0.17±0.47	0.26±0.61	0	0

Legend: A – large scale abattoir; B – small scale abattoir; n – number of carcasses *during 2015, *Salmonella* spp. was detected on two pig carcasses.

Discussion

TVC is the general indicator for hygienic operations indicating the overall hygiene in abattoirs (equipment, tools, workers), while EC counts indicate fecal contamination of carcasses. The TVC/EC levels detected on the carcasses do not serve *per se* for decision-making on carcass/meat acceptance or rejection, but rather serve as general indicators of slaughter hygiene (*Delhalle et al*., 2008). Low levels of TVC were detected at all times, either within the satisfactory or acceptable range. In both abattoirs, TVC on cattle carcasses were always within the regulatory requirements. Some other studies reflecting TVC levels on cattle carcasses showed different variations, such as a study carried out in Ethiopia where TVC levels were 5.21 log cfu cm^{-1} (*Gebeyehu et al*., 2013), in Algeria, 4.48 log cfu cm^{-1} (*Nouichi and Hamdi*, 2009), in Switzerland, between 2.1–3.1 log cfu cm^{-1} (*Zweifel et al*., 2005) and in Australia, 2.42 log cfu cm^{-1} (*Phillips et al*., 2001).

In both abattoirs, the EC levels were at all times within the satisfactory range for cattle and pig carcasses, respectively. A similar result was reported in another study conducted in Serbia, where the slaughter process hygiene was assessed in two large- and two small-scale abattoirs, accounting for 58.5% of Serbia`s national production of beef/pork meat (*Nastasijevic et al*., 2016). Our low *Salmonella* prevalence was also in accordance with an earlier study carried out in Serbian abattoirs (*Blagojevic et al.*, 2011). In the current study, *Salmonella* was absent from cattle carcasses, while it was detected on two pig carcasses in the large-scale abattoir. It is worth noting the current legislation (*EC*, 2005; *Serbia*, 2010), by which the presence of *Salmonella* on 2 of 50 cattle carcasses and on 5 of 50 pig carcasses is acceptable.

Also, based on available results from developed countries such as the USA and Ireland, as well as other countries such as Algeria and Turkey, where average contamination of bovine carcasses was 1.5% (Sofos, 2005), 7.6% (*Keogh et al*., 2001), 10% (*Nouichi and Hamdi*, 2009) and 10% (*Akkaya et al*., 2008), respectively, it can be concluded that slaughter hygiene in the chosen Serbian slaughterhouses was similar or better than that in some other developed countries.

It is worth noting that industrial-type, large-scale production meat establishments mostly have more developed risk-based meat safety management systems (HACCP-based) and more intensive cooperation with professional/scientific institutions and laboratories compared with small-scale establishments. This fact can be sometimes related to the higher level of slaughter process hygiene in large-scale meat establishments versus small-scale establishments. On the other hand, it should be kept in mind that small abattoirs with a smaller slaughter throughput have more opportunities to thoroughly conduct cleaning and disinfection protocols and to devote more attention to monitoring critical control points, which subsequently contributes to the higher level of hygiene.

Conclusion

Microbiological data on hygiene indicators are important for assessment of hygiene levels in abattoirs and control of carcass contamination. Risk categorization of abattoirs should be based on a process hygiene output through the use of indicator organisms, TVC and EC, monitored on carcasses. The indicators monitored on carcasses (TVC, EC) indicate whether the process hygiene functions acceptably, but they do not indicate control of the hazards *per se*. The presence of TVC indicate the overall hygiene in abattoirs (equipment, tools, workers), while the presence of EC on carcasses can indicate fecal contamination which can occur during slaughter/dressing. In addition, *Salmonella* spp. can serve as an indicator of the presence of pathogens on carcasses/meat. In this study, we compared the process hygiene levels between two selected abattoirs, a large-scale and a small-scale abattoir, over a period of five years for cattle carcasses and six years for pig carcasses. In total, 1180 cattle or pig carcasses were examined. The results revealed that in the large-scale abattoir, TVC were isolated from all cattle and pig carcasses. Mean TVC values for cattle carcasses were within the satisfactory range in 75% (n=225) of tested carcasses, while for 25% (n=75) of carcasses, TVC levels were within the acceptable range. TVC levels on pig carcasses were within the satisfactory range in 74.33% (n=275) of tested carcasses, while for 25.67% (n=95) of pig carcasses, TVC levels were within the acceptable range. In the small abattoir, TVC were also isolated from all cattle/pig carcasses, with levels always within the satisfactory range. Apparently higher TVC levels were observed in the large-scale abattoir versus the small abattoir, but both abattoirs still showed process hygiene levels were within the regulatory satisfactory range. In the large-scale abattoir, EC were isolated from 55% (n=165) of cattle carcasses and were always within the satisfactory range. On 62.16% (n=230) of tested pig carcasses, the EC levels were below the detection limit, while on 37.84% (n=140) of pig carcasses,

the detected EC levels were within the satisfactory range. In the small abattoir, low EC levels were observed on cattle/pig carcasses and were always within the regulatory satisfactory range.

Salmonella spp. prevalence was low, as this pathogen was not detected on cattle carcasses over the five year period, while only two positive findings were observed among the pig carcasses over six years.

Overall, the observed process hygiene levels in both abattoirs did not differ significantly, and were rather similar to process hygiene levels in other, developed EU countries. Development and vigorous implementation of self-control plans intended for monitoring hygiene indicators (TVC, EC) on cattle or pig carcasses can lead to achievement of satisfactory levels of slaughter hygiene, no matter the size and throughput of the abattoir. Further research should be carried out to establish an evidence-based interface between slaughter process hygiene, risk categorization of abattoirs and the frequency of inspection visits.

Disclosure Statement: No potential conflict of interest was reported by the authors.

References

Akkaya, L. Z. Cetinkaya, M. Alisarli, R. Telli & V. Gök. (2008). The prevalence of *E. coli* O157/O157:H7, *L. monocytogenes* and *Salmonella* spp. on bovine carcasses in Turkey. *Journal of Muscle Foods*, *19(4)*, 420–429.

Andino, A. & I. Hanning. (2015). *Salmonella enterica*: Survival, colonization, and virulence differences among serovars. *The Scientific World Journal*, 520179. http://doi.org/10.1155/2015/520179.

Antic, D., B. Blagojevic, M. Ducic, I. Nastasijevic, R. Mitrovic & S. Buncic. (2010). Distribution of microflora on cattle hides and its transmission to meat via direct contact. *Food Control, 21(7)*, 1025–1029.

Australian meat processor corporation. (2013). Meat Science Tutorial for QA Managers: The Colmslie, Cnr Junction & Wynnum Roads, Morningside, Qld 4170, URL: https://www.ampc.com.au/uploads/cgblog/id285/MeatScienceTutorialALLMaterialsandslidesFinal.pdf (10.09.2017.).

Blagojevic, B., D. Antic, M. Ducic & S. Buncic. (2011). Ratio between carcass and skin microflora as an abattoir process hygiene indicator. *Food Control, 22*, 186–190.

Bohaychuk, V. M., G. E. Gensler, & P. R. Barrios. (2011). Microbiological baseline study of beef and pork carcasses from provincially inspected abattoirs in Alberta, Canada. *The Canadian Veterinary Journal, 52(10)*, 1095–1100.

Delhalle, L., L. De Sadeleer, K. Bollaerts, F. Farnir, C. Saegerman, N. Korsak *et al*. (2008). Risk factors for *Salmonella* and hygiene indicators in the 10 largest Belgian pig slaughterhouses. *Journal of Food Protection, 71(7)*, 1320–1329.

Directorate: Veterinary services veterinary public health national department of agriculture republic of South Africa. (2007). Meat inspectors manual abattoir hygiene Internetsource:*https://www.westerncape.gov.za/assets/departments/agriculture/abattoirhygienemanual.pdf.*

EC (2004). Regulation (EC) No 853/2004 European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for on the hygiene of foodstuffs. *Official Journal of the European Union*.

EC (2005). Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs (vol. L 338). Brussels, Belgium: European Commission. *Official Journal of the European Union*.

EFSA (2013). Scientific opinion on the public health hazards to be covered by inspection of meat (bovine animals). *EFSA Journal, 11(6)*, 3266.

EFSA (2016). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2015. *EFSA Journal, 14(12)*, 4634.

Gebeyehu, A., M. Yousuf & A. Sebsibe. (2013). Evaluation of microbial load of beef of Arsi Cattle in Adama town, Oromia, Ethiopia. *Journal of Food Process Technol 4(6)*, 1–6.

Guide for the Application of Microbiological Criteria for Food, Ministry of Agriculture, Trade, Forestry and Water Management, first edition, Belgrade, June 2011.

Guo, C., R. M. Hoekstra C. M. Schroeder, S. M. Pires, K. L. Ong, E. Hartnett, E. & D. Cole. (2011). Application of Bayesian techniques to model the burden of human salmonellosis attributable to U.S. food commodities at the point of processing: Adaptation of a Danish model. *Foodborne Pathogens and Disease*, *8(4)*, 509–516. http://doi.org/10.1089/fpd.2010.0714.

International Organization for Standardization (ISO). (2002). Microbiology of food and animal feeding stuffs – Horizontal method for the detection of *Salmonella* spp. ISO 6579:2002. Geneva, Switzerland.

International Organization for Standardization (ISO). (2003). Microbiology of food and animal feeding stuffs – Horizontal methods for the detection and enumeration of Enterobacteriaceae – Part 2: Colony count method. ISO 21528–2:2004, Geneva, Switzerland.

International Organization for Standardization (ISO). (2003a). Microbiology of food and animal feeding stuffs – Horizontal method for the enumeration of microorganisms – Colony count technique at 30 degrees C. ISO 4833:2003, Geneva, Switzerland.

International Organization for Standardization (ISO). (2005). General requirements for the competence of testing and calibration laboratories. ISO 17025:2005. Geneva, Switzerland.

International Organization for Standardization (ISO). (2009). Microbiology of the food chain – Carcass sampling for microbiological analysis SRPS EN ISO 17604:2009.

Keogh, E., M. Kerr, L. McGuire & J. J. Sheridan. (2001). The extent of faecal and bacterial contamination of beef carcasses. In: Duffy, G., Garvey, P., Coia, J., Wasteson, Y. and McDowell, D. A, Concerted Action CT98–3935, verocytotoxigenic *E. coli* in Europe. Epidemiology of Verocytotoxigenic *E. coli*. Dublin: The National Food Centre, 141.

Koohmaraie, M., T. M. Arthur, J. M. Bosilevac, M. Guerini, S. D. Shackelford & T. L. Wheeler. (2005). Post-harvest interventions to reduce/eliminate pathogens in beef. *Meat Science, 71(1)*, 79–91.

Martelli, F., M. Lambert, P. Butt, T. Cheney, F. A. Tatone, R. Callaby & R. P. Smith. (2017). Evaluation of an enhanced cleaning and disinfection protocol in *Salmonella* contaminated pig holdings in the United Kingdom. *PLoS ONE*, *12*(*6*), e0178897. http://doi.org/10.1371/journal.pone.0178897.

Ministry of Agriculture, Forestry and Water Management Serbia. (2010). Ordinance on general and specific food hygiene requirements at any stage of production, processing and trade. Republic of Serbia. *Official Gazette of the Republic of Serbia*. No. 72/10.

Ministry of Agriculture, Forestry and Water Management Serbia. (2011). In: Guideline for the application of microbiological criteria.

Ministry of Agriculture, Forestry and Water Management Serbia. (2011). Ordinance on veterinary-sanitary conditions, general and special hygiene conditions for the production of food of animal origin. *Official Gazette of the Republic of Serbia*. No. 25/11.

Nastasijevic, I., R. Mitrovic & S. Buncic. (2008). Occurrence of *Escherichia coli* O157 on hides of slaughtered cattle. *Letters in Applied Microbiology, 46*, 126–131.

Nastasijevic, I., I. Tomasevic N. Smigic, D. Milicevic, Z. Petrovic & I. Djekic. (2016). Hygiene assessment of Serbian meat establishments using different scoring systems. *Food Control*, *62*, 193–200, http://dx.doi.org/10.1016/j.foodcont.2015.10.034.

Nouichi, S. & T. M. Hamdi. (2009). Superficial bacterial contamination of ovine and bovine carcasses at El-Harrach slaughterhouse (Algeria). *European Journal of Scientific Research, 38(3)*, 474–485.

Nørrung, B., & Buncic, S., 2008. Microbial safety of meat in the European Union. *Meat Science, 78(1–2)*, 14–24.

Nørrung, B., J. K. Andersen & S. Buncic. (2009). Main concerns of pathogenic microorganisms in meat. In: Todra F. (Ed) Safety of Meat and Processed Meat (Food Microbiology and Food Safety). Springer, New York, USA, pp. 3–30 (ISBN 978–0–387- 89025–8).

Phillips, D., J. Sumner, J. F. Alexander & K. M. Dutton. (2001). Microbiological quality of Australian beef. *Journal of Food Protection, 64*, 692–696.

Raseta, M., V. Teodorovic, J. Jovanovic, B. Lakicevic, I. Lazic-Brankovic & D. Vidanovic. (2015). The hygiene of the process of slaughtering and processing of pigs for one year on one slaughterhouse in the North Banat District in Serbia. *Meat Technology, 56(1)*, 26–3.

SFRJ (1989). Ordinance on the conditions that must be met by objects for slaughter of animals, processing, processing and storage of products of animal origin. *Official Gazette of the Socialist Federal Republic of Jugoslavia*, no. 53/89.

Small, A., C. James S. James R. Davies, E. Liebana, M. Howell, M. Hutchinson & S. Buncic. (2006). Presence of *Salmonella* in the red meat abattoir lairage after routine cleansing and disinfection and on carcasses. *Journal of Food Protection, 69*, 2342–2351.

Sofos, J. (2005). Improving the Safety of Fresh Meat. Elsevier. ISBN: 978–1–85573–955–0.

UK. **(2008).** The future of abattoirs. Note by agricultural and horticultural development board meat services. http://webarchive.nationalarchives.gov.uk/20120414053640/http://www.food.gov.uk/multimedia/pdfs/board/fsa080504a2.pdf (accessed on 2 December 2017).

Zweifel, C., D. Baltzer & R. Stephan. (2005). Microbiological contamination of cattle and pig carcasses at five abattoirs determined by swab sampling in accordance with EU Decision 2001/471/EC. *Meat Science, 69*, 559–566.

Paper received: 20.11.2017.
Paper corrected: 1.12.2017.
Paper: accepted: 4.12.2017.