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Short communication

# The effects of mandatory HACCP implementation on microbiological indicators of process hygiene in meat processing and retail establishments in Serbia

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ABSTRACT

A total of 48,246 microbiological test results were collected from 130 meat processing plants and 220 meat retail facilities over a seven year period: 41 months before and 43 months after HACCP implementation. Our results confirm a strong positive effect of mandatory HACCP implementation on process hygiene indicators in meat establishments. Significant reductions were observed in the number of hygiene indicator organisms on all types of surfaces examined and types of meat establishments investigated. The improvement of process hygiene was articulated as aerobic colony count reduction of at least 1.0 $\log_{10}$ CFU/cm$^2$ for food contact surfaces and over 2 $\log_{10}$ CFU/cm$^2$ for cooling facilities (refrigerators, freezers and other meat cooling devices). Meat handlers' hands hygiene was least positively affected. The period after mandatory HACCP implementation was also marked by a steady decline of positive *Enterobacteriaceae* and *Staphylococcus* samples. Process hygiene advances for meat processing plants and meat retail facilities were similar.



## 1. Introduction

Hygiene measures in meat production, processing and retail aim at assuring meat safety, preventing rapid spoilage of the meat and protecting its quality. Hazard Analysis and Critical Control Point (HACCP), which strongly relies on prerequisite programs including Good Hygiene Practices (GHPs) and Standard Sanitation Operating Procedures (SSOPs), provides improved process hygiene conditions that are necessary for the production of safe meat and meat products throughout the meat chain. By the end of the 20th century, HACCP had been mandated, implemented and was in routine operation in every meat company involved in international trade (Jenson & Sumner, 2012).

Microbiological testing of carcasses is commonly used for HACCP verification in abattoirs. In the European Union (EU), this is accomplished by determining whether aerobic colony counts and *Enterobacteriaceae* counts, the so-called hygiene indicator organisms, are within given acceptable ranges (European Commission, 2005). However, satisfactory verification results from the slaughtering lines do not guarantee safe meat or meat products. Furthermore, microbial counts from food contact surfaces can be, in some cases, higher than microbial counts from carcasses, so that meat can sustain an increase in microbial load during passage through the meat cutting and processing rooms (Nortjé et al., 1989a, 1989b).

Meat cutting and deboning operations, performed in meat processing plants, involve relatively intensive manipulation and handling of meat which markedly increases the microbial risks due to: (a) microbial cross-contamination via hands and utensils (knives, saws, conveyers, etc.); and (b) transfer of bacteria from the meat surface to the internal parts (Nørrung & Buncic, 2008). Personnel surfaces (hands and clothes) and other meat contact surfaces like equipment (saws and mincers), knives and cutting boards are also consistent contributors to contamination of meat and meat products at the retail level (Nortjé et al., 1989a).

In Serbia, HACCP was mandated by the Veterinary Law (Anonymous, 2005) which obliged all animal source food producers, regardless of their size, to adopt and implement a food safety system based on the

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principles of GHP and HACCP (article 82). The deadline was initially January 1st 2009 but later, with the adoption of a new food safety law (Anonymous, 2009), this was extended to June 1st 2011. A recent survey revealed that 93.5% of Serbian abattoirs, meat processors and retailers have a complete and certified HACCP system in place, while 6.5% had implemented HACCP, but they had no third party certification (Tomašević et al., 2013).

The effect of HACCP on process hygiene indicators in abattoirs has been examined before (Hutchison, Thomas, Small, Buncic, & Howell, 2007; Mackey & Roberts, 1993; Nastasijevic, Mitrovic, Popovic, Tubic, & Buncic, 2009), but to the best of our knowledge it has never been done for the continuing part of the meat supply chain: meat processing plants and meat retail facilities.

Therefore, our study was designed to determine whether the mandatory implementation of HACCP systems in meat processing plants and meat retail facilities had any significant effect on their microbiological indicators of process hygiene.

## 2. Materials and methods

### 2.1. Sampling

A total of 48,246 swab samples were analyzed from two types of meat establishments: 130 meat processing plants and 220 meat retail facilities. The period covered was seven years (2008 to 2014), divided into two terms: the first was from January 1st 2008 until May 31st 2011 (a period of 41 months and before mandatory HACCP implementation), and the second was from June 1st 2011 until December 31st 2014 (a period of 43 months and after HACCP became obligatory).

Samples were taken from three types of surfaces: food (meat) contact surfaces (FCS) (cutting boards, machines, knives and slicers, tables and containers), cooling facilities (CF) (refrigerators, freezers and other meat and meat product cooling devices) and meat handlers' hands (HS). Swabs were obtained over a measured surface area using a sterile template (10 × 10 cm) and a viscose tip swab using a technique based on the ISO 18593 method. The number of samples per year and type of meat establishment and surface examined are presented in Table 1.

### 2.2. Microbiological methods

During the first period (January 1st 2008–May 31st 2011), samples were analyzed according to the Regulation on methods for microbiological analysis and superanalysis of food, No 25/1980 C.F.R (1980) in force, for aerobic colony count (ACC) using methods coherent with ISO 4833:2003. The new Regulation on general and specific food hygiene requirements at any stage of production, processing and trade, No. 72/2010 C.F.R. (2010), effective from June 1st 2011, legally prescribed methods that were used in the second period of our investigation. All samples were analyzed according to ISO for ACC (ISO 4833:2003), *Enterobacteriaceae* (ISO 21528-2:2004), coagulase positive *Staphylococcus* (ISO 6888-1:1999), *Salmonella* (ISO 6579:2002) and *Listeria monocytogenes* (ISO 11290-1:1998). Samples were examined in an ISO/IEC 17025:2005 accredited laboratory.

### 2.3. Analysis of results

Categorical variables (classes of surface hygiene) were expressed as percentages. Chi-square test for association was used to discover possible relationships between results of microbiological indicators of process hygiene and the period they were sampled. Yate's correction was calculated when the expected frequency was less than 5. The level of statistical significance was set at 0.05. Statistical processing was performed using Microsoft Excel 2010 and SPSS Statistics 17.0.

## 3. Results and discussion

Bacterial numbers of 3.0 $\log_{10}$ CFU/cm$^2$ once were regarded as indicative of good hygiene or of an efficient meat commercial operation (Sheridan & Lynch, 1979). Today, consumer demands for safer meat are continually commanding higher and stricter hygiene standards at all levels of the meat supply chain. The limit that distinguishes dirty (or unsatisfactory) from clean (or satisfactory) food contact surface is not defined by current Serbian or EU regulations. Recent research in the food service industry suggested different values for this limit, ranging from 1.7 $\log_{10}$ CFU/cm$^2$ (de Oliveira et al., 2014) to 0.6 $\log_{10}$ CFU/cm$^2$ (Garayoa, Díez-Leturia, Bes-Rastrollo, García-Jalón, & Vitas, 2014). For the purpose of our investigation, all the process hygiene indicator results (numbers of bacteria) (n) were divided into four classes as follows: Class I ($n \le 1$ $\log_{10}$ CFU/cm$^2$); Class II (1 $\log_{10}$ CFU/cm$^2$ < $n \le 2$ $\log_{10}$ CFU/cm$^2$); Class III (2 $\log_{10}$ CFU/cm$^2$ < $n \le 2.7$ $\log_{10}$ CFU/cm$^2$); and Class IV ($n \ge 2.7$ $\log_{10}$ CFU/cm$^2$).

Chi-square tests confirmed statistically significant associations between the classes of microbiological indicators of process hygiene results and the period they were sampled, before or after mandatory HACCP implementation, for all three types of surfaces examined and for both meat processing and meat retail establishments (Table 1). The most evident improvement of process hygiene indicators was observed for food contact surfaces. Before HACCP, 90.45% of the food contact surface ACCs in meat processing plants and 98.3% of the food contact surface ACCs in meat retail were above 2 $\log_{10}$ CFU/cm$^2$. This is similar to the findings of Cetin, Kahraman, and Buyukunal (2006) in Turkish red meat processing plants, where the mean total mesophilic aerobic count on food contact surfaces was 2.58 $\log_{10}$ CFU/cm$^2$ before HACCP was introduced. In our study, after mandatory HACCP implementation, these values dropped below 2 $\log_{10}$ CFU/cm$^2$ in 96.38% of cases for meat plants and 85.8% of cases for meat retail (Table 1). This concurs with the study of Hutchison et al. (2007), and their conclusion that bacterial numbers from food contact surfaces in red meat processing plants decreased significantly in a period of four years after compulsory HACCP implementation in United Kingdom.

The work of Evans, Russell, James, and Corry (2004) demonstrated that bacteria were present on all food refrigeration equipment

**Table 1**
Number of samples in meat establishments by types of surfaces.

| | | 2008 | 2009 | 2010 | 2011[a] | 2011[b] | 2012 | 2013 | 2014 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Meat plants | FCS | 698 (84.9%) | 628 (83.1%) | 801 (82.1%) | 366 (86.9%) | 420 (81.1%) | 954 (79.7%) | 1134 (84.1%) | 1164 (81.2%) | 6165 |
| | HS | 81 (9.9%) | 67 (8.9%) | 103 (10.6%) | 26 (6.2%) | 54 (10.4%) | 147 (12.3%) | 140 (10.4%) | 159 (11.1%) | 777 |
| | CF | 43 (5.2%) | 61 (8.1%) | 72 (7.4%) | 29 (6.9%) | 44 (8.5%) | 96 (8%) | 74 (5.5%) | 111 (7.7%) | 530 |
| Total | | 822 | 756 | 976 | 421 | 518 | 1197 | 1348 | 1434 | 7472 |
| Meat retail | FCS | 4797 (88.1%) | 2026 (72.6%) | 2624 (69.8%) | 1181 (66.7%) | 2193 (67.2%) | 5129 (68.3%) | 6008 (73%) | 5665 (70.7%) | 29,623 |
| | HS | 495 (9.1%) | 614 (22%) | 867 (23.1%) | 430 (24.3%) | 719 (22%) | 1351 (18%) | 1269 (15.4%) | 1542 (19.2%) | 7287 |
| | CF | 150 (2.8%) | 149 (5.3%) | 268 (7.1%) | 159 (9%) | 349 (10.7%) | 1026 (13.7%) | 958 (11.6%) | 805 (10%) | 3864 |
| Total | | 5442 | 2789 | 3759 | 1770 | 3261 | 7506 | 8235 | 8012 | 40,774 |

N — represents the number of samples; (%) represents their share in the sample (totals may not equal to 100% because of rounding); FCS — food contact surfaces, HS — meat handlers' hands, CF — cooling facilities; 2011[a] — January 01st 2011–May 31st 2011; 2011[b] — June 01st 2011–December 31st 2011.