MICROBIOLOGICAL QUALITY OF MEAT PREPARATIONS AND MEAT PRODUCTS

Aija Melngaile, Elina Ciekure, Olga Valcina

Institute of Food Safety, Animal Health and Environment BIOR, Lejupes Street 3, Riga, Latvia, e-mail: aija.melngaile@bior.gov.lv

Abstract

The aim of the research was to perform trend analysis to reveal probable gaps and shortcomings in monitoring of microbiological contamination of meat preparations and meat products produced in Latvia to highlight proposals for further improvements. The results on microbiological contamination of foodstuffs obtained in the frame of producers' self-control within HACCP procedures were used in the research. In total, 13 food types, including minced meat, breaded pork chop, different types of sausages, smoked meat products, aspic and liver pate were investigated. Using single factor analysis of variance (ANOVA) significant differences were revealed between food types, as well as large fluctuations in aerobic plate counts (APC) were demonstrated. According to the findings of the research, APC was significantly different (p=0.001) for sausages. The maximum mean APC (6.16±6.36 lg CFU g^{-1}), as well as maximum APC (6.68±6.36 lg CFU g^{-1}) was found for liver sausage. APC was largely variable for smoked meat products. Significant difference (p=0.01) was revealed with regard to APC for aspics tested one and six days after production. Hygiene indicatororganisms (*Escherichia coli*) and pathogens (e.g. *Salmonella spp*.) most often were detected in meat preparations. Presence of coliforms was detected in aspics and liver pate. The results of the research suggest that development and usage of guidelines of good manufacturing practice for purposeful monitoring of microbiological contamination risk of meat preparations and meat products is relevant to ensure high level of protection of consumers' health.

Keywords: microbiological contamination, meat preparations and products, good manufacturing practice.

Introduction

The safety of food must be assured by a preventative approach based on the application of a Hazard Analysis Critical Control Point (HACCP) at all stages of food chain. The HACCP system is a structured approach for identifying hazards and defining and implementing systems of adequate control. Risk-based programmes have been proved successful in achieving hazard control to the extent required for consumer protection. Microbiological examination of food and environmental samples is generally recommended to validate and verify the efficiency of foods safety and quality control (ICMSF, 2011; IFST, 1997).

Foodborne disease or microbiological spoilage of food can result from the failure or inability to control microorganisms at one or more stages of food production. Therefore, the microbiological testing at various stages of food production is relevant to reveal and understand the characteristic trends in distribution of microbiological contamination (ICMSF, 2011; Schaffner, 2007; Burlingame and Pineiro, 2007; IFST, 1997).

It should be mentioned that only one official regulation concerning the microbiological quality of meat preparations is stated in food safety legislation, namely, *Salmonella* spp. contamination must not be found in 10 g of minced meat and meat preparations intended for use after thermal processing. As regards ready-to-eat meat preparations, no legal requirement for microbiological safety is stated in the legislation (Commission Regulation 2073/2005).

To monitor microbiological quality of meat preparations and meat products guidelines and recommendations of international and national level have been developed in addition to legal requirements. According to the guidelines of good manufacturing practice the level of total microbiological contamination of raw meat and raw meat preparations should not exceed 10^5 (maximum 10^7) CFU g^{-1} and of thermally processed meat products – 10^4 CFU g^{-1}. *Escherichia coli* contamination in raw meat and raw meat preparations should not exceed 10^2 (maximum 10^4) CFU g^{-1} and *Enterobacteriaceae* and *Escherichia coli* contamination in meat products – 10^2 (maximum 10^4) and 10 (maximum 10^3) CFU g^{-1}, respectively (ICMSF, 2011; IFST, 1997).

It is commonly suggested that microorganisms can enter meat preparation like sausages from meat, spices, and other ingredients, as well as from processing environment, equipment, and handlers that can have a significant impact on the microbiological status of the end-products. In general, heating during technological processing of meat products is an effective tool to reduce microbial counts of end-products (Güngör, 2010).

Development of preventive food safety assurance systems comprises both the identification of important food safety hazards and the introduction of regular monitoring measures in critical control points of technological processes. It is widely recognised that management of technological processes should be based on detailed analysis of product characteristics and process conditions to assess the potential impact on quality and safety of the ready-to-eat foods (Schaffner, 2007; Burlingame, Pineiro, 2007).

The aim of the research was to perform trend analysis to reveal probable gaps and shortcomings in monitoring of microbiological contamination of meat preparations and meat products produced in Latvia to highlight proposals for further improvements.

Materials and Methods

The data on microbiological contamination of food products obtained in frame of producers' self-control within HACCP procedures (December 2012 – January 2014) were used to analyse microbiological quality of

meat preparations and meat products produced in Latvia. Food samples were taken at three meat processing companies and were stored at temperature +4 °C after sampling and during delivering to the laboratory. All samples of meat preparations were taken one day after production, but samples of meat products were taken on different days of shelf-life (namely, one to 11 days after production) to evaluate distribution of microbiological contamination.

During the research food products were divided into two compatibility groups: meat preparations (no thermal processing used during production) and meat products (thermally processed foodstuffs). In total 144 samples of meat preparations and 141 samples of meat products were analysed for the aerobic plate count (APC). 724 samples of meat preparations and products were analysed for presence of hygiene indicatororganisms (coliforms and *Escherichia coli*) and pathogens (*Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus aureus*, and sulfite – reducing clostridia).

To perform the mathematical analysis of the analytical results, food products of the two compatibility groups were grouped into 13 compatibility types on the base of characteristic ingredients and/or production technology, namely: minced meat (110 samples, including pork, beef and mixed), hot-smoked meat products (33 samples), frankfurters and small sausages (33 samples), cooked sausages (29 samples), breaded pork chops (24 samples), aspics (19 samples), kebab or minced pork skewers with added spices (10 samples), semi-dried sausages (10 samples), hot-smoked sausages (six samples) liver sausages (four samples), semi-smoked sausages (four samples), liver pate (two samples), and cold-smoked sausages (one sample).

Following standards were used for testing of microbiological quality of meat preparations and products: standard LVS EN ISO 4833-1:2014 was used for detection of Aerobic plate counts (APC), standard LVS EN ISO 11290-2/A1:2007 amended by standard LVS EN ISO 11290-2:1998/A1:2005 – for testing of *Listeria monocytogenes*, standard GOST R 52815-2007 – for detection of *Staphylococcus aureus*, standard LVS EN ISO 6579:2003 amended by standard LVS EN ISO 6579:2003/AC:2006 – for testing of *Salmonella spp.*, standard GOST 29185-91 – for testing of presence of sulphite-reducing clostridia, standard LVS ISO 16649-2:2007 – for detection of presence of *Escherichia coli*, and standard GOST R 52816-2007 – for detection of coliforms in food samples.

The statistical analysis of the analytical data was performed using single factor analysis of variance (ANOVA). Results on microbiological testing of cold-smoked sausage were excluded from further statistical analysis because only one sample was tested. In cases when p-value was $p<0.05$, it was considered that features under research are mutually dependent with probability of 95%. The data of mathematical analysis were described with help of histograms.

Results and Discussion

The results of the mathematical analysis indicate that APC values for meat products and meat preparations are not significantly different (p=0.23) (Fig. 1 and Fig. 2).

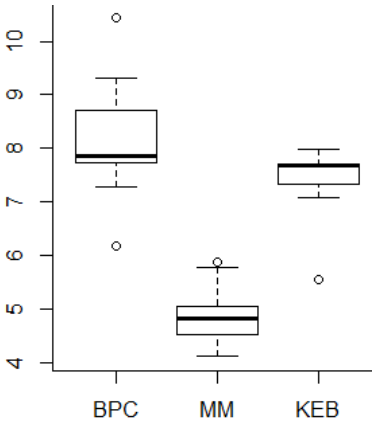

Figure 1. Minimum, maximum and median of APC levels in meat preparations (lg CFU g^{-1})
BPC – breaded pork chops, MM – minced meat, KEB – kebab

The findings of the research suggest that meat products, which are subjected to thermal processing during the production process, may still contain high numbers of microorganisms.

The results of the mathematical analysis indicate that the value of APC within the group of meat preparations (foodstuffs that have not undergone thermal processing) is substantially different (p=0.02) and dependent on the method of technological treatment. The highest maximum APC value (10.43±9.47 lg CFU g^{-1}) and the highest mean APC value (9.14±9.47 lg CFU g^{-1}) was found for samples of breaded pork chops (Fig. 1). Significant difference was not revealed for APC in kebab with added paprika and kebab with added herbs (p=0.15). Despite the fact that samples of meat preparations were taken and analysed only one day after production a huge variation between APC values was observed. Standard deviation of APC for breaded pork chops and minced meat was even higher than the mean value of APC (Table 1).

Standard deviation is usually used to describe the distribution in relation to the mean value. Basically, a large standard deviation means that the values in a statistical data set are farther away from the mean, on average. Thus, from mathematical point of view, a large standard deviation found in frame of the research reflects a large variation between APC values (or the existence of data with extreme values) for the types of meat preparations that were studied. From food safety viewpoint, the results that deviate significantly from the trend may indicate a tendency towards a situation which is out of control and may highlight the need for attention before control is lost. It is always very essential to understand the nature of potential hazards that may be presented by raw materials (ICMSF, 2011; Schaffner, 2007; IFST, 1997).

Table 1

Mean value, standard deviation and median of APC (lg CFU g^{-1}) for meat preparations and meat products

Type of meat preparation or product	Mean value	Standard deviation	Median
Minced meat	5.08	5.16	4.83
Kebab	7.64	7.48	7.67
Breaded pork chops	9.14	9.74	7.86
Cold-smoked sausages	1.00	-	1.00
Semi-dried sausages	3.01	2.85	3.10
Liver pate	3.51	1.85	3.51
Hot-smoked sausages	3.99	3.73	4.08
Cooked sausages	4.86	5.52	2.04
Frankfurters, small sausages	4.91	5.58	2.90
Smoked meat products	4.94	5.55	2.56
Semi-smoked sausages	5.12	5.41	3.51
Liver sausage	6.16	6.36	5.69
Aspic, day 1	4.56	4.73	4.19
Aspic, day 2	5.85	6.08	3.23
Aspic, day 6	8.33	8.40	8.24

The lowest maximum, minimum and mean APC values were found for minced meat samples. The mean value of APC for raw meat ($5.08x10^5 \pm 5.16x10^5$ CFU g^{-1}) is still in line with international guidelines of good manufacturing practice and Finnish recommendations to good quality of minced meat, however, the huge standard deviation suggests the large variability of microbiological quality of minced meat produced in Latvia. The maximum and mean APC values for breaded pork chops are well above the value recommended in the international guidelines (10^7 CFU g^{-1}) (ICMSF, 2011; IFST, 1997; Skrökki, 1997).

The results of the mathematical analysis indicate that the value of APC within the group of meat products (foodstuffs that have been thermally processed) is substantially different (p=0.0005) and dependent on the method of technological processing. As aspic samples were analysed on several days after production – one, two or six days after production – the APC values for aspics were excluded from the mathematical analysis.

The findings of the research suggest that microbiological quality of ready-to-eat meat products should be improved. The maximum and mean values of APC for liver sausages and semi-smoked sausages, as well as maximum APC values for frankfurters, small sausages and cooked sausages are not in line with international guidelines of good manufacturing practice (10^5 CFU g^{-1}) and are close to the maximum acceptable level (10^7 CFU g^{-1}) (ICMSF, 2011; IFST, 1997). The highest maximum APC (6.68±6.36 lg CFU g^{-1}) and the highest mean APC (6.16±6.36 lg CFU g^{-1}) was found for samples of liver sausage (Table 1, Fig. 2). High maximum and mean values of APC were also revealed for semi-smoked sausages and smoked meat products.

A huge variation between APC values was observed. Standard deviation of the mean values of APC for many meat products was much higher than the mean value of APC (Table 1). Like in case with meat preparations, the large standard deviations indicate that the APC values are largely dispersed and extreme values are farther away from the mean value. Thus, the large standard deviations found in frame of the research reflect a large variability of APC values within types of meat products that were studied. However, from food safety point of view the results that deviate significantly from the common trend may indicate a tendency towards a situation which is out of control and may highlight the need for attention before control is lost (ICMSF, 2011; Schaffner, 2007; IFST, 1997). Comparatively less variations in APC values were revealed for hot-smoked sausages and semi-dried sausages.

The results of the mathematical analysis indicate that the value of APC for aspics analysed one, two and six days after production is substantially different (p=0.01). In addition, the correlation coefficient r^2=0.75 indicates a strong positive correlation between level of APC and day of storage (Fig. 3). It is necessary to emphasize that the mean value of APC for aspics analysed six days after production (8.33±8.40 lg CFU g^{-1}) was about 300 times higher than for aspics analysed only one day after production (4.56±4.73 lg CFU g^{-1}). Maximum APC value that was observed for aspic tested six days after production was the highest one within the group of meat products (8.70±8.40 lg CFU g^{-1}).

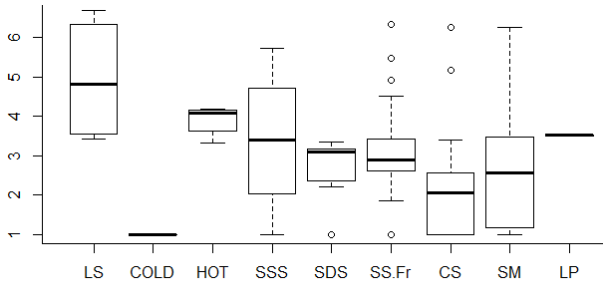

Figure 2. Minimum, maximum and median of APC levels in meat products (lg CFU g^{-1})

LS – liver sausages, COLD – cold-smoked sausages, HOT – hot-smoked sausages, SSS – semi-smoked sausages, SDS – semi-dried sausages, SS.Fr – small sausages and frankfurters, CS – cooked sausages, SM – smoked meat, LP – liver pate

The statistically significant difference (p=0.001) was found with regard to APC for different types of sausages. The minimum APC for the most types of sausages was <1 lg CFUg^{-1} with the exception of liver sausages and hot-smoked sausages, the minimum APC of which was 3.43±6.36 lg CFU g^{-1} and 3.32±3.73 lg CFU g^{-1}, respectively (Table 1, Fig. 2).

The maximum APC value (6.68±6.36 lg CFU g^{-1}) was found for liver sausage.

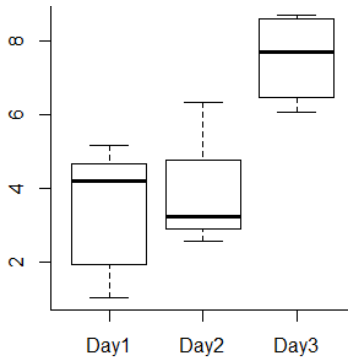

Figure 3. APC level in aspics lg CFU g^{-1}, referring to different days of storage

Day1 – one day after production, Day 2 – two days after production, Day 6 – six days after production

The research revealed a huge fluctuation between APC values for liver sausages produced in different factories, namely the APC values for liver sausage tested on the day of production (5.99 lg CFU g^{-1}) and for liver sausage tested two days after production (6.68 lg CFU g^{-1}) were much higher than for liver sausage the sample of which was analysed 10 days after production (3.43 lg CFU g^{-1}). Unlike for liver sausages, comparatively low APC was revealed for liver pate (3.52 lg CFU g^{-1}) even 11 days after production that may suggest more use of food preservatives.

Although in general it could be expected that APC for cooked meat products should be higher than for dried meat products, no significant difference was detected with regard to APC for smoked sausages and cooked sausages (p=0.55). The findings may suggest about inadequate parameters of technological processing or cross-contamination of smoked sausages after production.

Like for liver sausages a huge variation in APC values was found for smoked pork products produced in different factories; for example, APC varied greatly from <1 lg CFU g^{-1} to 6.26 lg CFU g^{-1} on the day of production of smoked pork products, as well as for sample tested on the day of production the APC value was much higher (6.26 lg CFU g^{-1}) than for several other samples tested 5 days after production (<1 lg CFU g^{-1}).

Hygiene indicatororganisms and pathogens were detected in 72 (10%) of 724 meat product samples tested.

In total, coliforms were tested in 77 samples of meat products, and only two samples – samples of aspic and liver pate – were positive. The presence of *Escherichia coli* (≥1 lg CFU g^{-1}) was detected in 28% of 188 samples tested. *Escherichia coli* were not found in thermally processed meat products. Most often *Escherichia coli* were detected in kebab samples, namely it was detected in 19 of 20 kebab samples tested. *Escherichia coli* were detected in 31 minced meat samples (in 23% samples of 135 samples tested). Statistically significant difference (p=0.008) was revealed in relation to *Escherichia coli* count for minced meat (mean value 2.04±1.94 lg CFU g^{-1}) and for kebab (mean value 3.11±3.40 lg CFU g^{-1}). The average *Escherichia coli* count in breaded pork chop was 1.70±1.45 lg CFU g^{-1}. The results indicate that *Escherichia coli* count in kebab exceed 10^2 CFU g^{-1} that is internationally recommended reference value of good hygiene practice (ICMSF, 2011; IFST, 1997).

Pathogenic microorganisms were mainly found in raw meat preparations. *Salmonella spp.* were detected in 8 minced meat samples of 282 samples of meat preparations and meat products tested. According to the results of *Salmonella* serotyping, *Salmonella typhimurium* were revealed in five tests.

Listeria monocytogenes were detected in 4 minced meat samples of 110 samples of meat preparations and meat products that were tested for the presence of *Listeria monocytogenes*.

Presence of *Staphylococcus aureus* was not detected in 29 samples of sausages and smoked meat. Sulphite – reducing clostridia were found in one sample of semi-dried sausage.

It should be taken into account that the potential for growth and/or toxin production of residual microbial population in the end-products depends on the types of organisms present in food and their ability to grow to a level of concern under the storage conditions applied during the shelf life (ICMSF, 2011; Schaffner, 2007; IFST, 1997). Therefore, the microbiological quality of raw meat and raw meat preparations, as well as methods of technological processing of meat and meat preparations is of great importance to control the microbiological contamination of ready-to-eat meat products.

The findings of the research demonstrate characteristic trends in prevalence of microbiological contamination in meat preparations and meat products produced in Latvia, including:

- high variability of microbiological quality of meat preparations and meat products was revealed during shelf-life of foodstuffs, suggesting that foods of significantly different microbiological quality are marketed;
- high numbers of microorganisms in thermally unprocessed meat preparations, especially in breaded pork chops were demonstrated, indicating that maximum and mean APC values can be well above the international guidelines of good manufacturing practice;
- also, high numbers of microorganisms in certain thermally processed meat products were detected, indicating that maximum and mean values of APC for liver sausages, semi-smoked sausages, as well as for frankfurters, small sausages and cooked sausages are not in line with international guidelines of good manufacturing practice;
- microbiological contamination of meat products was generally not dependent on the method of

technological processing, demonstrating that high risk products can be found within different meat products types – for example, statistically significant difference was not found between APC values of smoked and cooked sausages;

- the mean value of APC for aspics increased dramatically within six days after production, proving that setting of adequate "use by" is not carefully investigated;
- pathogenic and indicatororganisms were found in raw meat preparations, indicating that raw meat and raw meat preparations can be a source of pathogens and further thermal processing is therefore of great importance, including giving precise cooking instructions to final consumers on labels;
- the presence of coliforms was detected in aspics and liver pate, suggesting that occasionally presence of pathogens can not be excluded.

The most probable reasons of high microbial counts in meat preparations and meat products might be poor hygienic quality of raw meat and other ingredients, inadequate storage and thawing conditions, as well as contamination from technological equipment and via hands of personnel. In addition, the inadequate temperature-time parameters of thermal processing, cross-contamination of ready-to-eat products after production process or due to contaminated packaging material can enhance the microbial load of end-products.

A clear understanding of the effects of food handling practices and processing technologies on microorganisms and, in particular, on pathogens in foods, including their survival and growth characteristics is essential (ICMSF, 2011; Schaffner, 2007; IFST, 1997). The results of the research suggest that purposeful investigation of the microbiological quality of meat preparations and meat products with the aim to perform trend analysis of microbiological contamination should be carried out at the sites of production. In order to reduce presence, survival and multiplication of pathogens in end-products, verification of good manufacturing practice and monitoring procedures, as well as validation of overall HACCP procedure is of great importance.

Conclusions

A huge load of total microbiological contamination in meat preparations and meat products can lead to introduction of pathogenic microorganisms in foods therefore risk assessment on the base of trend analysis is relevant.

To conclude on bottle-necks during production of meat preparations and products, purposeful testing of indicatororganisms can be recommended. The analysis of trends in microbiological contamination of food and environmental samples should be used to improve theoretically developed HACCP plans at the level of individual food production companies. In addition, quality of marketing conditions should be studied by producers for better understanding of changes in microbiological quality of foods during shelf-life.

The results of the research suggest that development of guidelines on good manufacturing practice to explain common principles of trend analysis and purposeful monitoring of microbiological contamination of meat preparations and meat products is essential to ensure continuous improvement of microbiological quality of foods and thereby a high level of protection of consumers' health.

Acknowledgment

This study was made possible through the kind contribution and support of the Latvian Federation of Food Enterprises.

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