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MICROBIOLOGICAL RISK ANALYSIS IN CATERING ESTABLISHMENTS

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The epidemiological data suggest that the food preparation process in public catering establishments involves the risk of food microbiological contamination. To develop a preventive food safety assurance system based on HACCP (Hazard Analysis and Critical Control Points) principles, adequate identification, monitoring and communication of food safety hazards are important considerations. The aim of the research was microbiological risk analysis of catering establishments. Statistical analysis was used in microbiological risk assessment and to ensure science-based proposals for control of microbiological contamination and prevention of outbreaks of food-borne infections. The results on microbiological testing of 17 192 food samples and 17 604 surface swab samples were analysed using the SPSS 13.0 and MS EXCEL software packages. Statistically significant differences in microbiological contamination of food and environmental surfaces with regard to Aerobic Plate Count, coliforms and S. aureus *were found. Impact of technological processing on safety of ready-to-eat foods was demonstrated. Petrifilm rapid test methods were tested for use as self-control purposes. The results of the research demonstrate characteristic trends in contamination of foods and environmental objects in catering establishments and ensure scientific justification for setting priorities with regard to relevant control measures during technological processing and serving of food.*

Key words: *risk analysis, microbiological risk assessment, catering food safety, HACCP.*

INTRODUCTION

Improvement of food quality and safety is the overall aim of food policy to achieve a higher level of protection of consumer health. Food should not contain contamination that can create risk to human health. The primary responsibility with regard to implementation of food safety legislation rests with food business operators. To fulfil legal requirements, food establishments need to establish appropriate food safety management procedures based on HACCP (Hazard Analysis and Critical Control Points) principles (Farber *et al*., 2000; Luning *et al*., 2006).

The epidemiological data suggest that food preparation processes in catering establishments are often associated with increased food microbiological contamination risk (Griffith and Clayton, 2005; Koppanen *et al*., 2005; Szabo, 2005; Bohm *et al*., 2007). Pathogenic microorganisms can enter food due to unhygienic food handling procedures, and can multiply in food due to inadequate food storage, chilling, thawing and processing parameters (Pourkomailian, 2005; Scmhid *et al*., 2007).

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 (Kārkliņa *et al*., 2005; Burlingame and Pineiro, 2007; Schaffner, 2007).

According to global food safety standards, 'risk' means a function of the probability of an adverse health effect consequential to a hazard, and 'risk analysis' means a process consisting of three interconnected components: risk assessment, risk management and risk communication (Anonymous, 2006). It should be emphasized that implementation of risk management and risk communication measures should always be based on identification of objective risk factors (Stringer, 2005; Špoģis, 2005; Rivža *et al*., 2007). Microbiological risk assessment can be used as a supportive tool for establishment of scientifically justified control measures within HACCP to improve the efficiency of risk management and communication procedures (Reij M.W *et al.*, 2004; Sprenger, 2004; Anonymous, 2005; Buchanan, 2005; Tebbutt, 2007; Hugas *et al.*, 2007; Melngaile and Karklina, 2007; 2006; Lammerding, 2007; Fretz, 2007; Rodgers, 2005). The concept of risk analysis should be applied for development of a food safety assurance strategy of both the food businesses and the governmental food safety surveillance and control institutions (Andersen *et al.*, 2007). It should be mentioned that catering establishments still face serious problems in relation to identification of food safety hazards and implementation of adequate monitoring procedures (Bolton *et al.*, 2008; Eves and Dervisi, 2005; Hielm *et al.*, 2006).

The aim of the research was to investigate the application of microbiological risk analysis in public catering establishments. In order to achieve the aim of the research, the following tasks were identified a) to assess microbiological contamination risk that results from technological processing of foods in public catering establishments, including food cross-contamination risk; b) to highlight proposals for further improvement of microbiological risk management and communication procedures in public catering establishments.

MATERIALS AND METHODS

Microbiological testing of food samples. Results on microbiological testing of 17 192 food samples from catering establishments obtained in the frame of the state surveillance programme and available in the Database of the Food and Veterinary Service of Latvia, including 3152 Aerobic Plate Count tests, 4481 coliform tests, 2138 *Staphylococcus aureus* tests, and 5283 *Salmonella* spp. tests, were statistically analysed.

Microbiological testing of surface swab samples. Results on microbiological testing of 17 604 surface swab samples from catering establishments that were obtained in the frame of the state's surveillance programme and available at the Database of the Food and Veterinary Service of Latvia, including 8934 coliforms' tests, 5113 *S. aureus* tests, and 3385 *Salmonella* spp. tests, were statistically analysed.

Testing methods. The following testing methods were used in the frame of the state surveillance programme: a) Aerobic Plate Count (APC) in foods was determined according to the standard method LVS ISO 4833:2003 "Microbiology. General directions for enumeration of microorganisms. Colony counting method at 30 ^{o}C"; b) *Enterobacteriaceae* count in foods and environmental surface swab samples was determined according to the standard method ISO 21528-2:2004 "Microbiology of food and animal feeding stuffs. Horizontal methods for the detection and enumeration of *Enterobacteriaceae* – Part 2: Colony – count method"; c) *Staphylococcus aureus* count in food samples was determined according to the standard method LVS EN ISO 6888-1/A1-2003 "Microbiology of food and animal feeding stuffs – Horizontal method for enumeration of coagulase positive *Staphylococcus aureus* – Part 1: Method, using environment"; d) Coliforms in surface swab samples were determined in accordance with the test method VVMDC-T-012-010.5-2000 "Methods for microbiological analysis of surface swabs – Part 2: Detection of coliforms"; e) *Staphylococcus aureus* in surface swab samples was tested in accordance with the test method VVMDC-T-012-010.5-2000 "Method for microbiological analysis of surface swabs – Part 5: Detection of *Staphylococcus aureus"*.

Approbation of *Petrifilm* rapid test method. The *Petrifilm* rapid test method was tested for monitoring of cleaning efficiency – disinfection procedures in catering establishment, using ready-to-use selective media for cultivation of microorganisms. Swabs were taken from 20 visually clean surfaces, taking into account known significant trends in distribution of microbiological contamination. 3M Microbiology Products (USA) for enumeration of microorganisms were used for detection of aerobic plate count (APC), *Enterbacteriaceae, Escherichia coli, Staphylococcus aureus*, yeast and mould countc in swab samples.

Data arrangement for mathematical analysis. For statistical analysis, the following encoding of data was made:

1) food samples were grouped into 14 identification classes, 31 groups and 142 types, taking into account the food main components and characteristic methods of technological processing;

2) surfaces were grouped into 16 identification classes, 90 groups and 187 types, taking into account the characteristic application of equipment, utensils, constructions and other objects;

3) methods of technological processing were grouped into 18 groups taking into account the way of technological processing, including characteristic sequence of technological processes during food preparation processes.

Statistical analysis. Microbiological contamination of foods and surfaces of equipment and utensils was described by features: Aerobic Plate Count (APC), coliforms, *Staphylococcus aureus* and *Salmonella* spp. The statistical data were processed using software package SPSS 13.0.

Testing results on coliforms, *Staphylococcus aureus* and *Salmonella* spp. were qualitative parameters. Presence was designated as "1" and not detected ase "0". The qualitative features were ranked with regard to the following factors: identification classes, groups and types of foods; identification classes, groups and designations of surfaces; methods of technological processing; and types of microorganisms. Significant differences ($P < 0.05$) in empirical and theoretical distributions were determined using the Chi-Square test.

Aerobic Plate Count was expressed quantitatively as colony-forming units (CFU) g^{-1}. Analysis of variance ANOVA was used to test for differences in APC among public catering establishments, identification classes, groups and types of foods and methods of technological processing. Homogeneity of variance was tested. The post hoc Scheffe criterion was used in cases with similar variances and Dunnet's T3 criterion when variances were not similar.

MS EXCEL software was used for graphical description of the data. Proportions were shown as pie charts. Other data were depicted as bar charts and histograms.

RESULTS

Microbiological risk assessment with regard to ready-to-eat foods. The results of the statistical analysis indicate that the mean value of APC in ready-to-eat foods, as well as probability of the presence of coliforms and *S. aureus* in ready-to-eat foods, significantly depended on the method of food technological processing (P = 0.000) (Figs. 1 and 2). Increased microbiological contamination risk was proven for foods that were prepared using mechanical processing, for both thermally unprocessed foods and thermally processed and chilled foods. Characteristic trends in microbiological contamination were also detected for thermally processed foods.

The APC of ready-to-eat foods significantly differed among the identification classes of ready-to-eat foods (Fig. 3), as well as among certain groups and types of foods (P = 0.000). The mean value of APC was significantly lower for thermally processed foods, such as hot soups, grain and vegetable foods, fish foods and meat foods. The mean value of APC was considerably higher for chilled foods, e.g. chilled entry foods, pastry foods, salads and dairy products.

The APC significantly differed for farinaceous foods, salads and pastry foods, with higher mean APC for foods with meat components. According to the results of microbiological risk assessment, ready-to-eat foods were grouped into four categories:

- thermally processed foods, the APC of which was usually less than 1000 CFU g^{-1}: thermally processed soups, grain foods, seafood, vegetable foods and meat foods;

- ready-to-eat foods, the APC of which was usually 1000–5000 CFU g^{-1}: thermally processed pasta foods, farinaceous foods and different dessert foods. A relatively large standard deviation was found for pasta foods (2.9), farinaceous foods (3.0), and different dessert foods (3.1);

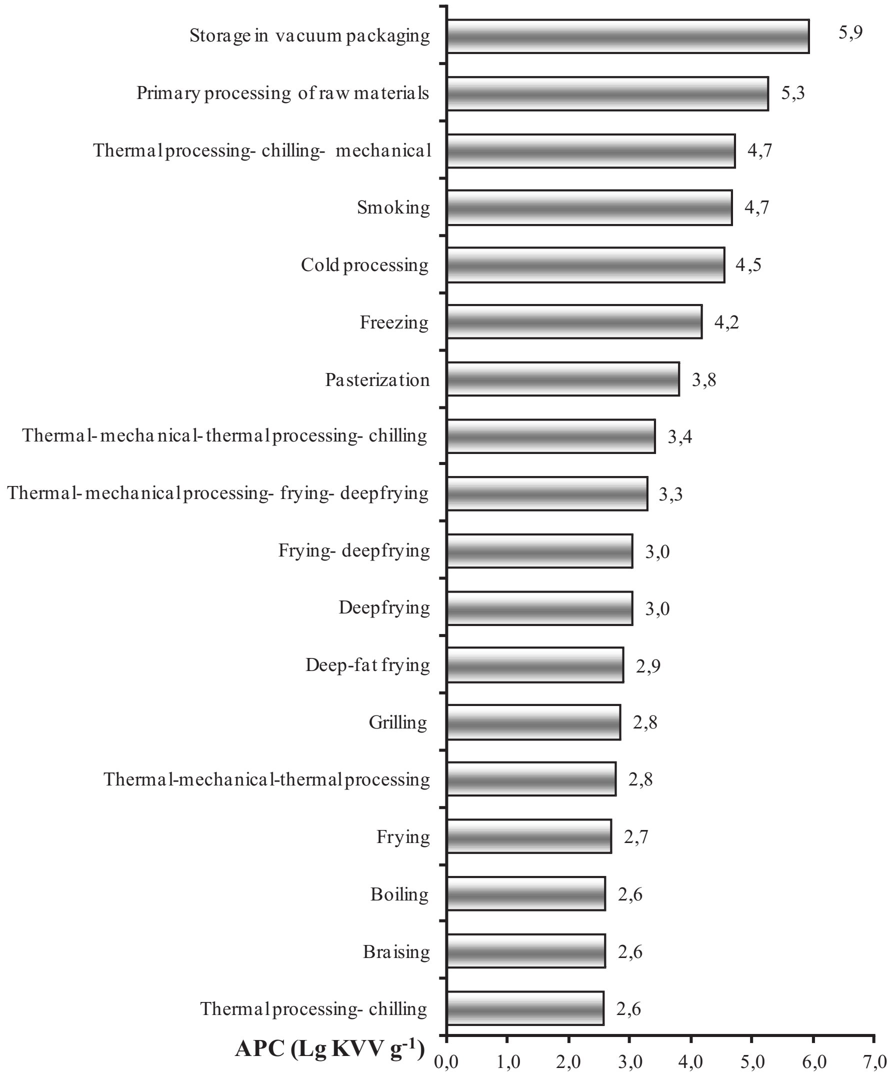

Fig. 1. Impact of the technological processing on APC (Aerobic Plate Count) of ready-to-eat foods (P = 0.000).

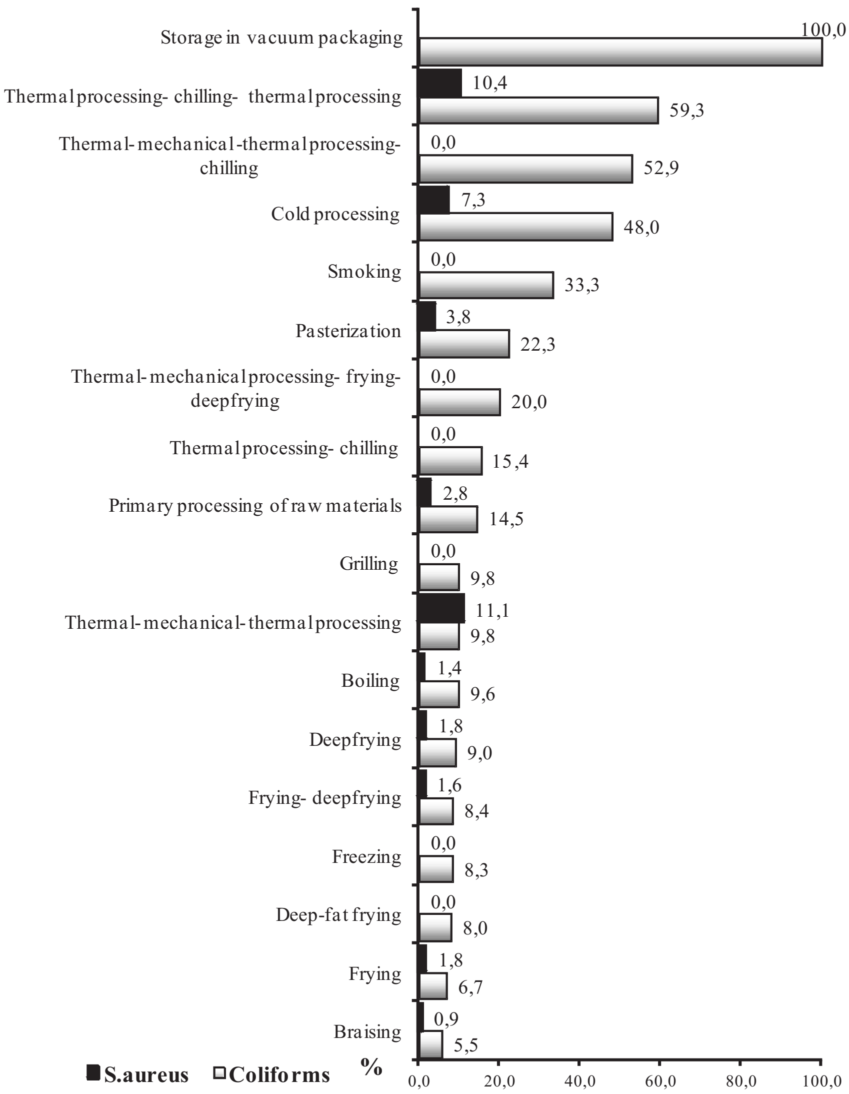

Fig. 2. Impact of the technological processing on the probability of presence of coliforms and *S. aureus* in ready-to-eat foods (P = 0.000).

- ready-to-eat foods, the APC of which was usually 5000–10 000 CFU g^{-1}: curd foods, egg foods, cold entry foods, milk product foods. A relatively large standard deviation was found for curd foods (3.3), egg foods (5.3), and chilled entries (3.8);

- ready-to-eat foods, the APC of which was usually more than 10 000 CFU g^{-1}: pastry foods and different salads (standard deviation 3.1 and 3.2, respectively).

Significant differences were observed in probability of presence of coliforms and *S. aureus* in foods of different identification classes (Fig. 4), groups and individual types of ready-to-eat foods (P = 0.000). APC and occurrence of coliforms and *S. aureus* in food samples were relatively low.

Relatively higher contamination risk with regard to coliforms and *S. aureus* was shown for the following chilled food groups: vegetable salads and salads containing components of animal origin, desert sweets, chilled meat entries and chilled curd foods. In the case of thermally processed foods, pasta and farinaceous foods had higher contamination risk.

Taking into account the mean APC value, as well as probability of presence of coliforms and *S. aureus* in different foods, higher microbiological contamination risk was observed for certain types of ready-to-eat foods: fried and braised meat and offal foods, especially fried poultry and fried minced-meat foods; pasta foods with meat components; pancakes with meat or curd stuffing; soups prepared on milk basis and rissole soup; salads containing raw vegetable components and salads containing cooked vegetable components; meat and fish entry foods; certain dessert sweets — dessert creams, mousse, sweet porridges; and for pastry foods with cream stuffing.

Microbiological risk assessment with regard to direct and indirect food contact surfaces. Significant differences were found in probability of presence of coliforms and *S. aureus* on different surfaces that come into direct or indirect contact with foods (P = 0.000) (Fig. 5). Relatively higher contamination risk was shown for utensils used for storage, display and serving of ready-to eat foods (e.g. bowls, pots, servers, ladles, spoons used for salads and dessert foods, pastry vessels, juice glasses), for utensils and equipment used for preparation of chilled foods (e.g. vegetable cutting boards, knifes, graters), as well as for surfaces

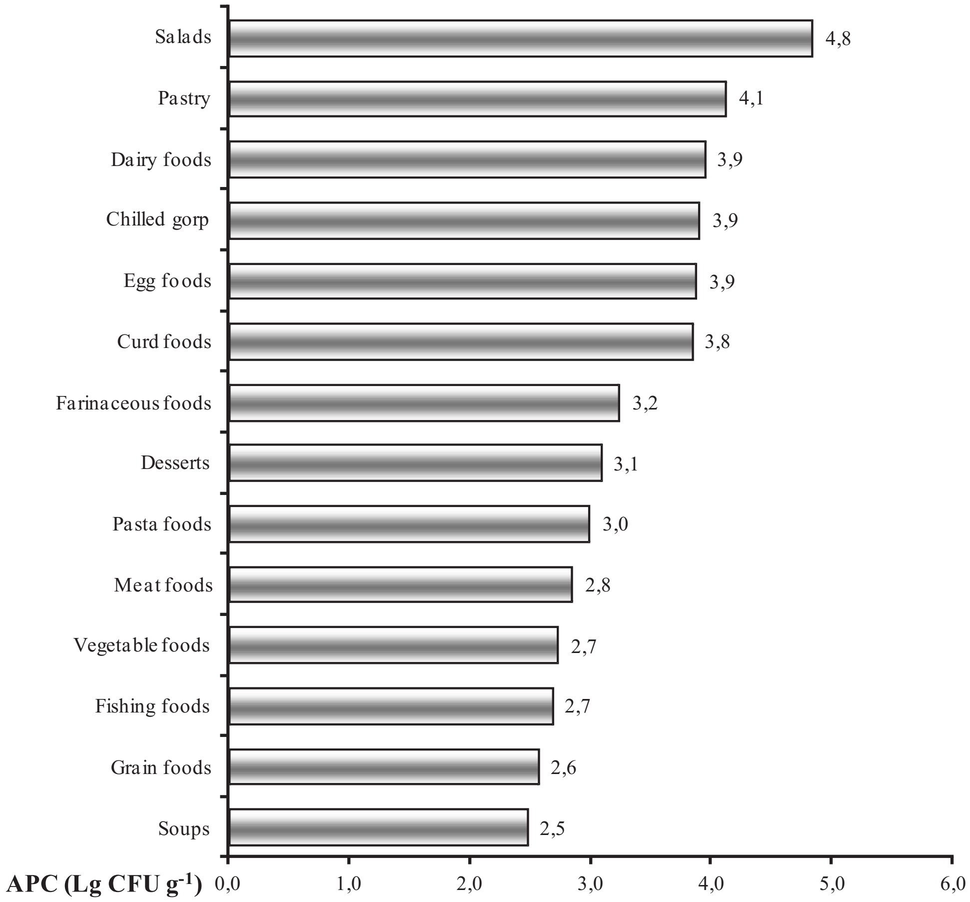

Fig. 3. Mean APC (Aerobic Plate Count) within identification classes of ready-to-eat foods (P = 0.000).

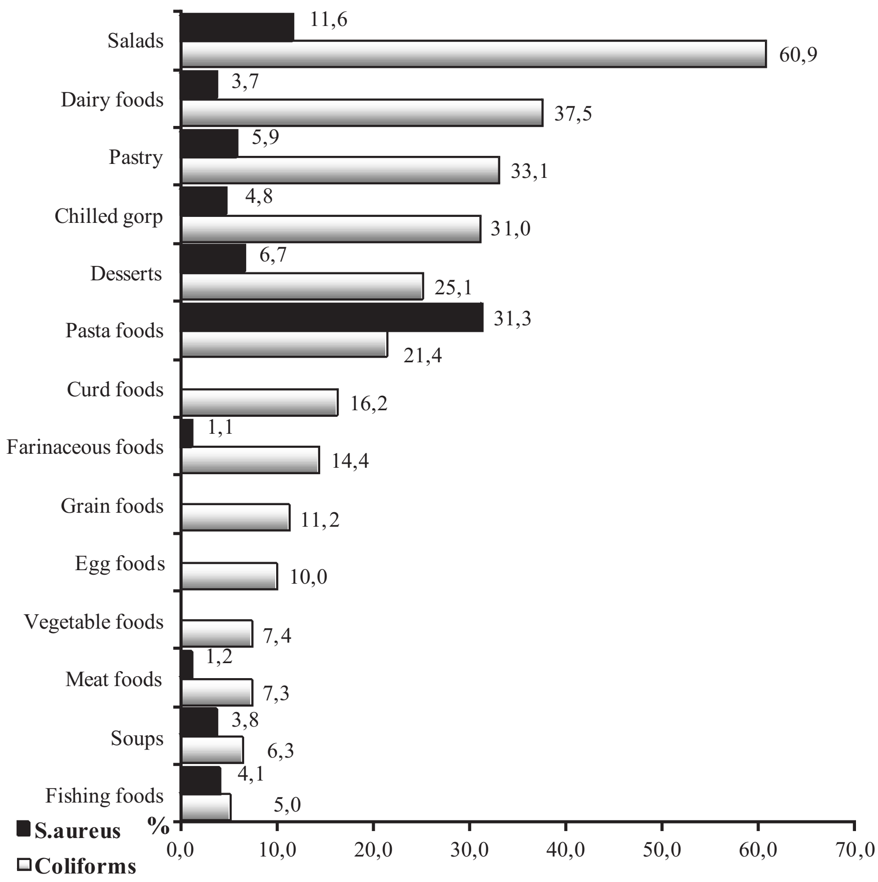

Fig. 4. Probability of presence of coliforms and *S. aureus* within the identification classes of ready-to eat foods (P = 0.000).

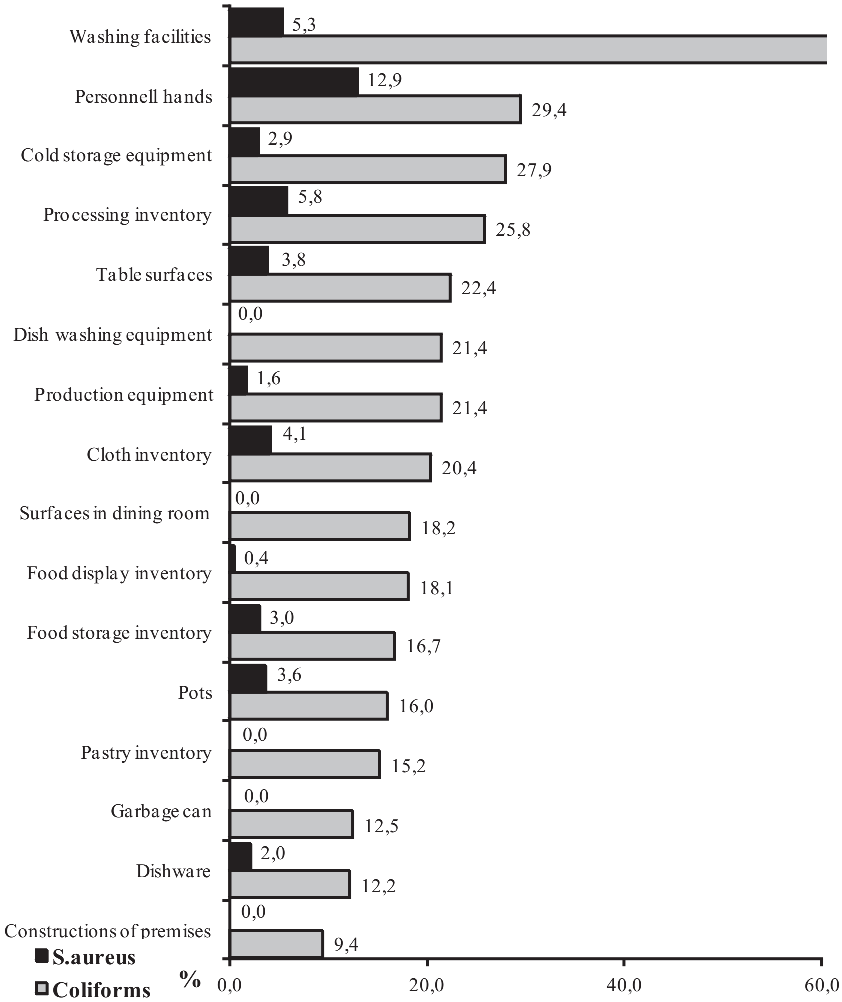

Fig. 5. Probability of the presence of coliforms and *S. aureus* on direct and indirect food contact surfaces (P = 0.000).

of certain work-tables (e.g. work-tables for salad an dessert preparation), sink taps and personnel hands. The results indicated that coliforms and *S. aureus* were most often found on surfaces that come into contact with ready-to-eat foods; surfaces that come into direct contact with personnel hands; and surfaces that come into contact with clean dishes. In total, the presence of coliforms was detected on 118 different contact surfaces (63% of surfaces examined), and the presence of *S. aureus* on 34 contact surfaces (18% of surfaces under investigation).

Taking into account that rapid hygiene tests have been recommended for verification of self-control measures in different areas of food industry (Park *et al*., 2001; Schoeller and Ingham, 2001; Ferrati, 2005; Silva *et al*., 2005; Sousa, 2005; Nyachuba and Donnelly, 2007), the approbation of *Petrifilm* rapid test methods in catering establishments was carried out during the study. Swabs were taken from surfaces for which the highest contamination risk was suggested by the statistical analysis. Significant microbiological contamination (APC), including *Enterobacteriaceae, E. coli, S. aureus,* yeasts and moulds was detected on 20 visually clean surfaces that come into contact with foods and hands of food service personnel. For example, the biggest APC values were observed in swab samples that were taken from surface of hands of food service personnel (1.1×10^4 and 4.2×10^3 CFU cm^{-2}), drink containers (6.5×10^3 CFU cm^{-2}), dessert bowls (2.8×10^3 CFU cm^{-2}) and salad bowls (1.7×10^3 CFU cm^{-2}). All tested microorganisms, i.e. *Enterobacteriaceae, E. coli, S. aureus,* yeasts and moulds were detected on visually clean surfaces of salad bowls and vegetable cutting knives. Presence of *S. aureus* was detected on surfaces of 12 different utensils and equipment, due to presence of those bacteria on surface of hands of two food service personnel.

DISCUSSION

It is widely recognized that adequate preventive measures should be put in place to eliminate or reduce microbiological contamination of ready-to-eat foods in catering establishments. According to the research results, the main risk factors that lead to microbiological contamination of foods are: cross-contamination of foods due to poor hygiene practice, survival of bacteria due to insufficient temperature-time regime during thermal processing of foods, as well as multiplication of bacteria due to inadequate food chilling and storage conditions. Similar risk factors are mentioned in publications of other authors (Soriano *et al.*, 2002; Evans *et al*., 2004; Beumer and Kusumaningrum, 2005; Koppanen *et al*., 2005; Medus, 2005; Bohm *et al*., 2007; Scmhid *et al*., 2007). It should be emphasized that, unlike previous studies, the distribution of microbiological contamination was examined by statistical analysis. The results of research carried out by the authors suggest that implementation of preventive hygiene measures is a critical step that may have substantial impact on catering food safety; unfortunately, the efficiency of hygiene procedures is not adequately controlled.

According to findings of the research the presence of hygiene indicator-microorganisms in ready-to-eat foods can be also detected in cases when overall APC is relatively low. Taking into account that even small amounts of pathogenic microorganisms can cause illness of food consumers, trends in distribution of microbiological contamination should be analysed and used to develop adequate control arrangements in a timely manner.

The statistical data obtained showed significant differences in distribution of microbiological contamination with regard to foods and food contact surfaces, and therefore, can be successfully used for improvement of procedures for both the technological processing of foods and the cleaning and disinfection of contact surfaces. The results on microbiological risk assessment can be successfully used for ranking of foods and food contact surfaces with regard to microbiological contamination, as well as for purposeful modelling of food microbiological contamination risk with regard to impact of certain technological processes. For example, the results on risk assessment suggest that there is high probability of cross-contamination of salads and desserts during preparation and serving of them in catering establishments, as we observed a probability of presence of coliforms and *S. aureus* (Fig. 6; Fig. 7). It should be mentioned that food and swab samples are rarely analysed within self-control procedures of catering establishments (e.g. only one ready-to-eat food sample or aggregated swab sample during period of one-two years) and do not provide suitable information on the actual distribution of microbiological contamination within the course of technological processing of foods.

The data obtained in frame of the state's surveillance and control programmes suggest that control of *Salmonella spp.* in ready-to-eat foods and on food contact surfaces almost

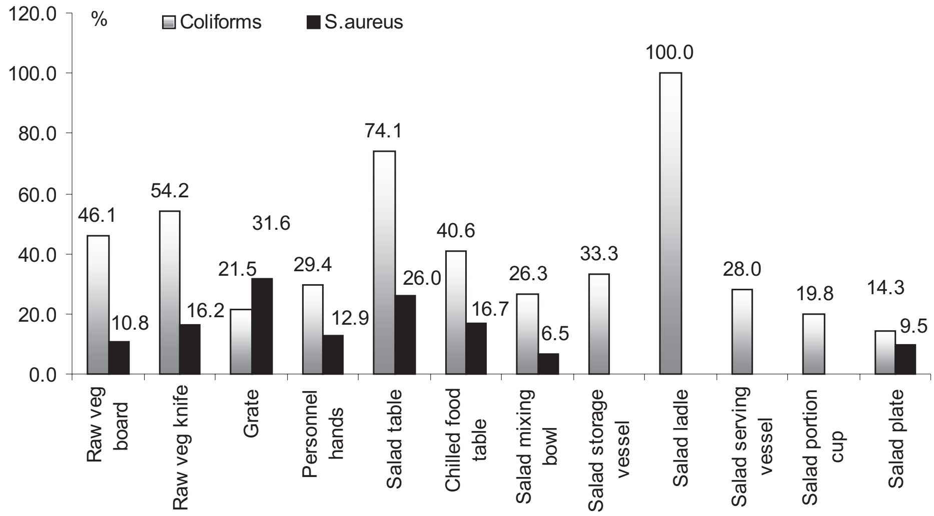

Fig. 6. Risk assessment with regard to food contact surfaces that contribute to cross-contamination of fresh vegetable salads.

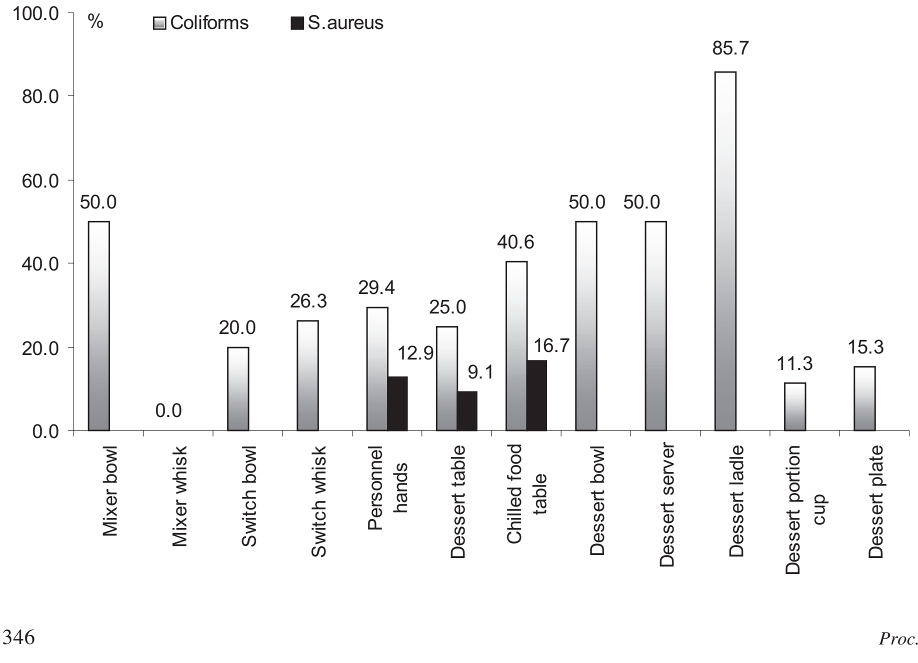

Fig. 7. Risk assessment with regard to food contact surfaces that contribute to cross-contamination of desserts

always give negative data that cannot be used for trend analysis in frame of HACCP procedures. According to data obtained during the research, 5283 food samples and 3385 surface swab samples were tested to monitor presence of *Salmonella* spp. and only one test result was positive, i.e. *Salmonella* spp. was detected in one sample of fried minced-meat product. It can be concluded that *Salmonella* spp. tests did not reveal characteristic trends in distribution of microbiological contamination, and therefore did not ensure relevant information for improvement of food safety management procedures.

The results of the research suggest that activities of microbiological risk management and communication can be implemented at several levels, namely at the level of identification class, group or individual type of ready-to-eat foods, according to the method of technological processing of food and/or taking into account food cross-contamination risk due to contact with contaminated surfaces.

The application of *Petrifilm* rapid test methods demonstrated that purposeful taking and operative testing of swab samples with emphasis on risky surfaces that have been identified by statistical analysis of risk ensures rapid feedback information on conformity of hygiene arrangements and necessity of corrective measures that should be taken immediately to avoid cross-contamination of ready-to-eat-foods. Results on approbation of the *Petrifilm* rapid test methods suggest that a large amount of microorganisms, including *Enterobacteriaceae, E. coli* and *S. aureus*, yeasts and moulds, can be present on visually clean surfaces that come into direct or indirect contact with ready-to-eat foods.

Microbiological risk assessment is tightly connected with development and improvement of microbiological risk management and communication measures in the frame of the HACCP procedure, the starting point of which should be objective analysis of microbiological hazards. The practical implementation of risk analysis in public catering establishments is summarized in Figure 8, which reflects the relationship between microbiological risk assessment and the HACCP procedure (Fig. 8).

The conclusion is that setting of priorities based on microbiological risk assessment is of great importance to ensure adequate monitoring and control activities with regard to catering food safety:

1. Random testing of food and surface swab samples in the frame of self-control procedures of catering establishments does not provide sufficient information on microbiological contamination of ready-to-eat foods and food contact surfaces. Trends in distribution of microbiological contamination should be analysed on a systematic basis.

2. Application of methods of mathematical statistics for microbiological risk assessment helps to reveal important trends in contamination of ready-to-eat foods and food contact surfaces and ensures science-based information for setting of priorities with regard to control of microbiological hazards in ready-to-eat foods.

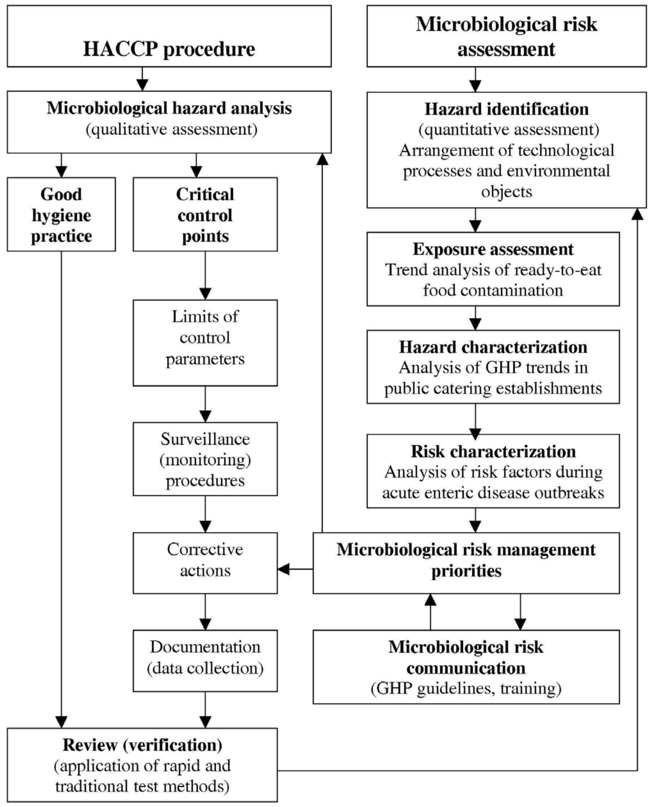

Fig. 8. Practical implementation of risk analysis in public catering establishments.

3. Application of the *Petrifilm* rapid test methods for purposeful identification of microorganisms on food contact surfaces and rapid assessment of adequacy of cleaning-disinfections procedures are a helpful tool to improve catering food safety.

4. Data on microbiological risk assessment should be used in development of science-based guidelines of good hygiene practice to improve adequacy and efficiency of self-control procedures of public catering establishments.

5. Data on microbiological risk assessment should be applied for risk-based inspection planning and setting of inspection priorities in the frame of state surveillance and control programmes in the catering area.

6. The results on microbiological risk assessment should be used for training of employees of public catering establishments, students of higher and vocational education establishments who study food safety management and food inspectors who are involved in surveillance and control in the public catering area.

7. Microbiological risk analysis can be applied in catering establishments to ensure objective data on distribution of microbiological hazards and to implement purposeful risk management and communication procedures in the frame of HACCP procedures to prevent outbreaks of food-borne diseases.

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MIKROBIOLOĢISKĀ RISKA ANALĪZE SABIEDRISKĀS ĒDINĀŠANAS UZŅĒMUMOS

Epidemioloģiskie dati liecina, ka ēdienu gatavošanas process sabiedriskās ēdināšanas uzņēmumos ietver ēdienu mikrobioloģiskās piesārņošanās risku. Lai izveidotu profilaktisku, uz *HACCP* principiem balstītu pārtikas nekaitīguma nodrošināšanas sistēmu, ir būtiski veikt atbilstošu pārtikas drošuma apdraudējumu identifikāciju, monitoringu un komunikāciju. Pētījuma mērķis bija izpētīt mikrobioloģiskās riska analīzes metodoloģijas pielietošanu ēdināšanas uzņēmumos. Lai veiktu mikrobioloģiskā riska novērtēšanu un izstrādātu zinātniski pamatotus priekšlikumus mikrobioloģiskā piesārņojuma kontrolei un pārtikas izcelsmes infekciju uzliesmojumu novēršanai, izmantotas matemātiskās statistikas metodes. Lietojot SPSS 13.0 un MS EXCEL programmatūras, analizēti 17 192 ēdienu un 17 604 virsmu nomazgājumu paraugu mikrobioloģiskās testēšanas rezultāti. Noskaidrotas statistiski nozīmīgas ēdienu un vides virsmu mikrobioloģiskā piesārņojuma atšķirības saistībā ar kopējo mikrobioloģisko piesārņojumu un zarnu nūjiņu grupas baktēriju un *S. aureus* klātbūtni. Atklāta tehnoloģiskās apstrādes ietekme uz gatavo ēdienu nekaitīgumu. Lai īstenotu paškontroli, aprobētas *Petrifilm* ātrās testēšanas metodes. Pētījuma rezultāti liecina par raksturīgām ēdienu un vides objektu mikrobioloģiskā piesārņojuma tendencēm ēdināšanas uzņēmumos un nodrošina zinātnisku pamatojumu prioritāšu izvirzīšanai, lai ēdienu tehnoloģiskās apstrādes un pasniegšanas laikā ieviestu nepieciešamos kontroles pasākumus.