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Original Scientific Paper

Longitudinal microbiological evaluation of hygiene practices in retail food shops

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ABSTRACT

This study presents a comprehensive microbiological assessment of process hygiene in 49 retail food shops over four years (January 2021 to December 2024). A total of 613 swabs from food contact surfaces and 303 swabs from food handlers' hands were analyzed to evaluate compliance with hygiene standards. Results indicated a gradual improvement in hygiene practices, with non-compliant food contact surfaces decreasing from 6.42% in 2022 to 3.30% in 2024, attributed to enhanced training and sanitation protocols. Additionally, 2.97% of food handlers' hands were non-compliant according to swab counts, primarily due to elevated aerobic colony counts, with non-compliance rates of 5.45% in 2021, 7.27% in 2022, and a decrease to 1.94% in 2024. The findings underscore the importance of continuous monitoring and targeted interventions to mitigate microbial contamination risks. Despite progress, challenges remain in maintaining optimal hygiene standards, emphasizing the need for ongoing training and adherence to hygiene protocols within the retail food sector to protect public health and prevent foodborne illnesses. Future research should focus on the long-term efficacy of training programs and sanitation practices to establish best practices for the industry.

1. Introduction

Maintaining rigorous process hygiene in retail food establishments is paramount for safeguarding public health, preventing foodborne illnesses, and ensuring compliance with stringent food safety regulations (*Rani et al*., 2023). This study addresses the critical need for continuous monitoring and evaluation of microbiological parameters on food contact surfaces and food handlers' hands, which are primary vectors for cross-contamination (*Kebede & Getu*, 2023). Such assessments are crucial because inadequate hygiene practices, including improper handwashing and contaminated surfaces, significantly contribute to the microbial load in food preparation environments, thereby elevating the risk of foodborne disease outbreaks (*Josefsen et al.*, 2011; *Fallahizadeh et al*., 2025). Furthermore, understanding the prevalent microbial loads on these surfaces and hands allows for the targeted implementation of effective sanitation protocols and hygiene training programs, which are essential for mitigating food safety risks (*Josefsen et al*., 2011). This comprehensive investigation provides critical insights into the efficacy of current hygiene protocols within

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diverse retail settings, highlighting areas that require enhanced intervention to achieve optimal food safety standards. This research, therefore, aims to systematically evaluate the microbiological status of food contact surfaces and food handlers' hands in retail shops over four years, providing a robust dataset for assessing hygiene compliance and identifying potential areas for improvement. This longitudinal study utilized a systematic sampling approach to gather comprehensive data, which is essential for understanding the ecological persistence of microorganisms in retail environments (*Josefsen et al*., 2011; *Janecko et al*., 2023).

2. Materials and methods

During four years (from January 2021 to December 2024), an assessment of process hygiene was carried out in 49 retail shops. Overall, a total of 613 swabs of food contact surfaces and 303 swabs of food handlers' hands were investigated for microbiological parameters of process hygiene (Table 1).

2.1. Swab samples

Swabs from the food contact surfaces and food handlers' hands were taken after cleaning, washing and disinfection procedures. Sampling was conducted according to the standard method *SRPS EN ISO 18593* (2018). On the sampling day, swabs were transported to the laboratory in a hand-held refrigerator and analyzed within 24 hours. All samples were analyzed in an accredited laboratory according to *SRPS ISO/IEC 17025* (2006).

Table 1. Number of swabs sampled each year

Year	Food contact surfaces	Food handlers' hands
2021	112	55
2022	109	55
2023	180	90
2024	212	103
Total	**613**	**303**

2.2. Microbiological examinations

Swabs from the food contact surfaces and food handlers' hands were tested for aerobic colony count (ACC) according to *SRPS EN ISO 4833-1* (2014) and *Enterobacteriaceae* (ENT) in line with *SRPS EN ISO 21528-2* (2017). Results of the microbiological analyses were expressed as the number of bacteria per cm^2 (CFU/cm^2) and number of bacteria per swab (CFU/swab), for swabs taken from the food contact surfaces and food handlers' hands, respectively.

2.3. Evaluation of microbiological results

Evaluation of the microbiological contamination results was carried out in accordance with the limit values set by the self-control plans of the food business operators (Table 2).

Table 2. Microbiological criteria in the self-control plans of the food business operators

Microorganism group	Porcelain, glass, smooth metal food contact surfaces	Plastic, wood, and stone food contact surfaces	Food handlers' hands
Aerobic colony count	≤ 10 CFU/cm^2	≤ 30 CFU/cm^2	≤ 2000 CFU/swab
Enterobacteriaceae	≤ 1 CFU/cm^2	≤ 1 CFU/cm^2	≤ 10 CFU/swab

3. Results and discussion

Over a comprehensive four-year period, spanning from January 2021 to December 2024, a detailed analysis was conducted across 49 retail shops in Serbia, focusing on the examination of 613 swabs collected from various food contact surfaces. These surfaces included critical items such as cutting boards, slicing machines, knives, refrigerator doors, and metal working surfaces, all of which play a pivotal role in food safety and hygiene practices. In 2021, 112 swabs were examined, followed by 109, 180, and 212 swabs in 2022, 2023, and 2024, respectively, as detailed in Table 1. This progressive increase in the number of swabs examined over the years indicates a growing commitment to monitoring and ensuring food safety standards within these retail environments.

The results of the analysis revealed that 3.59% (22 out of 613) of the food contact surfaces failed to meet the compliance criteria established in the self-control plans mandated for food business operators. Notably, the rate of noncompliance varied across the years: in 2022, the noncompliance rate was 6.42%, which then decreased to 4.44% in 2023, and further dropped to 3.30% in 2024, as illustrated in Table 3. These findings align closely with previous studies conducted by *Legnani et al.* (2004), *Garayoa et al.* (2014), and *Golić et al.* (2019). However, a stark contrast is observed in the research conducted by *Moračanin et al*. (2017), which reported a significantly higher noncompliance rate of 41.96%. The progressive reduction in the percentage of non-compliant swabs from 2022 to 2024 suggests that enhanced training initiatives for employees on the correct implementation of sanitation procedures are crucial for effective good hygiene practices (GHP) and hazard analysis critical control point (HACCP) protocols. This emphasis on training is essential for fostering a culture of food safety and compliance within retail operations.

Throughout the four-year study, the primary factor contributing to the noncompliant results for food contact surfaces was identified as an unacceptable aerobic colony count (ACC). The data showed that in 2022, a staggering 100% of noncompliant swabs were attributed to elevated ACC levels, followed by 75% in 2023 and 85.71% in 2024. This trend underscores the importance of continuous monitoring and the need for stringent sanitation practices to mitigate microbial contamination risks in food handling environments.

During the four years (from January 2021 to December 2024), in the same retail shops, 303 swabs from food handlers' hands were examined. In 2021 and 2022, 55 hand swabs were examined, in 2023, 90, and in 2024, 103 hand swabs (Table 1).

The microbiological examination of these swabs revealed that 2.97% (9 of 303) of the swabs failed to meet the compliance criteria outlined in the self-control plans mandated for food business operators. The data indicated a reasonably consistent level of hygiene among food handlers across the four years, with non-compliance rates reported as follows: 5.45% in 2021, 7.27% in 2022, although a notable decrease to 0% and 1.94% in 2023 and 2024, respectively, as presented in Table 4. A critical observation from the findings was the prevalence of elevated aerobic colony counts, which accounted for 77.78% of the non-compliant results across all years studied. This trend aligns with previous research conducted by *Jovanović et al.* (2021) and *Ivanović et al.* (2013), which reported similar hygiene challenges among food handlers. In contrast, a study by *Rašeta et al.* (2012) indicated a significantly higher rate of non-compliance, with percentages reaching as high as 30.0%, highlighting the

Table 3. Microbiological status of the food contact surfaces

Year	Number of swabs	Noncompliant		Finding	Frequency		Finding	Frequency	
		n	%		n	%		N	%
2021	112	0	/	ACC	/	/	ACC + ENT	/	/
2022	109	7	6.42	ACC	7	100.00	ACC + ENT	/	/
2023	180	8	4.44	ACC	6	75.00	ACC + ENT	2	25.00
2024	212	7	3.30	ACC	6	85.71	ACC + ENT	1	14.29

ACC – aerobic colony count; ENT – *Enterobacteriaceae* count.

Table 4. Microbiological status of the swabs from food handlers' hands

Year	Number of swabs	Noncompliant		Finding	Frequency		Finding	Frequency	
		n	%		N	%		n	%
2021	55	3	5.45	ACC	3	100.00	ACC + ENT	/	/
2022	55	4	7.27	ACC	3	75.00	ACC + ENT	1	25.00
2023	90	0	/	ACC	/	/	ACC + ENT	/	/
2024	103	2	1.94	ACC	1	50.00	ACC + ENT	1	50.00

ACC – aerobic colony count; ENT – *Enterobacteriaceae* count.

ongoing concerns regarding microbial contamination in food handling environments.

These findings emphasize the need for ongoing training and adherence to hygiene protocols among food handlers to minimize the risk of microbial contamination and ensure the safety of food products served to consumers.

4. Conclusion

The comprehensive microbiological assessment conducted over four years in 49 retail food shops reveals significant insights into the hygiene practices related to food contact surfaces and food handlers' hands. The study shows a gradual improvement in compliance with hygiene standards, particularly noted by the reduction in non-compliant food contact surfaces, which decreased from 6.42% in 2022 to 3.30% in 2024. This suggests that enhanced training and implementation of sanitation protocols among food handlers are effective in mitigating microbial contamination risks.

However, the presence of non-compliant results, particularly related to elevated aerobic colony counts, underscores the ongoing challenges faced in maintaining optimal hygiene standards. The findings emphasize the critical importance of continuous monitoring and evaluation of hygiene practices in retail food establishments. Addressing the identified areas of concern through targeted interventions and training programs is essential for further reducing microbial loads and ensuring food safety compliance.

Overall, this study highlights the necessity for sustained efforts in improving hygiene practices within the retail food sector, which is vital for protecting public health and preventing foodborne illnesses. Future research should focus on exploring the long-term impact of training programs and sanitation protocols on hygiene compliance to establish best practices for the industry.

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