

Food safety and quality assessment of an automated vending machine for smoothies – A case study

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ABSTRACT

The food robotics revolution is driving a shift in the vending machine sector from conventional pre-packaged sales to on-site food manufacture. As these machines develop into small-scale food processing points, it is critical to guarantee food safety. The implementation of automated Clean-in-Place (CIP) techniques, in addition to manual cleaning, is modelled after food production practices, where hygiene is maintained without direct human intervention. These days, running these modern, multifunctional vending machines requires giving the highest priority to food safety and putting rigorous control measures in practice.

This case study aimed to implement a CIP procedure in a vending machine and assess microbial contamination. Water, blender, and smoothies were microbiologically analyzed to evaluate the microbial safety of ingredients, equipment, and the final product.

Microbiological analysis showed that none of the samples was contaminated with three major pathogens: *Listeria monocytogenes*, *Salmonella* spp., and *Escherichia coli*. This study showed the importance of the Clean-in-Place (CIP) process in automated vending machines.

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KEYWORDS

vending machines, food safety and quality, good hygiene practices (GHP), clean-in-place (CIP), HACCP

INTRODUCTION

Vending machines offer a variety of food and drinks like sandwiches, snacks, and hot and cold beverages. Most of those products are pre-packaged food products and hot drinks made from powders (Saltmarsh, 2023). Smoothies are one of the most well-liked drinks right now due to the health and nutrition claims (Plasek et al., 2021). Vending machines now provide shakes, hot soups, and smoothies. As food robotic technology is developing, vending machines increasingly become small food production plants (Masters, 2022). This development also brings new challenges, such as the hygienic-sanitary requirements of the vending machines.

In vending machine business, cleaning food contact materials is generally done by manual on-site cleaning (Hall et al., 2007). The parts are removed by the vending operator, brushed with detergent, and then rinsed with hot water (Saltmarsh, 2023). A disinfection step may also be needed for some vending machines. According to Egan et al. (2007), 97% of all foodborne outbreaks were caused by food mishandling by the operators. Hunter (1992) claimed that the high number of total viable counts (TVC) and coliforms in drinks from vending machines was caused by insufficient cleaning. Nelms et al. (1997) found that *Bacillus cereus* made the workers sick after they drank hot chocolate from the contaminated vending machine. According to this, hot drink vending machine food poisoning was the first case that was reported.

In the food industry, Clean-in-Place (CIP) is a commonly used technique for efficiently cleaning process equipment without disassembly or reassembly. Due to its high level of automation, CIP systems enable complete traceability of cleaning activities while delivering consistent and reproducible cleaning (Moerman et al., 2013). Therefore, CIP can also be used in vending machines to ensure food safety.

According to Matthews and Horacek (2015), most research on vending machines focused on their accessibility, product availability, and healthfulness. There are limited studies on the hygienic-sanitary quality of vending machines (Hunter, 1992; Hall et al., 2007; Raposo et al., 2015; Cardaci et al., 2016; Cossu et al., 2016; Godic Torkar et al., 2017; Caggiano et al., 2023). Crina et al. (2020) stated that good manufacturing practices (GMP) and good hygiene practices (GHP) are the essential factors in the HACCP system to guarantee food safety. Hunter (1992) recommended the induction of HACCP system for all vending machine companies to ensure food safety. On the other hand, there is an absence of information on GHPs for food vending machines. Research on the food safety of vending machines is crucial to advancing knowledge because the on-site food processing vending machine industry is still relatively recent in the food sector.

This work aimed to implement an automated CIP procedure into place and check how effectively the blender cleans itself so that the hygiene of the on-site food processing vending machine could be appropriately guaranteed.



MATERIALS AND METHODS

Company description and scope

This study was conducted in Alberts NV, in Wijnegem, Belgium. The company produces vending machines for smoothies, soups, and healthy shakes. Freshly frozen fruits and vegetables are blended with hot water and delivered to the customers. Even though the HACCP has been implemented in all production lines, this work only describes how automated cleaning procedures have been applied to the production of smoothies.

Study phases

Present work was conducted in smoothie production with a brand-new vending machine on the production site. An accredited laboratory performed sampling and microbiological analysis to conduct neutral studies. The method of Fernández-Segovia et al. (2014) was used when deciding the study phases of this research. Three stages; defining microbial limits, devising the automated cleaning programmes (ACPs), and microbial analyses-validation of the cleaning programmes were done in order.

RESULTS AND DISCUSSION

Defining microbial limits

According to Krahulcová et al. (2021), only the presence of *Escherichia coli* is subject to detection limits for smoothies under European law (European Commission, 2005). In this study, in addition to the detection limit for *E. coli*, microbial levels for two pathogens, *Listeria monocytogenes* and *Salmonella* spp., were also employed from the regulation's annexes when determining criteria for smoothies. Category 1.2, 'ready-to-eat foods able to support the growth of *L. monocytogenes*, other than those intended for infants and for special medical purposes category' was chosen for *L. monocytogenes*, whereas category 1.20, 'unpasteurised fruit and vegetable juices (ready-to-eat)' was chosen to determine the limits for *Salmonella*. Microbial limits for three pathogens are demonstrated in Table 1.

Table 1. Microbial limits of three pathogens for smoothies

Microorganism	Sampling plan		Limits		Analytical reference method
	n	c	m	M	
<i>Listeria monocytogenes</i>	5	0	Absence in 25g		EN/ISO 11290-1
<i>Salmonella</i>	5	0	Absence in 25g		EN/ISO 6579
<i>E. coli</i>	5	2	100 cfu g ⁻¹	1,000 cfu g ⁻¹	ISO 16649- 1 or 2

Note. n = the number of units comprising the sample; c = the number of sample units giving values over m or between m and M. Adapted from Regulation of the European Commission of 15 November 2005 on microbiological criteria for foodstuffs, 2073/2005/EC, by European Commission (2005). Copyright 2005 by the European Commission.



Devising the automated cleaning programmes

ACP procedure consists of three cleaning cycles. Each cycle was planned to reduce/eliminate the microorganisms. The first cycle is called After Smoothie Cleaning and takes place after every smoothie production. The second cleaning cycle is called the 3 Hours Cleaning Cycle and it automatically occurs every three hours. Finally, the last cleaning cycle is called Full Cleaning Cycle and it happens at the end of each day. Each cleaning cycle includes three stages: rinsing with cold water, sanitizing with hot water around 85–90 °C, and sterilizing with steam more than 100 °C. The difference between the cycles is the duration of the stages. For example, the duration of the rinsing with cold water after smoothie cleaning cycle was longer than the other two because the main aim of this stage was to remove the food residues from the blender. In contrast, the duration of the sterilizing stage was the longest in 24 h full cleaning cycle since the goal was to eliminate the microbial load at the end of the day. 3 Hours cleaning cycle is the milder version of full cleaning cycle. The duration of the steps was decided concerning the D-values (time to reduce the microbial population by 90%) and z-values (the number of degrees (Celsius) required to change a D-value by one factor of ten) of the target population. Time-temperature combinations were decided in guidance from British Retail Consortium Global Standards (BRC, 2018). Standard states that the target microorganism *L. monocytogenes* must be destroyed by a minimum temperature and time combination of 70 °C for two minutes, or an equivalent combination of time and temperature using a z value of 7.5. The daily cycle of cleaning programmes is represented in Table 2.

Manual cleaning of the food contact materials and the other parts of the vending machine during refilling is still inevitable. During this study, manual cleaning was decided to be done with food-safe antibacterial wipes and disinfectant to clean the dust and food residues from the surfaces. Manuals were created for manual cleaning, and the operators were trained. Cleaning procedures differ between vending machines, and the HACCP system needs to include those specific cleaning methods for each type of vending machine (Godic Torkar et al., 2017).

Microbial analysis-validation of the cleaning programmes

This study used a rigorous sampling approach, collecting samples twice in August and October 2022, to evaluate microbial contamination in water, smoothies, and surface of blender. To ensure statistical reliability, 26 samples in total were taken, with 13 samples obtained each month. Aseptic sampling was used to get the samples, with sterile swabs used for the surfaces of the blender and sterile containers used for the samples of water and smoothies. The procedures for two days plan and sampling intervals are shown in Table 3. Samples were collected and analyzed by the accredited laboratory according to the ISO standards mentioned in Table 1 (ISO 6579-1:2017, 2017; ISO 11290-1, 2017; ISO 16649-1, 2018).

Table 2. Properties of automated cleaning cycles

Cleaning Step	Frequency	Purpose
After Smoothie	After each smoothie production	Cleaning
3 Hours	3 h	Sanitation
Full Cleaning	12 h	Sterilization



Table 3. Sampling plan during the cleaning validation

Day	Action	Time	Sample		
Day 1	Manual Cleaning	8:50			
	After Manual Cleaning	9:00	Swab 1	Water Sample 1	
	End of Day	16:00	Swab 2	Water Sample 2	Smoothie 1
	24h Full Cleaning	16:20			
Day 2	After 24h Full Cleaning	16:30	Swab 3		
	24h Full Cleaning	8:50			
	After 24h Full Cleaning	9:00	Swab 4	Water Sample 3	
	End of Day	16:00	Swab 5	Water Sample 4	Smoothie Sample 2
	Manual Cleaning	16:20			
	After Manual Cleaning	16:30	Swab 6	Smoothie Sample 3	

All samples were investigated to check whether they contained any of the three significant pathogens, *E. coli*, *Salmonella*, and *Listeria monocytogenes*. Three pathogens were not detected in any of the analyzed categories after a comprehensive analysis of 26 samples taken from smoothies, water, and blender swabs.

Krahulcová et al. (2021) found *E. coli* in one of the twenty samples when they investigated the microbial quality of smoothies from fresh bars. Raposo et al. (2015) concluded that food mishandling and lack of temperature control may be the reasons for detecting *L. monocytogenes* from samples in vending machines. On the contrary, Hall et al. (2007) investigated hot-drinks vending machines and concluded that detergent-based weekly on-site manual cleaning efficiently kept the microbial load at a desired level.

Our study was conducted on a brand-new machine. Thus, those results cannot confirm whether they are caused by efficient cleaning methods or materials that were analyzed were not contaminated initially. However, a visual inspection was also done after each cleaning to check for any food residue on the blender. No residue was found on the blender in these two days.

Based on our investigation, all available research in the literature was based on manual cleaning of the vending machines. There is no study on the CIP system of vending machines, and more research is needed on automated cleaning procedures to compare results with existing literature.

Karaman et al. (2012) pointed out that implementing the HACCP system is complex for small or medium-sized enterprises (SMEs) due to a lack of technical expertise and food-handling practices. And according to Saltmarsh (2023), most vending machines are managed by SMEs; therefore, broadening the knowledge of the cleaning procedures of the vending machines can help these companies implement HACCP.

CONCLUSIONS

Applying automated cleaning procedures in addition to manual cleaning can contribute to assuring the food safety of vending machines. It can decrease the frequency of manual interventions, and therefore it can also reduce the risk of food mishandling by vending machine operators.



This case study was completed over two months using a brand-new vending machine. To gain more information, longer-term and more extensive research on different vending machines in the field is required. The number of studies focusing on microbial loads of smoothies and vending machines is scant. The methodology and findings from this study can underlie future research regarding the effective cleaning of vending machines.

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