Microbiological Performance of Dairy Processing Plants Is Influenced by Scale of Production and the Implemented Food Safety Management System: A Case Study

BEATRICE ATIENO OPIYO,* JOHN WANGOH, AND PATRICK MURIGU KAMAU NJAGE

Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya

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ABSTRACT

The effects of existing food safety management systems and size of the production facility on microbiological quality in the dairy industry in Kenya were studied. A microbial assessment scheme was used to evaluate 14 dairies in Nairobi and its environs, and their performance was compared based on their size and on whether they were implementing hazard analysis critical control point (HACCP) systems and International Organization for Standardization (ISO) 22000 recommendations. Environmental samples from critical sampling locations, i.e., workers’ hands and food contact surfaces, and from end products were analyzed for microbial quality, including hygiene indicators and pathogens. Microbial safety level profiles (MSLPs) were constructed from the microbiological data to obtain an overview of contamination. The maximum MSLP score for environmental samples was 18 (six microbiological parameters, each with a maximum MSLP score of 3) and that for end products was 15 (five microbiological parameters). Three dairies (two large scale and one medium scale; 21% of total) achieved the maximum MSLP scores of 18 for environmental samples and 15 for the end product. Escherichia coli was detected on food contact surfaces in three dairies, all of which were small scale dairies, and the microorganism was also present in end product samples from two of these dairies, an indication of cross-contamination. Microbial quality was poorest in small scale dairies. Most operations in these dairies were manual, with minimal system documentation. Noncompliance with hygienic practices such as hand washing and cleaning and disinfection procedures, which is common in small dairies, directly affects the microbial quality of the end products. Dairies implementing HACCP systems or ISO 22000 recommendations achieved maximum MSLP scores and hence produced safer products.

Like any other food business, the dairy industry is faced with the challenge of implementing good hygiene practices to ensure production of safe products. Some dairies have made significant efforts and investments in designing and implementing good hygiene practices, using hazard analysis and critical control point (HACCP) systems (7), and following International Organization for Standardization (ISO) 22000 recommendations (29) as part of their food safety management systems (FSMSs). The aim of these approaches has been to produce safer products and to meet the established statutory and regulatory requirements.

An FSMS is a company-specific system of control and assurance activities that help the company guarantee food safety (33). Control activities are conducted to prevent microbial contamination, prevent growth of microorganisms present in production areas, and reduce the levels of pathogens. These activities include cleaning, disinfection, and analysis and control of critical points. Assurance activities are conducted to assure food safety and include development of sampling plans, performance of internal audits, and validation and verification of the FSMS (34). Control activities therefore are concerned with keeping product and process conditions within acceptable limits, and assurance activities are concerned with the evaluation of system performance (46). Performance of an FSMS therefore greatly affects the microbiological quality and safety of end products (33, 35).

Various researchers have shown that two of the major causes of microbial contamination and growth in food products are dirty food contact surfaces and poor personal hygiene practices among food handlers (15, 37, 38, 51). The main sources of cross-contamination have been equipment, food contact surfaces, and food handlers’ hands (1, 9, 17, 48). According to Evans et al. (16), food contact surfaces can be a source of contamination when surfaces are not effectively cleaned or remain wet between cleaning and use. Walker et al. (50) found that food handlers play a major role in possible cross-contamination because these workers can be asymptomatic carriers of foodborne disease–causing microorganisms.

Monitoring and verifying the effectiveness of cleaning and sanitation programs and procedures established by a processor is of great importance if the operator is to achieve an acceptable level of food safety. Environmental sampling can be done by taking swabs from cleaned surfaces and food
Microbial analysis of hand handlers' hands. Various processors have used analysis of bacteriological swabs in combination with other tests to verify the efficiency and effectiveness of cleaning procedures, which is important for monitoring the presence of specific pathogens. Early detection of pathogens allows suitable action to be taken to eliminate the pathogen, which increases the safety level an operator can achieve. Environmental sampling is a tool to ensure that products meet the relevant food safety requirements.

The microbial assessment scheme (MAS) methodology developed by Jacxsens et al. (33) can be used to determine the efficacy of implemented quality control and assurance activities by performing microbiological analyses. System audits combined with microbiological sampling and analysis give insight into the performance of implemented control and assurance activities and the actual microbial quality, which is the food safety output (34).

The dairy industry consists of large, medium, and small scale facilities with varied practices and controls for ensuring product safety. Few studies have been done on the actual practices used in these dairies and the effect of such practices on the safety of the dairy products. This study was conducted to investigate the actual hygiene practices used at dairies, using the Kenyan dairy industry as a case study. The effect of these practices on the microbiological quality of food contact surfaces and food handlers’ hands and ultimately on the microbiological quality of the end products was studied. Using MAS, we were able to compare the effects of size of the production facility, the ability to achieve safer products, and implementation of an FSMS on product safety.

MATERIALS AND METHODS

Description of the dairies studied. Fourteen dairies (D1 through D14) were selected for this study: two dairies produced pasteurized milk, one produced ice cream, one produced cheese, and the rest produced yoghurt plus one or more of the other dairy products. The daily production capacity of the dairies was 1,000 to 170,000 liters of milk per day. Small dairies (D7, D8, D9, D10, and D13) processed fewer than 10,000 liters with a workforce of fewer than 50 employees, medium dairies (D1, D3, D4, D11, and D14) processed 10,000 to 50,000 liters of raw milk per day with a workforce of 50 to 100 employees, and large dairies (D2, D5, D6, and D12) processed more than 50,000 liters of raw milk per day with a workforce of more than 100 employees.

MAS. The MAS tool (33) was used to carry out objective measurement of the performance of an FSMS by validation of various control and assurance activities performed in the dairies during production. The MAS involved identification of critical sampling locations (CSLs), selection of appropriate microbiological parameters to be analyzed, assessment of sampling frequency, selection of sampling and analytical methods, data processing, and interpretation of results (34). The MAS did not include a statistical sampling plan because the primary aim was to obtain a picture of the current effectiveness of the core safety assurance activities (2, 3, 45). Swab samples collected at critical process locations, from personnel, and from end products during production were analyzed for various microbiological parameters.

Sampling was supplemented by system audits with observations of the implemented FSMS at the time of sampling. Interviews and discussions were held with individuals in charge of the systems to determine the actual practices and operations at each dairy.

Identification of CSLs and sampling methods. CSLs were selected based on published information. The CSLs included food contact surfaces (11, 47), hands of food workers (1, 4, 18, 33), and end products (Table 1). These areas are considered to be in direct contact with semifinished products (CSL1, CSL3, and CSL6) or final products (CSL1, CSL2, CSL4, and CSL5), and any high microbiological loads at these locations would result in unsafe products (CSL7).

Hands (CSL1) were considered critical because they are a potential source of cross-contamination and can be a source of Staphylococcus aureus (1, 4, 18). Microbial analysis of hand samples was done to give an indication of the actual performance of personal hygiene practices (33).

Working surfaces such as packing tables are the most contaminated of food contact surfaces, and cross-contamination can result because these surfaces are in direct contact with food (11) and are frequently touched by workers (47). Equipment in direct contact with food and packaging materials could be a potential source of contamination. CSL2 to CSL6 were defined for these surfaces. CSL4 and CSL5, both packaging materials, were of different types and undergo different treatments or preparations before use.

The actual microbiological quality of the end products (CSL7) was determined to compare the safety of the end products as affected by the practices at various critical process stages important for final product safety and quality.

Samples were collected at each of the CSLs from each dairy for analysis. The 98 total samples consisted of 84 swab samples and 14 end product samples. Swab samples were collected from hands and/or gloves (CSL1) of workers who handle food items at the packing tables or are in direct contact with food contact surfaces. Swab samples of food contact surfaces that contact either semifinished products (CSL3 and CSL6) or final products (CSL2, CSL4 and CSL5) and samples of final product (CSL7) also were collected. The environmental samples (swabs) were linked to samples of the final product for comparison of results. Samples were analyzed for similar selected parameters (Table 1) to provide information on the microbiological load at each sampling location on the processing line of each dairy.

Selection of microbiological parameters. Microbiological parameters selected were three categories of microorganisms: pathogens, hygiene indicators, and utility parameters. Samples were checked for Salmonella because this pathogen is associated with dairy products (21). Hygiene (fecal) indicators were Escherichia coli and Enterobacteriaceae (14). S. aureus was selected as an indicator of personal hygiene and correct hand washing practices (1, 12). Total coliforms were an indicator of overall performance of production processes. Utility indicators were yeast, molds, and total viable bacteria counts (TVCs) (20).

Microbiological parameters selected for the environmental samples and the hand swabs were similar in all sampling locations and dairies (Table 1). Microbiological parameters for end product samples differed depending on the type of dairy product that was in production at the time of sampling. A total of 95 analyses of quality parameters, 378 analyses of hygiene indicators, and 98 analyses of foodborne pathogens were performed.

Assessment of sampling frequency. Sampling frequency was the same as described by Jacxsens et al. (33) with modifications. Samples were collected only once during production in each of the
**TABLE 1. Analyzed microbiological parameters and legal requirements or microbial guidelines for selected critical sampling locations (CSLs) for food contact surfaces, food handlers, and end products**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Analytical method</th>
<th>Food handlers’ hands or gloves (CSL1)</th>
<th>Food contact surfaces (CSL2–CSL6)</th>
<th>End products (CSL7)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total viable bacteria</strong></td>
<td>Environmental samples: ISO 4833:2003 (24); end products: BS 4285, Sect. 2.1, 1984 (5)</td>
<td>$m &lt; 1.9 \log \text{CFU/cm}^2; M &gt; 3 \log \text{CFU/cm}^2$</td>
<td>$m &lt; 1.9 \log \text{CFU/cm}^2; M &gt; 3 \log \text{CFU/cm}^2$</td>
<td>Yoghurt: $m = 0; M = 3 \times 10^4 \text{CFU/ml}$</td>
</tr>
<tr>
<td></td>
<td>Environmental samples: ISO 4832:2006 (32); end products: BS 4285, Sect. 3.7, 1987 (6)</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Pasteurized milk: $m = 0; M = 10 \text{CFU/ml}$</td>
</tr>
<tr>
<td></td>
<td>ISO 21528-2:2004 (27)</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Dairy cream: $m = 0; M = 10 \text{CFU/g}$</td>
</tr>
<tr>
<td></td>
<td>ISO 11866-2:2005 (31)</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Ice cream: $m = 0; M = 10 \text{CFU/g}$</td>
</tr>
<tr>
<td></td>
<td>ISO 6888-1:1999/Amd 1:2003 (25)</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Good, $\leq 1$; average, $1.8$; bad, $\leq 2.5$; intolerable, $&gt; 2.5 \log \text{CFU/16 cm}^2$</td>
<td>Cheese: $m = 0; M = 10 \text{CFU/g}$</td>
</tr>
</tbody>
</table>

- CSL1, hands and/or gloves of food handler; CSL2, working or packing table surface; CSL3, cleaned jacketed vessel; CSL4, packaging material, cup or container; CSL5, packaging material, porch; CSL6, milk can or product transfer container; CSL7, end product. ND, analysis was not done; $m$, maximum level of bacteria per test volume considered acceptable; $M$, maximum level of bacteria per test volume considered marginally acceptable (values at or above $M$ are unacceptable).

- According to the legal criteria established in Kenya Standards (39–43).

- According to the recommendations by Herbert et al. (19).

- According to microbiological guidelines of the LFMFP-UGhent (49).
dairies because the objective of the study was to provide an overall microbiological profile at each of the CSLs in every dairy, to evaluate the current FSMS at each dairy, and to compare the microbiological performance of the different dairies during production.

Selection of sampling method and method of analysis. The horizontal method for collecting samples from surfaces using contact plates and swabs in accordance with ISO 18593:2004 (26) was adopted for environmental sampling. This method was used to detect and enumerate viable microorganisms from food contact surfaces and food handlers’ hands or gloves. A sample area of 50 cm$^2$ was used for surfaces. Swabs covered 25 cm$^2$ (5 by 5 cm square) of each food handler’s hand. A sterilized steel template was used to define the swabbing area.

Analytical methods based on ISO standards were used for analysis of the samples (Table 1). Analyses were performed in an ISO 17025:2005 (30) accredited laboratory.

Microbial safety level profiles. Microsoft Office Excel 2007 (Microsoft, Redmond, WA) was used to make tables and graphs to visualize the levels of microbiological contamination at the specific CSLs in each dairy during production. Microbial safety level profiles (MSLPs) were calculated from the microbiological data to give an overview of contamination. This overview enabled comparison of the microbial contamination at each CSL in the different dairies, giving some insight into the overall levels of microbial contamination, which are related to the control and assurance activities (33) and the good hygiene practices.

Standard deviations were not needed to evaluate the variability in a single dairy because sampling was performed only once at each of the CSLs; in the MAS, variation is not accounted for during calculation of MSLPs.

The results were evaluated in two phases. First, the individual results for each microbiological parameter at each CSL were evaluated for all dairies. The results were then compared with defined legal criteria established in the respective Kenya standards (39–43) for the end products. Because there are no legal criteria established for food contact surfaces, the microbiological values established by the Laboratory of Food Microbiology and Food Preservation at the University of Gent (LFMFP-UGhent) (10, 49) and the recommendations made by Herbert et al. (19) were used for comparisons (Table 1) and to evaluate whether the hygiene practices in each dairy were adequate for reducing the possibility of contamination.

The second phase of evaluation was the assignment of the MSLPs. For each dairy, the individual results for each analyzed parameter were evaluated across the CSLs by assignment of an MSLP score to each type of microbiological parameter. Each microbiological parameter was assigned a score from 1 to 3. A good result (level 3) was defined as when legal criteria or guideline values were respected and no improvements were needed because the control and assurance activities were adequate to control microbial hazards. A moderate result (level 2) was defined as when legal criteria or guideline values were exceeded in some situations and improvements were needed in a single control activity of the FSMS. A poor result (level 1) was defined as when legal criteria or guideline values were exceeded and improvements were needed for multiple control activities of the FSMS. The total sum of these levels gave the MSLP score (33, 44). The maximum MSLP score for CSL1 through CSL6 was 18 (six microbiological parameters with a maximum MSLP score of 3 for each) and that for CSL7 was 15 (five microbiological parameters with a maximum MSLP score of 3 for each). The evaluation resulted in the score attribution system summarized in Table 2.

<table>
<thead>
<tr>
<th>Score</th>
<th>Benchmarks$^a$</th>
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<tbody>
<tr>
<td>0</td>
<td>$R &gt; M$, organism present in $x$ grams or on the surface</td>
</tr>
<tr>
<td>1</td>
<td>$R = M$</td>
</tr>
<tr>
<td>2</td>
<td>$m &lt; R &lt; M$</td>
</tr>
<tr>
<td>3</td>
<td>$R \leq m$, organism absent in $x$ grams and on the surface</td>
</tr>
</tbody>
</table>

$^a$ Legal criteria for end products or microbiological guidelines for food contact surfaces and hands (33, 43). $R$, results obtained from analysis; $m$, maximum level of bacteria per test volume considered acceptable; $M$, maximum level of bacteria per test volume considered marginally acceptable (values at or above $M$ are unacceptable).

Scores were allocated as follows. When the legal criteria or the guideline values were below the minimum acceptable value for a specific microorganism at a specific CSL, the specific hygiene practices in the FSMS at that location were considered to be working properly, and a score of 3 was given. A score of 2 was given when the results were less than the maximum level considered marginally acceptable but more than maximum level considered acceptable. A score of 1 was given when the results were the same as the maximum level considered marginally acceptable. When the legal criteria or the guideline values were exceeded for a specific microorganism at a specific CSL, the specific hygiene practices in the FSMS at that location were considered to be not working properly, and a score of zero was given. This score indicates that corrective action(s) is required to change this noncompliance situation and improve the FSMS performance (33).

RESULTS

System audit findings. Dairies D2, D3, D5, D11, and D12 were implementing an FSMS based on either HACCP or ISO 22000 standards (29). The dairies had well-documented systems with adequate record keeping. For dairies other than D3, the FSMSs were certified by an external certification body. D2 and D11 recently received their certification. All of these dairies had a well-functioning clean-in-place (CIP) system and appropriate equipment maintenance and calibration programs. The majority of workers were well trained and practiced appropriate personal hygiene. Verification activities were performed after cleaning to confirm the efficacy of cleaning protocols. D1 and D7 were just beginning to document and implement food safety systems. D4, D6, D8, D9, and D10 had no established FSMS but were implementing to varying degrees good hygiene practices as defined for the dairy industry (8).

Large dairies (D2, D5, D6, and D12) generally had appropriate and adequate machinery and well-trained staff. Small dairies (D7, D8, D9, D10, and D13) lacked well-defined or documented procedures for cleaning equipment and surfaces. They had no adequate hand washing facilities, and some workers did not have appropriate protective clothing. In D4, D8, D10, and D13, most operations were manual, including packing, and workers were not well trained in technical and hygiene matters. D10 did not have a CIP system. D13 had a CIP system but had no documented
cleaning instructions for the system, the system was not regularly inspected, and the efficacy of the cleaning process was not verified. D4, D10, and D13 did not have sufficient or well-managed sanitary facilities.

**Microbial assessment: hands and/or gloves of food handlers.** The large dairies (D2, D5, and D12) achieved higher MSLP scores (17, 18, and 18, respectively) for hand swabs (CSL1) compared with medium and small dairies. D3 (medium dairy) also achieved the maximum MSLP score of 18 (Fig. 1A). *E. coli* was detected on the hands of a food handler at D4 (medium dairy) and at D10 and D13 (small dairies) but not at the large dairies. *S. aureus* was found on hands of a food handler at D7. Most small and medium dairies had high counts of total coliforms 0.1 to >1.2 log CFU/cm². Coliforms were not detected on the food handlers’ hands in the large dairies and D3 and D9 (medium dairies). *Enterobacteriaceae* counts on hand swabs were 0.3 to >1.2 log CFU/cm² in small and medium dairies and 0.1 (D2) to 0.9 (D6) log CFU/cm² in large dairies. *Enterobacteriaceae* were not detected in D8, D3, D5, and D12. In dairies other than D3, all the food handlers’ hands at the other small and medium dairies had high TVCs. *Salmonella* was not detected on the hands of any food handler (Fig. 1A).

**Microbial assessment: food contact surfaces.** Large processors (D2, D5, D6, and D12) achieved the maximum MSLP score of 18 for most of the food contact surfaces (Fig. 1B through 1F). The poorest performing dairy was D13 (small dairy), which had MSLP scores of 12 at CSL4, 8 at CSL3, and 6 at CSLs 2, 5, and 6. D10 (small dairy) had MSLP scores of 9 for all food contact surfaces. D4 (medium dairy) MSLP scores ranged from 8 at CSL4 to 17 at CSL3.

Packaging materials (CSL5 and CSL6) had high TVCs, total coliform counts, and *Enterobacteriaceae* counts among the small dairies (D7, D8, D9, D10, and D13) and one medium dairy (D4). TVCs, total coliforms, and *Enterobacteriaceae* counts were 0.1 to 4.5 log, 0.1 to >1.2, and 0.1 to >1.2 log CFU/cm², respectively, for these dairies.

**Microbial assessment: end products.** Three dairies (D3, D5, and D12) achieved the maximum MSLP score of 15, followed by D2, D6, and D14 with scores of 14 each. D1 and D9 had MSLP scores of 13. The poorest performing dairies with MSLP scores of 10 and below were D4 (medium dairy) and D7, D10, and D13 (small dairies). *E. coli* was detected in the end products of two small dairies, D10 and D13.

**DISCUSSION**

The effect of implemented hygienic practices and the control and assurance activities on the microbiological quality of food contact surfaces, food handlers’ hands, and ultimately of the end products was studied. Hygienic practices and the control and assurance activities are used to control microbiological growth and cross-contamination that could arise from contaminated surfaces and/or food handlers’ hands.

Based on the results of the MSLPs for pathogens, level 3 was attributed because no *Salmonella* was detected at any CSL, which implies acceptance according to legal requirements and guidelines. Thus, indicates that the FSMS in the dairies was effective for controlling this pathogen. The results correspond to those obtained by Jacxsen et al. (33), who attributed level 3 to *Salmonella* because this pathogen was not detected on the hands and food contact surfaces or on fresh, intermediate, and final meat products. However, for pathogenic microorganisms with low prevalence (<1 to 5%), inherent limitations in sampling schemes determine the level of contamination that is detectable (44).

**MAS** results revealed unsatisfactory performance for dairy D7, where personal hygiene was placed at level 0 because of the presence of *S. aureus*. Microbiological guidelines recommend that this microbe be absent on all tested surfaces. This dairy must improve personal hygiene practices by better training of personnel (12). A level of 0 was also attributed to this dairy for yeast and molds at CSL7. The results were above the maximum legal criteria of 100 cells per g.

Among the food contact surfaces considered in this study, jacketed vessels such as milk tanks (CSL3) had high MSLP scores compared with other surfaces; 8 (57%) of 14 had the maximum score of 18, 3 (21%) had a score of 17, and only 2 (14%) had a score below 10. These surfaces were cleaned using CIP systems with well-documented procedures and instructions on performing the cleaning under controlled conditions. Verification was performed after cleaning operations to confirm the adequacy of cleaning. However, D10 and D13 had low MSLP scores of 9 and 8, respectively, at CSL3. D10 (small dairy) did not have a CIP system. Although D13 (another small dairy) had a CIP system, there were no documented cleaning instructions for using the system, the system was not regularly inspected to ensure proper functioning and mechanical integrity, and verification of the efficiency of cleaning was not performed.

The food contact surfaces with the lowest scores were manually cleaned equipment such as milk cans and product transfer containers (CSL6). Only 5 (36%) of the 14 dairies achieved the maximum MSLP score of 18, and the lowest score was 6. Effective cleaning of food contact surfaces is an important component of an FSMS (36). Poor performance can be attributed to lack of well-defined and/or documented procedures and guidelines for cleaning of such equipment in most of the dairies. Verification to confirm the adequacy of cleaning operations was seldom performed. Such equipment is used to transfer processed product from the larger processing or holding tanks to the packaging section in dairies D4, D7, D8, and D10, where packing of products such as yoghurt is done manually. In such cases, surfaces of the equipment (CSL6) that are not adequately cleaned can come into contact with finished products just before packaging, posing a high risk of cross-contamination and partly explaining why end product (CSL7) MSLP scores at D4, D7, D8, and D10 were relatively low.

Dairies D3, D5, and D12 representing 21% of the dairies achieved the maximum MSLP score of 15 at CSL7 (end product) and achieved maximum scores of 18 at each of the sampling points (CSL1 to CSL6), with the exception of D12, which had a score of 17 at CSL1. The FSMSs of
FIGURE 1. Microbial safety level profile scores for critical sampling locations (CSL1 through CSL7) at 14 dairies in Nairobi and its environs. (A) CSL1, hands and/or gloves of food handler; (B) CSL2, working or packing table surface; (C) CSL3, cleaned jacketed vessel; (D) CSL4, packaging material, cup or container; (E) CSL5, packaging material, porch; (F) CSL6, milk can or product transfer container; (G) CSL7, end product.
dairies D5 and D12 (large dairies) had been certified for more than 3 years. These dairies periodically undergo external verification of implemented control and assurance activities through certification and surveillance audits. D3 (medium size dairy) has implemented a HACCP system for more than 8 years. Although their system has not been certified by an external body, they occasionally have second party audits conducted by their main customers, the airlines. The airline companies are motivated to ensure stringent controls in supplier operations to meet the high customer food safety requirements. D12 also supplies airlines. External and internal audits conducted frequently at these dairies partly explain the high performance of their FSMSs.

Among the large dairies, D6 did not achieve maximum MSLP scores for the end product and CSL1. Although the dairy has appropriate and adequate machinery and well-trained staff, they are not implementing a HACCP system or any other FSMS in their production processes. FSMS implementation enhances and improves the control and assurance activities through routine audits and checks to verify that the implemented FSMS results in safer foods.

Dairies D2 and D11 had just received certifications of their FSMSs and hence had implemented these programs for a relatively very short time, which may explain why the end product (CSL7) did not achieve the maximum MSLP score. These dairies will need to continue to improve the performance of their FSMSs.

The sample from the food handler (CSL1) at dairy D14 had high coliform counts (Fig. 1A). This worker was responsible for handling, cutting, and packing cheese. The working table (CSL2) on which cheese was cut also had high of coliform counts (Fig. 1B). The containers (CSL6) used for transferring cheese to the packing area had poor performance in terms of total coliforms (Fig. 1F). This dairy had an MSLP score of 14 and did not achieve the maximum MSLP at CSL7 because of high coliform counts in the end product, above the maximum legal limit of 10 CFU/ml. These high counts could be attributed to cross-contamination from CSL1, CSL2, and CSL6. Although the dairy had been implementing a HACCP system for more than 3 years, their system was not certified and they did not have second party or internal audits.

E. coli was detected in hand swabs (CSL1) collected at D4, D10, and D13 and in the end products (CSL7) from D10 and D13. The presence of this organism in the end products could be attributed to cross-contamination. The food handler at dairy D4 was involved in manual packing of yoghurt (filling, capping, and sealing) because of a breakdown of the packing machine. In D13, the food handler also manually packed the product because the dairy had no packing machine. In D10, the food handler was involved in weighing ingredients such as flavors and sweeteners to be mixed with the product after the heat treatment step. Cross-contamination of the ingredients or packaging material could have come from the food handler, resulting in E. coli in the final product. The detection of E. coli at CSL1 and CSL7 was in contrast to the results obtained by Lahou et al. (44) for three production processes in a catering establishment.

The dairies with the poorest performance were those in which operations were manual and food handlers were not well trained on technical and hygiene matters. All of these poorly performing dairies were small, with the exception of D4. The results obtained for a number of the microbial parameters, especially TVC, total coliforms, and Enterobacteriaceae, at most of the CSLs in these dairies were unsatisfactory; the counts were higher than the recommended level. In a study on microbiological levels of selected food contact surfaces, Domenech-Sanchez et al. (13) found that about a quarter of the surfaces had microbiological contamination levels higher than the recommended levels. Results of the present study indicate that improvements in some core assurance activities in the FSMSs of small dairies are needed.

Dairies that had very low MSLP scores at CSL1 (food handlers’ hands), indicating inadequate hand washing practices, also had low MSLP scores at CSL7 (end product). Most of these dairies were small. These dairies also had low MSLP scores at CSL6, which included surfaces that were manually cleaned. Low MSLP scores are an indication of insufficient cleaning procedures by the dairies. Noncompliance with hygienic practices such as hand washing and cleaning and disinfection procedures therefore directly affects the microbial quality of the end products. Two dairies (both large) that achieved the maximum MSLP scores of 18 at each of the process sampling points (CSL1 through CSL6) also achieved the maximum MSLP score of 15 for the end product (CSL7). Three small dairies had the lowest MSLP scores of 9 or 10 for the end product (CSL7) and generally performed poorly, with low scores for the other CSLs. Large dairies are better situated than small and medium dairies for achieving safer dairy products. Dairies that were implementing a HACCP system or following ISO 22000 guidelines achieved the maximum MSLP scores and hence had safer end products than did dairies that were not implementing either system.

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