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Food safety, livestock health, and productivity of a dairy farm following implementation of a certificated Hazard Analysis and Critical Control Points system

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ABSTRACT. This study examined the safety and productivity data analysis of a dairy farm over a 3-year period following the implementation of a Hazard Analysis and Critical Control Point (HACCP) system in 2018. The CCP was "the selection of milking cows" and the critical limit was "the withholding period has passed". No deviation from the critical limit was observed, the safety of the milk is ensured. In addition, the average daily milk yield per cow increased, while the average number of somatic cells/ml decreased. The number of cows with newly diagnosed mastitis increased, and the product excluded. These results suggest that the HACCP system had a positive effect on milk yield per cow and led to a decrease in somatic cells.

KEYWORDS: critical control point, farm hazard analysis and critical control points system, mastitis, milk yield, somatic cell count

Food business operators (FBOs) are responsible for providing safe food. As defined by the Codex Alimentarius, the Hazard Analysis and Critical Control Point (HACCP) system is a science-based systematic approach that identifies specific hazards and potential control measures [2]. FBOs will ensure food safety by implementing good hygiene practices (GHPs) and HACCP system. The system can also be used in the agricultural sector, where it is referred to as "farm HACCP" or the "Good Agricultural Practice (GAP)" system [3]. Although the HACCP system for food manufacturing ensures food safety only, the farm HACCP standards aim to assure not only food safety but also animal health and welfare [9].

To improve the safety of livestock products, it is important to improve hygiene management within individual farms while reducing the risk of pathogenic contamination and raising healthy livestock. In August 2009, the Japanese Ministry of Agriculture, Forestry and Fisheries (MAFF) published the farm HACCP certification standards [9], which aim to improve the hygiene management of livestock farms, thereby ensuring the safety of livestock products. The farm HACCP certification standards consist of seven chapters. Following an introduction covering the scope of the Farm HACCP, the relevant literature, and a glossary (chapter 1), the standards describe the responsibilities of farm managers (chapter 2), preparations for a hazard analysis (chapter 3), the establishment of GHPs, the development of an HACCP plan (chapter 4), education and practice (chapter 5), evaluation, improvement, and hygiene management system updates (chapter 6), and requirements related to documentation and records regarding hygiene management (chapter 7). To obtain the farm HACCP certification, the farm must satisfy the requirements described in these standards.

The farm HACCP certification requires the establishment of a prerequisite program (PrP) that includes a number of sanitation standard operation procedures (SSOPs) as well as education and training of farm workers. Moreover, after the introduction of the farm HACCP system, food safety management and livestock hygiene management must be continually reviewed via the plan–do–check–action (PDCA) cycle. The farm HACCP standards aim to assure food safety and livestock health. Ensuring milk hygiene is accomplished in part by ensuring the health of milking cows, and this can be achieved by implementing the PrP. For example, Boersema *et al.* [1] showed that serum immunoglobulin G levels in calves substantially improved in dairy farms following the introduction of an HACCP system.

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In this study, we examined food safety as well as livestock health and productivity at a dairy farm from 2018 to 2020, following the implementation of a farm HACCP system. The dairy farm developed the HACCP plan in September 2016, initiated implementation of the plan in May 2018, and obtained the farm HACCP certification in June 2019. The aim of this study was to investigate the effect of the HACCP-based food safety management system by analyzing CCP monitoring data and production data, including milk yield, somatic cell count, number of mastitis cases, and amount of waste milk. The replacement rate of milking cows was about 30% in 2018, about 30% in 2019, and about 40% in 2020.

The target farm was a dairy farm with approximately 110 dairy cows and 100 dairy heifers, all bred in a free-stall barn. The farm created and implemented control measures (an HACCP plan and PrPs) in accordance with the farm HACCP certification standards published by MAFF. For food safety, the farm decided to implement the step "selection of milking cows" as a CCP in the HACCP plan because the farm nearly had an accident in 2015, which highlighted the importance of having a management plan. A potential chemical hazard that was identified was residual antibiotics in the milk. Failure to keep track of antibiotic-inoculated cows was an occurrence factor. Control measures included checking the ear tag number on a whiteboard at the milking site against the ear tag number of cows with red vinyl tape wrapped on the fetlock of both back legs. Inoculated cows were milked by farm workers, who collected the milk in buckets. The critical limit for preventing contamination with antibiotics in bulk milk was "the withholding period has passed". The monitoring method involved checking the ear tag number on a whiteboard at the milking site against the ear tag number of the cows with red vinyl tape wrapped on the fetlock of both back legs. And then checking off the box on the whiteboard as well as the antibiotics cattle checklist before milking in the morning and evening.

The livestock health and productivity goals were set as "reducing the number of somatic cells" and "fewer cases of mastitis", which are important hygiene management targets for animal health on the farm. The exact targets were a monthly average of 170,000 somatic cells/ml or less and a maximum of 5 cows with mastitis per month. We planned for these goals to be achieved through the implementation of the PrP. Observation of cows in the milking barn, hygiene of the cowbed, proper milking method and time, hygiene and inspection of the milking equipment, and proper feeding management were also introduced as SSOPs in the PrP. We created and implemented a program to provide training and education on the HACCP plan and PrP for the farm's workers. The farm's HACCP team held monthly meetings.

By introducing this monthly review, the HACCP team also aimed to confirm the progress of the hygiene management goals and consider improvement measures where necessary. CCP monitoring was performed at each milking time and inspection items such as milk yield, somatic cell count, the number of mastitis cases, and the waste milk ratio for each month were measured from April 2018 to December 2020. To determine the number of somatic cells, bulk milk testing results were obtained from the Dairy Association three times a month. Linear approximations were obtained from the inspection results, and statistical differences (*t*-test: $P<0.05$) between annual means were determined using spreadsheet software (Excel 365, Microsoft Corp., Redmond, WA, USA).

There were no cases of deviation from the CCP (i.e., no contamination of milk with residual antibiotics) after the introduction of the farm HACCP system. Thus, the farm was able to completely prevent the risk of residual drug contamination as a chemical hazard.

Figure 1 shows the average daily milk yield per animal for each month of the three-year study. The mean ± standard deviation (SD) was 33.77 ± 1.46 kg in 2018, 33.69 ± 0.98 kg in 2019, and 35.06 ± 0.97 kg in 2020. Milk yield was statistically higher in 2020 than in 2018 and 2019. The linear approximation was Y=0.0424X + 33.488, with values tending to increase over the three-year study period.

The monthly average somatic cell count per ml is shown in Fig. 2. The mean ± SD was 228,000 ± 42,900 cells/ml in 2018, 203,000 ± 60,800 cells/ml in 2019, and 163,000 ± 23,900 cells/ml in 2020. The somatic cell count was statistically lower in 2020

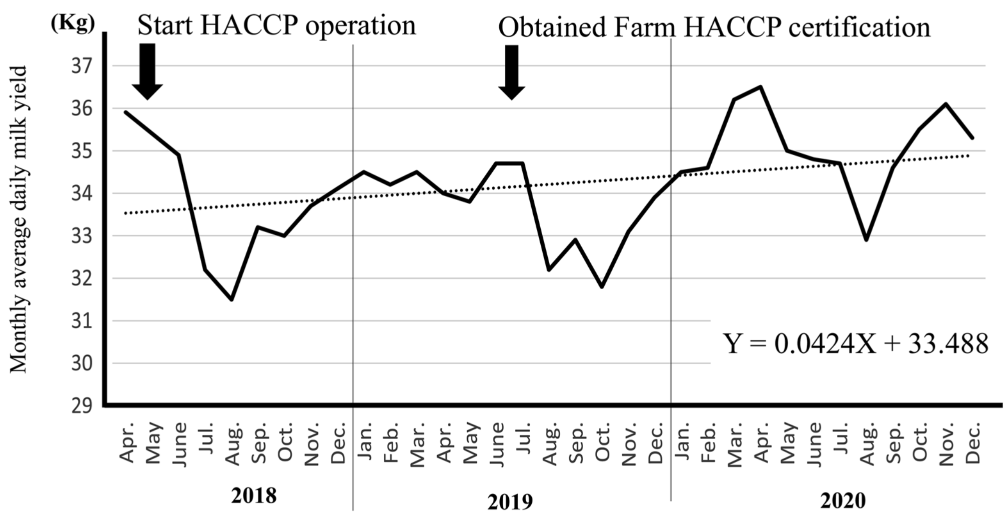

Fig. 1. The trend in monthly average daily milk yield per animal per month across the three-year study period. The dotted line shows the linear approximation (Y=0.0424X + 33.488). Milk yield was statistically higher in 2020 than 2018 and 2019 ($P<0.05$).

than 2018, and the linear approximation was Y=−3,225X + 250,284, with a decreasing trend across the three-year study period. The achievement rate of the hygiene management target for somatic cell number (monthly average of 170,000 cells/ml or less) was 11.1%, 41.6%, and 83.3% in 2018, 2019, and 2020, respectively.

Figure 3 shows the monthly number of new mastitis cases in each year. The mean number of new cases (± SD) increased to 3.78 ± 1.72 cows/month in 2018, 4.58 ± 2.11 cows/month in 2019, and 7.33 ± 2.87 cows/month in 2020. The number of new mastitis cases was statistically higher in 2020 than in 2018 and 2019, and the linear approximation was Y=0.1557X + 2.7159. As a result, the achievement rate of the hygiene management target for the number of new mastitis cases (5 or less per month) was 88.8, 66.6%, and 41.6% in 2018, 2019, and 2020, respectively.

Figure 4 shows the monthly amount of waste milk for each year. The mean ratio (± SD) of waste milk also increased to 3.67 ± 0.81% in 2018, 4.42 ± 1.04% in 2019, and 5.95 ± 1.19% in 2020. The ratio was statistically higher in 2020 than in 2018 and 2019, and the linear approximation was Y=0.0938X + 3.0987, with an increasing trend across the three-year study period, similar to the results of number of mastitis cases shown in Fig. 3.

Using the above results, we were able to evaluate the effect of the introduced farm HACCP plan on livestock health and productivity. In terms of milk safety, the reliable selection of milking cows was therefore deemed successful based on the HACCP

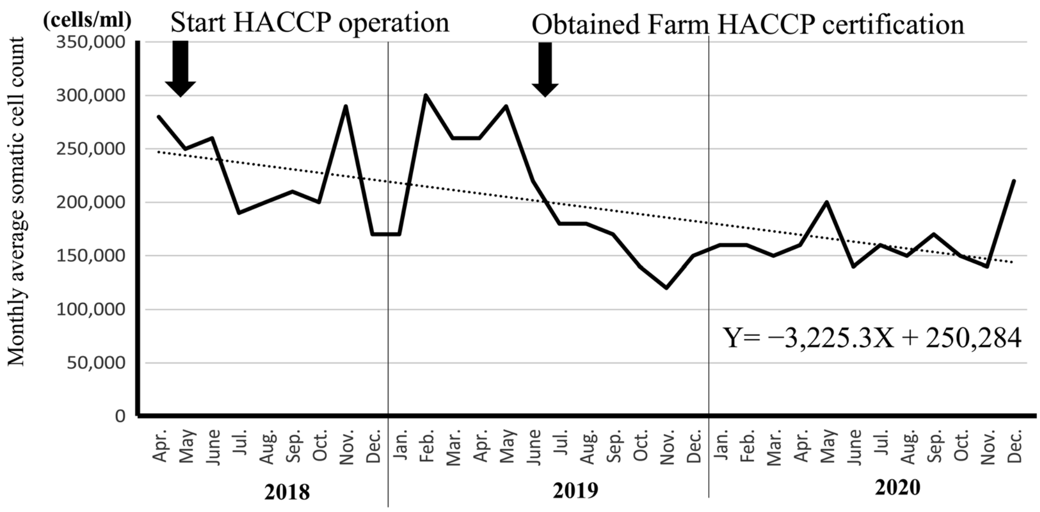

Fig. 2. The trend in monthly average somatic cell count across the three-year study period. The dotted line shows the linear approximation (Y=−3,225X + 250,284). The somatic cell count was statistically lower in 2020 than 2018 (*P*<0.05). The hygiene management target was set at a monthly average of 170,000 cells/ml or less.

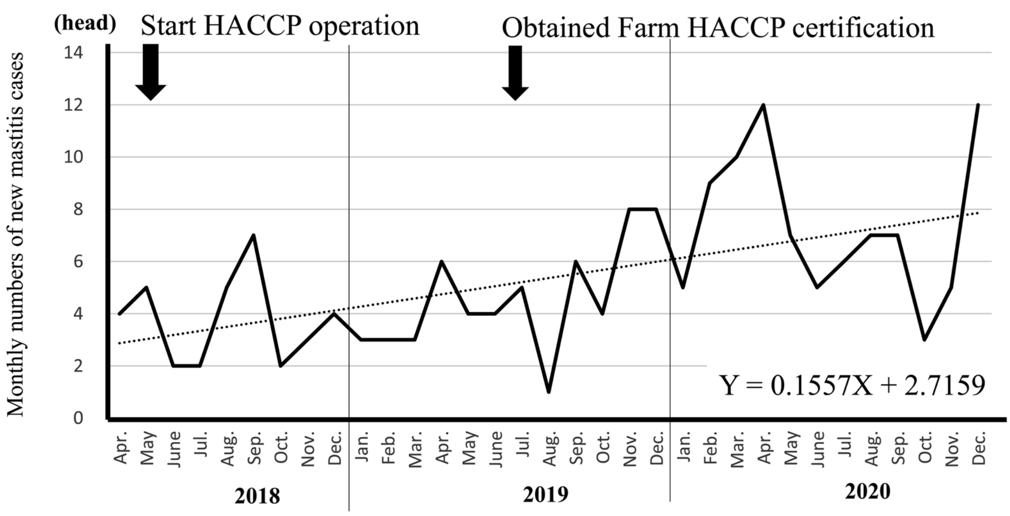

Fig. 3. The trend in monthly numbers of new mastitis cases across the three-year study period. The dotted line shows the linear approximation (Y=0.1557X + 2.7159). The number of new cases was statistically higher in 2020 than 2018 and 2019 (*P*<0.05). The hygiene management target was set at a monthly average of 5 new cases or less.

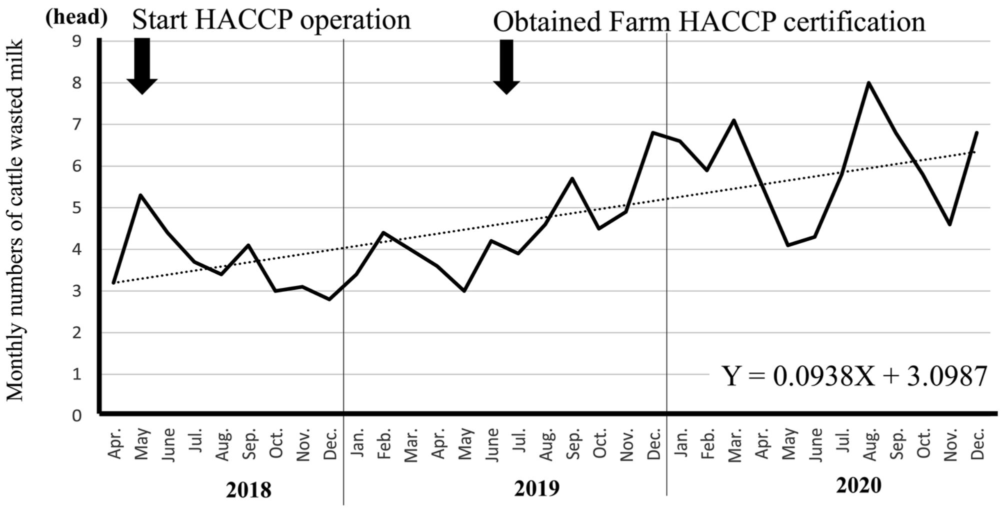

Fig. 4. The trend in monthly numbers of cattle wasted milk across the three-year study period. The dotted line shows the linear approximation (Y=0.0938X + 3.0987). The number of the cattle was statistically higher in 2020 than 2018 and 2019 (P<0.05).

plan. The average daily milk yield per animal tended to increase over the three-year study, and although no major changes to overall feeding management were made following the introduction of the farm HACCP system, efforts were made to improve breeding conditions, including determining estrous status, confirming pregnancy, and implementing an ovsynch program, following the recommendations of the managing veterinarian. The calving interval decreased from an initial 450 days to 400 days, which seemed to have had a positive effect on the daily milk yield, similar to the result reported by Kurokawa *et al.* [8]. Gonçalves *et al.* [4] previously suggested that improving the health of individual cows was highly effective in increasing the daily milk yield. The introduction of a farm HACCP therefore seems to have helped to maintain overall livestock health, resulting in an increase in milk yield per cow.

After introducing the farm HACCP, the monthly average somatic cell count tended to decrease across the three-year study period, and the hygiene management target for the number of somatic cells (monthly average of 170,000 cells/ml or less) was largely achieved in 2020. When calculating the number of somatic cells, cows being treated for mastitis were also considered on the premise that they were excluded from the shipped milk. The factors behind the decrease in somatic cell number is therefore thought to have been linked to measures taken against mastitis; however, the following points were also noted. Over-milking is one of the main causes of mastitis and subsequent increases in somatic cell factors [7]. By creating and following a milking guide, milking time was more manageable and subsequently shortened, preventing over-milking and reducing the number of somatic cells.

Across the three-year study period, the monthly number of new mastitis cases increased, and as a result, the hygiene management target (monthly number of 5 or less) was not achieved. This is thought to have been related to increased awareness via education and training, which increased early detection of mastitis. The aim of the education and training was to give workers the ability to detect abnormal cows, including suspected cases of mastitis. Accordingly, as discussed above, this resulted in a decrease in the number of somatic cells. Thus, the introduction of a manual milking method, and unified management via education and training is thought to have had a positive, unified effect among workers. The education and training also taught workers the optimal milking method to prevent mastitis. Furthermore, bedding soiled with manure tends to adhere to the udders, increasing the risk of infection, while seasonal high temperatures and humidity are also important cause of infection [5, 6, 10]. Accordingly, a new shed was constructed in June 2021. Because the number of cattle on the farm has not changed, it is expected that the incidence of environmental mastitis will decrease as a result of improvements in the rearing density and bedding conditions.

The ratio of waste milk represents that of postpartum cows, those treated with antibiotics, and those suspected of having mastitis to the total number of milked cows. Thus, an increase in waste milk can result from an increase in cows with mastitis and those treated with antibiotics. In this study, the increase is thought to have been due largely to the increase in the number of mastitis cases. It is often difficult to control mastitis because of the number of related factors, and onset can also have hidden causes such as environmental hygiene, the milking process, worker hygiene, and so on. The findings of this study suggest a problem with the implementation of the current HACCP plan or PrP.

The farm HACCP standards aim to assure not only food safety but also animal health and welfare. Food safety at the farm has been effectively realized as a result of implementing the farm HACCP system. In terms of animal health, this study revealed an increase in milk yield, with a decrease in the number of somatic cells, although the number of mastitis cases remains a problem. These results seemed to be effects of the early detection of mastitis cows through the PrP. In a future study, we would like to develop methods to ensure the effectiveness of the HACCP plan, especially by following up on management targets that lead to reductions in the number of new mastitis cases. In addition, we would like to confirm how the investigated data, including CCP monitoring data, production data and replacement rate of milking cows, change over time.

CONFLICTS OF INTEREST. The authors declare no conflicts of interest.

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