

Food safety, livestock health, and productivity of a layer farm following implementation of a certified HACCP system in Japan

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Abstract

This study examined the safety and productivity of a layer farm over a 3-year period following the implementation of a farm Hazard Analysis and Critical Control Points (HACCP) system in 2019. The critical control point was “automatic egg collection” and no deviations from critical limits were observed, indicating the eggs were safe. In addition, the egg production rate increased and the feed conversion rate decreased. In contrast, the viability after the introduction of a farm HACCP system, in which the replenishment of new hens was discontinued after forced molting, showed an increasing trend. These results suggest that the HACCP system had a positive effect on the productivity of egg-laying hens.

Keywords: average feed conversion rate, egg production rate, farm hazard analysis and critical control point (HACCP) system, viability

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Introduction

To improve the safety of livestock products, it is important to improve hygiene management at individual livestock farms and to implement consistent hygiene management from farm to table (Codex Alimentarius International Food Standards, 2020; Global G.A.P., 2020; Ministry of Agriculture Forestry and Fisheries, Japan, 2009). Food business operators are responsible for providing safe food. In August 2009, the Japanese Ministry of Agriculture, Forestry and Fisheries published Hazard Analysis and Critical Control Point (HACCP) certification standards for farms (Ministry of Agriculture Forestry and Fisheries, Japan, 2009), which aim to improve the hygiene management of livestock farms, thereby ensuring the safety of livestock products in Japan. Farm HACCP introduces the concept of Codex HACCP (Codex Alimentarius International Food Standards, 2020.) to farms in order to improve hygiene management on livestock farms by implementing control points aimed at preventing biological, chemical, and physical hazards (e.g., microorganisms, antibiotics, foreign substances) and continuously monitoring them.

We have previously published analyses of the food safety, livestock health, and productivity of a dairy farm (Akaike *et al.*, 2022), a fattening farm for Japanese black cattle (Akaike *et al.*, 2023) and a farrow-to-finish swine farm (Akaike *et al.*, 2024) following the implementation of a certified HACCP system. In these studies, the potential hazards were chemical (residual antibiotics) and physical (residual needle fragments). The critical control point (CCP) was “the selection of milking cows, shipping cattle, or shipping swine.” No deviation from the critical limit (the withholding period has passed) was observed during the observation period, indicating that the milk, beef, and pork were safe. However, by implementing good manufacturing practices (GMPs) that included a number of sanitation standard operation procedures as well as providing education and training to farm workers, the somatic cell counts in the milk decreased while the milk yield per dairy cow increased at the dairy farm (Akaike *et al.*, 2022), beef cattle treated for bovine respiratory disease less than 6 months after the introduction of cattle decreased at the Japanese black cattle farm (Akaike *et al.*, 2023) and pigs born alive per litter improved (Akaike *et al.*, 2024). As mentioned above, the implementation of GMPs led to healthier livestock, higher productivity, and fewer infectious diseases.

We considered *Salmonella enterica* subsp. *enterica* serovar Enteritidis (SE) contamination is an important hazard for eggs produced on the hen farm. Chousalkar *et al.* (2018) reported that *Salmonella enterica* subsp. *enterica* is one of the most commonly reported causes of foodborne illness in humans worldwide. Contaminated food products of animal origin, particularly eggs and egg products, are frequently implicated in outbreaks of human salmonellosis (Chousalkar *et al.*, 2018). SE has been the major cause of foodborne salmonellosis outbreaks in humans over the last 20 years, with contaminated hen eggs being the most important vehicle for infection (Gantois *et al.*, 2009).

The aim of this study was to investigate the effect of a HACCP-based food safety management system by analyzing CCP monitoring data and production data, including the mean feed conversion rate, egg production rate, and viability.

Materials and Methods

A farm information: A layer farm began making a farm HACCP plan, including GMPs, in December 2019 and began providing educational training. Implementation of the HACCP plan began in January 2020, and farm HACCP certification was obtained in November 2020. The layer farm had 380,000 adult hens (60% Boris Brown and Julia, 40% Julia Light), which were housed in cages inside nine windowless henhouses. Layer chicks were usually introduced at 120 days of age, forced molting was performed in laying hens at 440–480 days, and the out date was at 750 days of age. In 2019, because of the high price of eggs, the farm postponed the out date for laying hens by about 30 days, making it 780 days. Each of the nine henhouses was lot-renewed roughly every 18 months. Eggs from this hen farm are collected at the farm by an automatic egg collection system and transported to the company's grading and packing center by truck. The farm had 22 employees, and the HACCP team consisted of four farm workers, one veterinarian (a professional farm HACCP advisor), and two representatives from a veterinary drug supplier. The farm performed a hazard analysis and then created and implemented control measures (i.e., a HACCP plan and GMPs) in accordance with the farm HACCP certification standards published by the Japanese Ministry of Agriculture, Forestry and Fisheries (2009).

Hazard Controls of the farm: A potential biological hazard was the contamination of eggs by SE. To ensure food safety, the farm decided on CCP 1b (a biological hazard for its HACCP plan, which involved the removal of eggs presumed to be contaminated with *Salmonella*). The critical limit for preventing contamination with SE in eggs was “no eggs sucked by dead hens.” The monitoring method involved visually checking and recording any retained eggs tucked by dead hens before the start of automatic egg collection.

Management targets: The hygiene management targets were improving the egg production rate and reducing the feed conversion rate. We did not set specific numerical targets for improving the health of the hens. During the farm's HACCP team meetings, the following facts were reported: a lack of sanitation response as required by law, outbreaks of poultry red mite (*Dermanyssus gallinae*), overlooking anomalies during patrols of the farm, variations in work procedures, and a lack of recordkeeping.

Activity of HACCP team: We held numerous meetings to discuss what measures to take to address these issues, and based on advice from a clinical veterinarian, we decided to implement GMPs, including the following sanitation standard operation procedures: observation of chickens in the laying houses by patrols, early treatment of sick chickens,

removal of dead chickens, sanitation inside and outside the laying houses, and countermeasures against red mites. In addition, we created and implemented a program to provide education and training on the HACCP plan and GMPs for the farm's workers.

The training for the HACCP plan and GMPs: The training for the HACCP plan and GMPs for this farm, as well as daily on-site guidance, was provided by the HACCP team leader. Regular training for feeding sanitation management and disease control was provided by a clinical veterinarian, and basic information about feed additives was provided by a sales representative of a veterinary drug supplier. The farm's HACCP team held monthly meetings in which they performed data analyses of the results. By introducing this monthly review, the HACCP team also aimed to confirm the progress of efforts to achieve the hygiene management goals and to consider improvement measures where necessary.

Inspection items, measurements, and statistical processing: In this study, inspection items such as mean annual feed conversion rate, egg production rate, and viability were measured from 2018 to 2021, and CCP monitoring was performed every day from 2020 to 2021. We obtained these data from the monthly farm records. Until 2018, this farm purchased new hens to replenish the stock after forced molting. This practice was discontinued after the introduction of the HACCP system in 2019 in order to reduce the risk of importing infectious diseases such as avian influenza from the outside. Linear approximations were obtained from the inspection results, and statistically significant differences (*t*-test, chi-square test, and Fisher's exact test; $p < 0.01$) between annual means were calculated using spreadsheet software (Excel 365, Microsoft Corp., Redmond, WA).

Result and Discussion

There were no cases of deviation from the CCP (i.e., shipping no eggs sucked by dead hens. Accordingly, there were no cases of salmonella food poisoning from

eating eggs shipped by this farm after the implementation of the HACCP plan. Thus, the farm was able to prevent the risk of salmonella contamination in eggs as a biological hazard.

Figure 1 shows the mean annual feed conversion rate. The mean $\pm$ standard deviation of the feed conversion rate was 2.17 % $\pm$ 0.11 % in 2018, 2.18 % $\pm$ 0.16 % in 2019, 2.15 % $\pm$ 0.05 % in 2020, and 2.10 % $\pm$ 0.09 % in 2021. There were no statistically significant differences in the mean feed conversion rate according to the *t*-test. The linear approximation was $Y = -0.026X + 2.217$ ($R^2 = 0.752$). Feed efficiency improved to 2.11 in 2021 after certification compared with 2.17 in 2018 before HACCP implementation, although the difference was not significant.

Figure 2 shows the mean annual egg production rate. The mean $\pm$ standard deviation of egg production rate was 78.9 % $\pm$ 4.8 % in 2018, 81.9 % $\pm$ 6.8 % in 2019, 78.4 % $\pm$ 4.7 % in 2020, and 81.4 % $\pm$ 3.7 % in 2021. There were no statistically significant differences in mean egg production rates according to the *t*-test. The linear approximation was $Y = 0.407X + 79.121$ ($R^2 = 0.0917$). The egg production rate improved to 81.4% in 2021 after certification compared with 78.9% in 2018 before HACCP implementation, although the difference was not significant.

Figure 3 shows the mean annual viability rate. The mean $\pm$ standard deviation of viability was 95.1% $\pm$ 1.4% in 2018, 93.3% $\pm$ 2.5% in 2019, 93.7% $\pm$ 0.8% in 2020, and 93.5% $\pm$ 1.0% in 2021. In 2018, the final year in which new hens were purchased to replenish the stock after forced molting, the average viability was statistically higher compared with 2019, 2020, and 2021, according to the *t*-test. In 2019, because of the high price of eggs, the farm postponed the out date for laying hens by about 30 days, making it 780 days. However, despite the replenishment of hens being discontinued around the same time, these results were not statistically different according to the *t*-test. The linear approximation from 2019 to 2021 was $Y = 0.133X + 93.228$ ($R^2 = 0.444$). Extending the breeding period for laying hens would be expected to reduce the mean viability rate, but this did not occur.

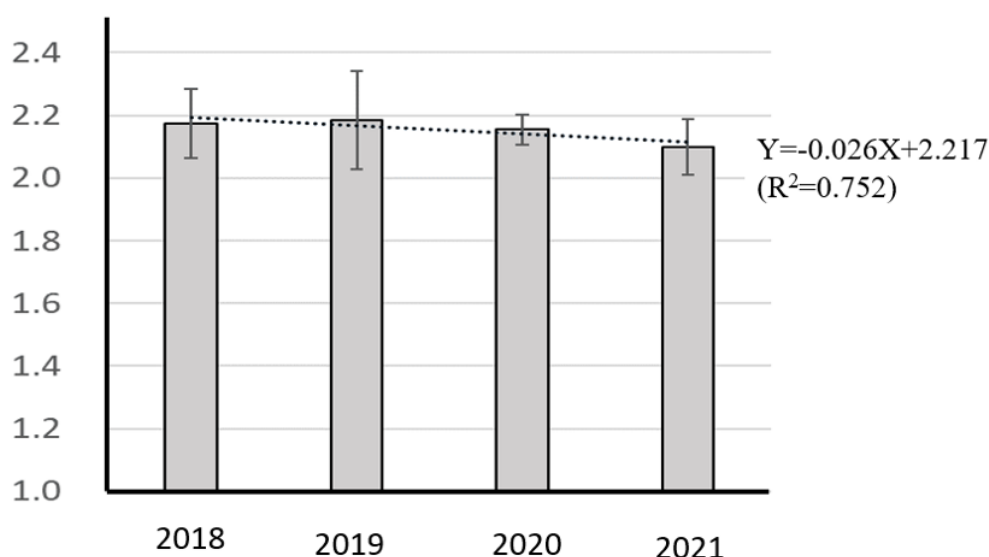


Figure 1 Trend in the mean annual feed conversion rate during the four-year study period.

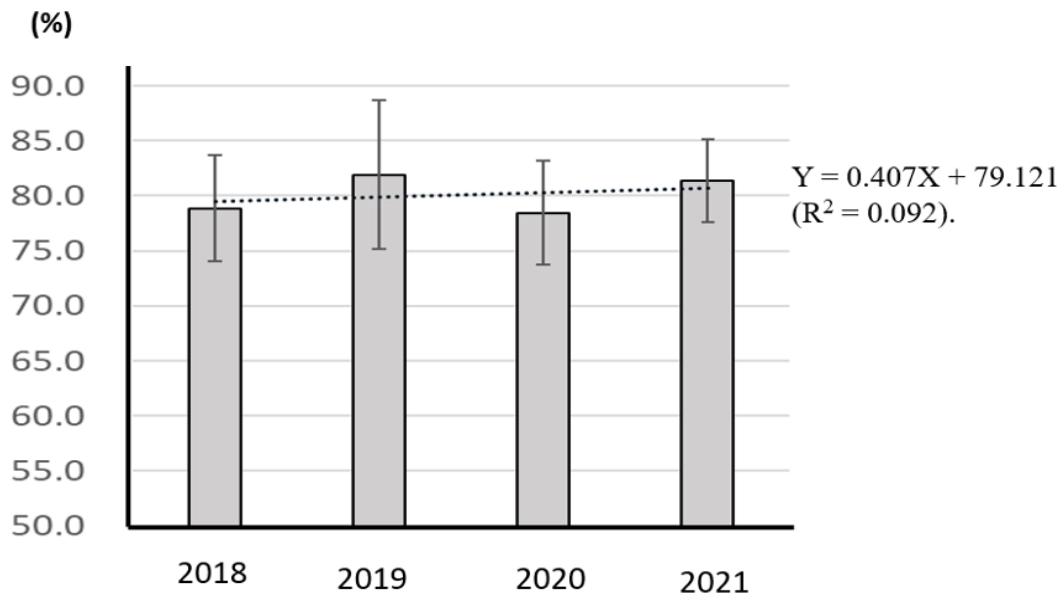


Figure 2 Trend in the mean annual egg production rate during the four-year study period.

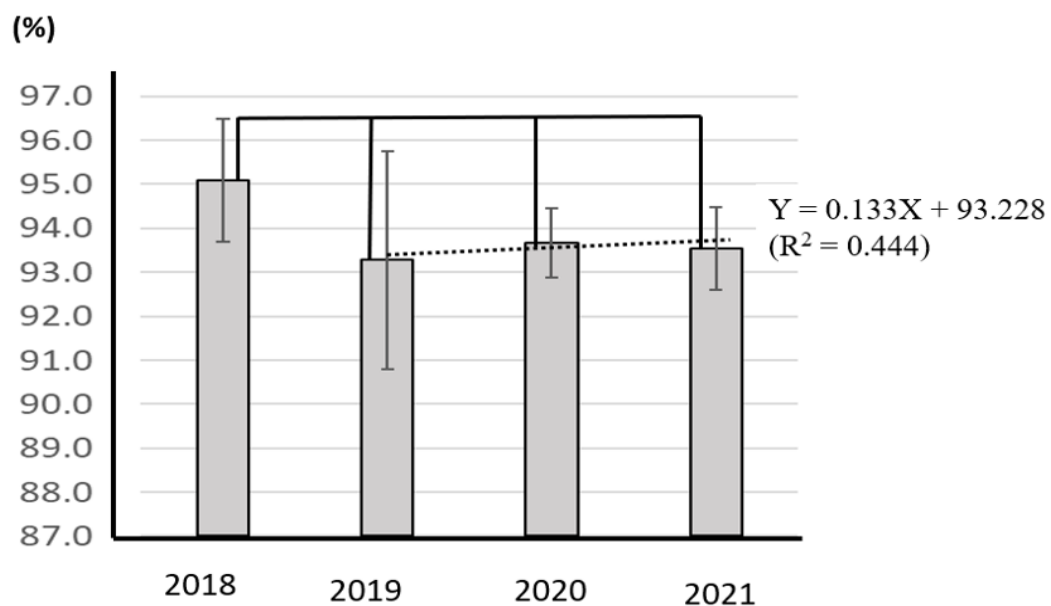


Figure 3 Trend in the mean annual viability rate during the four-year study period.

Although the data are not shown, there was no increase in the number of deaths, and no chickens showed clinical signs of infectious diseases; therefore, it seems that there was no introduction of infectious disease from the outside.

Using the above results, we were able to evaluate the effect of the implemented farm HACCP system on livestock health and productivity. In terms of egg safety, the removal of eggs trapped by dead hens was deemed successful based on the HACCP plan. Because there were no deviations from the items set by the CCP, the eggs produced by the hens were considered safe. The hygiene management targets were improving the egg production rate and reducing the feed conversion rate. After the implementation of the HACCP plan, efforts were made to improve both livestock health and hygiene management by using GMPs. There were no statistically significant differences in feed conversion

ratio from year to year, but a trend toward improvement was observed based on the linear approximation $Y = 0.0257X + 2.2171$ ($R^2 = 0.752$). In 2021, the feed conversion ratio became $2.10\% \pm 0.09\%$. We achieved the indicator range indicated in section 2.1 of the Commercial Hen Feeding and Management Guidelines, Ghen Corporation (2021). Farooq *et al.* (2002) reported poor feed efficiency of chickens housed in overcrowded and unhygienic conditions. This farm is considered to be well maintained in terms of hygiene and stocking density because the feed conversion ratio was improving. Watanabe *et al.* (1975) reported that in an analysis of economic efficiency with a hen egg cost of JPY 185/kg and a feed cost of JPY 38/kg, an improvement in the feed conversion ratio of 0.1 led to an increase in gross earnings of about JPY 28 for the whole period (252 days) and that an improvement of 0.07–0.08 was obtained, suggesting

that the effect on economic efficiency was extremely large. It is estimated that the introduction of HACCP was effective in increasing the profits of this poultry farm.

The difference in egg production rate was also not statistically significant between years but did start to increase based on the linear approximation $Y = 0.4067X + 79.121$ ($R^2 = 0.0917$). Egg production rates can be influenced by a number of factors (Gantois *et al.*, 2009; Oguntunji and Alabi, 2010; Silva *et al.*, 2013; Yoshida *et al.*, 2011). Vandana *et al.* (2021) reported that heat stress reduces growth, reproductive performance, and egg production in poultry birds. Heat stress due to high environmental temperatures has been implicated in marked adverse effects on egg production and eggshell quality in hens (Oguntunji and Alabi, 2010). In addition, Yoshida *et al.* (2011) reported that high environmental temperature negatively influences ovarian function and consequently reduces egg production in laying hens. The egg production rate in 2020 was 78.44, the lowest of the study period, but the spawning rate in August of that year was also the lowest (74.2). According to a report by the Japan Meteorological Agency, temperatures in the farm area exceeded 35°C for 16 days in August 2020, the highest number of days on record, and the highest mean maximum temperature was 34°C. These high temperatures likely affected the spawning rate. Meanwhile, Arkle *et al.* (2006) reported that symptoms of red mite (*Dermanyssus gallinae*) infestation include reduced production, poor egg quality, increased mortality, and compromised welfare. From 2018 to October 2021, there were sporadic outbreaks of red mite infection despite the use of pesticides. However, since the introduction of more effective pesticides in October 2021, the number of sporadic outbreaks has decreased. Although no significant results were obtained throughout the study period, the hygiene management targets for 2019 and 2021 were achieved by building on the previous year's results.

Viability was 95.1% in 2018. In 2019, when the practice of purchasing new hens to replenish the stock was discontinued, viability ranged from 93.3% to 93.5%, and there were no statistically significant differences in mean viability according to the t-test. However, viability was considered to have improved based on the linear approximation $Y = 0.4067X + 79.121$ ($R^2 = 0.0917$). Fulton (2017) reported that the top 15 causes of normal mortality, in order of prevalence, were egg yolk peritonitis, hypocalcemia, gout, self-induced molt, salpingitis, being caught by a spur, intussusception or volvulus (twisted intestine), cannibalism (pick out), tracheal plug, septicemia, fatty liver syndrome, internal layer, layer hepatitis, persecution, and prolapsed vent. Other causes noted were hyperthermia (during summer), trauma, coccidiosis, ovarian neoplasia, being egg-bound, urolithiasis, peritonitis (not egg yolk-induced), leg fracture, being caught in the structure, tumor (other than ovarian origin), wing fracture, exsanguination, and cardiomyopathy. Because no deaths due to epidemic infestation were observed on this farm during the study period, it is likely that the deaths were caused by any of the above.

This farm started making its farm HACCP plan, including GMPs, in December 2019 and began providing educational training. Implementation of the HACCP plan began in January 2020, and farm HACCP certification was obtained in November 2020. Food safety at the target farm was effectively realized as a result of implementing a farm HACCP system. In terms of animal health, the study showed that the animals maintained viability beyond 2019, and both the feed conversion rate and egg production rate improved. These results are suggested to be due mainly to the effects of the GMPs. In a future study, we would like to continue to monitor the productivity results as well as develop methods to ensure the effectiveness of the farm HACCP system, especially by following up on management targets.

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