**Henhouse Feeding Style and *Salmonella* Enteritidis Contamination in Unvaccinated Flocks of Egg Farms, April 1994–March 2001**

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**ABSTRACT.** From April 1994 to March 2001, monitoring tests (surveillance) for contamination of *Salmonella* Enteritidis (SE) at commercial egg farms and farm traceback inspections for cases of SE foodborne illness were carried out in the Himeji Livestock Hygiene Service Center jurisdiction of Hyogo Prefecture, Japan. SE vaccination was not performed before the outbreak of SE-associated foodborne illness, and SE contamination of a farm was recognized. In the surveillance, the year average percentages of identified SE-positive farms were 6.1% in farms with floor feeding in an open-type henhouse (F-OH) and 12.7% in farms with cage feeding in a windowless-type henhouse (C-WH), but 0% in farms with only cage feeding in an open-type henhouse (C-OH). The highest identified proportion of SE-positive farms among all styles of farms was found (4.3%) in April 1997–March 1999. Farm traceback inspections were performed in 2 of 7 farms feeding by F-OH and in 5 of 9 farms feeding by C-WH in this period. Easier contamination with SE was found for C-WH or F-OH than for C-OH. Ninety percent of the birds (3,632,000 birds at 70 farms) are fed at these easier contamination farms by C-WH (89% of birds in 13% of farms) or F-OH (1% of birds at 10% of farms). Integrated sanitary requirements and SE vaccinations are especially necessary on farms feeding by F-OH or C-WH. Since 1999, these countermeasures have been performed, and SE foodborne illnesses and affected patients in Hyogo Prefecture have gradually decreased.

**KEY WORDS:** environmental monitoring, housing, poultry, *Salmonella*, vaccine.


Salmonellosis is one of the most common foodborne diseases, with an estimated 800,000 to 4 million human infections reported each year in the United States alone. From 1996 to 1999, *Salmonella* Enteritidis (SE) illness rates declined 48% [9]. Contamination of egg products by SE is the most commonly identified source of human foodborne illness [26]. Of the many serovars of *Salmonella*, SE is commonly associated with foodborne illness in Japan, as in other industrial countries [13,27,28]. Of outbreaks involving 10 or more cases, 41 were due to SE in 1993 (55%), 75 were due to SE in 1994 (70%), 69 were due to SE in 1995 (71%) and 84 were due to SE in 1996 (76%) [23, 24].

In terms of the relationship between egg-layer henhouse style and *Salmonella* isolation rate in the henhouse, the *Salmonella* isolation rate in the henhouse seems to be associated with whether the premises are windowless or open, and roof rats appear to be the most important vectors in the spread of SE in windowless henhouses because the detected SE (PT6) from birds and rats coincided with each other [19].

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In terms of the relationship between egg-layer henhouse style and *Salmonella* isolation rate in the henhouse, the *Salmonella* isolation rate in the henhouse seems to be associated with whether the premises are windowless or open, and roof rats appear to be the most important vectors in the spread of SE in windowless henhouses because the detected SE (PT6) from birds and rats coincided with each other [19].

In a survey of SE in spent hens and the relationship to farming style in Hokkaido, Japan, *Salmonella* was isolated from the birds of 10 layer hen farms, and all of these hens were raised in henhouses without windows. No *Salmonella* was isolated from birds raised in henhouses with windows. In the windowless henhouses, salmonellae were isolated from 46 (21.8%) of 260 birds in henhouses with 4 to 6 cages piled up vertically and from 6 (2.5%) of 240 samples from the henhouses with 4 to 5 cages piled in a slanting manner [29].

From April 1994 to March 2001, monitoring tests (surveillance) for the contamination of SE in commercial egg farms and farm traceback inspections for cases of SE foodborne illness (farm traceback inspections) were executed in the Himeji Livestock Hygiene Service Center (LHSC) jurisdiction of Hyogo Prefecture, Japan. From the results of our surveillance and the farm traceback inspections, a relationship between henhouse feeding style and SE contamination was suggested.

The intent of this study was to clarify the relationship between henhouse style and SE contamination and to identify the necessity of integrated sanitary requirements including SE vaccination at farms with the type of henhouse style that is considered to facilitate SE contamination.

**MATERIALS AND METHODS**

Investigation of egg-laying hen numbers and henhouse...
styles: From April 1994 to March 2001, we visited every layer farm (70 farms) in the Himeji LHSC jurisdiction and investigated the egg-laying hen numbers and bird flock environments each year. In particular, feeding style (cage or free-range) and henhouse structure (open-wall poultry house style or windowless-wall poultry house style) were investigated. For farms at which owner consent was obtained, surveillance of Salmonella contamination for every bird flock (1–21 flocks) was carried out because cases of SE foodborne illness associated with shell eggs or shell egg-related foods were increasing in Hyogo Prefecture.

There are three henhouse feeding styles for laying hens in the LHSC jurisdiction: Cage feeding in an open-type henhouse (C-OH), cage feeding in a windowless-type henhouse (C-WH) and floor (barn) feeding (including free-range field feeding) in an open-type henhouse (F-OH).

C-OH: C-OH is the most common henhouse style in Japan. The henhouse is an open-sided poultry house. To shut out rain, waterproof sheets are used in combination with a winch. Almost all cages are stepped cages. Feed is supplied to a hopper by an automatic feeder or by hand. Drinking water is supplied by a Mini Cup Automatic Waterer or a nipple drinker with a drip cup. Poultry manure is collected under cages. Elevated floor poultry houses also exist. Eggs are gathered by hand. At large-scale egg farms, automatic egg gatherers (in line egg belt) are used.

C-WH: C-WH is a henhouse with a conventional cage system. The walls of such henhouses are windowless. Such henhouses have an air inlet and outlet and ventilation fan. Almost all henhouse ventilation systems use negative pressure. Piled conventional cage systems of some companies were found. Feed is supplied to a hopper by an automatic feeder, and drinking water is supplied by a Mini Cup Automatic Waterer or a nipple drinker with a drip cup. Poultry manure is disposed of in a gutter for feces. Lighting is managed by a program. In almost all farms, an automatic egg gatherer (in line egg belt) was found to be used.

F-OH: F-OH includes free-range field feeding. However, almost all such farms in our jurisdiction used floor feeding. The floor is made of concrete and is covered with litter such as sawdust. The henhouse is open-sided with a wire mesh wall. In organic production, the floor is earth. Feed is supplied by a chain feeder or a hopper, and drinking water is supplied by a bell drinker at almost all farms. Hens lay eggs in wooden nests, and the eggs are gathered by hand. To collect eggs, an egg tray and a container box are used. Mixed feeding with males and females is also carried out at some farms.

Surveillance of Salmonella contamination: For the first four years (April 1994–March 1998), we performed surveillance at different egg farms (29 farms). We selected the different farms from the three henhouse style randomly. Since April 1998, we performed surveillance at every farm at which owner consent was obtained and at contaminated farms where the owners had performed some treatments. Some farms had repeated inspections, whereas others did not. Therefore, we calculated the SE detection percentage from the number of positive farms for that year. Moreover, the identified SE-positive farm percentage was calculated from the positive rate for all 70 farms, as the percentage of total farms at which surveillance was carried out in a year was low and the positive rate for the inspected farms overestimated the SE contamination.

For the purpose of surveillance, dust from 10 sites in facilities, such as cages, hoppers, egg belts and gutters for feces (containing dried rat excrement, spider nests and insects) [dust] was collected in sample bags (Whirl-Pak Bags, Nasco, Fort Atkinson, WI, U.S.A.) by hand with disposable polyester gloves. The drug swab technique (DS) was also performed [3-6, 18,30]. For this, a gauze pad dipped in 20% skimmed milk water was dragged through the aisles between the cages (in the case of cage feeding) or on the floor (in the case of floor feeding) for more than 15 min.

Farm traceback inspections: Whenever foodborne illness caused by Salmonella (especially SE) from shell eggs and shell egg-related food broke out, we investigated the egg farm and grading and packing (GP) center. From April 1994–March 2001, we performed farm traceback inspection at 7 farms (A, B, C, D, E, F and G). Information on foodborne illnesses and egg farms that were suspected of producing Salmonella(SE)-contaminated eggs was supplied through the Medical Division of Hyogo Prefecture Environment Life Medical Section or a local health and welfare office (LHWO). GP centers were investigated by the staff of an LHWO and farms were investigated by the staff of the LHSC. LHWO traceback inspections were performed with 100 collected eggs at GP centers, and LHSC traceback inspections were performed with the dust and DS for every flock (henhouse) at egg farms. The details of the LHSC inspection methods are the same as mentioned above.

Continuous inspections at the 7 traced back egg farms: Farms A and G were the farms at which our inspections of Salmonella contamination for all the henhouses were performed continuously to establish the farm HACCP sanitation system. Farms B, C, D and F were inspected in the surveillance from April 1994–March 1997. Farm E was a farm for which samples were brought to our laboratory before a foodborne illness broke out.

Salmonella culture technique (method): Dust and DS samples were suspended in peptone water and subjected to enrichment culture with tetrathionate broth (TTB, DIFCO, Detroit, MI, U.S.A.). Subsequently, samples were cultured on desoxycholate hydrogen sulfide lactose (DHL) agar (Eiken Chemical, Co., Ltd., Tokyo, Japan) containing novobiocin (Wako Pure Chemical Industries, Ltd., Osaka, Japan) and incubated for 24 hr at 37.8°C. Isolates were biochemically identified using an API 20 E system (BioMerieux, Marcy L’Etoile, France) and serotyped by slide and tube agglutination with salmonella O and H group antisera (Denka Seiken Co., Ltd., Tokyo, Japan).

Statistical analysis: The relationship between henhouse feeding style and SE detection in the surveillance (April 1994 to March 2001) was analyzed by Chi-squared test. The relationship between surveillance periods was analyzed by Tukey’s test.
RESULTS

Egg-laying hen numbers and henhouse style: The farm percentages of the various henhouse feeding styles in terms of layer farm number and proportion of the total number of birds are shown in Fig. 1. In the Himeji LHSC jurisdiction in 1999, the total number of layer farms was 70, and the total number of layer birds was 3,632,000. In terms of percentage of farms, 77% of the farms fed birds by C-OH only, 10% of the farms fed birds by F-OH and 13% fed birds by C-WH. In terms of percentage of birds, 10% of birds were fed by C-OH only, and 1% of birds were fed by F-OH, or F-OH and C-OH. Feeding by C-WH, or C-WH and C-OH accounted for 89% of the birds. No birds in these farms were vaccinated with SE vaccine before a farm traceback inspection.

Surveillance of Salmonella contamination: The results of the Salmonella surveillance for farms and henhouses of various feeding styles are shown in Tables 1–1 and 1–2. The year average percentages of farms identified as SE-positive were 6.1% and 12.7% for farms feeding by F-OH and C-WH, respectively. In contrast, among the farms feeding by C-OH only, the level of SE-positivity was 0%. In farms in which surveillance was executed, the percentages of confirmed SE-positive farms of the three styles during April 1994–March 2001 were 0% (farms feeding by C-OH only), 28.6% (farms feeding by F-OH) and 44.4% (farms feeding by C-WH). Significant differences were present between the farms with C-OH only and the farms with F-OH or C-OH (P<0.01). From comparison of the SE-positive farm percentages for each period (PFP), the level in April 1997–March 1999 was found to be highest (4.3%) in terms of the total number of farms for all henhouse feeding styles (Table 1–1). In terms of the number of henhouse inspected in the surveillance, the year average percentages of SE-positive henhouses were 12.2% for F-OH, 14.6% for C-WH and 1.5% for C-OH. All of the SE-positive henhouses with feeding by C-OH belonged to farms that also fed by F-OH or C-WH (Table 1-2). In the surveillance, other Salmonella serovars besides SE were detected. Salmonella serovars detected in each period are shown in Table 2. In the C-OH-style henhouse, 3 serovars were detected. In the F-OH-style henhouse, 6 serovars were detected. However, 19 serovars were detected in the C-WH-Style henhouse.

Farm traceback inspection: The farms at which we executed farm traceback inspection or were suspected as being sources of foodborne illnesses, as well as the cases of foodborne illnesses that broke out in these periods, are shown in Table 3. From April 1994 to March 2001, farm traceback inspections were carried out for seven farms. Five farms (A, B, C, D and E) were feeding birds by C-WH, or C-WH and C-OH and two farms (F and G) were feeding birds by C-WH, or F-OH and C-OH. No farm feeding birds by only C-OH was included. Farm A caused three cases of foodborne illness in one year (1997), while farm E caused two cases (1998). Farm C caused four cases in one year (1999). However, we could not confirm contamination. SE was detected from dust or DS samples in all farms except farm C. Farm C had a self-administered HACCP system, and we only checked the self-inspection results. There were 150,000 to 560,000 hens at these egg farms fed by C-WH, or C-WH and C-OH and 12,000 to 12,600 hens fed by...
Results of continuous inspections and countermeasures (treatment) at the 7 farms: SE detections at the 7 farms are shown in Table 4. In farms A and G, SE was not detected during the period of April 1994–March 1996. In farm A, SE was detected from dust and DS in C-WH mainly in April 1997–March 1998. In the samples for C-OH, SE was detected from one dust sample containing rat feces. In farm G, SE was detected from dust and DS in April 1996–March 1997. SE spread rapidly from henhouse to henhouse and from farm to farm. Farms were sharing egg trays and container boxes, and SE was detected from the swab samples of these items.

In the surveillance of farms B (1998), C (1996), D (1996) and F (1995), SE was not detected. SE contamination was first detected by the traceback inspection surveillance (except in farm C). In terms of the samples that were brought to our laboratory from farm E, SE was detected from 1 of 7 henhouse samples before an outbreak of SE foodborne illness. SE vaccinations were used in 6 of 7 farms after the outbreak of foodborne illness and identification of farm contamination. At farm A, countermeasures to eliminate rodents in particular were carried out. At farm G, continuous surveillance, disposal of contaminated flocks, all-in-all-out production of flocks per farm branch unit, disinfection and introduction of Salmonella-free chicks were carried out.

**DISCUSSION**

From the results of farm traceback inspections, the method of traceback inspection was thought to be success-
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Ful. Farm traceback inspections were performed for all farms suspected of contamination. Dust and DS samples of all henhouses (flocks) enabled the identification of farm SE contamination at every traceback farm except farm C. However, in the low-contamination cases (farm B or D) and at the beginning of contamination (farm E 1997–1998), the rate of identification of SE-positive henhouses was low, and there were cases in which either D or DS was SE-positive. Therefore, inspections of both D and DS for all henhouses at a farm are necessary. Carrique-Mas [5, 6] recommended a “wet” method (ten dust and ten feces samples) for mostly main production systems (cage, barn and free-range) in the EU and described that boot swabs were the preferred method for the collection of feces, especially in floor systems.

Moreover, Davies [10] described that no single sample type was found to be suitable for identifying all contaminated houses. We considered that the combination of dust and DS samples was preferable in the surveillance and farm traceback inspections, as recommended by Caldwell et al. [3, 4], Mallison et al. [18] and the Japanese Society on Poultry Disease [30].

In the surveillance, we also collected dust and DS samples from all flocks at the farms. The percentages of farms identified as SE positive in each period might be indicative of the actual SE contamination percentages in each style of henhouse, although the proportion of farms inspected was low.

From the results of our surveillance and farm traceback inspections, C-WH and F-OH were found to be more easily contaminated with SE than C-OH.

Moreover, the percentages of farms feeding by F-OH and C-WH that were identified as SE positive were significantly higher than that of the farms feeding by C-OH only.

The effect of the flow of air on horizontal transmission of SE has been recognized in the windowless-type henhouses [1, 20].

Table 2. Henhouse style and Salmonella enteritidis (SE) and Salmonella serovar detection in the monitoring tests (April 1994–March 2001)

<table>
<thead>
<tr>
<th>Henhouse style</th>
<th>F-OH Serovars</th>
<th>C-OH Serovars</th>
<th>C-WH Serovars</th>
</tr>
</thead>
<tbody>
<tr>
<td>April 1994–March 1995</td>
<td>S. Agona, S. Mbandaka</td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 1996–March 1997</td>
<td>SE</td>
<td>SE, S. Infantis</td>
<td></td>
</tr>
<tr>
<td>April 2000–March 2001</td>
<td></td>
<td></td>
<td>SE, S. Agona, S. Infantis, S. Bareilly, S. Montevideo</td>
</tr>
</tbody>
</table>

(SE): SE detection at the farms with henhouse styles of C-OH and C-WH, or C-OH and F-OH.

Table 3. Henhouse style and Salmonella enteritidis (SE) foodborne illness cases / year at farms at which SE foodborne illness traceback inspections were executed (April 1994–March 2001)

<table>
<thead>
<tr>
<th>Henhouse style</th>
<th>Farm containing C-WH</th>
<th>Farm containing F-OH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period/Farm</td>
<td>C-OH and C-WH</td>
<td>C-WH only</td>
</tr>
<tr>
<td>April 1997–March 1998</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>April 1998–March 1999</td>
<td>1 (1)</td>
<td>1</td>
</tr>
<tr>
<td>April 1999–March 2000</td>
<td>1 (4)</td>
<td>1</td>
</tr>
<tr>
<td>April 2000–March 2001</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

April 1994–March 1997: Farm traceback inspections associated with SE-contaminated eggs were not executed. C-OH: in cages of open-type henhouses. F-OH: on the floor of open-type henhouses. C-WH: in cages of windowless-type henhouses. Values in parentheses indicate cases not identified but suspected.
other serotypes of *Salmonella* are likely to remain in the henhouse, as shown in the surveillance results (Table 2). In the studied period, disinfection of cage systems was not performed after shipping out of spent hens because washing and disinfection causes electrical problems in C-WH systems. The hens that had a conventional cage system in windowless henhouses were large-scale farms in our LHSC jurisdiction (Fig. 1). This could cause many cases of foodborne illness if they become contaminated because they produce so many eggs per day. Disinfections of henhouses and their facilities, as well as SE vaccination, are necessary in the C-WH henhouse style. A disinfectant comprised of formaldehyde or glutaraldehyde applied at the recommended concentration was used at farm E. Additionally, SE-vaccinated layers were introduced into some farms (A, B, C, D and E).

Generally, the most prevalent route of infection of *Salmonella* has been thought to be oral inoculation (horizontal transmission) with contaminated feed and infected drinking water [20,21], although the original source of SE contamination is considered to be infected chicks [22], as SE frequently exhibits transovarian infection (vertical transmission) [17, 25, 31].

At the farms feeding layers by F-OH, bell drinkers were usually used, and the drinking water was likely to be contaminated with *Salmonella* from feces of infected birds. Oral SE inoculation via drinking water could occur easily if contaminated chicks (hens) were present [21]. In organic natural feeding of layers, hens were feeding with male birds and produced fertilized eggs for consumption. Sexual transmission of SE might occur [25]. In Japan, eggs from F-OH are preferred for raw consumption (for example, sukiyaki, tamagokake-gohan) because the eggs seem to be fresher, more natural and tastier, as presented in advertisements showing birds receiving natural feed and fresh water in a healthy environment, which is reminiscent of ancient Japanese food styles. Fertilized eggs are also thought to be more nutritious than unfertilized eggs among some people. This might be one of the reasons that eggs from F-OH frequently cause foodborne illness. Moreover, at farms feeding by F-OH, dust containing dried feces could fly up in the air of the henhouse following sudden movement of hens, thus respiratory infection could easily occur, like in farms with C-WH. As for the effect of cleaning and disinfection, the percentages of recovery of *Salmonella* in the cleaned henhouses and disinfected henhouses were variable. Eradication of the percentages of recovery of *Salmonella* from feces of infected birds.

**Table 4. *Salmonella enteritidis*(SE) detection at the 7 farms at which SE foodborne illness traceback inspections were executed (April 1994–March 2001)**

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</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>C-OH</td>
<td>a1-4</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 2/4, DS: 1/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>Vac</td>
<td>Vac</td>
<td>Disinfection</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>b1-7</td>
<td>D: 0/7, DS: 0/7</td>
<td>D: 1/7*, DS: 0/7</td>
<td>D: 2/2*, DS: 2/2</td>
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</tr>
<tr>
<td></td>
<td>C-WH</td>
<td>c-2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 1/2</td>
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<td>D: 0/2, DS: 0/2</td>
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<tr>
<td></td>
<td></td>
<td>d1-3</td>
<td>D: 0/1, DS: 0/1</td>
<td>D: 0/3, DS: 2/3</td>
<td>D: 0/4, DS: 2/4</td>
<td>D: 0/2, DS: 0/2</td>
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<td>D: 0/5, DS: 0/5</td>
<td>Vaccination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>e1-2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 1/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>(1999)</td>
</tr>
<tr>
<td>B</td>
<td>C-WH</td>
<td>a-b</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 1/2</td>
<td>D: 0/2, DS: 0/2</td>
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<td>Vaccination (2002)</td>
</tr>
<tr>
<td></td>
<td>C-OH</td>
<td>c-e</td>
<td>D: 0/3, DS: 0/3</td>
<td>D: 0/3, DS: 0/3</td>
<td>D: 0/3, DS: 0/3</td>
<td>D: 0/3, DS: 0/3</td>
<td>D: 0/3, DS: 0/3</td>
<td>D: 0/3, DS: 0/3</td>
<td>Vaccination (2002)</td>
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<tr>
<td>C</td>
<td>C-OH</td>
<td>a-f</td>
<td>D: 0/6, DS: 0/6</td>
<td>SI check (-)</td>
<td>SI check (-)</td>
<td>SI check (-)</td>
<td>SI check (-)</td>
<td>SI check (-)</td>
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<tr>
<td></td>
<td>C-WH</td>
<td>g-1</td>
<td>D: 0/6, DS: 0/6</td>
<td>SI check (-)</td>
<td>SI check (-)</td>
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<td>D: 0/5, DS: 0/5</td>
<td>D: 0/5, DS: 0/5</td>
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<td>Vaccination (1999)</td>
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<tr>
<td></td>
<td>F-OH</td>
<td>f-j</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 1/4, DS: 0/4</td>
<td>D: 1/4, DS: 0/4</td>
<td>D: 1/4, DS: 0/4</td>
<td>D: 1/4, DS: 0/4</td>
<td>D: 1/4, DS: 0/4</td>
<td>Disinfection</td>
</tr>
<tr>
<td></td>
<td>II F-OH</td>
<td>a-e</td>
<td>D: 0/5, DS: 0/5</td>
<td>D: 0/5, DS: 0/5</td>
<td>D: 0/5, DS: 0/5</td>
<td>D: 0/5, DS: 0/5</td>
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<td>Disinfection</td>
</tr>
<tr>
<td></td>
<td>III F-OH</td>
<td>a-d</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>D: 0/4, DS: 0/4</td>
<td>HACCP system</td>
</tr>
<tr>
<td></td>
<td>IV F-OH</td>
<td>a-b</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>D: 0/2, DS: 0/2</td>
<td>Test and dispose</td>
</tr>
</tbody>
</table>

H style: Henhouse style. C-OH: in cages of open-type henhouses. F-OH: on the floor of open-type henhouses. C-WH: in cages of windowless-type henhouses. I-V: Farm branch name. HN: Henhouse number (flocks). D: Dust. DS: Drug swab. SE-positive flock number / inspected flock number. Vac: Vaccinated. SI check: Self-performed SE monitoring results were checked. Grey areas: Farm-associated foodborne illness outbreak. *: Dust containing rodent feces. Demolished: henhouse was demolished. Bold text indicates results of SE foodborne illness traceback inspections. Normal text indicates results of monitoring tests. Farm A and farm G were farms at which our inspections of *Salmonella* contamination were performed continuously to establish the farm HACCP sanitation system. YearA-YearB: from April in Year A to March in Year B. Vaccination (Year C): Since Year C vaccination.
from contaminated poultry farms, particularly free-range farms. Moreover, SE (PT4) was also found in soil samples of a free-range breeding chicken farm after 8 months and in feces from wild mice, foxes and cats. The organism was also found in adult and larval forms of ground beetles and centipedes [12]. At farm G, all of the SE-infected flocks were depopulated, and the empty henhouses were cleaned and disinfected after shipping of spent layers. The fields were sprinkled with lime, and the surfaces of the henhouses were coated with liquid lime. Moreover, formaldehyde was used in open-type henhouses covered with a plastic sheet. Cleaning and disinfection were repeated until no SE was detected.

The percentage of SE-contaminated layer farms is suggested to be related to the henhouse feeding style for these reasons.

SE foodborne illness associated with eating shell eggs or shell egg-related food have occasionally broken out in Hyogo Prefecture, Japan (Fig. 2), like outbreaks of SE infection elsewhere in the world [8, 9,14-16, 27, 28]. SE foodborne illness peaked in 1998, as shown in the annual results of SE contamination (Table 1–1). In the beginning of the period of our surveillance and farm traceback inspection, sanitary requirements including the use of SE vaccinations were not in place in our LHSC jurisdiction. It was also the beginning of the period of SE vaccine usage in Japan. Moreover, the farms that used an SE vaccine were those suspected of being contaminated with SE at that time. Therefore, the owners of layer birds did not preferentially choose to use an SE vaccine.

In the United States, the CDC [8] reported that the rate of SE isolates increased from 0.6 per 100,000 population in 1976 to 3.6 per 100,000 in 1996. The incidence of SE infection in humans has decreased greatly since 1996 owing to three key interventions aimed at preventing the contamination and growth of SE in eggs [2]. The Pennsylvania Egg Quality Assurance Program has also shown progress in reducing SE infection in participating flocks [15].

Since 1999, integrated sanitary requirements for all egg farms, such as the all-in-all-out arrangement of flocks, disinfection of henhouse and cage systems and introduction of salmonella-free chicks have been put in place, and a date marking system for shell eggs has been established; producers also reconsidered the importance of fresh and safe eggs. Moreover, usage of SE vaccination has gradually become prevalent in the LHSC jurisdiction, and an SE vaccine is now, in 2010, used for almost all cases of F-OH and C-WH. The Hyogo Prefectural Shell Egg and Liquid Egg HACCP Program had also started in 2005, in which SE vaccines are recommended. Outbreaks of SE foodborne illness associated with eating raw or undercooked shell eggs have decreased in the LHSC jurisdiction (Fig. 2). In 2009, one outbreak of foodborne illness occurred due to contaminated eggs from farm E (C-WH). The owner had stopped using SE vaccinations and relied on a single use of wood vinegar [33] as a protective hygiene method. As part of the integrated sanitary requirement programs, SE vaccination is necessary. Layers fed by C-WH and F-OH in particular require vaccination.

Recently, poultry welfare has drawn attention in the Japanese egg production industry. Following a change in feeding henhouse style, control programs for SE might have to be changed. We have to pursue a more reasonable control program, ideally referring to the results of monitoring tests.

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REFERENCES


