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Monitoring the hygiene of chicken hatcheries in Taiwan during 1999-2001

Su-Jen Chen[1], Tsui-Er Lee[1], Eve-Ming Wang[1], Ta-Jen Cho[2], Ching-Ho Wang[1]

[1]Department of Veterinary Medicine, National Taiwan University; and [2]National Animal Industry Foundation, Taipei, Taiwan, ROC

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Microorganism contamination in hatcheries and eggs has a serious impact on the viability and quality of chicks as well as on the overall growth performance of chickens. Microbiological agents are present in the fluff when chicks hatch. Detecting microorganisms in fluff is a convenient method for evaluating the hygienic status in a hatchery. Fluff samples from 31 hatcheries collected over 3 years were tested for the total bacterial count, the presence of *Salmonella* spp., and fungus to evaluate the hygienic status of hatcheries in Taiwan from 1999 through 2001. The total bacterial score from the fluff samples was calculated and expressed as a bacterial score in a log scale. Most hatcheries had a bacterial count ranged from scale 1 to 3. Among the hatcheries, 13% to 29% were contaminated with *Salmonella* spp.; and 33% to 73% were contaminated with fungi in different quarters. The third quarter of each year was the most contaminated period ($p<0.01$). According to the data obtained from the fluff tests, hatcheries keep their hygienic status and supply good quality chicks by cleaning and disinfecting.

Key words: Bacterial count, fluff, fungus, hatchery, *Salmonella*

There were 3 grandparent stocks and no less than 200 parent stocks that provide about 178 million broiler chicks in Taiwan in 2001 [1]. Providing a healthy chick is critical for broiler performance. Good hygiene practices in hatcheries are necessary for reducing microorganism contamination in broilers. Where egg contamination has occurred during incubation, some embryos may die shortly after hatching. Newly hatched chicks may be infected by microorganisms adhering to fluff and down present in the hatcher [2,3]. Without bacterial growth control in hatcheries, poor-quality chicks may be produced, resulting in increased mortality, decreased feed efficiency and growth rate [4]. As a result, mortality up to 20% can occur within the first few days after hatching [5]. Fluff from chicks is a convenient material to send by mail to a laboratory for evaluation of the hygienic status in a distant hatchery. From January 1999 through December 2001, 31 hatcheries participated in this monitoring program at different periods using fluff tests. Data on the hygienic status from those hatcheries are reported in this investigation.

Materials and Methods

Hatcheries

Thirty-one hatcheries (Table 1) in Taiwan participated and sent fluff samples regularly for fluff tests at different years. Included were 3 grandparent (GP) farms and 28 parent stock (PS) farms. The 3 GP farms are located at Yangmei, Pingjen, and Miaoli. Most PS farms are located at southern Taiwan. All hatcheries except 3 (no. 4, 6, and 42) incubated the eggs from their own breeder farms. Most of them were established more than 30 years ago.

About 15% (31/200) of the total hatcheries, which produced about 91% (384/420) of the broiler chicks weekly, participated this fluff test monitoring program.

Fluff

The hatcheries collected fluff on the hatching days, which were on Mondays and Thursdays. After turning off the electrical fan in the hatcher, the fluff was collected from the surfaces of racks, hatcher baskets, basket frames, doors, or hatcher corners. One fluff sample from each hatcher was put in a clean envelope or a clean sealed plastic bag and sent our laboratory by mail. Normally the samples reached the laboratory within 1 to 2 days. The fluff test was conducted once a week according to methods provided by Arbor Acres Farm (Glastonbury, CT, US) with a few modifications, as shown in the following descriptions.

Bacterial score

Dry fluff 0.5 g was placed into 50 mL of sterile distilled water. One mL (100x dilution) and 0.1 mL (1000x dilution) of the diluted sample was placed into one Petri dish plate each after shaking well and settling for 5 min. Then, 18 mL of 48°C tryptic soy agar (TSA,

Corresponding author: Dr. Ching-Ho Wang, Department of Veterinary Medicine, National Taiwan University, P.O. Box 23-3, Taipei, 106, Taiwan, ROC. E-mail: chingho@ntu.edu.tw

Merck, Darmstadt, Gemany) was added and swirled gently in each plate. The bacterial colonies were counted after 24 h of incubation at 37°C. The total bacterial score (BS) was calculated from the 2 dilutions and expressed as a bacterial score in a log scale ranging from 2 to 6, representing 10^2 to 10^6 bacteria per gram of fluff. No bacterium growing in the 2 dilutions was expressed as 1 log.

Salmonella isolation

Salmonella isolation was performed only in the third quarter of each year. The fluff in the original dilution described in the bacterial score section was added with a 2x concentration of selenite brilliant-green enrichment broth (Merck) and incubated at 42°C for 24 h. Samples were then streaked onto brilliant green agar (Merck) and incubated for 24 h at 37°C. The small pink colonies were picked for further identification on triple sugar iron agar slants (Difco Laboratories, Detroit, MI, US), lysine decarboxylase agar (Difco), and SIM medium (Difco). Those that matched the biochemical characterization of *Salmonella* spp. were confirmed by poly-O antiserum (Difco).

Fungus identification

The same plates described in the bacterial score section were incubated for an additional 24 h at 25°C to develop mold colonies. The colonies showing threadlike branches were considered to be fungus by naked eyes. The plate was recorded as fungus positive if more than one colony of mold was found.

Statistical analysis

Bacterial scores in different quarters were compared

Table 1. Hatcheries participated the fluff test monitoring program from 1999 to 2001

Hatchery no.	Location	Production purpose	Weekly production (x10^4 chicks)	
			Broilers	Layers
1	Taoyuan	BB	20	
2	Pingtung	LB		4
3	Nantou	BB	5	
4	Hsinchu	BB	20	
5	Taoyuan	GP	NA	
6	Tainan	BB	60	
8	Taichung	GP	15	
9	Hsinchu	BB	NA	
10	Changhua	LB	1	
11	Miaoli	BB		5
13	Pingtung	BB	8	
14	Taichung	BB	22	
17	Tainan	BB	8	
18	Ilan	LB	25	
19	Tainan	LB		4
20	Tainan	BB		5
21	Nantou	BB	10	
23	Taichung	BB	40	
25	Tainan	BB	7	
26	Tainan	BB	15	
27	Taoyuan	BB	8	
28	Taichung	BB	5	
29	Hsinchu	BB	30	
31	Pingtung	BB	5	
32	Chiayi	BB	12	
33	Nantou	BB	5	
34	Tainan	BB	5	
35	Pingtung	BB	5	
36	Miaoli	GP	20	
37	Miaoli	BB	12	
42	Changhua	BB	20	
Total	31		384	18

Abbreviations: BB = broiler breeder; LB = layer breeder; GP = grandparent broiler breeder; NA = not available

with those in the first quarter of each year by analysis of variance and followed by t test at the 99% significance level [6]. Different contamination rates for different microorganisms in fluff samples collected in different quarters were compared by chi-square test or Fisher's exact test when any expected value was less than 5 at 99% significant level [7].

Results

The fluff sample BS from different hatcheries in different quarters of different years are shown in Tables 2, 3, and 4. In the first quarter (January-March) of 1999, most hatcheries had a BS of 3 to 4. Only 3 hatcheries had a BS less than 2. However, in the first quarter of 2001, 9 hatcheries had a BS less than 2. The hygienic status of many hatcheries had progressed during the 3-year fluff test monitoring program.

Salmonella was found in a few hatcheries (Tables 2, 3 and 4); 20%, 29%, and 12% of the hatcheries were contaminated with *Salmonella* in 1999, 2000, and 2001, respectively. *Salmonella* spp. was restricted to only certain hatcheries. Hatcheries no. 13 and no. 20 were the most contaminated. Contamination with *Salmonella* spp. might have originated from breeders, because *Salmonella* spp. was isolated despite thoroughly disinfecting in these 2 hatcheries [8]. Consequently, some chicks from hatchery no. 20 had salmonellosis in the offspring ranches.

The percentage of fungus contamination rates varied from 1% to 33% in different hatcheries (Tables 2, 3, and 4). The moisture in the egg storage room of hatchery no. 14 was closely related to its fungus contamination state. Fungus contamination rates were reduced after decreasing the humidity by cleaning out the floor sump. A total of 33% to 73% of the hatcheries were contaminated. The third quarter was the most contaminated for the whole year ($p<0.01$), which might have resulted from the high humidity during that period.

Discussion

Although only 31 hatcheries participated in the monitoring program, they representative nearly 90% of the hatching chicks provided by all hatcheries in Taiwan. This fluff test monitoring program is thus an important indicator of the chick quality in Taiwan.

In general, eggs contain no bacteria when they are laid and become contaminated later by the feces, litter, nest, and equipment [9]. Scott and Swetnam [10] indicated that microorganism contamination of eggs could result in increasing numbers of rotten or unhatched eggs, systemic infections, and subsequent poor chick quality. The problem lay in implementing the stringent hygiene requirements needed in hatcheries to minimize contamination and maximize chick quality. Newly hatched chicks may be infected by microorganisms adhering to fluff and down present in the hatcher [4]. Without control of bacterial growth in hatcheries, poor-quality chicks may be produced, resulting in increased mortality, decreased feed efficiency and growth rate, and poor flock uniformity. Where egg contamination has occurred during incubation, some embryos may die in the shell and some chicks may die shortly after hatching. Mortality up to 20% can occur within the first few days after hatching [2]. The importance of effective sanitation is clearly recognized by most hatchery operators in Taiwan. However, the hatcheries in Taiwan are always too small to perform fluff tests themselves and require a laboratory to do the test. Because this is the first time this kind of monitoring was performed in Taiwan, the hygienic status of most hatcheries was unsatisfactory at the beginning. However, the hatchery sanitation was much better in the later quarters. Hygiene in hatcheries has improved greatly due to the actions of the hatchery managers in requesting the staff to clean and disinfect the hatchery machinery and environment.

Good hygienic practice is the best way to reduce poultry contamination in a hatchery [9]. New buildings and equipment do not necessarily result in good hygiene. Two new hatcheries exhibited poor hygiene results due to bad practices and handling. Building and furnishing a hatchery is a huge investment of capital that will, hopefully, last a long time. Nine old buildings built and designed before good hygiene practice was introduced have great sanitary problems. A number of cracks and crevices in floor and wall surfaces harbored bacterial contamination sites. Crossover points, where clean eggs from the setter were exposed to areas contaminated by chick fluff from the hatcher and other hatcher debris, were major sources of contamination. In those old hatchers, such crossover points were common and were often difficult to remove from the hatchery layout.

Although hatchability and chick quality were improved, leading to the lowest mortality rate at growing farms, reports on chick conditions were not performed in this study. The relationship between hatchery hygienic status and chick mortality was not studied.

Following this fluff test monitoring program, considerable improvements have been made in many hatcheries in Taiwan. Environmental sanitation problems can result in huge expenses if they are left untreated or undetected [2]. Therefore, hatchery managers should follow this regular monitoring program to detect problems in their hatcheries.

Table 2. Bacterial scores, *Salmonella* and fungus contamination in fluff samples from different hatcheries in different quarters[a] of 1999

Hatchery no.	Mean BS (n)[b]				Contamination rate (%)				
					Salmonella[c]	Fungus[d]			
	1st	2nd	3rd	4th	3rd	1st	2nd	3rd	4th
1	2.4 ± 0.6 (31)	2.6 ± 0.0 (4)	2.3 ± 1.1 (39)	2.4 ± 0.5 (51)	0	0	0	0	0
2	1.6 ± 0.4 (45)	1.8 ± 1.5 (41)	1.2 ± 0.3 (38)[e]	1.1 ± 0.1 (26)[e]	0	0	0	0	0
3	3.0 ± 0.7 (69)	3.1 ± 1.0 (66)	3.1 ± 0.6 (75)	3.1 ± 0.5 (60)	0	0	0	5	8
4	3.4 ± 1.0 (100)	3.0 ± 1.5 (86)	2.9 ± 1.6 (94)[e]	2.4 ± 0.9 (90)[e]	0	1	0	3	8
5	3.1 ± 0.7 (24)	3.4 ± 1.5 (15)	3.3 ± 2.1 (15)	3.1 ± 2.4 (34)	0	0	7	7	12
6	3.7 ± 2.1 (32)	3.2 ± 2.3 (15)	2.3 ± 1.9 (21)	2.4 ± 1.6 (27)	0	0	0	0	0
8	2.1 ± 1.0 (39)	1.7 ± 1.1 (48)	1.7 ± 0.4 (44)	NA	0	0	0	0	NA
9	2.0 ± 1.3 (78)	1.9 ± 0.9 (62)	1.3 ± 0.2 (91)[e]	1.0 ± 0.0 (87)[e]	0	0	0	0	0
10	1.7 ± 1.1 (19)	2.7 ± 1.0 (94)[e]	2.4 ± 0.5 (89)[e]	2.6 ± 0.5 (89)[e]	0	0	0	20	13
11	2.8 ± 1.2 (63)	2.4 ± 1.8 (70)	2.3 ± 1.0 (70)	2.5 ± 0.7 (91)	0	0	0	0	0
13	3.2 ± 1.1 (50)	4.0 ± 0.9 (44)[e]	3.9 ± 0.3 (52)[e]	3.2 ± 0.6 (48)	12	0	0	6	2
14	4.3 ± 0.2 (191)	4.2 ± 0.4 (159)	4.1 ± 0.3 (147)	2.9 ± 0.5 (144)[e]	0	4	5	14	14
17	4.6 ± 0.2 (116)	4.5 ± 0.2 (84)	4.3 ± 0.1 (109)	4.1 ± 0.1 (76)[e]	1	2	6	25[e]	9
18	3.3 ± 0.7 (22)	3.2 ± 0.9 (24)	3.5 ± 0.9 (32)	2.9 ± 3.8 (34)	0	0	4	6	0
19	3.9 ± 2.0 (27)	4.7 ± 0.3 (20)[e]	3.1 ± 1.1 (44)	3.1 ± 1.1 (50)	0	0	0	9	2
20	3.7 ± 0.4 (147)	3.1 ± 0.4 (160)[e]	3.8 ± 0.3 (176)	3.6 ± 0.3 (129)	5	1	1	2	1
21	3.3 ± 0.5 (79)	2.9 ± 1.2 (113)	2.4 ± 0.3 (129)[e]	2.4 ± 0.3 (98)[e]	2	0	2	1	4
23	3.2 ± 0.6 (212)	2.1 ± 1.0 (185)[e]	1.9 ± 0.3 (222)[e]	1.9 ± 0.3 (200)[e]	4	0	0	2	0
25	4.7 ± 0.3 (109)	4.7 ± 0.2 (121)	4.5 ± 0.1 (108)	3.5 ± 0.6 (97)[e]	0	3	17[e]	14[e]	13[e]
26	3.2 ± 1.0 (63)	1.9 ± 0.4 (65)[e]	2.3 ± 0.6 (117)[e]	1.9 ± 0.5 (143)[e]	0	2	0	7	2
27	3.7 ± 1.5 (68)	2.3 ± 1.8 (69)[e]	1.6 ± 0.5 (89)[e]	1.3 ± 0.3 (72)[e]	0	1	0	2	0
28	3.3 ± 0.7 (168)	3.0 ± 0.4 (153)	3.4 ± 0.4 (121)	2.7 ± 0.6 (199)[e]	2	3	8[e]	33[e]	10[e]
29	3.0 ± 1.0 (79)	2.2 ± 0.9 (109)[e]	2.4 ± 0.4 (134)[e]	2.2 ± 0.6 (148)[e]	0	0	0	1	5
31	3.7 ± 1.2 (16)	4.2 ± 0.8 (24)[e]	3.1 ± 4.3 (4)	3.1 ± 0.7 (30)	0	6	17	25	20
32	3.5 ± 0.5 (42)	3.5 ± 0.4 (45)	4.1 ± 0.3 (43)[e]	2.2 ± 0.6 (43)[e]	0	0	0	2	2
33	2.7 ± 0.6 (56)	2.1 ± 0.4 (44)[e]	2.4 ± 0.8 (42)	1.9 ± 0.8 (52)[e]	0	0	0	2	0
34	5.5 ± 0.0 (6)	3.7 ± 6.1 (23)[e]	1.9 ± 0.6 (28)[e]	1.5 ± 0.6 (67)[e]	0	33	13	0	0
35	NA	NA	NA	3.4 ± 0.3 (20)	NA	NA	NA	NA	25
36	1.0 ± 0.0 (3)	2.5 ± 1.5 (15)[e]	1.5 ± 2.0 (7)	1.0 ± 0.0 (13)	0	0	0	0	0
37	4.2 ± 0.1 (30)	3.9 ± 0.5 (35)	3.2 ± 0.8 (54)[e]	2.8 ± 0.8 (60)[e]	0	0	0	2	2
42	4.3 ± 0.2 (21)	4.2 ± 1.2 (16)	4.1 ± 0.3 (14)[e]	3.2 ± 0.4 (12)[e]	0	0	13	21	8
No. of hatchery contaminated/total no. of hatchery (%)					6/30 (20)	10/30 (33)	1/30 (37)	22/30 (73)[e]	19/30 (63)

Abbreviations: BS = bacterial score; NA = sample not available

[a]1st quarter = January to March; 2nd quarter = April to June; 3rd quarter = July to September; 4th quarter = October to December.

[b]Values are expressed as log mean BS in fluff samples (n = total number of fluff samples).

[c]Percentage of samples contaminated with *Salmonella* in all fluff samples.

[e]Percentage of samples contaminated with fungus in all fluff samples.

[e]Significant difference from the first quarter within the same hatchery ($p<0.01$).

Table 3. Bacterial scores, *Salmonella* and fungus contamination in fluff samples from different hatcheries in different quarters[a] of 2000

Hatchery no.	Mean BS (n)[b]				Contamination rate (%)				
					Salmonella[c]	Fungus[d]			
	1st	2nd	3rd	4th	3rd	1st	2nd	3rd	4th
1	1.8 ± 0.2 (124)	2.0 ± 0.4 (138)	2.2 ± 0.7 (139)	1.9 ± 0.3 (92)	0	0	0	2	0
2	NA	1.1 ± 0.0 (9)	NA	1.1 ± 0.1 (36)	NA	NA	0	NA	0
3	2.4 ± 0.3 (36)	2.6 ± 0.6 (65)	3.4 ± 0.4 (39)[e]	2.9 ± 0.1 (34)[e]	0	0	0	8	3
4	2.3 ± 0.5 (110)	2.7 ± 0.2 (94)[e]	2.8 ± 0.5 (119)[e]	2.5 ± 0.2 (102)	0	1	0	3	10[e]
5	1.8 ± 1.1 (24)	3.0 ± 2.5 (18)[e]	2.4 ± 1.5 (24)	2.1 ± 1.5 (14)	0	0	0	0	0
6	1.5 ± 0.7 (19)	2.4 ± 1.3 (24)[e]	1.7 ± 0.9 (21)	2.2 ± 1.4 (18)	0	0	0	0	0
8	2.0 ± 0.3 (20)	1.8 ± 0.1 (12)	1.3 ± 0.1 (16)[e]	2.3 ± 0.6 (28)	0	5	8	0	0
9	1.1 ± 0.0 (84)	1.1 ± 0.1 (92)	1.1 ± 0.1 (99)	1.0 ± 0.0 (107)	0	0	0	0	0
10	2.6 ± 0.4 (23)	2.0 ± 0.6 (106)[e]	2.6 ± 0.5 (74)	1.9 ± 0.2 (104)[e]	0	0	6	9	3
11	1.7 ± 0.5 (77)	2.6 ± 1.1 (63)[e]	2.8 ± 0.6 (84)[e]	1.7 ± 0.5 (56)	6	0	0	0	2
13	2.7 ± 0.2 (45)	2.3 ± 1.2 (16)	3.3 ± 0.3 (64)[e]	2.8 ± 0.2 (71)	11	0	6	2	1
14	3.3 ± 0.3 (209)	2.7 ± 0.7 (190)[e]	2.7 ± 0.4(170)[e]	2.9 ± 0.4 (201)[e]	0	13	8	24[e]	6
17	3.8 ± 0.1 (63)	3.3 ± 0.6 (85)[e]	3.9 ± 0.3 (90)	3.4 ± 0.1 (82)[e]	0	0	1	4	1
18	2.9 ± 4.3 (31)	2.7 ± 4.0 (30)	3.3 ± 0.1 (38)	3.0 ± 3.9 (38)	3	0	0	5	0
19	3.3 ± 0.7 (50)	2.9 ± 1.4 (52)	3.8 ± 0.4 (36)[e]	3.5 ± 0.3 (34)	0	2	0	11	9
20	2.9 ± 0.2 (120)	2.8 ± 0.3 (159)	3.1 ± 0.3 (140)	2.8 ± 0.4 (142)	24	0	0	1	0
21	2.6 ± 0.3 (105)	2.2 ± 0.4 (138)[e]	2.7 ± 0.3 (111)	2.2 ± 0.4 (79)[e]	0	1	1	5	3
23	2.5 ± 0.5 (116)	1.7 ± 0.5 (112)[e]	2.0 ± 0.8 (101)[e]	1.4 ± 0.2 (94)[e]	2	0	2	1	0
25	3.7 ± 0.6 (76)	3.4 ± 0.2 (106)	3.6 ± 0.3 (68)	3.0 ± 0.3 (55)[e]	3	7	14	4	9
26	2.0 ± 0.4 (138)	1.9 ± 0.5 (102)	2.4 ± 0.4 (126)[e]	2.1 ± 0.5 (90)	1	1	1	0	2
27	1.5 ± 0.3 (45)	1.2 ± 0.2 (79)[e]	1.4 ± 0.4 (55)	1.2 ± 0.3 (53)[e]	0	0	0	0	0
28	3.7 ± 0.4 (252)	3.3 ± 0.3 (204)[e]	3.3 ± 0.6(129)[e]	2.4 ± 0.4 (141)[e]	2	4	3	16[e]	16[e]
29	1.7 ± 0.2 (138)	2.0 ± 0.2 (142)[e]	2.4 ± 0.4 (134)[e]	1.7 ± 0.2 (130)	0	0	0	1	2
31	2.5 ± 0.7 (25)	3.0 ± 0.6 (12)	5.0 ± 0.2 (2)[e]	3.4 ± 0.6 (12)[e]	0	16	17	0	4
32	1.9 ± 0.0 (36)	1.9 ± 0.7 (53)	2.3 ± 1.0 (45)	1.6 ± 0.6 (53)	0	0	2	9	0
33	1.5 ± 0.3 (40)	1.9 ± 0.2 (45)[e]	NA	NA	NA	0	2	NA	NA
34	1.7 ± 0.8 (11)	1.4 ± 0.2 (15)	1.4 ± 0.3 (32)	1.4 ± 0.3 (18)	0	9	0	0	0
36	1.2 ± 0.3 (13)	1.1 ± 0.1 (10)	1.8 ± 1.1 (9)	2.9 ± 0.6 (11)[e]	0	0	0	0	18
37	3.0 ± 0.2 (45)	2.2 ± 0.5 (60)[e]	3.1 ± 0.7 (12)	NA	0	0	0	0	NA
42	2.2 ± 0.3 (8)	3.3 ± 0.1 (7)[e]	3.6 ± 0.9 (26)[e]	2.0 ± 0.5 (4)	0	0	0	23	25
No. of hatchery contaminated/total no. of hatchery (%)					8/28 (29)	10/29 (34)	13/30 (43)	17/28 (61)	16/28 (57)

Abbreviations: BS = bacterial score; NA = sample not available

[a]1st quarter = January to March; 2nd quarter = April to June; 3rd quarter = July to September; 4th quarter = October to December.

[b]Values are expressed as log mean BS in fluff samples (n = total number of fluff samples).

[c]Percentage of samples contaminated with *Salmonella* in all fluff samples.

[d]Percentage of samples contaminated with fungus in all fluff samples.

[e]Significant difference from the first quarter within the same hatchery ($p<0.01$).

Table 4. Bacterial scores, *Salmonella* and fungus contamination in fluff samples from different hatcheries in different quarters[a] of 2001

Hatchery no.	Mean BC (n)[b]				Contamination rate (%)				
					Salmonella[c]	Fungus[d]			
	1st	2nd	3rd	4th	3rd	1st	2nd	3rd	4th
1	2.4 ± 0.3 (111)	2.5 ± 1.1 (128)	1.5 ± 0.3 (166)	2.7 ± 0.2 (183)[e]	0[e]	0	0	0	0
2	1.1 ± 0.0 (82)	1.8 ± 1.2 (59)[e]	1.2 ± 0.1 (72)	1.2 ± 0.1 (34)	0	0	0	1	0
3	NA	2.9 ± 1.0 (38)	2.8 ± 0.3 (42)	NA	0	NA	0	2	NA
4	2.0 ± 0.5 (103)	2.4 ± 1.0 (94)	2.3 ± 0.4 (114)[e]	2.1 ± 0.6 (117)	0	2	1	3	0
5	2.6 ± 0.5 (21)	1.7 ± 1.0 (18)[e]	1.9 ± 0.2 (9)[e]	2.7 ± 1.2 (27)	0	0	0	0	0
6	1.0 ± 0.0 (6)	1.1 ± 0.2 (6)	1.7 ± 0.8 (40)[e]	2.1 ± 1.1 (62)[e]	5	0	0	5	0
8	1.1 ± 0.0 (39)	1.3 ± 0.3 (26)	1.9 ± 0.3 (25)[e]	1.5 ± 0.7 (27)[e]	0	0	0	0	0
9	1.0 ± 0.0 (91)	1.3 ± 0.7 (85)	1.0 ± 0.0 (97)	1.0 ± 0.0 (88)	0	0	0	0	0
10	2.3 ± 0.3 (149)	2.2 ± 0.9 (101)	1.4 ± 0.1 (24)[e]	2.1 ± 0.3 (102)	0	2	14[e]	21[e]	8
13	2.8 ± 0.4 (82)	3.8 ± 0.7 (15)[e]	2.9 ± 0.5 (28)	3.1 ± 0.4 (48)	0	2	20[e]	11	0
14	3.1 ± 0.2 (174)	1.9 ± 1.0 (182)[e]	1.3 ± 0.2 (175)[e]	1.3 ± 0.2 (157)[e]	0	3	3	4	0
17	3.3 ± 0.2 (69)	4.2 ± 0.2 (74)[e]	3.4 ± 0.4 (75)	3.3 ± 0.3 (78)	0	0	4	17[e]	18[e]
18	3.1 ± 0.1 (51)	2.7 ± 0.3 (63)[e]	2.8 ± 3.1 (63)[e]	2.1 ± 1.8 (89)[e]	0	0	0	3	0
19	3.4 ± 0.1 (24)	4.0 ± 0.3 (35)[e]	3.2 ± 0.8 (36)	3.1 ± 0.9 (27)	0	0	0	0	0
20	3.2 ± 0.1 (128)	3.7 ± 0.2 (105)[e]	3.0 ± 0.3 (127)	2.5 ± 0.2 (117)[e]	11	0	1	1	0
21	1.9 ± 0.2 (83)	2.6 ± 0.4 (81)[e]	2.2 ± 0.5 (70)[e]	2.1 ± 0.3 (72)[e]	0	1	6	3	0
23	1.8 ± 1.5 (94)	1.9 ± 1.2 (63)	1.7 ± 0.4 (72)	1.4 ± 0.3 (61)[e]	0	0	0	0	0
25	3.1 ± 0.4 (65)	3.8 ± 0.5 (77)[e]	3.3 ± 0.2 (60)	2.2 ± 0.5 (56)[e]	0	6	10	20	9
26	2.2 ± 0.6 (83)	2.0 ± 0.8 (109)	2.0 ± 0.7 (146)	2.3 ± 0.5 (171)	0	2	3	8	2
27	1.1 ± 0.1 (52)	1.4 ± 0.8 (49)	1.4 ± 0.5 (36)	NA	0	0	0	0	NA
28	2.8 ± 0.3 (138)	2.6 ± 0.5 (215)	2.3 ± 0.3 (242)*	2.7 ± 0.3 (104)	1	8	14	24[e]	26[e]
29	1.9 ± 0.3 (132)	2.7 ± 0.6 (132)[e]	1.8 ± 0.2 (162)	1.3 ± 0.1 (162)[e]	0	3	0	2	2
31	2.2 ± 1.1 (8)	3.5 ± 1.2 (16)[e]	NA	NA	NA	0	6	NA	NA
32	1.7 ± 0.6 (47)	1.8 ± 0.6 (47)	1.3 ± 0.3 (49)[e]	1.4 ± 0.4 (49)[e]	0	0	2	2	2
34	NA	NA	1.2 ± 0.1 (19)	1.0 ± 0.0 (14)	0	NA	NA	0	0
36	3.1 ± 0.1 (7)	3.9 ± 0.4 (6)	3.7 ± 0.1 (4)	2.0 ± 1.0 (9)[e]	0	0	33	0	11
No. of hatchery contaminated/total no. of hatchery (%)					3/25 (12)	9/24 (38)	13/25 (52)	16/25 (64)	8/23 (35)

Abbreviations: BS = bacterial score; NA = sample not available

[a]1st quarter = January to March; 2nd quarter = April to June; 3rd quarter = July to September; 4th quarter = October to December.

[b]Values are expressed as log mean BS in fluff samples (n = total number of fluff samples).

[c]Percentage of samples contaminated with *Salmonella* in all fluff samples.

[d]Percentage of samples contaminated with fungus in all fluff samples.

[e]Significant difference from the first quarter within the same hatchery ($p<0.01$).

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