Sero-Epidemiological Survey of Egg-Transmitted Bacterial Diseases in Broiler Breeder Flocks in Korea

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The purpose of this study was to investigate the immune status or infection rates for primary egg-transmitted bacterial diseases such as pullorum disease-fowl typhoid (PD-FT), *Mycoplasma gallisepticum* (MG) infection, and *Mycoplasma synoviae* (MS) infection among 70 broiler breeder flocks throughout Korea between July 2011 and August 2011. The sero-prevalence of flocks and individual chickens for PD-FT was 50.0% and 9.7%, respectively. The prevalence of PD-FT sero-positivity increased over time from rearing to advanced age period. The sero-positive rate of flocks and individual chickens for *Salmonella* Gallinarum 9R (SG 9R) was 95.7% and 83.6%, respectively. Only two flocks in the brooding period and one flock in the laying period out of all flocks tested were sero-negative for SG 9R. When evaluating MG infection rates, 63 flocks were sero-positive. This excluded two flocks in the brooding period, one flock in the rearing period, and four flocks in the laying period. The sero-prevalence of individual chickens was as high as 66.1% and 67.8% in the rearing and laying periods, respectively. Additionally, birds that were an advanced age period had a high sero-prevalence rate of 86.6%. The rates of sero-positivity for MS infection among flocks and individual chickens were 88.6% and 64.2%, respectively. Data from the present investigation confirmed that the sero-prevalence of PD-FT, MG infection, and MS infection among broiler breeder flocks in Korea is very high. Consequently, we recommend that a national intervention strategy should be established in the near future to eradicate these diseases from broiler breeder flocks.

Key words: broiler breeder flock, egg-transmitted bacterial disease, immune status, infection rate, sero-prevalence

J. Poult. Sci., 51: 435-443, 2014

Introduction

Pullorum disease (PD) caused by *Salmonella* (*S.*) Pullorum (SP), fowl typhoid (FT) caused by *S. Gallinarum* (SG), and mycoplasma infections caused by *Mycoplasma gallisepticum* (MG) and *M. synoviae* (MS) are important egg-transmitted bacterial diseases of poultry. These diseases not only affected breeder chickens but can also be spread to their offsprings, and cause significant economic loss in the poultry

industry due to decreased egg production and high mortality (Liljebjelke *et al.*, 2005).

Countries with well-developed poultry industries such as the United States and United Kingdom implemented government policies that direct destruction or slaughter programs for disease control. These programs include the National Poultry Improvement Plan (NPIP) and Poultry Health Scheme (PHS) that were designed to eradicate PD. As a result of the eradication policies, PD in breeder flocks was eliminated in these countries (Shivaprasad and Barrow, 2008; USDA, 2009). PD has long caused significant damage in poultry farms in Korea, but spread of this disease has drastically decreased due to the implementation of test-and-slaughter policies for breeder chicken since the late 1970s (Kim, 1992). After the first case of FT in the layer flocks

Received: December 10, 2013, Accepted: April 3, 2014

Released Online Advance Publication: April 25, 2014

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was reported in 1992 (Kim *et al.*, 1995), this disease spread rapidly throughout Korea. It caused significant economic losses in Korean poultry farm, especially layer farms, and has been serious problem in the poultry industry until recently (Lee *et al.*, 2003; Kwon *et al.*, 2010).

The poultry industry in Korea has taken a great interest in monitoring mycoplasma infection since the importation of various hatching eggs and day-old chicks from abroad in 1964. Chronic respiratory disease caused by MG is difficult to control using test-and-slaughter policies in breeder flocks because this disease can be spread via horizontal transmission through fomites or direct contact as well as egg transmission (Kleven and Ferguson-Noel, 2008). Therefore, the frequency of MG infection outbreaks in Korea has become very high (Kwon *et al.*, 2010). After infectious synovitis caused by MS was first reported in Korea in 1979, extensive and persistent outbreaks of this disease (similar to MG infection) has resulted in substantial economic losses due to decreased hatchability and chick quality in breeder flocks and offspring (Namgoong *et al.*, 1979; Feberwee *et al.*, 2005; Kleven and Ferguson-Noel, 2008).

In Korea, there were less than 10 layer breeder farms. Most of these facilities have good management and biosecurity practices similar to those in countries with well-developed poultry industries. On the other hand, there were over 300 broiler breeder farms with variable-size ranges in Korea. Many of these farms have had poor management and biosecurity practices. Consequently, decreased egg production and poor egg quality due to increased infection rates of various poultry disease have been a concern.

The purpose of this study was to investigate and analyze the immune status or infection rates of primary egg-transmitted bacterial diseases in broiler breeder flocks throughout Korea that cause severe health problems among broiler breeder chicken as well as their offsprings and result

in severe economic losses.

Materials and Methods

Sample Collection

A total of 70 broiler breeder flocks on 62 farms from different regions of Korea were selected for this study and surveyed between July 2011 and August 2011. These included 21 flocks on 21 farms from Jeolla, 25 flocks on 21 farms from Chungcheong, 11 flocks on 11 farms from Gyeonggi and Gangwon, and 13 flocks on nine farms from Gyeongsang (Fig. 1). Blood samples were taken from 10~20 randomly selected chickens per flock. Three mL of blood were aseptically collected from the wing vein of each chicken. Sera were separated, heat-inactivated at 56°C for 30 min, and used for a rapid serum plate agglutination test according to the guidelines of the Animal and Plant Quarantine Agency (APQA, 2003).

Classification of Broiler Breeder Flocks by Breeding Period

Broiler breeder flocks were classified according to breeding period based on maternal antibody levels, growth stage of the chickens, *etc* (Table 1). The vaccination program (Table 2) generally used in broiler breeder flocks in Korea was also considered. As a result, the 70 broiler breeder flocks were categorized as being in the brooding period (two flocks), rearing period (a total of 13 flocks including three “early” flocks and 10 “late” flocks), and laying period (a total of 43 flocks including 21 “early” flocks and 22 “late” flocks). Additionally, 12 flocks were in the advanced age period. Each flock was assigned a number from 1 to 70 based on sampling date.

Rapid Serum Plate Agglutination Test

A rapid serum plate agglutination test specific for MG and MS infection was performed according to the guidelines of APQA (2003). A positive result was defined as the appearance of a granulated agglutinate within 2 min. Anti-

Fig. 1. Geographical location of 62 broiler breeder farms surveyed.

Table 1. **Classification of 70 broiler breeder flocks according to breeding period**

	Brooding period	Rearing period			Laying period			Advanced age period	Total
		Early	Late	Subtotal	Early	Late	Subtotal		
Age (wk)	0~4	5~14	15~23	5~23	24~45	46~64	24~64	65≤	—
No. of flocks	2	3	10	13	21	22	43	12	70

Table 2. **General vaccination program for broiler breeder flocks in Korea**

Age	Vaccine	Route
1 day	Marek's disease (live)	Subcutaneous injection
	Newcastle disease (live)	Spray
	Infectious bronchitis (live)	Spray
5 days	Coccidiosis (live)	Drinking water or spray in feed
2 weeks	Infectious bursa disease (live)	Drinking water
3 weeks	Newcastle disease (killed)	Intramuscular injection
	Infectious bronchitis (killed)	Intramuscular injection
	Infectious bursa disease (killed)	Intramuscular injection
4 weeks	Newcastle disease (live)	Spray
	Infectious bronchitis (live)	Spray
5 weeks	Infectious laryngotracheitis (live)	Intraocular
	<i>Mycoplasma gallisepticum</i> (live)	Intraocular
7 weeks	Avian encephalomyelitis (live)	Wing web
	Fowl pox (live)	Wing web
9 weeks	Fowl typhoid (live)	Intramuscular injection
10 weeks	Newcastle disease (killed)	Intramuscular injection
	Infectious bronchitis (killed)	Intramuscular injection
	Egg drop syndrome (killed)	Intramuscular injection
12 weeks	Infectious laryngotracheitis (live)	Intraocular
	<i>Mycoplasma gallisepticum</i> (live)	Intraocular
13 weeks	Newcastle disease (live)	Spray
	Infectious bronchitis (live)	Spray
14 weeks	Avian encephalomyelitis (live)	Drinking water
16 weeks	Newcastle disease (killed)	Intramuscular injection
	Infectious bronchitis (killed)	Intramuscular injection
	Infectious bursa disease (killed)	Intramuscular injection
	Reovirus (killed)	Intramuscular injection
18 weeks	Fowl typhoid (live)	Intramuscular injection

bodies against PD-FT and *S. Gallinarum* 9R (SG 9R) were detected with antigens supplied by Green Cross Veterinary Products (Yongin, Korea) and APQA, respectively, as authorized methods in Korea (APQA, 2003). The appearance of any visible agglutinate within 1 min was considered positive.

Results

Distribution of Sero-positive Rates for PD-FT

Sero-prevalence for PD-FT among broiler breeder flocks according to breeding period is presented in Table 3. No sero-positive flocks were identified in the brooding and early rearing periods. Sero-positive flocks were first observed in the late rearing period. The overall prevalence of sero-positivity for PD-FT among the flocks and individual

chickens in the late rearing period was 30.0% and 4.1%, respectively. The overall prevalence of PD-FT sero-positivity in the laying period was 62.8% (early: 57.1% and late: 68.2%) for the flocks and 11.6% (early: 9.6% and late: 13.7%) for individual chickens. The overall sero-prevalence rates for PD-FT of the flocks and individual chickens in the advanced age period were 41.7% and 11.9%, respectively.

The sero-prevalence for PD-FT of each flock is shown in Table 4–7. All the individual chickens in three flocks tested in the early rearing period were sero-negative for PD-FT. In the late rearing period, seven out of 10 flocks were sero-negative, and the sero-positive rates of the remaining flocks were 6.7–21.4%. Among 12 sero-positive flocks identified in the early laying period, 11 had sero-positive rates of below 21.4% while one (No. 56) had a high rate of 80%. In the late

Table 3. Distribution of sero-positive rates for PD-FT, SG 9R, MG, and MS among 70 broiler breeder flocks according to breeding period

Breeding period		PD-FT		SG 9R		MG		MS	
		Flock (%) ^a	Individual (%)	Flock (%)	Individual (%)	Flock (%)	Individual (%)	Flock (%)	Individual (%)
Brooding period		0/2 (0)	0/30 (0)	0/2 (0)	0/20 (0)	0/2 (0)	0/24 (0)	0/2 (0)	0/24 (0)
Rearing period	Early	0/3 (0)	0/45 (0)	3/3 (100)	25/44 (56.8)	3/3 (100)	19/44 (43.2)	2/3 (66.7)	15/43 (34.9)
	Late	3/10 (30.0)	6/145 (4.1)	10/10 (100)	125/145 (86.2)	9/10 (90.0)	106/145 (73.1)	10/10 (100)	96/144 (66.7)
Subtotal		3/13 (23.1)	6/190 (3.2)	13/13 (100)	150/189 (79.4)	12/13 (92.3)	125/189 (66.1)	12/13 (92.3)	111/187 (59.4)
Laying Period	Early	12/21 (57.1)	29/303 (9.6)	20/21 (95.2)	252/292 (86.3)	18/21 (85.7)	165/290 (56.9)	18/21 (85.7)	155/289 (53.6)
	Late	15/22 (68.2)	42/307 (13.7)	22/22 (100)	256/304 (84.2)	21/22 (95.5)	239/306 (78.1)	21/22 (95.5)	240/304 (78.9)
Subtotal		27/43 (62.8)	71/610 (11.6)	42/43 (97.7)	508/596 (85.2)	39/43 (90.7)	404/596 (67.8)	39/43 (90.7)	395/593 (66.6)
Advanced age period		5/12 (41.7)	21/176 (11.9)	12/12 (100)	161/175 (92.0)	12/12 (100)	149/172 (86.6)	11/12 (91.7)	118/168 (70.2)
Total		35/70 (50.0)	98/1006 (9.7)	67/70 (95.7)	819/980 (83.6)	63/70 (90.0)	678/981 (69.1)	62/70 (88.6)	624/972 (64.2)

^a No. of positive/no. of tested

laying period, seven out of 22 flocks were sero-negative and 11 had sero-positive rates less than 20%. Additionally, four flocks had a high sero-prevalence that fell between 33.3 and 60.0%. Among five sero-positive flocks found in the advanced age period, four had a high sero-positive rate (21.4~60.0%) and the remaining flock had a low rate of sero-positivity of 6.7%.

Distribution of Sero-positive Rates for SG 9R

Sero-prevalence of the SG 9R in broiler breeder flocks according to breeding period is presented in Table 3. In the brooding period, all of the individual chickens in two flocks surveyed were sero-negative for the SG 9R while all flocks were sero-positive in the rearing period. The overall sero-positive rate of the individual chickens in the rearing period was as high as 79.4% (early: 56.8% and late: 86.2%). In the laying period, 42 (97.7%) out of 43 flocks were sero-positive for the SG 9R, and the overall sero-prevalence of the individual chickens was as high as 85.2% (early: 86.3% and late: 84.2%). In the advanced age period, all 12 flocks tested were sero-positive for the SG 9R, and overall sero-prevalence for the individual chickens was highest (92%) relative to all other breeding periods.

Sero-prevalence for SG 9R among each flock is shown in Table 4-7. The sero-prevalence for each flock in the early rearing period varied widely between all three flocks tested. In the late rearing period, three out of 10 flocks had moderate sero-positive rates of 60% while the remaining flocks had high sero-positive rates of 93.3%~100%. In the early laying

period, all individual chickens in one (No. 60) out of 21 flocks were sero-negative for the SG 9R. Sero-prevalence for the remaining flocks was as high as 71.4~100%. Among 22 flocks surveyed in the late laying period, one flock (No. 62) had a low sero-prevalence rate of 13.3%, and three flocks had moderate sero-positive rates of 46.7~61.5%. The remaining flocks had high sero-positive rates of 80.0~100%. The sero-positive rates for the SG 9R among 12 flocks in the advanced age period were evenly distributed from 78.6 to 100%.

Distribution of Sero-positive Rates for MG Infection

The sero-prevalence for MG infection among broiler breeder flocks according to breeding period is presented in Table 3. No sero-positive flocks were found in the brooding period. Three flocks were sero-positive for MG infection in the early rearing period, and the overall sero-positive rate for the individual chickens was 43.2%. In the late rearing period, nine (90%) out of 10 flocks surveyed were sero-positive for MG infection, and the overall prevalence of sero-positivity for individual chickens was as high as 73.1%. In the laying period, 39 (90.7%) out of 43 flocks were sero-positive for MG infection (three early flocks and one late flock were not), and the overall sero-prevalence for the individual chickens was 67.8% (early: 56.9% and late: 78.1%). In the advanced age period, all 12 flocks were sero-positive for MG infection and the overall sero-prevalence for the individual chickens was as high as 86.6%.

The sero-prevalence for MG infection among each flock is

Table 4. Distribution of sero-positive rates for PD-FT, SG 9R, MG, and MS among two flocks in the brooding period

Flock No.	No. of chickens tested				No. of positive chickens (%)			
	FD-FT	SG 9R	MG	MS	PD-FT	SG 9R	MG	MS
61	15	10	12	12	0	0	0	0
63	15	10	12	12	0	0	0	0
Total	30	20	24	24	0	0	0	0

Table 5. Distribution of sero-positive rates for PD-FT, SG 9R, MG, and MS among 13 flocks in the rearing period

Flock No.		No. of chickens tested				No. of positive chickens (%)			
		FD-FT	SG 9R	MG	MS	PD-FT	SG 9R	MG	MS
Early stage	12	15	15	15	14	0	15 (100)	2 (13.3)	12 (85.7)
	41	15	15	15	15	0	6 (40.0)	3 (20.0)	0
	49	15	14	14	14	0	4 (28.6)	14 (100)	3 (21.4)
Subtotal		45	44	44	43	0	25 (56.8)	19 (43.2)	15 (34.9)
Late stage	6	15	15	15	15	0	14 (93.3)	15 (100)	14 (93.3)
	37	12	12	12	12	2 (16.7)	12 (100)	9 (75.0)	9 (75.0)
	40	14	14	14	14	0	14 (100)	14 (100)	10 (71.4)
	45	15	15	15	15	0	9 (60.0)	15 (100)	15 (100)
	52	14	14	14	14	3 (21.4)	14 (100)	7 (50.0)	5 (35.7)
	53	15	15	15	15	1 (6.7)	14 (93.3)	11 (73.3)	9 (60.0)
	59	15	15	15	15	0	9 (60.0)	0	4 (26.7)
	64	15	15	15	15	0	15 (100)	15 (100)	15 (100)
	65	15	15	15	15	0	15 (100)	15 (100)	13 (86.7)
	70	15	15	15	14	0	9 (60.0)	5 (33.3)	2 (14.3)
Subtotal		145	145	145	144	6 (4.1)	125 (86.2)	106 (73.1)	96 (66.7)
Total		190	189	189	187	6 (3.2)	150 (79.4)	125 (66.1)	111 (59.4)

shown in Table 4–7. The sero-prevalence for three flocks tested in the early rearing period was 13.3%, 20.0%, and 100%, respectively. In the late rearing period, all the individual chickens in five out of 10 flocks were sero-positive for MG infection and sero-positivity rates for two flocks was as high as 73.3% and 75.0%. Additionally, two flocks had moderate sero-positive rates of 33.3% and 50.0%, respectively, and one flock (No. 59) was sero-negative for MG infection. Among 21 flocks surveyed in the early laying period, three flocks (No. 3, 60, and 69) were sero-negative for MG infection. The sero-prevalence for eight flocks was as high as 80.0–100%, and that for the remaining flocks had a wide range of 13.3–69.2%. In the late laying period, 16 out of 22 flocks had high sero-positive rates of 86.7–100%. In contrast, five of these flocks had low or moderate sero-positive rates of 18.2–33.3%, and the remaining flock (No. 66) was sero-negative. Sero-positive rate for two out of 12 flocks in the advanced age period was about 50%, and those of the remaining flocks were as high as 73.3–100%.

Distribution of Sero-positive Rates for MS Infection

The sero-prevalence for MS infection in broiler breeder flocks according to breeding period is presented in Table 3.

All the individual chickens in two flocks were sero-negative for MS infection in the brooding period. In the rearing period, 12 (92.3%) out of 13 flocks were sero-positive for MS infection, and the overall prevalence of sero-positivity for the individual chickens was 59.4%. The sero-prevalence (66.7%) for individual chickens in the late rearing period was significantly higher than that (34.9%) observed in the early rearing period. In the laying period, 39 (90.7%) out of 43 flocks were sero-positive for MS infection (three early flocks and one late flock were not). The overall sero-prevalence for individual chickens was 66.6%, which was higher than that observed in the rearing period. In addition, the sero-prevalence for individual chickens rapidly increased from 53.6% in the early laying period to 78.9% in the late rearing period. In the advanced age period, the individual chickens in one flock were sero-negative for MS infection. The overall sero-positivity rate for individual chickens was 70.2%.

The sero-prevalence for MS infection of each flock is shown in Table 4–7. One (No. 41) out of three flocks was sero-negative for MS infection in the early rearing period, and the sero-prevalence for the other two flocks was 21.4%

Table 6. Distribution of sero-positive rates for PD-FT, SG 9R, MG, and MS among 43 flocks in the laying period

Flock No.	No. of chickens tested				No. of positive chickens (%)				
	FD-FT	SG 9R	MG	MS	PD-FT	SG 9R	MG	MS	
Early stage	2	10	7	8	9	0	6 (85.7)	4 (50.0)	7 (77.8)
	3	14	14	14	14	2 (14.3)	14 (100)	0	7 (50.0)
	4	15	12	13	13	0	11 (91.7)	5 (38.5)	3 (23.1)
	8	15	15	15	15	1 (6.7)	14 (93.3)	15 (100)	15 (100)
	9	15	15	15	13	0	14 (93.3)	14 (93.3)	0
	16	13	13	13	12	0	13 (100)	6 (46.2)	10 (83.3)
	19	15	15	15	14	1 (6.7)	13 (86.7)	2 (13.3)	0
	20	15	15	15	15	1 (6.7)	12 (80.0)	8 (53.3)	0
	26	12	12	12	12	1 (8.3)	11 (91.7)	7 (58.3)	5 (41.7)
	31	15	15	15	15	0	12 (80.0)	2 (13.3)	15 (100)
	32	15	15	15	15	2 (13.3)	15 (100)	12 (80.0)	11 (73.3)
	36	14	14	14	14	3 (21.4)	10 (71.4)	14 (100)	13 (92.9)
	39	15	15	15	15	0	13 (86.7)	15 (100)	15 (100)
	43	15	15	15	15	1 (6.7)	14 (93.3)	14 (93.3)	15 (100)
	51	15	14	13	13	1 (6.7)	14 (100)	7 (53.8)	8 (61.5)
	54	15	13	13	13	0	12 (92.3)	9 (69.2)	8 (61.5)
	56	15	15	15	15	12 (80.0)	15 (100)	15 (100)	15 (100)
	57	15	15	15	15	3 (20.0)	13 (86.7)	13 (86.7)	3 (20.0)
	58	15	13	13	15	0	11 (84.6)	3 (23.1)	3 (20.0)
	60	15	15	12	12	0	0	0	1 (8.3)
	69	15	15	15	15	1 (6.7)	15 (100)	0	1 (6.7)
Subtotal	303	292	290	289	29 (9.6)	252 (86.3)	165 (56.9)	155 (53.6)	
Late stage	1	14	9	11	14	1 (7.1)	8 (88.9)	2 (18.2)	7 (50.0)
	10	15	15	15	15	2 (13.3)	15 (100)	13 (86.7)	12 (80.0)
	13	15	15	15	15	1 (6.7)	15 (100)	15 (100)	4 (26.7)
	15	13	13	13	13	1 (7.7)	8 (61.5)	4 (30.8)	10 (76.9)
	21	15	15	15	15	2 (13.3)	15 (100)	15 (100)	15 (100)
	22	14	15	15	15	6 (42.9)	15 (100)	15 (100)	15 (100)
	23	13	15	15	14	5 (38.5)	15 (100)	15 (100)	14 (100)
	25	12	12	12	12	0	11 (91.7)	12 (100)	10 (83.3)
	27	12	12	11	11	0	11 (91.7)	11 (100)	11 (100)
	29	10	10	15	10	0	8 (80.0)	15 (100)	10 (100)
	30	12	12	12	12	0	10 (83.3)	12 (100)	12 (100)
	33	15	15	15	15	5 (33.3)	8 (53.3)	14 (93.3)	13 (86.7)
	35	12	12	12	12	1 (8.3)	10 (83.3)	12 (100)	5 (41.7)
	42	15	14	14	14	1 (6.7)	14 (100)	14 (100)	14 (100)
	44	15	15	15	15	0	15 (100)	15 (100)	15 (100)
	47	15	15	14	15	2 (13.3)	13 (86.7)	14 (100)	12 (80.0)
	48	15	15	15	15	0	7 (46.7)	3 (20.0)	15 (100)
	50	15	15	15	15	2 (13.3)	12 (80.0)	15 (100)	15 (100)
	62	15	15	12	12	3 (20.0)	2 (13.3)	4 (33.3)	3 (25.0)
	66	15	15	15	15	0	15 (100)	0	15 (100)
	67	15	15	15	15	1 (6.7)	14 (93.3)	4 (26.7)	13 (86.7)
68	15	15	15	15	9 (60.0)	15 (100)	15 (100)	0	
Subtotal	307	304	306	304	42 (13.7)	256 (84.2)	239 (78.1)	240 (78.9)	
Total	610	596	596	593	71 (11.6)	508 (85.2)	404 (67.8)	395 (66.6)	

and 85.7%. In the late rearing period, sero-positive rates for three out of 10 flocks were 14.3~35.7%, and those for seven flocks were as high as 60.0~100%. Among 21 flocks surveyed in the early laying period, sero-positive rates for five flocks were as low as below 10%, those for five flocks were

20.0~50.0%, and the rates for 11 flocks was 61.5~100%. In the late laying period, 17 out of 22 flocks had high sero-positive rates of 76.9~100%, and four of 22 flocks had moderate sero-positive rates of 25.0~50.0%. All of the individual chickens in the remaining flock (No. 68) were

Table 7. Distribution of sero-positive rates for PD-FT, SG 9R, MG, and MS among 12 flocks in the advanced age period

Flock No.	No. of chickens tested				No. of positive chickens (%)			
	FD-FT	SG 9R	MG	MS	PD-FT	SG 9R	MG	MS
5	15	14	15	15	0	13 (92.9)	15 (100)	12 (80.0)
7	20	20	16	16	0	16 (80.0)	14 (87.5)	14 (87.5)
11	15	15	15	15	9 (60.0)	15 (100)	15 (100)	13 (86.7)
14	15	15	15	15	0	15 (100)	15 (100)	3 (20.0)
17	15	15	15	15	4 (26.7)	15 (100)	12 (80.0)	14 (93.3)
18	15	15	15	14	0	15 (100)	11 (73.3)	12 (85.7)
24	12	12	12	12	0	11 (91.7)	6 (50.0)	12 (100)
28	12	12	12	12	0	10 (83.3)	12 (100)	12 (100)
34	13	13	13	13	4 (30.8)	11 (84.6)	13 (100)	4 (30.8)
38	14	14	14	14	3 (21.4)	11 (78.6)	14 (100)	0
46	15	15	15	15	0	15 (100)	15 (100)	10 (66.7)
55	15	15	15	12	1 (6.7)	14 (93.3)	7 (46.7)	12 (100)
Total	176	175	172	168	21 (11.9)	161 (92.0)	149 (86.6)	118 (70.2)

sero-negative for MS infection. On the other hand, the sero-positive rates for nine out of 12 flocks in the advanced age period were as high as 66.7~100%, and those for two flocks were as moderate as 20.0~30.8%. All of the individual chickens in the remaining flock (No. 38) were sero-negative for MS infection.

Discussion

PD is a classical poultry disease. Both infected parent stocks and offspring infected by transovarian transmission suffer severe symptoms at the apparent onset of this disease. However, it is known that most of the chickens continue to lay eggs as healthy carrier animals when farms maintain good hygiene practices and the chickens have a low infection rate (Shivaprasad and Barrow, 2008).

The present study showed that the sero-positive rate of PD-FT in Korea was 50.0% for broiler breeder flocks and 9.7% for individual chickens. These values were slightly lower than those from a study by Kim *et al.* (1980) who reported 65.9% for flocks and 17.2% for individual chickens, and those for grandparent flocks for 2 years (65.5% for flocks and 16.9% for individual chickens) reported by Song *et al.* (2009). In particular, the PD-FT sero-positive flocks appeared in the late rearing period in the present study. This was slightly different from the results of a study by Kim *et al.* (2006) who was unable to identify PD-FT infection in breeder flocks over 40 wk old. On the other hand, our study showed a high sero-positive rate of 20~60% for flocks by breeding period against PD-FT, and that of more than 30% for individual chickens in particular flocks in the laying period. In addition, more than 60% of individual chickens in some flocks were sero-positive for PD-FT, and there is a high possibility that the chicken farmers in Korea may sustain serious damage caused by this disease. Therefore, it is thought that flocks and individual chickens found to be sero-positive by serological tests must be methodically destroyed. In particular, the present study showed that the sero-positive

rate for PD-FT of flocks and individual chickens tended to increase in proportion to age. This is a result of increased exposure to PD-FT relative to increasing age and time spent in the breeding environment. On the other hand, revised guidelines for the control and prevention of PD-FT recently adopted by the Ministry of Agriculture, Food and Rural Affairs (MAFRA; Korea) only recommends testing performed by a national testing institute. Korea is far from joining the ranks of developed poultry-raising countries as long as PD exists in the poultry industry. Under this circumstance, it is also impossible to export commercial chicks abroad. Therefore, it is necessary to revise the current guidelines for the control and prevention of PD-FT.

FT has caused catastrophic damage to poultry farms in Korea, particularly layer farms, since the first case in the field was reported in 1992 (Kim *et al.*, 1995). In order to prevent this disease, a live vaccine made from the SG 9R strain was produced and is still in use. *S. Gallinarum*, the causative pathogen of this disease, has the same antigenic structure as *S. Pullorum*, the pathogen that causes PD (Shivaprasad and Barrow, 2008). Thus, it is difficult to determine whether antibodies found in breeders vaccinated against FT are ones produced in response to a vaccine or infection with PD-FT (Kang *et al.*, 2010). For this reason, the SG 9R vaccine has not been administered to breeders in any country where FT occurs. In Korea, this vaccination has been allowed for layers but not breeders. However, the present investigation showed that most of the broiler breeder flocks were vaccinated against this disease except for two in the brooding period and one flock in the early laying period. This is evidence for a violation of provisions established by the disease control authorities. Moreover, the vaccine antibody was found in a broiler breeder flock (No. 62) that was never vaccinated against this disease according to the farmer. There is a possibility of horizontal transfer of SG 9R vaccine strain between farms with the field occurrence of FT due to restoration of some pathogenicity of the SG 9R vaccine strain

(Silva *et al.*, 1981). In particular, the high sero-positive rate for SG 9R of flocks in the advanced age period was evenly distributed from 78.6 to 100%. From an immunological perspective, the sero-positive rate for individual chickens in each flock should be lower than any other breeding periods in the absence of booster vaccination. It was thought that booster vaccination was performed to prevent field infection with this disease in the advanced age period. It has been also reported that the SG 9R vaccine strain was recently isolated from egg-laying hens affected by factors impairing immune function such as marek's disease (Silva *et al.*, 1981; Kwon and Cho, 2011). These findings underscore the urgent necessity for disease control authorities to discuss measures for prohibiting the vaccination of breeder flocks in Korea, and to monitor the possible restored pathogenicity of all vaccine strains including SG 9R as well as the safety of these vaccines for chickens.

Chronic respiratory disease caused by MG infection is a transovarian disease that occurs worldwide and has spread year by year in Korea since it was first reported in field-infected chickens in 1967 (Kim, 1992). Serious damage is caused not only by this disease but also by secondary respiratory complications such as colibacillosis, infectious bronchitis, and newcastle disease (Kleven *et al.*, 1972; Ley, 2008). The present study showed that the sero-positive rates for MG infection were 90.0% for flocks and 69.1% for individual chickens. This was similar to the results reported by Seong *et al.* (1993) for 30-wk-old broiler breeder flocks (92.0%) in the early 1990s, and for broiler breeder flocks (88.7%) reported by Kwon *et al.* (2010). In the present investigation, sero-positive flocks were first found in the rearing period, and only seven out of 70 flocks were sero-negative. The antibody-positive rate for individual chickens increased from 66.1% to 86.6% in proportion to age in days, and recurrent infection was continuously observed. Similar to our study, Seong *et al.* (1993) reported that the sero-positive rate of MG infection began to be measurable in 7-wk-old flocks and tended to rise over time.

Government-funded vaccines against this disease have been provided to breeder farms in Korea for a long time. It is impossible to simply believe that the sero-positive rates found in the present study are due to field infection (Namgoong *et al.*, 1992; Yoon *et al.*, 2006). Therefore, it is not possible to propose countermeasures against this disease without performing serological testing after determining whether MG vaccination has been performed. Above all, it is absolutely impossible to eradicate transovarian diseases including MG by vaccination alone. It seems logical to expect that this disease can be controlled by vaccination only if sequential cleaning is first performed by culling infected chickens of pure-breeding lines along with grandparent stocks and parent stocks for each chicken breed. Ultimately, it is desirable to implement policies to eliminate infected chickens in breeder flocks after testing.

Although infectious synovitis caused by MS in poultry mainly results in symptoms such as inflammation of the leg joint, sole of the foot, and sternal bursa, this condition can

account for more than 30% of mortality among pullets (Kleven *et al.*, 1972). The present study showed that the sero-positive rate for MS was 88.6% for flocks and 64.2% for individual chickens. This rate was higher than that for breeder flocks (77%) reported by Kwon *et al.* (2010) and individual chickens (36%) on layer and broiler farms without vaccination on a national scale reported by Jang *et al.* (2010). The vaccine against MS infection has been used abroad (Kleven *et al.*, 2008) but has never been allowed in Korea (Jang *et al.*, 2010). Therefore, the sero-positive rates observed in our study can be due to field infection of broiler breeder flocks raised in Korea, indicating that birds on most broiler breeder farms in this country have been infected with MS. Thus, it is estimated that the occurrence of MS infection will be more severe without vaccination. It is therefore necessary to carefully consider the use of vaccines against MS infection. On the other hand, the overall infection rate of this disease rapidly rose with increased age, and the sero-positive rates in the late laying period and advanced age period were more than 70%. These results are similar to those from a previous study (Kwon *et al.*, 2010). Similar to infection with MG, MS infection requires cleaning for breeders and commercial chickens. Therefore, this would necessitate the implementation of national disease control policies.

Our study provided baseline data to help prevent decreased productivity of broiler breeder and broiler farms by reducing the incidence of several important diseases as well as establishing a basis for stable development of the broiler industry in Korea. In order to join the ranks of countries with developed poultry industries, there is an urgent need to eliminate not only PD-FT, which can be described as the most representative transovarian infectious disease, but also MG and MS infection. Judging from the high infection rates observed in the present investigation, farmers who are engaged in the poultry industry need to comply with regulations and guidelines in order to eradicate these diseases. Furthermore, effective government-led disease prevention measures should be implemented as soon as possible.

Acknowledgments

This study was carried out with the support of "Technology Development Program for Bio-industry (Project No. 311007-5)", Ministry of Agriculture, Food and Rural Affairs, Republic of Korea.

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