

# A comparison of post-mortem findings in broilers dead-on-farm and broilers dead-on-arrival at the abattoir

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**ABSTRACT** Broiler mortality during transport to abattoirs (dead-on-arrival/DOA) evokes concern due to compromised animal welfare and associated economic losses. The general aim of this study was to characterize pathological lesions associated with mortality in broilers close to slaughter. The specific aim was to investigate whether disease at the end of the growth period may be a predisposing factor for DOA by describing and comparing the pathological findings in broilers dead-on-farm (DOF) in the final days of the production cycle and in broilers DOA from the same flocks. Gross post-mortem examinations were performed on 607 broilers from 32 flocks, either DOF (371) or DOA (236). In DOF broilers, the most common pathological lesions were lung congestion (37.7%), endocarditis (29.4%), and

ascites (24.0%), whereas the most common findings in broilers DOA were lung congestion (57.2%) and trauma (24.6%). Lung congestion was more prevalent among DOA broilers compared to DOF broilers ( $P$ -value of  $> 0.001$ ). A possible cause behind the pathological finding lung congestion is sudden death syndrome (SDS). The study indicates that steps in the transportation process *per se* cause the majority of pathological lesions such as lung congestion and trauma that may have led to the mortalities registered. Pre-existing diseases such as ascites and osteomyelitis may also predispose for DOA. Thus, factors relating to on-farm health, catching, and transportation are all areas of future investigation in order to reduce transport mortalities and to enhance welfare in broilers.

**Key words:** broiler, dead-on-arrival, mortality, post-mortem examination, welfare

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## INTRODUCTION

Broiler meat production is one of the largest animal productions worldwide. Commercial broiler production has increased over the last 15 years: in the year 2000, the broiler industry was estimated to comprise 20 billion birds (breeders not included) (SCAHAW, 2000) and in 2012 the number of broilers slaughtered worldwide had increased to 59.8 billion (The Poultry Site, 2015). The size of the production makes transportation of broilers to abattoirs the largest commercial translocation of any single class of livestock in the world. There is an increasing concern for the welfare of food-producing animals (De Jong et al., 2012) and welfare legislations are rapidly evolving. Transport mortality specifically has been emphasized as a welfare problem in broilers (EFSA, 2004). Consequently, broilers dying during transport to the abattoirs, so called dead-on-arrival (DOA), are mandatorily recorded in member states of

the European Union (European Union Council Directive 2007/43/EC, 2007).

Reported DOA numbers vary substantially between studies; 0.12% (Haslam et al., 2008), 0.18% (Chauvin et al., 2011), 0.25% (Vecerek et al., 2006; Lund et al., 2013), 0.35% (Petracci et al., 2006), and 0.46% (Nijdam et al., 2004). The total DOA number in Norway in 2014 was 0.11% (Animalia, 2014).

To improve welfare of broilers worldwide, it is necessary to investigate possible risk factors of DOA, thereby identifying areas of potential intervention and improvement. The welfare of broilers in relation to handling and transportation has been reviewed in previous papers (Knowles and Broom, 1990; Nicol and Scott, 1990) and in general, mortality during transport has been found to relate to several factors from farm to abattoir (Chauvin et al., 2011). Reported stressors and risk factors in connection with catching and transport of broilers are water and feed withdrawal, handling, social disruption, noises, acceleration, vibrations, temperature changes, and exposure to crowded and novel environments (Bayliss and Hinton, 1990; Warriss et al., 1999; Nijdam et al., 2004; Whiting et al., 2007; Terlouw et al., 2008; Mitchell and Kettlewell, 2009).

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**Table 1.** Characteristics of the 32 flocks.<sup>1</sup>

Parameter	Mean	Std. dev.	Minimum	Maximum
Flock size	18,374	3,173.55	11,250	25,500
Slaughter age (in days)	31.2	1.09	30	34
Slaughter weight (in g) <sup>2</sup>	1,222	92.01	1,034	1,516
Daily weight gain (in g)	39.2	1.96	34.5	44.6
Mortality rate during the first rearing week (%)	1.03	0.58	0.33	3.02
Total on-farm mortality rate (%)	2.96	0.94	1.17	4.96
Total transport mortality rate (%)	0.09	0.06	0.01	0.30
Foot-pad lesion score	11.19	14.72	1	63

<sup>1</sup>Data from “the Norwegian Broiler Control”-program, a system owned by the abattoirs used as a production tool to record economics, welfare and mortality.

<sup>2</sup>Carcass weight after removal of head, feet, internal organs and feathers.

The most frequent pathological lesions reported in broilers DOA are infectious diseases, cardiovascular disorders and traumas (Nijdam et al., 2006; Lund et al., 2013). Furthermore, high cumulative mortality on-farm has previously been associated with DOA (Whiting et al., 2007; Chauvin et al., 2011). These findings may indicate a relationship between diseases on-farm in the last stage of the production period and DOA. Norway reports the total mortality on-farm to be 2.8% (Animalia, 2014) during the production period which lasts for about 30 to 32 days. Comparable dead-on-farm (DOF) numbers from the Netherlands were 4.1% (Velkers et al., 2011) and mortality numbers on-farm from the Welfare Quality<sup>®</sup> assessment protocol in Dutch, Belgian, British, and Italian flocks were 2.9% (De Jong et al., 2012). A major proportion of mortality in fast growing broilers on-farm are caused by cardiovascular disorders, with sudden death syndrome (SDS) and ascites being the most common underlying causes (Julian, 2005; Olkowski, 2007). Stress has been found to be a likely trigger for SDS in broilers, even several days after the stress episode (Olkowski et al., 2008) and rapidly growing broiler hybrids are especially vulnerable to stress-induced myopathies (Mitchell, 1999). Drain et al. (2007) reported no association between the prevalence of broilers DOF on the last day before slaughter and broilers DOA. However, little is known about the role of diseases present during the final days of the growth period as a predisposing factor for transport mortality in broilers, and, to the author’s knowledge, studies that have compared post-mortem findings in DOF and DOA broilers of the same age are not available. Therefore, the aim of this study was to describe and compare the pathological findings in dead broilers in the final days of the production cycle on-farm and in broilers dead during transport from the same flocks.

## MATERIALS AND METHODS

### Study Population and Design

A case-to-case study was designed to sample a study base comprising 32 commercial broiler flocks over a 12 months period from February 2012 to February 2013, representing 5.2% of all Norwegian broiler producers.

All broilers were of the hybrid Ross 308, mixed gender, fed ad libitum, and with a mean slaughter age of 31.2 days (Table 1). The flocks were slaughtered at 4 different abattoirs representing different geographic and climatic regions in Norway. Eight broiler flocks were submitted from each of the 4 slaughterhouses.

A 2-stage cluster sample of flocks was chosen, based on estimated slaughter dates, representing all months of the year and regions. There were approximately 6 weeks between each sampling from each region, and the timeslot between the regions and farms were adjusted for in the sampling design to account for seasonal influences.

From each flock, a maximum of 15 DOF broilers from the final 3 days of the production period and ten DOA broilers were randomly selected at the abattoirs. The farmers were asked to rule out culled broilers and only send broilers having died without intervention. The broilers were submitted to gross post-mortem examination at the Department of Pathology, Norwegian Veterinary Institute. Those farms that did not cumulate 15 DOF broilers were enrolled with a fewer number of DOF broilers (range 5 to 15). The total sample for necropsy was 629 broilers, i.e., 390 were DOF and 239 were DOA, of which 22 birds (19 DOF, 3 DOA) were excluded due to autolytic decomposition, leaving 607 broilers in the study sample; 371 (61.1%) DOF and 236 (38.9%) DOA. The distribution of broilers received from the 4 different regions was 148, 153, 151, and 155 individuals respectively.

### Post-Mortem Examination

Necropsy examinations were conducted at the Dept. of Pathology, Norwegian Veterinary Institute by 5 trained pathologists. Virology, bacteriology, and histology were not performed. A total of 607 broilers were subjected to gross post-mortem examination. The examination of individual broilers followed a standard protocol developed by the Norwegian Veterinary Institute. Broilers were allocated to pathological categories according to findings. All pathological findings were registered and therefore some of the birds received more than one diagnosis. In addition, the primary cause of death or the likely cause of death was recorded separately (Table 2). The subcategories; fractures, muscular

**Table 2.** The most probable causes of mortality.<sup>1</sup>

Cause of death	Number of DOFs <sup>2</sup>	Number of DOAs <sup>3</sup>	Total
Sudden death syndrome	135	132	267
Endocarditis	104	8	112
Ascites	67	13	80
Trauma	13	58	71
Osteomyelitis	36	18	54
Others	16	7	23
Total	371	236	607

<sup>1</sup>Several broilers had more than one pathological finding, this list shows only the diagnose that was the likely cause of death (stated by pathologists). Therefore, the numbers will differ from tables showing all pathological findings.

<sup>2</sup>Dead-on-farm broilers.

<sup>3</sup>Dead-on-arrival broilers.

**Table 3.** Description of traumatic lesions with frequencies.

Classification of trauma	Total numbers <sup>1</sup>	Percentage of all broilers	Percentage of trauma cases
Fracture	41	6.75	56.94
Fracture of the vertebrae	22	3.62	30.56
Fracture of the skull	7	1.15	9.72
Fracture of the wings <sup>2</sup>	3	0.49	4.17
Fracture of femur/tibia	9	1.48	12.50
Liver rupture	37	6.10	51.39
Trauma to the muscles	9	1.48	12.50

<sup>1</sup>Broilers were registered with several traumas.

<sup>2</sup>Including epiphyseal detachment.

injuries, and intra-abdominal hemorrhages due to liver rupture, were assigned to one common variable; trauma (Table 3).

## Statistical Analysis

Pathology findings were continuously collected in a database (Microsoft Excel 2010) and reviewed for errors. No missing values were obtained. The database was transferred to the statistical package Stata version 13 SE (StataCorp LP, TX) for statistical analysis. Descriptive univariate analyses were performed for all dichotomous variables in the sample data. Contingency table analyses (chi-squared tests) were used to outline potential differences in the frequencies of pathological lesions associated with broilers DOF or DOA, respectively. These variables included lung congestion, endocarditis, ascites, osteomyelitis, trauma, tibial dyschondroplasia, hepatitis, and arthritis. A probability value  $P$  of  $\leq 0.05$ , with a 2-tailed distribution, was considered indicative of statistical significance. Flocks and regions were included in multivariable logistic regression for each pathological finding to control for clustering effects and climatic effects.

## RESULTS

### Descriptive Results

The mean DOF number for the 32 flocks was 2.96% (range: 1.17 to 4.96), while the mean DOA number was

0.09% (range: 0.01 to 0.3). Descriptive statistical characteristics of the flocks are listed in Table 1.

### Gross Pathological Findings

The post-mortem examinations revealed 19 different diagnostic groups. A description of the major pathological lesions (grouped by 20 or more observations), along with the sample frequencies, DOF, and DOA frequencies is given in Table 4. More than one diagnosis was given in 18.5% of the broilers, with an equal distribution among broilers DOF and DOA. No specific pathological findings were observed in 1.8% of the broilers.

### Pathological Lesions in Broilers DOF

Pathological lesions significantly associated with mortalities in broilers DOF versus DOA are presented in Table 5.

**Lung Congestion** At 37.7% incidence, lung congestion was the most common pathological finding among broilers DOF (Tables 4 and 5). An uneven circulatory disturbance in the pectoral muscles (mottled red and white) was a common finding associated with lung congestion. Some broilers also had congested spleen and/or liver. None of the broilers with lung congestion, either DOF or DOA, showed signs of chronic changes in the lungs or liver. Of all lung congestion cases among DOF broilers, 78.6% were classified with this as the only pathological finding, 13.6% had comorbidity with ascites, and only 2 broilers (1.43%) were classified with endocarditis and lung congestion. The remaining lung congested broilers had no common concurrent lesions. Among the 32 flocks; lung congestion ranged from 3 to 16 cases per flock. There was no significant difference in the frequency of lung congestion between the 4 different regions. Lung congestion was more common among broilers DOA than broilers DOF ( $P$ -value = 0.001) (Table 5).

**Endocarditis** Endocarditis was present in 29.4% of broilers DOF (Tables 4 and 5), and thus more common among broilers DOF than broilers DOA ( $P$ -value of  $< 0.01$ ). The fraction of DOA broilers with endocarditis was 4.2% (Table 4). Among the 32 flocks endocarditis ranged from zero to 11 cases per flock. One region attributed 39.5% of the endocarditis lesions ( $P$ -value of  $< 0.01$ ).

**Ascites** Ascites was present in 24.0% of DOF broilers, and it was more prevalent in broilers DOF than broilers DOA ( $P < 0.01$ ) (Table 5). Of broilers DOA, 10.2% had ascites (Table 4). There was also a difference in the frequency of ascites between the 4 regions of which 40.7% of the cases were attributed by only one of the 4 regions ( $P$ -value of  $< 0.01$ ). Ascites ranged between zero and 13 cases on farm level in total.

**Lesions of the Limbs** The most common leg-pathologies among broilers DOF were osteomyelitis (14.6%), tibial dyschondroplasia (2.7%) (Table 4), and

**Table 4.** Classification of gross pathological lesions<sup>1</sup> with numbers in DOF<sup>2</sup> and DOA<sup>3</sup> broilers and the total numbers for the study sample, percentages in parenthesis.

Diagnosis	Pathological findings	Numbers in DOFs, <i>n</i> = 371	Numbers in DOAs, <i>n</i> = 236	Total numbers, <i>N</i> = 607
Lung congestion	Congested and edematous lungs, with or without congestion of the liver and spleen, with or without mottled red and white pectoral muscles	140 (37.7)	135 (57.2)	275 (45.3)
Endocarditis	Irregular vegetation on the heart valves/ walls of the cardiac chambers (mural) enlarged spleen	109 (29.4)	10 (4.2)	119 (19.6)
Ascites	Accumulation of serous fluid in the abdominal cavity	89 (23.9)	24 (10.2)	113 (18.6)
Osteomyelitis	Necrosis of the femoral head or yellow foci in the proximal tibiotarsus	54 (14.6)	24 (10.2)	78 (12.9)
Trauma <sup>4</sup>	Fractures, liver rupture	14 (3.8)	58 (24.6)	72 (11.9)
Tibial dyschondroplasia	A large mass of cartilage which concerns the growth plate, primary in the proximal tibiotarsus	10 (2.7)	11 (4.7)	21 (3.5)
Hepatitis	Enlarged liver with grey and yellow foci	19 (5.1)	1 (0.4)	20 (3.3)
Arthritis	Fibrinous exudate in the joints	17 (4.6)	3 (1.3)	20 (3.3)
Total <sup>5</sup>		452 <sup>6</sup>	266	718

<sup>1</sup>Lesions with 20 or more observations.

<sup>2</sup>Dead-on-farm.

<sup>3</sup>Dead-on-arrival.

<sup>4</sup>Bruises not included.

<sup>5</sup>In several broilers, more than one diagnose was given.

<sup>6</sup>More pathological lesions were found in the DOFs than in the DOAs (*P* = 0.017).

**Table 5.** The main risk factors for dying on-farm and on transport. *N* = 607.

Pathological diagnosis <sup>1</sup>	Total numbers, <i>N</i> = 607	Numbers in DOFs <sup>2</sup> , <i>n</i> = 371	Numbers in DOAs <sup>3</sup> , <i>n</i> = 236	OR	95% confidence interval	<i>P</i> -value
Risk factors for dying on-farm						
Endocarditis	119	109	10	9.4	4.76-20.6	0.0001
Ascites	113	89	24	2.79	1.69-4.73	0.0001
Hepatitis	20	19	1	12.7	1.98-529.15	0.0016
Arthritis	20	17	3	3.7	1.06-20.05	0.03
Risk factors for dying on transport						
Lung congestion	275	140	135	2.2	1.56-3.12	0.001
Trauma	72	14	58	8.31	4.41-16.53	0.0001

<sup>1</sup>Diagnosis based on macroscopic examination.

<sup>2</sup>Dead-on-farm broilers.

<sup>3</sup>Dead-on-arrival broilers.

arthritis (4.6%) (Table 5). There was no difference between broilers DOF and DOA regarding the fraction of osteomyelitis. In 38.9% of the osteomyelitis cases in broilers DOF, this was the only pathological finding. In 24.1% of DOF broilers with osteomyelitis, endocarditis was also present. In total, 20.4% of broilers DOF with osteomyelitis had an additional arthritis. Osteomyelitis ranged from zero to 13 cases per flock. Arthritis (Table 5) was more prevalent among broilers DOF versus DOA (*P*-value of < 0.05); 85% of the broilers with arthritis were DOF. Arthritis was the single diagnosis in only 3 cases (15%), of which all were DOF. The other broilers DOF classified with arthritis (*n* = 14) had additional diagnoses, of which 11 had osteomyelitis. Tibial dyschondroplasia was present in 2.7% of all broilers DOF versus 4.7% in broilers DOA (Table 4) and never as a single diagnosis in DOF broilers.

**Less Common Diagnoses** Hepatitis was present in 5.1% of broilers DOF (Table 4) and was more common

in broilers DOF than DOA (*P* < 0.01) (Table 5). Traumatic lesions were present in 3.8% of DOF broilers, vs. 24.6% of broilers DOA (Table 5). Gizzard inflammation was found in 0.8% of broilers DOF and an equal frequency of broilers DOF showed signs of gizzard erosion and ulceration syndrome. Pneumonia was found in only 0.2% of broilers DOF. Lesions indicating infection in the spleen (septicemia) was detected in 1.3% of the broilers DOF. Cannibalism was found in 0.5% DOF broilers and articular gout was apparent in 1.4%.

### Pathological Lesions in Broilers DOA

Pathological lesions significantly associated with mortalities in broilers DOA vs. broilers DOF are presented in Table 5.

**Lung Congestion** This was the most common pathological finding among DOA broilers at 57.2%

(Table 4), and was thus more prevalent in broilers DOA than DOF ( $P$ -value of  $< 0.01$ ) (Table 5). Of all lung congestion cases among DOA broilers, 74.8% were classified with this as the only diagnosis. In 5.9% of the lung congested DOA broilers, it coincided with trauma. Other concurrent lesion observed were; osteomyelitis, tibial dyschondroplasia, arthritis, sepsis, ascites, and gizzard inflammation (data not shown).

**Ascites** Ascites was found in 10.2% of DOA broilers (Table 4). This diagnosis was more common among broilers DOF than broilers DOA ( $P$ -value of  $< 0.01$ ) (Table 5).

**Lesions of the Limbs** The most common leg pathologies among broilers DOA were osteomyelitis (10.2%), tibial dyschondroplasia (4.7%) (Table 4), and arthritis (1.3%) (Table 5). Arthritis was more common among DOF than DOA broilers ( $P$ -value = 0.03), while the other leg lesions showed no such difference. In 58.3% of the osteomyelitis cases among DOA broilers, osteomyelitis was the only pathological finding. Only one case of osteomyelitis in DOA broilers had a combination of osteomyelitis and endocarditis. No other lesions were significantly associated with osteomyelitis in broilers DOA.

**Trauma** Traumatic lesions accounted for 24.6% of the post-mortem findings in broilers DOA, making it more common in broilers DOA than in broilers DOF ( $P$ -value of  $< 0.01$ ) (Table 5). Some broilers were registered with several concurrent traumas. Overall, the most common traumatic lesion was fractures (56.9%), with fracture to the vertebrae being most frequent (53.7% of all fractures and 30.6% of all traumas) (Table 3). Liver ruptures with associated intra-abdominal hemorrhages were the second most frequent traumatic lesion (51.4% of all traumas). The distribution of traumas is given in Table 3.

**Less Common Diagnoses** Endocarditis was present in 4.2% of broilers DOA vs. 29.4% in broilers DOF (Table 5). Hepatitis accounted for 0.42% of the pathological lesions in DOA broilers (Table 5). Gizzard inflammation was found in 0.42% of broilers DOA and 0.85% showed signs of gizzard erosion and ulceration syndrome. Lesions indicating infection of the spleen (septicemia) was found in 0.85%.

## DISCUSSION

Briefly, the main results show that pathological findings indicative of chronic conditions such as ascites, hepatitis, and endocarditis were significantly more common in broilers DOF compared to broilers DOA. Lung congestion was common in both broilers DOF and DOA, however significantly more prevalent in DOA broilers. Traumas were also significantly more prevalent in broilers DOA vs. DOF.

Overall, lung congestion was the most common pathological finding in this study. Lung congestion is a common and often incidental finding in poultry, but

it may be indicative of SDS. Several reported necropsy findings in SDS broilers are similar to the post-mortem findings in the present study, including pulmonary congestion and edema, frothy transudate in the trachea, and congested liver (Ononiwu et al., 1979; SCAHAW, 2000; Siddiqui et al., 2009). In addition, SDS has been reported to be one of the most common causes of mortality in broiler production (SCAHAW, 2000; Julian, 2005; Olkowski, 2007). In the majority of broilers with lung congestion, there were no other lesions and the broilers were presumably healthy before death, which points in the direction of a sudden death. The incidence of lung congestion in broilers DOA in our study (57.2%) was in agreement with Lund et al. (2013) who found that lung congestion accounted for 66.1% of all broilers DOA. Our findings are considerably higher than Whiting et al. (2007), who found pulmonary edema, classified as acute heart failure/suffocation, in 23.4% of investigated DOA broilers. This discrepancy may be explained by different classifications; therefore, a direct comparison of the lung congestion results between studies is difficult. In addition; the mean DOA number in our study is relatively low compared to other studies (Nijdam et al., 2004; Petracci et al., 2006; Vecerek et al., 2006; Haslam et al., 2008; Chauvin et al., 2011; Lund et al., 2013) and therefore the percentages of different lesions are easily influenced by the low total number.

With 37.7%, lung congestion was the most common pathological lesion in broilers DOF. This is in accordance with SDS as a major contributor to on-farm mortality. However, the lesions were significantly more common in broilers DOA (57.2%). Stress is a known trigger for SDS and many broilers are highly susceptible to stress-induced cardiac arrhythmia and may die after sudden stress (Jones and Hughes, 1981; Olkowski et al., 2008). Therefore, it may be suggested that the stress involved with catching, crating, and transportation may have resulted in an increased occurrence of SDS in DOA broilers, as indicated by lung congestion.

However, lung congestion as an indication of SDS has to be interpreted cautiously, since it has been claimed that no specific gross lesions are pathognomonic for SDS (Julian, 2005). Thus, birds may also have died due to SDS without any detectable gross pathological lesions, suggesting that the numbers of SDS could be higher than reported here. Additionally, other factors such as heat stress may also have caused lung congestion. Previous studies have shown that broilers exposed to chronic heat stress displayed many of the same pathological lesions as found in the current study (Aengwanich and Simaraks, 2004). Rapidly growing broiler hybrids, including the Ross 308, may exhibit a reduced capacity for thermoregulation, making them more susceptible to heat stress during transport (Sandercock et al., 2006). Indeed, climatic conditions have been found to be associated with DOA (Chauvin et al., 2011), and heat stress is recognized as a major risk factor for DOA (Webster et al., 1993; Warriss et al., 2005; Petracci et al., 2006; Whiting et al., 2007) and

high temperatures may lead to heart failure (Elrom, 2001). The ambient as well as the in-vehicle temperatures were not recorded in this study. Although flocks were selected all year round, and the abattoirs included represented different geographic and climatic regions in Norway, the sample size was too limited to draw conclusions as to whether heat stress or other climatic conditions (ambient and in the vehicle) may have accounted for the findings reported here.

Suffocation is also reported as an important DOA risk factor (Bayliss and Hinton, 1990; Gregory and Austin, 1992; Whiting et al., 2007) and it may lead to post-mortem lesions similar to our results, including lung congestion (Whiting et al., 2007). Furthermore, the density in crates has been found to be associated with DOA (i.e., more space allowance being associated with lower mortality; Chauvin et al., 2011). It is however not known whether suffocation due to e.g., crowding during transport may have contributed to our findings. Although heat stress, suffocation and density in the crates may have contributed to lung congestion in broilers DOA, it is unlikely that these factors contributed to lung congestion in broilers DOF, strengthening the suggestion of SDS as a cause for the lung congestion.

However, this is only a theory since no histopathology was conducted and therefore we cannot draw conclusions about the etiology behind the common finding of lung congestion. It may be an incidental finding and we cannot rule out that the true cause of death was not discovered during post-mortem examination.

The fraction of trauma (defined as liver rupture, fractures, and muscular traumas) in the DOA study population (24.6%) is in accordance with published numbers of 22.7% (Lund et al., 2013), but slightly lower than what has been reported in other studies; 29.5% (Nijdam et al., 2006), and 35% (Gregory and Austin, 1992; Elrom, 2001). Liver rupture, with hepatic hemorrhage was found in 11% of DOA broilers. This is the same prevalence as reported by Elrom (2001), but it is slightly lower than the 14.6% found by Lund et al. (2013). Traumas were significantly more common in broilers DOA than in broilers DOF, where trauma was an uncommon finding. Trauma as a common lesion in DOA is in accordance with previous studies (Kettlewell and Mitchell, 1994; Elrom, 2001; Ritz et al., 2005; Whiting et al., 2007; Lund et al., 2013) which suggests that catching and transport are important risk factors for trauma, and that more careful bird handling is crucial to reduce DOA. It could be speculated if there is a relationship between different causes of acute mortality such as suffocation resulting in e.g., lung congestion and trauma. However, in this study there was no relationship between the pathological findings classified as lung congestion and trauma in broilers DOA.

Ascites and endocarditis together, here considered chronic disease, represented 53.4% of all findings in broilers DOF vs. 14.4% in broilers DOA. Our results are in support of ascites as a significant cause of on-farm

mortality in broilers worldwide (Tottori et al., 1997; Maxwell et al., 1998; SCAHAW, 2000; Balog, 2003). Similarly, endocarditis is also a significant cause for mortality and has been reported to account for 36% of the mortality on-farm (Velkers et al., 2011). This is slightly higher than our results (29.4%), but the 36% occurred during the entire growth period, while our study only focused on the last days of the production period. Ascites accounted for 10.2% of all lesions in broilers DOA, which is in accordance with other studies; 7.9% (Nijdam et al., 2006), and 7.6% (Whiting et al., 2007), but higher than the 2% reported in a Danish study (Lund et al., 2013). Pathological findings indicating the presence of other infectious diseases such as laryngitis, tracheitis, and arthritis have been stated as common macroscopic findings in broilers DOA (Nijdam et al., 2006). This was not confirmed by our study, as only three DOA broilers were identified with arthritis, and none with laryngitis or tracheitis. Our results indicate that chronic diseases such as ascites and endocarditis are important causes of mortality on-farm at the end of the production cycle, but not during transport. Management practices may explain this, if the framers have sorted out sick broilers unfit for travel prior to catching and transport. Still, 10.2% of all DOA broilers had ascites and further studies are needed to verify a potential causal explanation for ascites as a predisposing factor for DOA.

Osteomyelitis, tibial dyschondroplasia, and arthritis were overall, the most prevalent leg pathologies. In both broilers DOF and DOA, osteomyelitis was the most common post-mortem leg disorder and there was no difference in prevalence between the two groups. Osteomyelitis was found in 14.6% of DOF broilers, which is in agreement with McNamee and Smyth (2000) who found bacterial chondronecrosis with osteomyelitis in 12.3% of broilers dead (not culled) on-farm. In broilers DOA, osteomyelitis was found in 10.5%. Of DOF and DOA broilers, 38.9% and 58.3%, respectively, with osteomyelitis had this as a single post-mortem lesion, making it an important lesion in both broilers DOF at the end of the production cycle and in DOA broilers. Since no bacteriology were performed, we decline to conclude whether these broilers had generalized infections or died of other causes; i.e., a problem with walking to feed and water (Butterworth and Haslam, 2009). However, osteomyelitis is most commonly caused by *Staphylococcus aureus* (McNamee and Smyth, 2000) and 24.1% of all broilers DOF with osteomyelitis also showed signs of endocarditis. Therefore, a causal connection between these two infectious diseases and mortality on-farm cannot be ruled out. In contrast, only one DOA broiler with osteomyelitis had additional endocarditis. This difference remains unexplained.

Although not frequently diagnosed, there was a significant difference in arthritis between broilers DOF and DOA. Only three DOA broilers had arthritis in this study, which is in contrast to Nijdam et al. (2006) who reported polyserositis or arthritis in 21.9% of the

investigated DOA broilers. The low incidence of arthritis in both broilers DOF and DOA may be interpreted either as a low occurrence in the sample populations, or that farmers have culled sick broilers prior to transport. In broilers DOF, there was a numerical relationship between arthritis and osteomyelitis, indicating an association between these two infectious leg disorders. The same association was not found in broilers DOA.

Tibial dyschondroplasia, which is reported as the most common lesion in broiler legs (SCAHAW, 2000; Dinev et al., 2012), was not a frequent pathological finding in this study and there was no difference between broilers DOF and DOA.

Further large scale studies are needed to understand the role of infectious leg health disorders as a predisposing factor for transport mortality and to explore a potential relationship between leg health and mortality on-farm during the production cycle.

It has to be emphasized that the mean DOA for the flocks in our study was low (0.09%) compared to other European studies that report between 0.12% and 0.46% (Nijdam et al., 2004; Petracci et al., 2006; Vecerek et al., 2006; Haslam et al., 2008; Chauvin et al., 2011; Lund et al., 2013). In addition; the study population of DOA (236 broilers) is only a fraction of the total DOA population. This makes it difficult to draw firm conclusions regarding the prevalence of the pathological lesions in the sample population. However, the differences found between DOA and DOF broilers provides new insights to immediate and underlying pathological conditions associated with DOA and DOF.

## CONCLUSION

The results indicate that the majority of transport mortality may be attributed to factors related to the transport process *per se*, indicated by the pathological findings such as lung congestion and trauma. Lung congestion was the overall most common pathological finding and SDS is believed to play an important role. SDS is a major contributor to on-farm mortality and it is likely that the stress involved with catching and transport will cause even more mortalities due to SDS. To prevent mortality both on-farm and during transport, further studies are needed to fully understand risk factors and etiology for the most common pathological finding; lung congestion. Diseases already present on-farm may have contributed to a lesser but still important fraction of transport mortalities, as represented by the findings of ascites and osteomyelitis as the only pathological finding in broilers DOA. A potential link between infectious leg disorders and transport mortality in broilers warrants further investigations.

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