

Effects of age, weight, and housing system on prevalence of dead on arrival and carcass condemnation causes in laying hens

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ABSTRACT Causes of condemnation and dead on arrival (DoA) birds were studied at the slaughterhouse and effects of age, BW, and housing system were investigated. A total of 1,156 (0.18%) birds were found DoA and 20,754 carcasses out of 629,331 (3.30%) were condemned during postmortem inspection. The main reasons for condemnation were peritonitis, septicemia, salpingitis, emaciation, and tumors. The mean percentages of condemnation by septicemia and emaciation differed according to age and BW groups and were more common in batches of younger (≤ 87 wk) and lighter (≤ 1.88 kg) birds. Moreover, peritonitis and ascites differed significantly between age groups, occurring more frequently in batches of older hens. The presence of tumors of the reproductive system was more frequently observed in older and heavier hens.

This result raises the possibility of tumors being correlated with the higher number of prior ovulatory events. The total condemnation rate was lower in hens from organic systems, followed by free-range, and differed significantly from barns and cage systems. Carcasses with ascites and peritonitis were found more commonly in hens from cages and barns and both differed significantly from organic systems. Salpingitis was statistically more prevalent in barns, presenting differences from organic and free-range systems. Monitoring condemnation causes of end-of-lay hens at slaughter provided a better understanding of health and welfare issues in different housing systems and allowed to identify potential welfare problems, which can be used to improve management and welfare on farms.

Key words: condemnation cause, emaciation, laying hen, slaughterhouse, tumor

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INTRODUCTION

Meat inspection is one of the most widely implemented and longest running surveillance systems. It was primarily introduced to identify meat unfit for human consumption, and progressively recognized as a relevant source of data for monitoring animal health and welfare conditions (Stärk et al., 2014; Huneau-Salaün et al., 2015). A good example of this was the adoption of the Directive 2007/43/EC which provided minimum standards to ensure the protection of broilers during intensive production (European Union, 2007). Under this Directive, the official veterinarian should

monitor and follow-up parameters at the slaughterhouse which are important to identify welfare problems in poultry farms (Saraiva et al., 2016).

Conditions or diseases relatively common in birds can be recognized during slaughterhouse inspection as some pathological changes will affect the carcass appearance at the time of slaughter (Collins and Huey, 2015; Graff et al., 2017). Postmortem examination is important to identify some conditions, such as ascites, which are difficult to detect on farms or at antemortem inspection (EFSA, 2012). Cachexia and emaciation are difficult to differentiate at the slaughter-line, though the latter is associated with the presence of disease (Bremner and Johnston, 1996; Haslam et al., 2008). Septicemia is considered to be an important cause of rejection in poultry, principally due to bacterial infection by *Escherichia coli*. Other common organisms include *Staphylococcus* spp., *Pasteurella* spp., and *Salmonella* spp. (Bremner and Johnston, 1996; Collins and Huey, 2015). Infections with *Erysipelothrix rhusiopathiae* and

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Pasteurella multocida have also been reported in hens housed in litter-based systems, but not from in cage systems (Fossum et al., 2009). Ascites in laying hens is often associated with diseases of the abdominal cavity, particularly peritonitis and tumors (Tiwari et al., 2013), and is considered a sign of poor welfare in poultry farms (Butterworth and Niebuhr, 2009). Ovarian carcinoma and other reproductive system tumors can be highly prevalent in laying hens with metastasis affecting mainly the peritoneum and the visceral organs (Barua et al., 2009; Saraiva et al., 2013). Salpingitis is also a recurrent pathology in laying hens and is characterized by distension and inflammation of the oviduct with accumulation of caseous exudate of fibrin, granulocytes, yolk, and shell material (Landman et al., 2013). Concurrent peritonitis can arise through the compromised oviduct wall, leading to the spread of *E. coli* into the abdominal cavity and the accumulation of caseous exudate (Grist, 2006; Landman et al., 2013). Abscesses are less common in poultry than in other animals, but they can be found in laying hens with bumblefoot or following injuries due to feather pecking or cannibalism (Bremner and Johnston, 1996; Sherwin et al., 2010). Bruising can occur during crating, transport, uncrating, and shacking of poultry (Nijdam et al., 2005), and the number of animals dead on arrival (DoA) is considered a major welfare and health indicator of flocks transported to the slaughterhouse (Weeks et al., 2012).

It is important to determine the reasons and rates of condemnation in order to manage meat quality and safety, as well as to improve animal health and welfare (Salines et al., 2017). Moreover, pathologies of the reproductive system are usually associated with decrease in egg production which in turn can be an indicator of environmental stress (Zanella et al., 2000).

The aim of this study was to determine the prevalence of DoA birds and of carcass condemnation causes in end-of-lay hens flocks and investigate the effects of age, BW, and housing system.

MATERIALS AND METHODS

Population

Fifty-four farms of 4 different production systems were assessed in the slaughterhouse: cages, 34 (63%); barns, 10 (19%); free-range, 5 (9%); organic free-range, 5 (9%). The hybrids used were Lohmann Brown, ISA Brown, Lohmann Selected Leghorn, Hy-Line Brown, and Novogen Brown. All hens were vaccinated against Marek's disease, avian encephalomyelitis, infectious bronchitis, and Newcastle disease.

The study was performed along 3 consecutive years (2013–2015) in 1 slaughterhouse of poultry and all batches (224 shipments) of laying hens slaughtered during this period were considered.

The method of catching was manual in all flocks and each vehicle transported laying hens in crates made from LCS plastic. Once at the slaughterhouse, the vehicle was unloaded and the crates with the laying

hens were placed in a holding area. Batch size (number of birds per shipment) was on average $2,815 \pm 970$, ranging from 275 to 8,360 hens. Hens were, on average, 87 wk old, ranging from 68 to 131 wk per batch. The average BW per batch was 1.88 kg, ranging from 1.55 to 2.18 kg. The transport duration was on average 1 h 5 min (± 0 h 6 min). Transport distance was on average 57.5 (± 6.1 km) and the longest distance was 284 km.

Inspection at the Slaughterhouse

Birds were subjected to antemortem inspection and the number of DoA birds were accounted by batch immediately after slaughter and checked by the official veterinarian. Postmortem inspection was performed at the slaughter-line on 629,331 carcasses. The number and percentages of condemnation causes were recorded per batch of transport. The most frequent condemnation reasons were identified by the same official veterinarian and were found to be abscesses/cellulitis, ascites, extensive bruising, emaciation, salpingitis, septicemia, peritonitis, and tumors. In all these cases carcasses and offal were condemned and considered unfit for human consumption. Other causes of condemnation, unrelated to bird health condition and welfare, included mechanical trauma, fecal contamination, and poor bleeding. These were not included in this study and represented only 0.05% (290 birds) of the carcasses condemned.

Statistical Analysis

The effect ($P < 0.05$) of age, BW, and housing production system was studied using nonparametric tests (Mann-Whitney-Wilcoxon and Kruskal-Wallis tests) for percentage of DoA per batch of transport, as well for abscesses/cellulitis, ascites, emaciation, extensive bruising, peritonitis, salpingitis, septicemia, tumors, and total condemnation per slaughtered hen in each batch of transport. The cutoff for the analysis of age and BW effect was determined by mean values. These 2 groups consisted, respectively, of batches with ages between ≥ 68 and ≤ 87 wk ($n = 135$) and between > 87 and ≤ 131 wk ($n = 89$) and average BW between ≥ 1.55 and ≤ 1.88 kg ($n = 121$) and between > 1.88 and ≤ 2.18 kg ($n = 103$). Regarding the housing system, the effects of 4 different production systems were investigated namely, organic ($n = 10$), free-range ($n = 14$), barn ($n = 66$), and cage ($n = 134$) systems. Data analysis was carried out using XLSTAT (release 2011, Addinsoft, Paris, France).

RESULTS

The number of animals transported in 224 batches for slaughter were 630,487 and of these, 1,156 (0.18%) were found to be DoA. Postmortem examination included the inspection of 629,331 carcasses and offal at the slaughter-line and 20,754 (3.30%) carcasses were condemned by different causes. The number and percentages of condemnation reasons, as well as mean,

SE, range, minimum and maximum values of DoA, condemnation causes, and total condemnation, expressed as an average percentage per batch, are summarized in [Table 1](#).

The mean percentage of total condemnation of carcasses and offal rejected during postmortem inspection was 3.27% and differed considerably between batches, ranging from 0.61 to 19.90%. Of the total number of condemned (20,754) birds, 4,964 (23.9%) were condemned by peritonitis, 4,346 (20.9%) by septicemia, and 3,837 (18.5%) by salpingitis. Abscesses/cellulitis and extensive bruising were considered minor causes of condemnation, together comprising only 0.7% of rejections. Septicemia represented, at least in 1 batch, a maximum value of condemnation of 9.1%.

The effect of age groups (≥ 68 to ≤ 87 wk, $n = 135$ and > 87 to ≤ 131 wk, $n = 89$) on percentages of DoA birds, of condemnation causes, and total condemnation is presented in [Table 2](#).

Septicemia ($P = 0.002$) and emaciation ($P = 0.002$) were more common in younger hens (≥ 68 to ≤ 87 wk). In contrast, ascites ($P = 0.021$), peritonitis ($P = 0.030$), and tumors ($P = 0.046$) were more frequent in older hens (> 87 to ≤ 131 wk). Rates of total condemnation and of salpingitis were similar among age groups.

The effect of 2 BW groups (≥ 1.55 to ≤ 1.88 kg, $n = 121$ and > 1.88 to ≤ 2.18 kg, $n = 103$) on percentages of DoA birds, of condemnation causes, and of total condemnation, is presented in [Table 3](#).

Emaciation ($P < 0.001$), salpingitis ($P = 0.009$), and septicemia ($P < 0.001$) were more frequent in batches with BW below the mean value (1.88 kg). In contrast, tumors ($P = 0.046$) were more frequently observed in heavier hens. The percentage of birds with abscesses/cellulitis, bruising, and peritonitis did not differ between BW groups.

The effect of different housing systems on percentages of DoA birds, of condemnation causes, and total condemnation is presented in [Table 4](#).

Total condemnation rate was lower in hens from organic systems (1.94%), followed by hens from free-range (2.66%), and was similar in hens from barns (3.37%) and cages (3.39%). However, only hens maintained in organic production systems differed significantly from barn and cage hens. Peritonitis ($P = 0.011$) differed significantly between organic and barn systems ($P = 0.022$) and between organic and cage systems

($P = 0.038$), with cage systems presenting the highest prevalence (0.82%). Salpingitis followed the same tendency, with significant differences between organic and barn systems ($P = 0.002$) and between organic and cage systems ($P = 0.011$), with barn systems presenting the highest prevalence (0.66%). Ascites ($P = 0.001$) was more frequently identified in hens from cages (0.28%), presenting significant differences with hens from organic systems ($P = 0.008$) and free-range ($P = 0.029$). Organic and barn systems also differed statistically ($P = 0.037$).

DISCUSSION

In the present study, end-of-lay hens from 54 different farms were transported in 224 batches to the slaughterhouse and condemnation causes were identified at the slaughter-line. The average mortality was 0.17%, ranging from 0 to 1.67% per batch. The transport duration and distance were, on average, short. Few studies have been conducted on transport mortality in laying hens; however, [Weeks et al. \(2012\)](#) in a survey of 13.3 million hens transported for slaughter in Great Britain observed an average mortality of 0.27%, which was 0.10% higher than the value obtained in the present study. Another study ([Petracci et al., 2006](#)) showed a higher DoA mean value in Italian laying hens slaughterhouses (1.22%), with a very wide variation interval from 0 to 6.60%. Accordingly to the authors, the preslaughter mortality in laying hens was critical due to injuries produced during catching, cage removal, and crating, since osteoporosis in laying hens increases by the end of the laying period leading to a higher occurrence of fractures. Preslaughter mortality in summer was found to be dramatically higher (+42%), which could be explained by the high environmental temperatures (16.3°C–27.7°C) and RH (72.7%) normally observed in summer months compared to the other seasons of the year. Additionally, [Newberry et al. \(1999\)](#) monitored DoA rates of hens transported for slaughter in Canada and the United States and observed that mortality ranged from 0.7 to 2.3% depending on the duration of the journey. These authors explained the high mortality rates by claiming that relatively few poultry processing companies are willing to accept hens because of their low meat value compared with broiler chickens and turkeys. For this reason, hens in Canada and the United

Table 1. Number and percentage of dead on arrival and carcasses condemnation causes, as well as mean, SE, and range of variables, expressed as a mean percentage per batch.

Variables	No. condemned (%)	Mean (%)	SE of mean (%)	Range (%)	Minimum (%)	Maximum (%)
Dead on arrival	1,156 (0.18)	0.17	0.01	1.67	0.00	1.67
Abscesses/cellulitis	65 (0.01)	0.01	0.00	0.55	0.00	0.55
Ascites	1,579 (0.25)	0.25	0.01	1.25	0.00	1.25
Extensive bruising	77 (0.01)	0.01	0.01	0.27	0.00	0.27
Emaciation	3,690 (0.59)	0.58	0.03	3.31	0.06	3.37
Peritonitis	4,964 (0.79)	0.79	0.03	2.39	0.00	2.39
Salpingitis	3,837 (0.61)	0.62	0.03	3.30	0.00	3.30
Septicemia	4,346 (0.69)	0.66	0.05	9.07	0.00	9.07
Tumors	2,196 (0.35)	0.35	0.02	2.11	0.00	2.11
Total condemnation	20,754 (3.30)	3.27	0.13	19.29	0.61	19.90

Table 2. Level of significance of percentages (mean \pm SD) for dead on arrival, abscesses/cellulitis, ascites, emaciation, bruising, peritonitis, salpingitis, septicemia, tumors, and total condemnation according to age groups (≥ 68 to ≤ 87 wk, $n = 135$ and > 87 to ≤ 131 wk, $n = 89$).

Variables	Age ≥ 68 to ≤ 87 wk ($n = 135$)	Age > 87 to ≤ 131 wk ($n = 89$)	<i>P</i> -value
Dead on arrival (%)	0.19 \pm 0.23	0.14 \pm 0.14	ns
Abscesses/cellulitis (%)	0.01 \pm 0.04	0.01 \pm 0.06	ns
Ascites (%)	0.23 \pm 0.20	0.27 \pm 0.18	0.021
Emaciation (%)	0.61 \pm 0.51	0.51 \pm 0.36	0.002
Extensive bruising (%)	0.01 \pm 0.04	0.01 \pm 0.04	ns
Peritonitis (%)	0.80 \pm 0.40	0.87 \pm 0.43	0.030
Salpingitis (%)	0.63 \pm 0.39	0.62 \pm 0.34	ns
Septicemia (%)	0.66 \pm 0.97	0.55 \pm 0.36	0.002
Tumors (%)	0.33 \pm 0.28	0.38 \pm 0.37	0.046
Total condemnation (%)	3.31 \pm 2.25	3.22 \pm 1.49	ns

Significant difference ($P < 0.05$).

States tend to be transported through longer distances for slaughter than other types of poultry. In the present study, no significant age group effect or housing system effect was observed on DoA rates. However, a BW effect was found for the DoA rate, with lighter hens presenting a higher average mortality rate ($0.21 \pm 0.24\%$ vs. $0.13 \pm 0.14\%$). This is consistent with the findings of Weeks et al. (2012), who showed that highly significant risk factors ($P < 0.001$) related to the conditions of birds on farm, namely lower BW, will increase the risk of mortality on transport.

Among all the carcasses totally condemned, the most frequent carcass condemnation reasons were peritonitis (23.9%), septicemia (20.9%), salpingitis (18.5%), emaciation (17.8%), tumors (10.6%), and ascites (7.6%). Carcasses with extensive bruises, which were caused by traumatic lesions during preslaughter procedures, were subjected to total condemnation at the slaughter-line but represented only 0.37% of condemnations.

Few studies have reported the prevalence of condemnation causes in laying hens on farms and in slaughterhouses. Fossum et al. (2009) compared the mortality causes in laying hens in different housing systems and observed that colibacillosis was the most predominant disease in all housing systems. The most frequent pathological findings associated with colibacillosis consisted in acute or subacute fibrinous salpingitis, oophoritis, and peritonitis. According to Wahlstrom et al. (2001), the main causes of hen mortality on farms

included cannibalistic wounds, salpingitis, and coccidiosis. Kajlich et al. (2016) assessed, during postmortem examination, the prevalence and severity of lesions in non-cage hens from commercial farms and verified that septicemia lesions were observed in 23.1% of condemnations. Fulton, 2017 in an attempt to enable early detection of health problems in 16 egg producing flocks necropsied a representative sample to determine the cause of hen death, and the top 15 causes of normal mortality included egg yolk peritonitis, salpingitis, septicemia, internal layer, and prolapsed vent.

In relation to condemnation causes from the present study, ascites (0.23 ± 0.20 ; 0.27 ± 0.18 ; $P = 0.021$) was more frequent in batches of older hens. In broilers, the continuous selection for either growth rate or feed conversion ratio increases the pressure on metabolic processes and on the oxygen demand, increasing the occurrence of ascites (Gupta, 2011). However, in hens the presence of ascites has been associated with ovarian and oviduct carcinoma and is one of the features of advanced stages of ovarian cancer in chickens (Urlick et al., 2008). Based on this assumption, Tiwari et al. (2013) collected ascites-derived cells from hens, which were maintained in short-term culture for the determination of vascular endothelial growth factor expression. This study was the first to characterize malignant tumor cells derived from ascites of hens that had developed ovarian tumor. Barua et al. (2009) reported that laying hens develop epithelial ovarian tumors and exhibit a high rate of ovarian cancer (25–40%) in advanced ages.

Table 3. Level of significance of percentages (mean \pm SD) for dead on arrival, abscesses/cellulitis, ascites, emaciation, bruising, peritonitis, salpingitis, septicemia, tumors, and total condemnation according to BW groups (≥ 1.55 to ≤ 1.88 kg, $n = 121$ and > 1.88 to ≤ 2.18 kg, $n = 103$).

Variables	BW ≥ 1.55 to ≤ 1.88 kg ($n = 121$)	BW > 1.88 to ≤ 2.18 kg ($n = 103$)	<i>P</i> -value
Dead on arrival (%)	0.21 \pm 0.24	0.13 \pm 0.14	< 0.001
Abscesses/cellulitis (%)	0.01 \pm 0.04	0.01 \pm 0.06	ns
Ascites (%)	0.25 \pm 0.19	0.25 \pm 0.19	ns
Emaciation (%)	0.65 \pm 0.54	0.49 \pm 0.33	< 0.001
Extensive bruising (%)	0.01 \pm 0.04	0.01 \pm 0.04	ns
Salpingitis (%)	0.68 \pm 0.39	0.58 \pm 0.35	0.009
Septicemia (%)	0.73 \pm 1.02	0.48 \pm 0.31	< 0.001
Peritonitis (%)	0.82 \pm 0.41	0.79 \pm 0.42	ns
Tumors (%)	0.32 \pm 0.22	0.39 \pm 0.40	0.046
Total condemnation (%)	3.50 \pm 2.29	3.01 \pm 1.50	ns

Significant difference ($P < 0.05$).

Table 4. Level of significance of percentages (mean \pm SD) for dead on arrival, abscesses/cellulitis, ascites, bruising, emaciation, peritonitis, salpingitis, septicemia, tumors, and total condemnation according to the housing system (organic, n = 10; free-range, n = 14; barn, n = 66; and cage, n = 134).

Variables	Organic system (n = 10)	Free-range (n = 14)	Barn system (n = 66)	Cage system (n = 134)	P-value
Dead on arrival (%)	0.11 \pm 0.10	0.15 \pm 0.13	0.21 \pm 0.26	0.18 \pm 0.18	ns
Abscesses/cellulitis (%)	0.00 \pm 0.00	0.00 \pm 0.01	0.00 \pm 0.02	0.01 \pm 0.06	ns
Ascites (%)	0.11 \pm 0.08 ^a	0.16 \pm 0.17 ^{a,b}	0.24 \pm 0.16 ^{b,c}	0.28 \pm 0.21 ^c	0.001
Extensive bruising (%)	0.00 \pm 0.00	0.00 \pm 0.00	0.01 \pm 0.02	0.02 \pm 0.05	ns
Emaciation (%)	0.46 \pm 0.22	0.55 \pm 0.46	0.64 \pm 0.53	0.57 \pm 0.44	ns
Peritonitis (%)	0.50 \pm 0.14 ^a	0.61 \pm 0.25 ^{a,b}	0.82 \pm 0.34 ^{b,c}	0.82 \pm 0.46 ^c	0.011
Salpingitis (%)	0.36 \pm 0.17 ^a	0.49 \pm 0.27 ^{a,b}	0.66 \pm 0.30 ^c	0.63 \pm 0.41 ^{b,c}	0.001
Septicemia (%)	0.35 \pm 0.13	0.54 \pm 0.52	0.69 \pm 0.61	0.68 \pm 0.91	ns
Tumors (%)	0.19 \pm 0.14	0.31 \pm 0.24	0.30 \pm 0.24	0.39 \pm 0.36	ns
Total condemnation (%)	1.94 \pm 0.56 ^a	2.66 \pm 1.33 ^{a,b}	3.37 \pm 1.57 ^{b,c}	3.39 \pm 2.23 ^c	0.011

^{a-c}In each row, means with different superscript letters differ significantly ($P < 0.05$).

These findings further support the concept that ovulation with repeated cycles of rupture and repair of the ovarian epithelium may increase the number of proliferative events and genetic errors (Carver et al., 2011). The high ovulatory rate, almost daily, raises the possibility that tumors are correlated with the number of prior ovulatory events, justifying the presence of a higher prevalence of ascites in older hens.

In the present study, peritonitis (0.80 \pm 0.40; 0.87 \pm 0.43; $P = 0.030$) was more frequently observed in older hens. Continuous ovulation in laying hens is likely to contribute to a higher peritonitis incidence in older hens, due to the abdominal posture when various ova are released into the abdominal cavity, being surrounded by fibrinous material (Urick et al., 2008; Saraiva et al., 2013). Landman and Eck (2015) focussed on the pathogenesis, prevention, and treatment of peritonitis, and the economic and welfare impact. The economic losses consisted mainly in the decrease of egg production (Landman et al., 2013) with the decline in egg production of about 1 to 2% (Zanella et al., 2000).

In the present study, the percentage of carcasses condemned by septicemia was higher in younger (0.66 \pm 0.97; 0.55 \pm 0.36; $P = 0.002$) and lighter hens (0.73 \pm 1.02; 0.48 \pm 0.3; $P < 0.001$). This result can be related to downgrade conditions as a consequence of the presence of infectious agents or management procedures that also lead to a low growth rate. In poultry farms, infectious agents tend to be common to the whole flock and identification of microorganisms causing disease is highly recommended (Ansari-Lari and Rezaghali 2007; Collins and Huey, 2015). The most common bacterial infection diagnosed in laying hens has been *E. coli*, which has been reported in many countries as a frequent cause of disease in commercial laying hens, as well as in hens in experimental trials (Vandekerchove et al., 2004; Jordan et al., 2005; Fossum et al., 2009). Infectious diseases are a major health concern during laying, decreasing egg production and quality, directly by affecting the reproductive system, or indirectly affecting the health status of animals (Yaman and Yapicier, 2019). Ensuring that proper and effective measures are taken to detect infectious diseases at all relevant stages of production, processing, and distribution, is essential to reduce

prevalence and risk infectious agents pose to public health.

In the present study, emaciation (0.65 \pm 0.54; 0.49 \pm 0.33; $P < 0.001$) was more frequent in lighter birds, which is in agreement with other studies. According to Sherwin et al. (2010) and Saraiva et al. (2019), all housing systems produce a large amount of emaciated hens, but the type of housing system has a large effect on emaciation prevalence. Hens kept in cages were considerably heavier than those kept on litter (Wezyk et al., 2006; Saraiva et al., 2019). This can be explained by the fact that hens from non-cage systems are subjected to a greater possibility for disease and parasites spreading since hens are better exposed to litter and soil (Lay et al., 2011). Necropsy findings from a study of Reimers et al. (2019) concluded that intussusception of the proventriculus is also a cause of sporadic emaciation (prominent keel, marked muscle atrophy, and generalized serous atrophy of fat), culling, and mortality in older laying hens, although no etiologic agent was identified.

The total condemnation rate was lower in hens from organic systems, followed by free-range, and was significantly different from barns and cage systems. Carcasses with ascites and peritonitis were found more commonly in hens from cages and barns and both differed significantly from organic systems. Percentages of condemnation by peritonitis and by salpingitis in organic systems differed from both, barns and cage systems. Peritonitis was the most prevalent cause of condemnation in all housing systems, however, with a higher percentage in hens from barns and cages. Salpingitis was statistically more prevalent in barns, presenting differences from organic and free-range systems.

Emaciation was the second most frequent cause of condemnation in hens from organic and free-range systems; however, it showed a lower prevalence of carcasses condemnation when compared to birds from barns and cages. On the contrary, septicemia was the second most frequent cause of condemnation in barns and cage hens followed by salpingitis. Emaciation in hens from organic and free-range systems can probably be justified by the difficulties hens face in locating resources (Janczak and Riber, 2015). Feeding patterns can have an important effect on the intestinal

microflora composition of hens, which may impact the host nutritional status and intestinal health (Wang et al., 2016; Cui et al., 2017). Moreover, helminths have been more common in alternative systems compared with cages where they were rarely identified (Permin et al., 1999). Additionally, Kaufmann et al. (2011) observed in 18 organic free-range farms that almost all hens (99.6%) harbored at least one helminth species. A major challenge facing organic animal production systems is the management and treatment of health-related issues because in organic flocks the use of antibiotics and anthelmintics is restricted (Rodenburg et al., 2012; Sutherland et al., 2013).

Carcasses with ascites were found more commonly in hens from cages and barns, both differing from organic systems. Free-range and cage systems also differed for ascites. Probably birds in a more confined environment as in cage and barn systems have a higher probability to induce ascites by reducing oxygen availability. However, the higher prevalence of ascites observed in cage hens can also be related to the fact that hens in cages are normally slaughtered at older ages compared to hens from alternative non-cage systems.

CONCLUSIONS

The present study determined the main causes of carcass condemnation in end-of-lay hens and evaluated the influence of age, BW, and housing systems on these. Ascites, peritonitis, and tumoral lesions increased significantly with age, while emaciation and septicemia were observed more frequently in younger hens. Regarding BW, it was shown that in DoA birds, emaciation, salpingitis, and septicemia were more frequent in lighter hens. The type of housing systems influenced the percentage of ascites, peritonitis, salpingitis, and total condemnation rates, with hens from barns and cages showing statistical differences from organic systems.

General health status of flocks under different ages, BW, and housing systems may vary leading to carcasses of different quality and safety. Monitoring condemnation causes of end-of-lay hens at slaughter can help to support farm managers and veterinarians to initiate management check-ups, define the age of slaughter, and improve health and welfare in their housing systems.

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DISCLOSURES

None of the authors of this study has a financial or personal relationship with other people or organizations

that could inappropriately influence or bias the content of the study.

REFERENCES

- Ansari-Lari, M., and M. Rezagholi. 2007. Poultry abattoir survey of carcass condemnations in Fars province, southern Iran. *Prev. Vet. Med.* 79:287–293.
- Barua, A., P. Bitterman, J. S. Abramowicz, A. L. Dirks, J. M. Bahr, D. B. Hales, M. J. Bradaric, S. L. Edassery, J. Rotmensch, and J. L. Luborsky. 2009. Histopathology of ovarian tumors in laying hens: a preclinical model of human ovarian cancer. *Int. J. Gynecol. Cancer* 19:531–539.
- Bremner, A., and M. Johnston. 1996. *Poultry Meat Hygiene and Inspection*. W.B. Saunders Company Ltd., London; United Kingdom.
- Butterworth, A., and K. Niebuhr. 2009. Measures of poultry health status. Pages 39–65 in *Assessment of Animal Welfare Measures for Layers and Broilers - Welfare Quality Reports No. 9*. B. Forkman and L. Keeling, eds. SLU Service/Reproenheten, Uppsala, Sweden.
- Carver, D. K., H. J. Barnes, K. E. Anderson, J. N. Petite, R. Whitaker, A. Berchuck, and G. C. Rodriguez. 2011. Reduction of ovarian and oviductal cancers in calorie-restricted laying chickens. *Cancer Prev. Res.* 4:562–567.
- Collins, D. S., and R. J. Huey. 2015. *Poultry production, slaughter and inspection*. Pages 223–248 in *Gracey's Meat Hygiene*. 11th ed. John Wiley & Sons, Ltd., Queensland, Australia.
- Cui, Y., Q. Wang, S. Liu, R. Sun, Y. Zhou, and Y. Li. 2017. Age-related variations in intestinal microflora of free-range and caged hens. *Front. Microbiol.* 8:1310.
- EFSA Panel on Animal Health and Welfare. 2012. Scientific opinion on the use of animal-based measures to assess welfare of broilers. *EFSA J.* 10:2774.
- European Union. 2007. Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production. *Off. J. Eur. Union* L182:19–28.
- Fossum, O., D. S. Jansson, P. E. Etterlin, and I. Vågsholm. 2009. Causes of mortality in laying hens in different housing systems in 2001 to 2004. *Acta Vet. Scand.* 51:3.
- Fulton, R. M. 2017. Causes of normal mortality in commercial egg-laying chickens. *Avian Dis.* 61:289–295.
- Grafl, B., S. Polster, T. Sulejmanovic, B. Pürner, B. Guggenberger, and M. Hess. 2017. Assessment of health and welfare of Austrian laying hens at slaughter demonstrates influence of husbandry system and season. *Br. Poult. Sci.* 58:209–215.
- Grist, A. 2006. *Poultry Inspection: Anatomy, Physiology and Disease Conditions*. 2nd ed. Nottingham University Press, Nottingham, UK.
- Gupta, A. R. 2011. Ascites syndrome in poultry: a review. *Worlds. Poult. Sci. J.* 67:457–467.
- Haslam, S. M., T. G. Knowles, S. N. Brown, L. J. Wilkins, S. C. Kestin, P. D. Warriss, and C. J. Nicol. 2008. Prevalence and factors associated with it, of birds dead on arrival at the slaughterhouse and other rejection conditions in broiler chickens. *Br. Poult. Sci.* 49:685–696.
- Huneau-Salaün, A., K. D. C. Stärk, A. Mateus, C. Lupo, A. Lindberg, and S. Le Bouquin-Leneveu. 2015. Contribution of Meat Inspection to the surveillance of poultry health and welfare in the European Union. *Epidemiol. Infect.* 143:2459–2472.
- Janczak, A. M., and A. B. Riber. 2015. Review of rearing-related factors affecting the welfare of laying hens. *Poult. Sci.* 97:1454–1469.
- Jordan, F. T. W., N. J. Williams, A. Wattret, and T. Jones. 2005. Observations on salpingitis, peritonitis and salpingoperitonitis in a layer breeder flock. *Vet. Rec.* 157:573–577.
- Kajlich, A. S., H. L. Shivaprasad, D. W. Trampel, A. E. Hill, R. L. Parsons, S. T. Millman, and J. A. Mench. 2016. Incidence, severity, and welfare implications of lesions observed Postmortem in laying hens from commercial Noncage farms in California and Iowa. *Avian Dis.* 60:8–15.
- Kaufmann, F., G. Daş, B. Sohnrey, and M. Gaulty. 2011. Helminth infections in laying hens kept in organic free range systems in Germany. *Livest. Sci.* 141:182–187.

- Landman, W. J. M., A. Heuvelink, and J. H. H. van Eck. 2013. Reproduction of the *Escherichia coli* peritonitis syndrome in laying hens. *Avian Pathol.* 42:157–162.
- Landman, W. J. M., and J. H. H. van Eck. 2015. The incidence and economic impact of the *Escherichia coli* peritonitis syndrome in Dutch poultry farming. *Avian Pathol.* 44:370–378.
- Lay, D. C., R. M. Fulton, P. Y. Hester, D. M. Karcher, J. B. Kjaer, J. A. Mench, B. A. Mullens, R. C. Newberry, C. J. Nicol, N. P. O’Sullivan, and R. E. Porter. 2011. Hen welfare in different housing systems. *Poult. Sci.* 90:278–294.
- Newberry, R. C., A. B. Webster, N. J. Lewis, and C. Van Arnem. 1999. Management of spent hens. *J. Appl. Anim. Welf. Sci.* 2:13–29.
- Nijdam, E., E. Delezie, E. Lambooi, M. J. A. Nabuurs, E. Decuyper, and J. A. Stegeman. 2005. Comparison of bruises and mortality, stress parameters, and meat quality in manually and mechanically caught broilers. *Poult. Sci.* 84:467–474.
- Permin, A., M. Bisgaard, F. Frandsen, M. Pearman, J. Kold, and P. Nansen. 1999. Prevalence of gastrointestinal helminths in different poultry production systems. *Br. Poult. Sci.* 40:439–443.
- Petracci, M., M. Bianchi, C. Cavani, P. Gaspari, and A. Lavazza. 2006. Preslaughter mortality in broiler chickens, Turkeys, and spent hens under commercial slaughtering. *Poult. Sci.* 85:1660–1664.
- Reimers, N., D. Carver, and H. J. Barnes. 2019. Emaciation and sporadic mortality in older laying hens caused by intussusception of the proventriculus. *Avian Dis.* 63:107–110.
- Rodenburg, T. B., K. Reu, and F. A. M. Tuytens. 2012. Performance, welfare, health and hygiene of laying hens in non-cage systems in comparison with cage systems. Pages 210–223 in *Alternative Systems for Poultry – Health, Welfare and Productivity*. Poultry Science Symposium Series, vol. 30. V. Sandilands and P. M. Hocking, eds. CAB International, Glasgow, UK.
- Salines, M., V. Allain, H. Roul, C. Magras, and S. Le Bouquin. 2017. Rates of and reasons for condemnation of poultry carcasses: Harmonised methodology at the slaughterhouse. *Vet. Rec.* 180:516.
- Saraiva, S., A. Esteves, C. Saraiva, and F. Seixas. 2013. Reproductive pathology in laying hens – a pilot study. *Reproductive Biology, Biotechnology, animal welfare and Biodiversity*. *Reprod. Biol.* 13(supplement 2):55.
- Saraiva, S., A. Esteves, and G. Stilwell. 2019. Influence of different housing systems on prevalence of keel bone lesions in laying hens. *Avian Pathol.* 48:454–459.
- Saraiva, S., C. Saraiva, and G. Stilwell. 2016. Feather conditions and clinical scores as indicators of broilers welfare at the slaughterhouse. *Res. Vet. Sci.* 107:75–79.
- Sherwin, C. M., G. J. Richards, and C. J. Nicol. 2010. Comparison of the welfare of layer hens in 4 housing systems in the UK. *Br. Poult. Sci.* 51:488–499.
- Stärk, K. D. C., S. Alonso, N. Dadios, C. Dupuy, L. Ellerbroek, M. Georgiev, J. Hardstaff, A. Huneau-Salain, C. Laugier, A. Mateus, A. Nigsch, A. Afonso, and A. Lindberg. 2014. Strengths and weaknesses of meat inspection as a contribution to animal health and welfare surveillance. *Food Control* 39:154–162.
- Sutherland, M. A., J. Webster, and I. Sutherland. 2013. Animal Health and Welfare Issues Facing Organic Production Systems. *Animals* 3:1021–1035.
- Tiwari, A., J. A. Hadley, G. L. Hendricks, R. G. Elkin, T. Cooper, and R. Ramachandran. 2013. Characterization of ascites-derived ovarian tumor cells from Spontaneously occurring ovarian tumors of the chicken: Evidence for E-Cadherin Upregulation. *PLoS One* 8:e57582.
- Urick, M. E., J. R. Giles, and P. A. Johnson. 2008. VEGF expression and the effect of NSAIDs on ascites cell proliferation in the hen model of ovarian cancer. *Gynecol. Oncol.* 110:418–424.
- Vandekerchove, D., P. De Herdt, H. Laevens, and F. Pasmans. 2004. Colibacillosis in caged layer hens: Characteristics of the disease and the aetiological agent. *Avian Pathol.* 33:117–125.
- Wahlström, A., R. Tauson, and K. Elwinger. 2001. Plumage condition and health of aviary-kept hens fed mash or crumbled pellets. *Poult. Sci.* 80:266–271.
- Wang, L., M. Lilburn, and Z. Yu. 2016. Intestinal microbiota of broiler chickens as affected by litter management regimens. *Front. Microbiol.* 7:593.
- Weeks, C. A., S. N. Brown, G. J. Richards, L. J. Wilkins, and T. G. Knowles. 2012. Levels of mortality in hens by end of lay on farm and in transit to slaughter in Great Britain. *Vet. Rec.* 170:647.
- Wezyk, S., J. Krawczyk, J. Calik, and K. Połtowicz. 2006. Relationship between hen age, body weight, laying rate, egg weight and rearing system. *EPC 2006 - 12th Eur. Poult. Conf. Verona, Italy*, 10–14 Sept.
- Yaman, S., and O. S. Yapici. 2019. Bacterial diseases affecting egg production of laying hens. *Dairy Vet. Sci.* 11:555814.
- Zanella, A., G. L. Alborali, M. Bardotti, P. Candotti, P. F. Guadagnini, P. A. Martino, and M. Stonfer. 2000. Severe *Escherichia coli* O111 septicaemia and polyserositis in hens at the start of lay. *Avian Pathol.* 29:311–317.