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Original Article

Relationship Between Pre-Slaughter Factors and Major Causes of Carcass Condemnation in a Broiler Slaughterhouse under Federal Inspection

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Arthritis. Carcass. Myopathy. Quality.

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ABSTRACT

This study aimed to investigate the relationship between pre-slaughter factors and major causes of total or partial carcass condemnation in a broiler slaughterhouse under federal inspection. Data on total and partial carcass condemnations between 2018 and 2020 were collected from 10 broiler farms supplying a slaughterhouse located in northern Paraná State, Brazil. The total sample comprised 2,562,642 birds. The pre-slaughter factors analyzed were age at slaughter, stocking density, weight at slaughter, feed conversion, and mortality.Associations between causes of condemnation and pre-slaughter factors were analyzed using a generalized linear model with negative binomial distribution, a generalized linear model with quasi-Poisson distribution, and a generalized linear mixed model with Poisson distribution. Total carcass condemnations were mostly due to repugnant appearance (48.67%) and arthritis (26.56%), whereas partial carcass condemnations were mainly due to arthritis (31.02%), bruising (27.97%), and myopathies (15.18%). Mean age and stocking density were the pre-slaughter factors that most contributed to increasing total and partial condemnation rates, indicating that reducing stocking density and age at slaughter might be important strategies for minimizing economic losses associated with carcass condemnation.

INTRODUCTION

Chicken meat is widely consumed worldwide because of its high nutritional quality, easy accessibility, and reduced religious restrictions. In Brazil, *per capita* consumption reaches an average of 42.84 kg and chicken meat production holds great economic importance. In 2019, the country produced 13.245 million tonnes of chicken meat and had an export volume of 4.214 million tonnes, ranking as the world's second largest producer and largest exporter (ABPA, 2021).

The quality of chicken meat produced in Brazil is guaranteed by the Federal Inspection Service, responsible fordeciding whether carcasses are suitable for human consumption through criteria defined and established by the Regulatory Requirements for Industrial and Sanitary Inspection of Products of Animal Origin (RIISPOA) (BRASIL, 2017). Inspection includes *ante-* and *post-mortem* steps aimed at identifying animal carcasses that pose a risk to human health. In case of any abnormality, the carcass may be condemned as a whole or in part.

Total condemnation of poultry carcasses is mainly due to repugnant appearance, colibacillosis, contamination, airsacculitis, dehydration, and cachexia (Muchon *et al.*, 2019; Souza *et al.*, 2019), whereas the major causes of partial condemnation include dermatosis, contamination, cellulitis, airsacculitis, and bruising/fracture (Mu-

chon *et al.*, 2019).Causes of condemnation are multifactorial.They may be related to production systems (type of farm, feed management, stocking density), intrinsic to the animal itself (strain, sex, age at slaughter), or associated with problems occurring during slaughter, such as contamination and excessive scalding.

Carcass condemnation represents an important cause of economic lossin the poultry sector. Therefore, it is important to investigate the factors associated with carcass condemnation in order to mitigate losses and support the development of strategies to minimize future occurrences.

In view of the above, this study aimed to assess the relationship between pre-slaughter factors and the major causes of total and partial carcass condemnation of broiler chickens in a commercial slaughterhouse under federal inspection.

MATERIAL AND METHODS

Data collection

Data were collected from a commercial slaughterhouse located in northern Paraná State, Brazil. The slaughterhouse is licensed with the Brazilian Ministry of Agriculture, Livestock, and Food Supply (MAPA) and supervised by the Federal Inspection Service. The plant has a slaughter capacity of 220,000 birds per day.Data were collected from 10 chicken farms supplying the slaughterhouse from February 2018 to May 2020, totaling 110 batches and 2,562,642 birds.

The pre-slaughter factors analyzed were age at slaughter (days), weight at slaughter (kg), total mortality (calculated as the sum of mortality at the farm and during transport) (%), feed conversion, and stocking density (birds/m^2), as described in Table 1.

Slaughtering was performed according to the standard procedures of the slaughterhouse. The steps were as follows: electric stunning, bleeding, scalding, plucking, evisceration, and chiller cooling.

Data on total and partial carcass condemnation were collected from broiler farms in accordance with MAPA regulatory criteria and Decree No. 9,013 of 2017 (BRASIL, 2017). The causes of carcass condemnation were classified as abscess, airsacculitis, arthritis, repugnant appearance, cachexia, cellulitis, colibacillosis, contamination, bruising, dermatosis, dehydration, excessive scalding, delayed evisceration, fracture, poor bleeding, myopathy, salmonellosis, salpingitis, septicemia, andascitic syndrome.

Table 1 – Pre-slaughter factors of broiler chickens from 10 commercial farms supplying a slaughterhouse under federal inspection in Paraná State, Brazil, between February 2018 and May 2020.

Factor	Mean	Min	Max
Age (days)	48.228	43.000	57.000
Mean weight (kg)	3.480	2.749	4.220
Total mortality (%)	4.008	1.100	10.000
Feed conversion	1.730	1.584	1.950
Stocking density (birds/m^2)	12.020	5.080	17.920

Values are presented as mean, minimum, and maximum values.

Data analysis

Total and partial carcass condemnation data were subjected to descriptive analysis. Results are presented as frequencies (percentages), calculated from the ratio of the number of condemnations for a specific cause to the total number of condemnations.

A generalized linear model with negative binomial distribution, a generalized linear model with quasi-Poisson distribution, and a generalized linear mixed model with Poisson distribution (Faraway, 2016) were used to assess associations between causes of carcass condemnation and the pre-slaughter factors described in Table 1. Analyses were performed using RStudio software version 1.1.456 (R Core Team, 2018).The regression coefficient of each pre-slaughter factor was calculated to measure its strength of association with the response variable (cause of condemnation).

RESULTS AND DISCUSSION

Of the 2,562,642 slaughtered birds, 13,604 were fully condemned (0.53%) and 252,918 were partially condemned (9.87%). Similar results were described by Jaguezeski *et al.* (2020), who analyzed data from a slaughterhouse in western Paraná State from April 2015 to March 2016. The authors found that 0.41% of birds were fully condemned and 12.81% were partially condemned.

Of all condemnations (n = 266,522), 5.1% were total and 94.9% were partial. Partially condemned carcasses can still be used for human consumption, minimizing economic losses. Oliveira *et al.* (2016) assessed 1,612,647,133 carcasses condemned from 2006 to 2011 in Brazil and found that 85% were partially condemned and 15% were fully condemned.

As shown in Figure 1, the major causes of total condemnation were repugnant appearance, with 6,622 cases (48.67%), followed by arthritis, with 3,615 cases (26.56%), ascites, with 895 cases (6.84%), cachexia, with 781 cases (5.74%), excessive scalding,

with 733 cases (5.39%), and poor bleeding, with 642 cases (4.72%).

Repugnant appearance was also the major cause of total condemnation in a study by Souza *et al.* (2019), carried out from 2013 to 2017 in Brazil. Any change in carcass color, odor, or appearance, stemming from diseases, technopathies, or quality defects, can lead to condemnation for repugnant appearance (BRASIL, 2017). Given the diversity of the causes of repugnant appearance, it is difficult to control this factor.

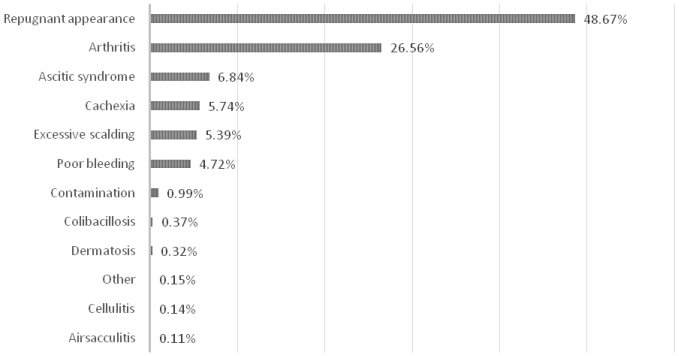

Figure 1 – Most frequent causes of total carcass commendations (%) of broilers (*n*= 13,604) from 110 batches of a slaughterhouse under federal inspection in Paraná State, Brazil, between 2018 and 2020.

Arthritis, the second largest cause of total carcass condemnation, is a growing concern in the global poultry industry because it leads to economic losses and poses a risk to public health. The disease not only affects slaughterhouses but may also impair animal performance or lead to death, given that affected broilers cannot feed or drink water properly, being predisposed to other diseases (Assunção *et al.*, 2018). Arthritis is difficult to control, as there are numerous infectious agents capable of causing the disease and individual and environmental factors that may contribute to disease onset, such as high weight gain, inadequate bed management, inadequate ventilation, high thermal amplitude, and severe winter conditions (Sellers, 2017; Marcon *et al.*, 2019).

The third cause of total condemnation was ascites (6.84%). Similar results were obtained by de Muchon *et al.* (2019), who found that the condition was responsible for 6.83% of condemnations between 2004 and 2014 in a slaughterhouse in Grande Dourados, Mato Grosso do Sul State. Genetic and environmental factors, such as strain (heavy broilers with metabolic overload), high thermal amplitude, and low temperatures contribute to ascites development, as they lead to hypoxia (Jaenisch *et al.*, 2001; Rosário *et al.*, 2004).

The following three causes of total condemnations had similar frequencies, namely cachexia (5.74%), excessive scalding (5.39%), and poor bleeding (4.72%). Carcasses affected by cachexia exhibit intense loss of muscle and fat (Rabaiolli *et al.*, 2016), caused by inadequate feed supply or diseases that affect organism functioning (BRASIL, 2017). Excessive scalding produces multiple lesions resulting from high scalding time/temperature (BRASIL, 1998). Inadequate or incomplete bleeding is identified by reddish areas on chicken skin (Freitas, 2015). Souza *et al.* (2019) found that excessive scalding, cachexia, and poor bleeding were responsible for 9.77%, 6.63%, and 4.30%, respectively, of total condemnations in a slaughterhouse in Paraná State.

The major causes of partial condemnation were arthritis (31.02%, *n* = 78,454), followed by bruising (27.97%, *n* = 70,749), myopathy (15.18%, *n* = 38,403), fracture (11.11%, *n* = 28,088), and cellulitis (9.00%, *n* = 22,761)(Figure 2). Muchon *et al.* (2019) classified the causes of condemnation recordedin a Brazilian slaughterhouse into two groups: (i) pre-fasting condemnation rates, associated with the poultryfarm, and (ii) post-fasting condemnation rates, associated with the slaughterhouse. In the first category, the major causes for partial condemnation were dermatosis (40.23%), airsacculitis(27.75%), and cellulitis (29.69%), whereas, in the second category, the major causes were contamination (76.90%) and bruising/fracture (22.70%). Our results agree with these findings, given that cellulitis, bruising, and fracture were among the main causes of partial condemnation. According to Paschoal *et al.* (2012), bruising/fracture (54.38%) and cellulitis (13.66%) were the main causes of partial condemnation between January 2011 and October 2012 in a slaughterhouse in northwestern Paraná State.

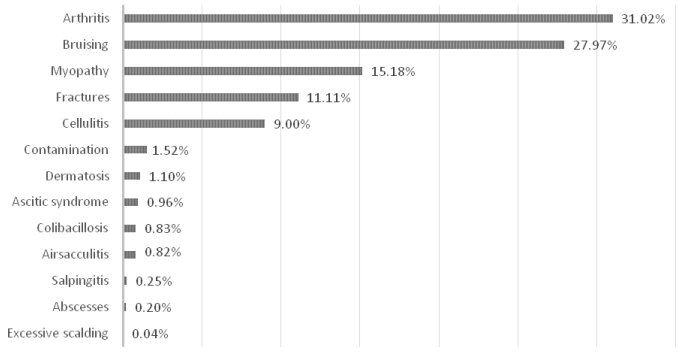

Figure 2 – Most frequent causes of partial carcass commendations (%) of broilers (*n*=252,918) from 110 batches of a slaughterhouse under federal inspection in Paraná State, Brazil, between 2018 and 2020.

Candido *et al.* (2021) assessed slaughterhouses under federal inspection in Espírito Santo State and found that bruising was the major cause of partial

condemnation. The authors also reported an increase in the occurrence of condemnation for myopathy, from 1.05% in 2018 to 4.77% in 2019. Myopathies are associated with rapid growth, a frequent occurrence in modern broilers, explaining the high frequency of these conditions in the majority of slaughterhouses in Brazil (Zanetti *et al.*, 2018).

Correlations between pre-slaughter factors (mean age, stocking density, mean body weight, feed conversion, and mortality) and the major causes of total condemnation are described in Table 2. Broiler age was correlated positively with cachexia and negatively with ascites, indicating that older age may increase condemnation for cachexia and decrease that for ascites. According to Duarte & Santana (2019), older animals are more susceptible to certain diseases and infections, which might be associated with condemnation for cachexia, given that the condition is caused by diseases such as colibacillosis (Duarte & Santana, 2019) and Marek's disease (Tambiev *et al.*, 2021). The decrease in condemnation for ascites with increasing age ($p<0.05$) might be due to the fact that ascites occurs mainly in birds aged 8 to 21 days. As affected birds grow older, they are more likely to be discarded as refuse or may even die as a result of the disease (Jaenisch *et al.*, 2001; Rosário *et al.*, 2004).

Table 2 – Relationships between pre-slaughter factors and major causes of total carcass condemnation of broilers from 110 batches of a slaughterhouse under federal inspection in Paraná State, Brazil, between 2018 and 2020.

Cause of condemnation	Mean age	Stocking density	Mean weight	Feed conversion	Mortality
Repugnant appearance	0.0696	0.1448[a]	–0.3221	–2.3547	0.0229
Cachexia	0.1581[a]	0.0143	–0.7011	–3.1722	0.0293
Poor bleeding	0.1006	0.0628	0.2019	–2.3183	0.2019[a]
Ascitic syndrome	–0.1101[a]	0.0933[a]	0.7171[a]	2.3758[a]	–0.0001
Overall total condemnation	0.0301	0.1250[a]	1.3067	–1.4561	0.071

[a]Significant at the 5% level by a generalized linear mixed model with Poisson distribution.

High stocking density was associated ($p<0.05$) with increased condemnation for repugnant appearance and ascites as well as withoverall total condemnation. Stocking density is a crucial factor in the poultry industry; excessively high densities may affect animal health, yield (Bilal *et al.*, 2021), biochemical parameters, reproductive performance (Ying *et al.*, 2021), condemnation rates, and mortality (Bergeron *et al.*, 2020), thereby leading to economic losses. It is difficult to establishthe optimal stocking density, given that this quantitative measure depends on qualitative factors, such as environmental and sanitary conditions. Ascitic syndrome is directly related to hypoxia, and several factors may reduce oxygen availability, including respiratory problems and poor air quality (Jaenisch *et al.*, 2001; Rosário *et al.*, 2004; Biswas, 2019) stemming from high stocking densities.

High body weight was also associated with increased condemnation ($p<0.05$) for ascites (Table 2), probably related to excessive oxygen expenditure by metabolic overload resulting from weight gain (Jaenisch *et al.*, 2001; Rosário *et al.*, 2004; Biswas, 2019). Contrary to the expected, feed conversion was positively associated ($p<0.05$) with condemnation for ascites. Hasani *et al.* (2017) and Das & Deka (2019) described ascitic syndrome as a serious disease of fast-growing chickens. Several factors can contribute to the development of the syndrome, namely sex, thermal amplitude, time of year, climate, respiratory problems, and air quality, which were not addressed in this study.

Mortality was associated with condemnation for poor bleeding (Table 2). It is hypothesized that blood loss might be impaired in unhealthy or stressed animals during bleeding procedures at the slaughterhouse.

Table 3 shows the correlations between pre-slaughter factors (mean age, stocking density, mean body weight, feed conversion, and mortality) and major causes of partial condemnation. Age was associated with increased condemnation for arthritis ($p<0.05$). In fact, according to Kieronczyk *et al.* (2017), aging has a major impact on skeleton development and joint problems in chickens.

Stocking density was associated with increased ($p<0.05$) partial condemnation for abscess, arthritis, bruising, dermatosis, fracture, and ascites. High stocking densities are associated with animal welfare problems (Avilés-Esquivel *et al.*, 2018), which may culminate in bed compaction, increased microbial load, and increased humidity, factors associated with the onset of arthritis, dermatosis, and ascites. It is also noteworthy that arthritis was the major cause of partial condemnation (Figure 2). Therefore, it is important to reduce stocking density to improve animal welfare and minimize losses caused by condemnation (Bergeron *et al.*, 2020).

Table 3 – Relationships between pre-slaughter factors and major causes of partial carcass condemnation of broilers from 110 batches of a slaughterhouse under federal inspection in Paraná State, Brazil, between 2018 and 2020.

Cause of condemnation	Mean age	Stocking density	Mean weight	Feed conversion	Mortality
Abscesses	–0.1253	0.1099[a]	1.2734	1.9218	0.0279
Airsacculitis[a]	0.0783	0.0421	–1.027	0.2175	–0.0993
Arthritis	0.2638[a]	0.1000[a]	–1.3484	–3.7879[a]	0.0119
Cellulitis[a]	0.1275	0.0106	–1.2153	–2.3927	0.0355
Colibacillosis[a]	–0.0698	0.0471	0.2639	3.6407	–0.0049
Contamination	0.0737	0.0593	0.962	–7.6399[a]	0.1686[a]
Bruising	0.1201	0.1225[a]	–0.5669	–3.1733[a]	0.035
Dermatosis	0.064	0.2254[a]	–0.1165	4.1915	–0.0666
Fracture	–0.0221	0.0897[b]	0.9694	–1.5813	0.0134
Myopathy	0.0461	0.0443	0.1993	–3.2825[c]	0.1095[c]
Ascitic syndrome	–0.0672	0.0956[a]	–0.1602	1.0465	0.1487[a]
Overall partial condemnation	0.1040[b]	0.0964[b]	–0.2826	–2.6078[b]	0.0159

[a]Significant at the 5% level by a generalized linear mixed model with Poisson distribution.

[b]Significant at the 5% level by a generalized linear model with quasi-Poisson distribution.

[c]Significant at the 5% level by a generalized linear model with negative binomial distribution.

Mean body weight did not influence (p>0.05) partial condemnation rates. However, worstfeed conversion led to a reduction (p<0.05) in partial condemnation for arthritis, contamination, bruising, and myopathy. Arthritis is an inflammatory process that leads to reduced feed intake, thereby affecting feed conversion, even when related parameters, such as weight gain, are low (Assunção *et al.*, 2018). Genetic selection for improved feed conversion might be associated with the occurrence of diseases, quality defects (Zanetti *et al.*, 2018; Granquist *et al.*, 2019), and rapid growth (Soglia *et al.*, 2018; Zanetti *et al.*, 2018), particularly in high-yielding strains (Assis *et al.*, 2019), thereby explaining the reduction in condemnation for contamination, bruising, and myopathies.

Total mortality was positively associated (p<0.05) with partial condemnation for contamination, myopathy, and ascites. Total mortality is multifactorial. Cadmus *et al.* (2019) observed that the major causes of mortality in chickens in the United States of America from 2015 to 2017 were neoplastic and lymphoproliferative diseases, followed by infectious and non-infectious diseases. Thofner *et al.* (2019), in analyzing four batches in Denmark, found that 55% of birds were killed by infectious diseases, 41% by non-infectious diseases, and 4% by unknown causes. Furthermore, the authors observed a peak in mortality at 40–49 weeks of age. Brochu *et al.* (2019) described that the major cause of mortality over a 2-year period (October 2015 to September 2017) in Ontario was infectious diseases, mainly respiratory diseases and Marek's disease. It is possible that birds from farms with high mortality rates may be carriers of infectious or non-infectious diseases, which would explain the increase in condemnation for contamination.

Of the pre-slaughter factors assessed here, stocking density was associated with the largest number of condemnation causes, including repugnant appearance (first cause of total condemnation), arthritis (second cause of total condemnation), bruising, and fracture (second and fourth cause of total condemnation, respectively), demonstrating the importance of controlling this parameter to minimize economic lossesin poultry production.

CONCLUSION

Total condemnation was mainly due to repugnant appearance (48.67%) and arthritis (26.56%), and partial condemnation was mainly caused by arthritis (31.02%), bruising (27.97%), and myopathy (15.18%). Broiler age and stocking density were the pre-slaughter factors that most contributed to total and partial condemnations. Thus, a reduction in stocking density and age at slaughter might reduce economic losses associated with condemnation.

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