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The prevalence, and factors associated with it, of birds Dead on Arrival at the slaughterhouse and other rejection conditions in broiler chicken

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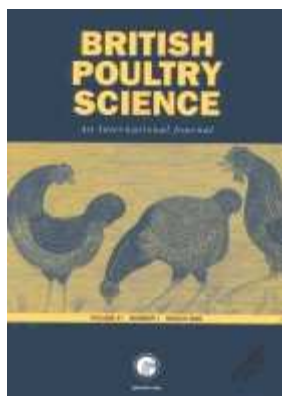
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Deleted: The p

1 **Prevalence and factors associated with it, of birds dead on arrival at the**
2 **slaughterhouse and other rejection conditions in broiler chicken**

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11 Running head: HUSBANDRY AND BROILER REJECTION CONDITIONS

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28 **Abstract** 1. Standardised data on husbandry were recorded for a flock of birds in one
29 house on each of 150 broiler farms in the UK during the 4 d prior to slaughter.

30 2. For each flock, the incidence of birds found dead on arrival (DoAs) and the Meat
31 Hygiene Service carcase rejection records were recorded at the slaughterhouse.

32 3. The mean percentage of birds in each flock found DoA was 0.12% (range 0% to
33 0.64%) and the mean percentage of Total Carcass Rejects (TCRs) for each flock was
34 1.23% (range 0.07% to 5.51%).

35 4. A general linear model was developed to examine factors associated with flock
36 percentage DoAs. Assuming a linear relationship, all other factors remaining the same, a
37 one percentage point (PP) increase in small/emaciated birds will result in a 0.155 PP
38 increase in DoAs and a 1 PP increase in wheat in diet 4 will result in a 0.003 PP decrease.
39 An increase by one in the total number of vaccines administered will cause a 0.029 PP
40 decrease in DoAs, a 1 g increase in live weight at slaughter will be associated with a
41 0.000043 PP increase and a 1 PP increase in mortality on farm would be associated with a
42 0.000044 PP increase. A 1 PP increase in Ross birds decreases DoAs by 0.0004 PPS:
43 there is also a seasonal effect.

44 5. The model developed for flock percentage TCRs found that a 1 PP increase in wheat in
45 the diet 3 will result in a 0.052 PP decrease in TCRs and a 1 PP increase in Ross birds
46 will cause a 0.009 PP decrease. A 1 PP increase in birds culled on farm will be
47 associated with a 0.03 PP increase in TCRs and the diagnosis of disease during the flock
48 cycle increases TCRs by 0.397 PPs. A one day increase in age at slaughter will result in a
49 0.046 PP increase in TCRs.

51 INTRODUCTION

52 Loss of birds due to death during transport and carcase rejects due to downgrading
53 conditions are an appreciable cause of loss of income for the broiler industry as well as
54 reflecting poor bird health and welfare on farm or during transport. Several authors have
55 used carcase downgrading and reject data to assess bird health and welfare on farm.
56 Yogaratnam (1995), for example, measured incidence of bacterial chondronecrosis in
57 broiler chickens at the slaughterhouse and ascites in the Canadian broiler flock has been
58 monitored using condemnation records from the slaughterhouse (Olkowski *et al.*, 1996).

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59 The causes of cellulitis in broilers have been investigated by examination of condemned
60 carcasses at the slaughterhouse (Elfadil *et al.*, 1996) and, more recently, trends in the
61 prevalence of cellulitis have been monitored by carcass inspection at the slaughterhouse
62 (St-Hilaire and Sears, 2003). Surveys of overall carcass condemnation at the
63 slaughterhouse have been used to monitor disease management on farm (Ansongdanquah,
64 1987) and to compare the management of poultry in standard, vegetarian-fed and free
65 range systems (Herenda and Jakel, 1994). There is also evidence that carcass
66 condemnation rates, in terms of total carcass rejects (TCRs) and number of birds found
67 dead on arrival (DoAs) at the plant, may reflect leg weakness on farm (Haslam, 2003).

68 Hall (2001) monitored the prevalence of wing and leg bruising, breast blisters,
69 hock burn and back scratches at the plant and found that these were higher in birds at a
70 stocking density of 34 kg per m² than those at 30 kg per m². In addition, rates of carcass
71 condemnation have been found to reflect certain housing conditions on farm, including
72 litter quality and atmospheric ammonia concentrations (Xin *et al.*, 1996). However,
73 many of these studies are old and may not be relevant to current bird genotypes and
74 contemporary husbandry systems, or are based on studies carried out in countries other
75 than the UK, where husbandry systems, bird stocking densities and slaughter weights
76 may differ from those usual in the UK broiler industry.

77 The provisions of the recently-agreed EU Broiler Directive require monitoring of
78 the prevalence of DoAs and carcass *post mortem* findings at the slaughterhouse but also
79 limit mortality rates on farm for farmers wishing to stock at densities higher than 39 kg
80 per m². The Directive requires that Member States regularly monitor premises stocking at
81 the higher densities and ensure that documentation accompanying birds from high density
82 flocks to the slaughterhouse includes daily and cumulative mortality.

83 The Official Veterinarian at the slaughterhouse is required to supervise collection
84 of records of DoAs and results of post mortem examination for each flock, including
85 contact dermatitis, parasite infestation and disease conditions. Where bird health and
86 welfare during the flock cycle appear, from the mortality and *post mortem* results, to have
87 been poor, the Official Veterinarian is obliged to inform the farmer and, if necessary, the
88 Competent Authority, which may take appropriate enforcement action. Such action may
89 include reduction in stocking density permitted for farms stocking at the higher densities.

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90 It is therefore necessary for enforcement bodies to know the normal mean and range of
91 flock percentage DoAs and carcass reject conditions in the UK flock in order to judge the
92 relative severity of these measures for reported flocks.

93 At the onset of this study, the current prevalence of carcass rejects, DoAs and
94 other conditions which cause carcasses to be rejected for human consumption in the UK
95 was not known. Aspects of catching, transport and lairage which affect rates of DoAs are
96 well established, reviewed by Baylis and Hinton (1990). However, there was insufficient
97 scientific evidence of the extent to which the prevalence of DoAs and carcass
98 downgrading, recorded at the slaughterhouse, is affected by different aspects of
99 husbandry, including stocking density on farm, or how they reflect leg health and other
100 aspects of bird welfare.

101 This paper reports on a study to determine the prevalence of DoAs and other
102 classes of carcass reject in the UK broiler flock, investigates the extent to which the
103 prevalence of DoAs and carcass rejects reflects bird health and welfare on farm, and
104 examines the effect of various aspects of flock health and husbandry on these. In the UK,
105 the data which will be used for enforcement action under the Broiler Directive will be
106 that recorded by Meat Hygiene Service (MHS) personnel or by plant personnel
107 supervised by the MHS. For this reason, MHS rejection data for the flocks examined on
108 the farm were used in this study.

109 110 MATERIAL AND METHODS

111 This study made use of some of the data collected for a large, on-farm, epidemiological
112 study of broiler leg health (Knowles *et al.*, 2008). Five major UK broiler companies took
113 part in these studies: these companies allowed access to any of their contract or company
114 farms and to their slaughterhouses. A random selection of farms was surveyed. The 5
115 companies supplied full lists of their farms. Flock visits by assessors were randomised to
116 farms and to a unit within the farm. The number of farms visited per company was
117 weighted by the number of birds produced by each company. The survey unit was a flock
118 of birds within a growing house within a farm: a total of 206 visits were made to each of
119 206 flocks, which were timed to occur within 4 d before slaughter.

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2 120 Farm data were collected by veterinary surgeons with postgraduate qualifications
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4 121 in Poultry Medicine and Production or Welfare Science, Ethics and Law. The survey
5
6 122 team was comprised of 18 veterinary surgeons from a wide variety of backgrounds. The
7
8 123 training, standardisation and re-standardisation of the survey team in data collection
9
10 124 protocols, including gait scoring, has been described by Haslam *et al.*, (2007).

11 125 Each farm visit consisted of three main stages: completion of an epidemiological
12 126 recording form, with the assistance of a representative of the farm, which provided a
13 127 description of the farm, house and flock; assessments made by the recorder alone; and,
14 128 assessment of the gait score of 250 birds, selected at random, within one house.

15
16 129 The on-farm recording form consisted of 134 questions and included: parent flock
17 130 information, including genotype/strain, health history and age; hatchery information,
18 131 including hatchery, distance and time transported and hatchery chick vaccination
19 132 programme; general information including number and weight of chicks placed, sex, time
20 133 of year, age at assessment and slaughter; specific husbandry practices including stocking
21 134 density and thinning practice; brooding conditions; a detailed nutritional profile,
22 135 including type of feed (pellet or meal) and percentage of whole or cracked wheat in each
23 136 of the feeds provided successively through the flock cycle; litter substrate; feeder and
24 137 drinker design and type; lighting programme; house age and construction details; target
25 138 temperature and ventilation profiles; water source; and, vaccination programme,
26 139 coccidiostats used, diseases diagnosed during the flock cycle and medication history.
27 140 During this visit, information on flock performance was collected, from house
28 141 documentation, including growth profile from weekly weighing, weekly mortality
29 142 pattern, weekly cull patterns, categorised by cause for culling and the number and weight
30 143 of birds removed during the flock cycle ('thinned'). Background information about the
31 144 management of the flock, was also recorded, including: bird:stockperson ratios; age and
32 145 broiler growing experience of stock people and their training and qualifications;
33 146 background information about the site and company, including size of sheds, number of
34 147 birds on site; and, types of biosecurity measures in place. Fifteen additional assessments
35 148 were made by the recorder alone, covering aspects such as air quality, cleanliness and
36 149 feed quality. Air quality, cleanliness and feed quality were assessed on 4-point simple
37 150 descriptive scales. Two hundred and fifty birds were gait scored within the house,
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3 151 selected at random, by reference to a pre-randomised location identifier. Birds were
4 152 selected from 10 locations, in groups of 25 to 30, by corralling at each location using a
5 153 hinged catching pen. Each bird was individually encouraged to walk out of the pen and
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7 154 was scored as it did so (Knowles *et al.*, 2008). At each location, litter quality was
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9 155 assessed by the method described by Tucker and Walker (1992) and Gordon and Tucker
10 156 (1993) on a Numerical Rating Scale of between 1 (dry and crumbly) and 5 (capped and
11 157 wet).

12
13 158 Of the 206 flocks visited on farm, 150 flocks were followed through the
14 159 slaughterhouse. Foot pad dermatitis and hock burn were measured, by trained,
15 160 standardised recorders, using standardised photographic scales to assign lesion scores, by
16 161 the methods described by Haslam *et al.* (2007). When the entire flock had been
17 162 processed, the recorder collected the Meat Hygiene Service (MHS) carcass rejection data
18 163 recorded by MHS personnel on the plant, including the total number of carcasses rejected,
19 164 the number of birds found DoA and the number birds classified as small or emaciated.

20 165 **Data analysis**

21 166 For each flock, DoA and carcase reject data recorded at the slaughterhouse were collected
22 167 in a summary categorisation system, based on the UK MHS carcase condemnation
23 168 categories, which allowed direct comparison between flocks using MHS reject data. The
24 169 8 summary rejection categories included all of the plant categories given by all of the
25 170 plants to similar lesions: descriptions of each category and the terms used by different
26 171 plants to describe these are given in Table 1. Rejection categories unrelated to bird health
27 172 and welfare, including 'machine damage' and 'contamination' were excluded from the
28 173 dataset. The reasons for capturing data in summary categories and the reliability of
29 174 measurement of the different categories of reject between slaughterhouses are discussed
30 175 later.

31 176 An Excel (Microsoft 2000) spread sheet was developed to process the MHS data
32 177 into summary categories: reject category domains were defined to capture the MHS data
33 178 from individual plants into the appropriate summary reject category, using nested
34 179 formulae. This was then converted to a percentage of the total number of birds processed
35 180 from the subject house, in order to allow comparison of reject data between
36 181 slaughterhouses.

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2 182 The mean, standard error and range of each reject category, including DoAs, were
3 183 calculated.

4 184 Several measures of stocking density were calculated, including: stocking rate
5 185 (birds placed per square metre); Biological Load Index (BLI) (stocking rate minus
6 186 mortality x weight at kill); stocking density (bird weight per square metre) at age of
7 187 inspection; stocking density at kill; projected stocking density at kill on the day of the
8 188 farm visit; stocking density prior to each thinning; average stocking density prior to
9 189 thinning; and highest stocking density throughout the flock cycle. These were calculated
10 190 using recorded or predicted weights and bird numbers at the specific times during the
11 191 flock cycle, recorded during the farm visits. Predicted weights were calculated using
12 192 standard growth curves. Bird numbers were adjusted according to mortality figures and
13 193 birds removed during previous thinning, as recorded on house records. The utility and
14 194 accuracy of using BLI in analysis of these data is discussed later.

15 195 The average litter quality score was calculated as the mean of the individual litter
16 196 scores.

17 197 The plant data were analysed in conjunction with data gathered during farm visits.
18 198 Scatterplots were first examined for all correlations to check for any linear or non-linear
19 199 relationships between the variables. Bivariate correlations were calculated between DoAs
20 200 and TCRs and all remaining variables, including each measure of stocking density, bird
21 201 weight and age, mean gait score on farm and mean litter quality score. The Spearman's
22 202 rho statistic, which is appropriate for analysis of bivariate correlations between variable
23 203 which are expressed as a percentage and close to zero, was calculated for each significant
24 204 correlation, to give an indication of the strength of the associations.

25 205 General linear models were then constructed, using the GLM Univariate Procedure
26 206 within the software package SPSS 14.0 for Windows, to determine the aspects of house
27 207 specification and flock husbandry which accounted for most of the variability found in
28 208 the data associated with the incidence of flock percentage DoAs and the percentage TCRs
29 209 rejects. Fifty one variables, which were measures of house husbandry and bird health,
30 210 were studied, of which 29 had a significant bivariate correlations with DoAs and 14 had
31 211 significant correlation with TCR. These subsets of variables were used for the initial
32 212 exploration of the models. Variables were retained in the model if their significance in the

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2 213 model was less than or equal to 0.05. To achieve the final models an iterative process was
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4 214 used which included examining models produced by both forward and backward stepwise
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6 215 procedures. Variables were retained in the model based on their significance and whether
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8 216 they appreciably improved the percentage of the variability in the data accounted for by
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10 217 the model. Variables which were close to significant ($P=0.05-0.1$) were reintroduced
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12 218 individually into the model as a last stage in the procedure to ensure that no significant
13
14 219 relationships were overlooked.

15
16 220 The regression coefficients (B) for each variable included in the final model form an
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18 221 equation in which the coefficient for a variable corresponds to the predicted change in
19
20 222 percentage DoAs (or percentage TCRs) given a unit change in the variable. Clearly, due
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22 223 to the survey nature of this study, explanatory variables in the models are not necessarily
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24 224 causative and can only be said to be 'associated' with DoA or TCRs.

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26 225 Data were collected from 8 different slaughterhouses belonging to 5 different
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28 226 companies, between September 2003 and March 2005, regularly throughout the year:
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30 227 visits were suspended between the end of the standardisation period, February 2003, and
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32 228 September 2003 due to the risk of spreading avian influenza and the occurrence of a heat
33
34 229 wave. DoA and carcass reject data were collected from approximately 1 679 900 birds.
35
36 230 Foot pad dermatitis and hock burn data were collected from approximately 149 000 birds.

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RESULTS

233 **Descriptive statistics and distribution frequencies**

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42 234 The prevalence of all reject categories, expressed as a percentage of total birds, was low
43
44 235 and skewed to the left. The mean, standard error and range of each reject category are
45
46 236 summarised in Table 2. Thus, for the UK flocks studied, the mean percentage of DoAs
47
48 237 was 0.12% (range 0% to 0.64%) and the mean percentage of TCRs for each flock found
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50 238 was 1.23% (range 0.07% to 5.51%). The greatest cause of rejection was acute internal
51
52 239 pathology, with a mean rejection rate of 0.44% of all birds slaughtered from the flock
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54 240 (range 0% to 5.03%). Small/emaciated birds was the next most important cause of
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56 241 rejection, with a mean of 0.21% and ascites and skin condition/abscess, were also fairly
57
58 242 important, both accounting for a mean of 0.18% of total birds.
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1
2 243 The frequency distributions for flock percentage DoAs and percentage TCRs from
3 244 this study are presented on Figures 1 and 2.

4 245 **Bivariate correlations**

5 246 Significant bivariate correlations, and Spearman's rho statistic, between average weight
6 247 and age at slaughter with TCRs and percentage of birds in individual reject categories,
7 248 including DoAs, ascites and acute internal pathology, are presented in Table 3. From
8 249 Table 3, it is clear that many reject measures, including percentage DoAs, are positively
9 250 correlated with both bird weight and age at slaughter: ascites and chronic pathology
10 251 showed the strongest and most significant associations, although the absolute number of
11 252 birds recorded with chronic pathology was very low and so this correlation may be
12 253 spurious.

13 254 The significant bivariate correlations, and Spearman's rho statistic, between TCRs
14 255 and the different categories of reject with percentage mortality on farm, mean bird gait
15 256 score measured on farm, contact dermatitis measured on plant and several measures of
16 257 stocking density, are presented in Table 4. Percentage DoAs showed a fairly strong,
17 258 significant, positive correlation with percentage bird mortality on farm. Percentage bird
18 259 mortality on farm was also very significantly, positively correlated with several
19 260 categories of carcass reject measured on plant, including TCRs, ascites and chronic
20 261 pathology. Both percentage DoAs and percentage total TCRs were positively correlated
21 262 with average gait score of birds, measured on farm.

22 263 Percentage DoAs, percentage of TCRs, ascites, and chronic pathology were
23 264 significantly positively correlated with average hock burn score, although these
24 265 correlations tended to be weak (Spearman's rho 0.2-0.3) or fairly weak (Spearman's rho
25 266 0.3-0.4). The percentage of small emaciated birds was weakly, negatively associated
26 267 with mean hock burn score and the prevalence of bruising was negatively correlated with
27 268 foot pad dermatitis score. Significant weak or very weak (Spearman's rho 0.1-0.2),
28 269 negative correlations were also found between percentage of TCRs and several measures
29 270 of stocking density, including stocking density calculated using average *post mortem*
30 271 weight at inspection, stocking density calculated using weight at slaughter and average
31 272 stocking density prior to thinning: these associations were unexpected. Percentage of
32 273 TCRs was fairly weakly, significantly correlated with BLI.

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274 Multiple regression models

275 The GLM Univariate procedure provides regression analysis for one dependant variable
276 by one or more variables. Multiple regression calculations are largely robust for
277 departures of a variable from a normal distribution. Inspection of the residuals from the
278 models developed for flock mean DoAs and TCRs indicated that these variables could
279 satisfactorily be treated as continuous. The univariate model developed to account for the
280 variability in the data with respect to flock mean DoAs is presented in Table 5.

281 Thus, the percentage of small emaciated birds, the percentage of wheat in diet 4, the
282 total number of vaccinations, live weight at slaughter, the percentage of Ross birds, the
283 percentage mortality on farm and the season of the year accounted for 40.5% of the
284 variability in levels of DoAs between flocks. The equation for the model for DoAs is:

$$\begin{aligned} 285 \\ 286 \text{DoAs} = & 0.151 + 0.155 \text{ SMLLRCTS} - 0.003 \text{ WHEATDT4} - 0.029 \text{ TNVAC} \\ 287 & 0.000043\text{LIVWTATSLTER} - 0.0004 \text{ GENOTYPAPC} + 0.000044\text{MORTPC} + \\ 288 & 0.018 \text{ SIN} \end{aligned}$$

289 where

290 DoAs = percentage of birds dead on arrival at the slaughterhouse

291 SMLLRCTS = percentage of birds rejected due to small size or emaciation

292 WHEATDIET4 = percentage of whole or cracked wheat in diet 4

293 TNVAC = total number of vaccinations administered to the flock

294 LVEWTATSLTER = mean live weight at slaughter

295 GENOTYPAC = percentage of birds in the flock which were genotype A

296 MORTPC = percentage of birds dying on farm during the flock cycle

297 SIN = sinusoidal curve accounting for seasonal effect

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299 Thus, assuming a linear relationship, all other factors remaining the same,
300 an increase in percentage of small and emaciated birds of 1 percentage point (PP) will
301 result in a increase in DoAs of 0.155 PP, an increase in the percentage of wheat in diet 4
302 of 1 PP will result in a decrease in DoAs of 0.003 PPs and an increase in the total number
303 of vaccinations of one will decrease DoAs by 0.029 PP. Similarly, an increase in average
304 live weight at slaughter of one gram within an average flock will cause an increase in

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3 305 DoAs of 0.0004 PP. Percentage of DoAs was also affected by bird genotype, with an
4 306 increase of 1 PP of Ross birds causing a reduction of 0.0004% in an average flock. An
5 307 increase in percentage mortality on farm of 1 PP was also associated with an increase in
6
7 308 DoAs of 0.0004 PP. There was an effect of season on DoAs, with a higher prevalence
8
9 309 being found in the summer months.

10 310 The univariate model developed to account for the variability in the data
11 311 with respect to TCRs is presented in Table 6. Thus, age of the birds at slaughter, the
12 312 percentage of wheat in diet 3, the percentage of Ross, rather than Cobb, birds, the
13 313 occurrence of disease during the flock cycle and the percentage of birds culled accounted
14 314 for 19.2% of the variability in rates of TCRs between flocks. The equation for the model
15 315 for percentage TCRs is:

16 316
17 317
$$\text{PCTCRs} = 0.194 - 0.053\text{WHEATDT3} - 0.009\text{GENOTYPEAPC} + 0.03\text{CULLPC} + +$$

18 318
$$0.379\text{ANYDISEASE} + 0.046\text{AGE AT SLAUGHTER}$$

19 319 where

20 320 PCTCRs = total percentage of carcasses rejected for human consumption at the
21 321 slaughterhouse

22 322 WHEATDIET3 = percentage of whole or cracked wheat in diet 3

23 323 GENOTYPAPC = percentage of Ross birds in flock

24 324 ANYDISEASE = disease recorded in the live birds during the flock cycle at any time

25 325 CULLPC = percentage of birds culled for any reason during the flock cycle
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36 327 Thus, assuming a linear relationship, all other factors remaining the same,
37 328 an increase in the percentage of wheat in diet 3 of 1 PP will result in a decrease in TCRs
38 329 of 0.053 PPs. Similarly, an increase in the percentage of Ross birds will cause a decrease
39 330 in TCRs of 0.009 PPs. An increase in percentage of birds culled on farm by 1 PP will be
40 331 associated with an increase in TCRs of 0.03PP and the diagnosis of disease in a flock
41 332 during the flock cycle would be an expected to increase TCRs by 0.397 PPs for an
42 333 average flock, assuming a linear relationship. An increase in age at slaughter of 1 d will
43 334 result in an increase in TCRs of 0.046 PPs.
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336 DISCUSSION

337 DoAs included birds found dead on arrival at the slaughterhouse and those culled as they
338 are unloaded from the lorry. Rates of DoAs found in this study are very low, at a mean
339 of 0.12% of all birds, representing 9.8% of TCRs in comparison to those reported by
340 Baylis and Hinton (1990), who found prevalence of DoAs to be of between 0.21% and
341 1.32% of all birds, with a mean of 0.42%. However, this earlier study reported on flocks
342 which were transported in fixed crates, rather than modular transport, as used currently in
343 the UK: trauma during loading and unloading, due to greater difficulty in using fixed
344 crates, may account for the higher incidence reported by these authors. In more recent
345 studies, the prevalence of DoAs was found to be between 0.22% and 0.42% of all birds
346 by Yogaratanam (1995) and between 0.24% of all birds (for free range birds) and 0.67% of
347 all birds (for vegetarian birds), by Herenda and Jakel (1994) which are still considerably
348 higher than those found in this study. The relatively low number of DoAs found in the
349 current study may be because the period of recording did not include periods of very hot
350 weather, when DoAs due to heat stress increase markedly. This was because farm data
351 was being collected for the study flocks and recorders were not permitted, by the
352 collaborating companies, to enter bird accommodation during very hot periods.
353 Alternatively, or in addition, rates of DoA may have decreased over time due to genetic
354 improvements in commercial bird strains or improved transport and husbandry systems
355 and disease prevention measures. Yogaratanam (1995), for example, reported that at the
356 time the data was recorded for his study, a virulent strain of Infectious Bursal Disease
357 (IBD) was widespread in the UK, which increased the amount of general infection due to
358 immunosuppression. An effective vaccination for IBD is now routinely used in broilers
359 in the UK.

360 The mean percentage TCRs found in this study was 1.23%, ranging from 0.07%
361 to 5.51%. This is similar to that found by Herenda and Jakel (1994), who found TCR
362 rates of between 1.18% of all birds (for free range birds) and 5.90% of all birds (for
363 vegetarian birds) while a mean of 2.00% of standard birds were rejected. However,
364 Yogaratanam (1995) found carcass rejection rates of over 3% of all birds in UK flocks and
365 Haslam (2003) found rejection rates ranged from 0.3% in an organic flock to 1.72% of
366 total birds in a traditional UK intensive flock. However, it is possible that the flocks

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3 367 examined for this current study may not completely reflect the full cross section of UK
4 368 poultry flocks. The Broiler Production Companies collaborating with this project
5 369 volunteered to do so, rather than being selected at random, and may therefore represent
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7 370 those companies with a more positive interest in broiler health and welfare. There exists,
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9 371 therefore, the possibility that the results presented for this study may underestimate the
10 372 incidence of DoAs and TCRs in the UK boiler industry. However, the sample taken for
11 373 this study was selected at random from 5 of the largest broiler production companies in
12 374 the UK, which between them slaughter an estimated 420 million birds annually (M Cook,
13 375 personal communication 2006), and therefore represents approximately 50% of the UK's
14 376 annual production of broiler chicken, estimated in 2004 to be 805 million birds (Leidahl,
15 377 2005).

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19 378 Data were collected into summary carcase rejection categories, rather than using
20 379 the raw MHS data, in order to improve the reliability of data recording between plants.
21 380 All MHS Meat Hygiene Inspectors (MHIs) undergo a rigorous, standardised training
22 381 course in meat inspection and regular continuing education and refer to the standard MHS
23 382 Operations Manual and should therefore classify similar pathologies into similar
24 383 categories. It was clear, by observation of MHIs working at inspection points at the
25 384 slaughterhouses, that carcasses with some pathology were consistently classified similarly
26 385 between plants, including DoAs, birds with ascites, small emaciated birds and bruising.
27 386 Chronic pathologies were only found at one of the slaughterhouses, discussed later, so
28 387 avoiding the risk of inconsistency of recording. However, for some categories, common
29 388 pathologies seemed to be classified differently in different plants: for example, an
30 389 excessively pink carcass was classified under 'abnormal smell/ colour' at one plant, under
31 390 'septicaemia/toxaemia' at another and under 'badly bled' at another. For our data set,
32 391 these were therefore all included in the category 'abnormal colour'. Similarly, internal
33 392 lesions in the coelom where there were fibrinous adhesions to one or more organs were
34 393 classified under different categories at different plants. For this reason carcasses recorded
35 394 as 'pericarditis', 'perihepatitis', 'air sacculitis', 'respiratory disease', 'peritonitis',
36 395 'septicaemia' (diagnosed at the evisceration inspection point) 'E. coli', 'enteritis' or
37 396 'bacterial necrosis' were all categorised as 'acute internal pathology' for our study.
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47 397 However, it is possible that there may be poorer reliability in our data for some categories
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2 398 than others due to the inconsistency in classification seen between plants for some
3 399 lesions. This may also account for some of the differences in the frequency of different
4 400 downgrade categories reported for different studies which report carcase rejection data.

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7 401 The main cause of carcase rejection found in this study was acute internal
8 402 pathology, which accounted for a mean of 0.44% of all birds, with a minimum of 0% and
9 403 a maximum of 5.03%, thus accounting for 35.8% of TCRs. This is lower than that found
10 404 by Yogaratnam (1995), of 0.67% of all birds or 42.8% of TCRs, for an equivalent
11 405 measure, described as 'pericarditis with perihepatitis/air sacculitis'.

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14 406 The next most frequent rejection condition found in this study was
15 407 small/emaciated birds, at a mean rate of 0.21% of all birds processed, accounting for
16 408 20.3% of all TCRs. This is lower than that found in the study by Yogaratnam (1995), at
17 409 0.31% of all birds, although this represented a similar proportion of TCRs, of 19.45%.

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20 410 Birds with ascites and birds with a skin condition or abscess accounted for the next
21 411 highest rejection rates, both at means of 0.18% of all birds, representing approximately
22 412 14.6% of TCRs. This is very low in comparison with previous studies, reviewed by
23 413 Olkowski *et al.* (1996), which found the prevalence of ascites to be up to 40% of all birds
24 414 reported in some studies. This reduction may be due to selective changes in bird
25 415 genotype over time to reduce the susceptibility of birds to ascites, as discussed by Deeb *et*
26 416 *al.*, (2002). More recently studies have found ascites incidence of between 0.05 and
27 417 0.26% of all birds, (Herenda and Jakel, 1994) and a mean of 0.12% (Yogaratnam, 1995),
28 418 which is similar to the prevalence found in this study. The percentage of birds with a skin
29 419 condition or abscess found in this study is high in comparison to that found by
30 420 Yogaratnam (1995), of 0.01% of all birds, or 0.62% of TCRs.

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33 421 Carcasses with abnormal colour accounted for a mean of 0.11% of all birds
34 422 respectively, representing 8.9% of TCRs. A prevalence of 0.47% of all birds, or 29.63%
35 423 of TCRs, were due to an equivalent category, of septicaemia/toxaemia/perihepatitis/air
36 424 sacculitis', in a study by Yogaratnam (1995) which is much higher than the prevalence
37 425 found in this study and which may be due to the effect of high prevalence of IBD
38 426 infection in the UK broiler flock at the time of the study, discussed earlier.

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41 427 The rejection rate for bruising was found to be a mean of 0.025% of all birds
42 428 respectively, representing approximately 2.0% of TCRs. The prevalence of bruising in
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3 429 this study is low in comparison to that found by Herenda and Jakel (1994), who found the
4 430 prevalence of this condition to be between 0.07% and 0.22% of all birds, which may
5 431 reflect changes in transport methods and equipment discussed earlier.

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7 432 The rejection rate for chronic pathology was found to be 0.004% of all birds and
8 433 0.3% of TCRs. Birds with chronic pathology included birds classified as having tumours
9 434 or Marek's Disease. This is considerably higher than found by Yogaratnam (1995), who
10 435 found 'tumours' to account for 0.0002% of all birds. Overall, it appears that the
11 436 incidence of tumours in broilers is still low. However, a rare skin form of Marek's
12 437 Disease has been reported which is characterised by a mononuclear infiltration of various
13 438 tissues and organs including the skin (Derakhshanfar and Ghanbarpoor, 2003). There are
14 439 recent reports of Marek's virus infecting birds as young as a few days of age (Venugopal
15 440 *et al.*, 1999), which may be due to reduced resistance in some genotypes of commercially
16 441 produced broilers since the study carried out by Yogaratnam (1995). In the current study,
17 442 all of the recorded incidences of chronic pathology were recorded at one plant which
18 443 processed a unique bird genotype.

25 444 **Bivariate correlations**

26 445 The positive bivariate correlations found between percentage TCRs, DoAs and several
27 446 other carcass reject categories, including ascites, abnormal colour, bruising, acute internal
28 447 pathology and chronic pathology, with age and weight, is unsurprising, as it might be
29 448 expected that older birds will have been exposed to the risk of disease for a longer period
30 449 and so are more likely to be affected. In addition, Reece *et al.* (1972) have shown that
31 450 older birds are more susceptible to heat stress and ascites, due to right side heart failure,
32 451 has also been shown to be more prevalent in older birds (Schlosberg *et al.*, 1989;
33 452 Bendheim *et al.*, 1992). Heavier birds have also been found to be more likely to be
34 453 affected by cellulitis (Elfadil *et al.*, 1996; St-Hilaire and Sears, 2003). Similarly, the
35 454 significant positive correlations between TCRs, DoAs and other reject conditions,
36 455 including ascites and chronic pathology, with percentage mortality on farm is expected,
37 456 as a higher prevalence of disease on farm is likely to be reflected by an increase in the
38 457 number of sick birds being transported, and so dying during transport, and a higher
39 458 number being affected by downgrading conditions.

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3 459 Significant positive bivariate correlations of both DoAs and percentage TCRs with
4 460 gait score are likely to be due to diseased birds tending to have both a higher gait score,
5 461 and so an increased risk of dying during transport, and also a condition which causes
6 462 rejection for human consumption. These positive correlations are of interest as one of the
7 463 aims of our study was to determine the extent to which DoAs and prevalence of carcass
8 464 rejects, recorded at the slaughterhouse, reflect bird welfare on farm. Clearly, both
9 465 percentage TCRs and DoAs reflect leg health on farm.

13 466 The significant positive correlations of ascites, chronic pathology and DoAs with
14 467 hock burn score may reflect the increased duration of contact between the litter and the
15 468 hocks of sick, and so less mobile birds, while the negative correlation between
16 469 small/emaciated birds and hock burn may reflect the greater mobility of such birds and
17 470 resultant reduced duration of contact between litter and hock and reduced pressure of
18 471 contact.

22 472 The negative correlations found between several measures of stocking density and
23 473 TCRs are counterintuitive, as increased stocking density would be expected to increase
24 474 stress, reduce litter and air quality and so increase disease risk and therefore carcass
25 475 rejects. This may be explained by the method by which producers predict stocking
26 476 density, using standard growth curves. Producers aim for a target final stocking density,
27 477 currently 38 kg per m² in the UK, using standard growth curves that predict average
28 478 performance for the bird genotype used, to determine the stocking rate at which birds are
29 479 placed and number of birds to be thinned prior to final slaughter. Flocks which have
30 480 above average growth rates, and so have a greater final mean bird slaughter weight and
31 481 possibly lower flock mortality, are likely to be birds least affected by disease and so have
32 482 a lower incidence of TCRs but higher final stocking density. It is significant that stocking
33 483 density does not appear in the multiple regression model developed to account for
34 484 variability of percentage of carcass rejects, discussed below. It is also of interest, in this
35 485 respect, that a very significant positive association between percentage TCRs and BLI
36 486 was found in this study. It is possible that BLI more closely reflects the biological load
37 487 going through a house during a flock cycle, and so the risk of stress and disease, than
38 488 stocking density measured at one point in time. However, BLI is an artificial measure
39 489 which does not take account of birds removed due to thinning.

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3 490 Clearly, the results of simple bivariate correlations may be misleading, as several
4 491 factors which all appear to have an overwhelming effect may simply be co-varying as a
5 492 group, and factors which have a small effect may be swamped by the effect of another
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7 493 which has a much larger effect. For this reason, multiple regression models were
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9 494 developed, for DoAs and percentage TCRs, which eliminate these problems. Clearly,
10 495 there is likely to be some variation of the target variable which is due to factors not
11 496 measured for any given study.

12 13 497 **Multiple regression models**

14 498 In many respects the multiple regression model developed to account for the variability in
15 499 percentage of DoAs is explicable. The variation with season is likely to be due to
16 500 increased mortality due to heat stress during the summer months. Other published studies
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18 501 have also reported a significant effect of season on the prevalence of DoAs (Baylis and
19 502 Hinton, 1990; Vecerek *et al.*, 2006). The increase in DoA due to the percentage of small
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21 503 or emaciated birds is likely to be because large numbers of these are likely to occur in
22 504 diseased flocks, in which there is a greater probability of birds dying during depopulation,
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24 505 transport and lairaging. The increase in DoAs with increase in on-farm mortality is also
25 506 likely to reflect disease on farm, predisposing to death in transport. On the contrary,
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27 507 increasing the number of vaccinations administered to the flock is likely to reduce disease
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29 508 incidence and so reduce the numbers dying during transport.

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31 509 Whole grain or cracked wheat may be incorporated, at inclusion rates varying from
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33 510 0% to 30% of the total feed, into broiler diets for the purposes of slowing growth, as well
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35 511 as to stimulate the gizzard and to encourage a healthy gut micro flora. Increasing the
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37 512 percentage of wheat in diet 4 decreased the percentage of DoAs, possibly by reducing
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39 513 bird growth rate and so the probability of birds dying due to Pulmonary Hypertension
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41 514 Syndrome (PHS) (right sided heart failure), as discussed by Julian (1993) and McGovern
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43 515 *et al.* (1999) or from heat stress, discussed by Deeb *et al.* (2002).

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45 516 The small increase in DoAs with increasing age may also be related to the increased
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47 517 susceptibility of heavier birds to PHS and heat stress. Similarly, the small effect of
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49 518 increases in the percentage of Ross birds rather than Cobb birds may be due to differing
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51 519 susceptibilities of different genotypes to PHS, heat stress and other diseases, such as has
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2 520 been shown for Marek's Disease (Venugopal *et al.*, 1999) and colibacillosis (Ask *et al.*,
3 521 2006).

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5 522 It is surprising that the model developed to account for the incidence of DoAs
6 523 accounted for such a high percentage of the variability in rates of DoAs between flocks,
7 524 as the effect on the prevalence of DoAs of factors during depopulation, transport and
8 525 lairaging, such as journey length, ambient temperature and relative humidity, stocking
9 526 density in the crates, crate type, catching team and the use of fans in the lairage, which
10 527 have previously been identified, reviewed by Baylis and Hinton (1990), were not
11 528 recorded for this study. However, the effects of ambient temperature are likely to be
12 529 included in the model by the seasonal effect on the prevalence of DoAs. In addition, it is
13 530 possible that the broiler production companies which were content to collaborate with
14 531 this study, and so are likely to be more interested in bird welfare, have used the findings
15 532 of earlier studies to put in place optimal conditions for bird catching and transport, such
16 533 as reducing journey times to less than the critical journey time of 4 h after which
17 534 mortality rates have been found to increase markedly (Warriss *et al.*, 1992).

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19 535 The model developed to account for variability in percentage TCRs rejects is also
20 536 explicable. The occurrence of disease during the flock cycle has by far the greatest effect
21 537 on the percentage of TCRs, which is also reflected by an increase in the percentage of
22 538 birds culled. The effect on TCRs of percentage of Ross birds rather than Cobb birds may
23 539 be due to genetic differences in susceptibility to disease, as discussed above. The possible
24 540 reasons for the effect of bird age and increased wheat percentage in diet on TCRs have
25 541 been discussed earlier.

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27 542 Surprisingly, no seasonal effect on TCRs was identified in this study as has been
28 543 found for the prevalence of DoA (Baylis and Hinton, 1990) and foot burn (Ekstrand *et*
29 544 *al.*, 1997; Haslam *et al.*, 2007). Seasonal effects on DoAs are thought to reflect ambient
30 545 temperature during harvesting and transport (Warriss *et al.*, 2005). The seasonal effect on
31 546 the prevalence of contact dermatitis is thought to be due to reduced winter ambient
32 547 temperatures causing farmers to reduce ventilation rates which leads to higher house
33 548 humidity and atmospheric ammonia concentrations and poor litter quality, discussed by
34 549 McIlroy *et al.*, (1987). However, it is possible that the different reject categories, which
35 550 constitute overall rejection rates, increase at different times of the year and so cancel out

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3 551 the effect of season. For example, DoAs due to heat stress tends to be higher in the
4 552 summer months whereas skin conditions due to poor litter are likely to be higher in the
5 553 winter months.

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7 554 The recently enacted EU Broiler Directive requires that the prevalence of DoAs be
8 555 monitored in birds going through slaughterhouses and the results of *post mortem*
9 556 examinations of birds recorded. The Directive also requires that, where the prevalence of
10 557 DoAs and disease conditions from a farm is high, this is reported to the Competent
11 558 Authority, which may take enforcement action, including requiring a reduced stocking
12 559 density of birds in subsequent flocks. It is therefore necessary for enforcing bodies to
13 560 know the mean and range of prevalence of DoAs and TCRs in the UK flock in order to
14 561 judge the relative severity of these measures for reported flocks. Our study has found that
15 562 the mean prevalence of DoAs in the UK broiler flock is 0.12%, ranging from 0% to
16 563 0.64% and that the mean prevalence of carcasses rejected for human consumption is
17 564 1.23%, ranging from 0.07% to 5.51%. Several factors have been identified, from
18 565 examination of bird husbandry conditions on the farm, which affect DoA and carcass
19 566 rejection rates.

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22 567 The results of our study suggest that changes in some aspects of flock management,
23 568 specifically measures which are aimed at reducing disease incidence of the flock during
24 569 the flock cycle, may reduce the prevalence of DoAs and TCRs. Improvement of
25 570 vaccination programmes to reduce disease incidence, the use of Ross, rather than Cobb
26 571 birds, the inclusion of wheat in grower rations and slaughter of birds at lower
27 572 ages/weights is likely to reduce both DoAs and TCRs, although the effect of genotype on
28 573 both conditions is small. There is a seasonal effect on the prevalence of DoAs but no
29 574 such effect was identified for the prevalence of TCRs. Further research would be
30 575 required to determine which specific changes to vaccination programmes are most
31 576 effective in reducing the prevalence of DoAs and TCRs, although optimum programmes
32 577 are likely to be specific to a farm, broiler production company or geographical area.

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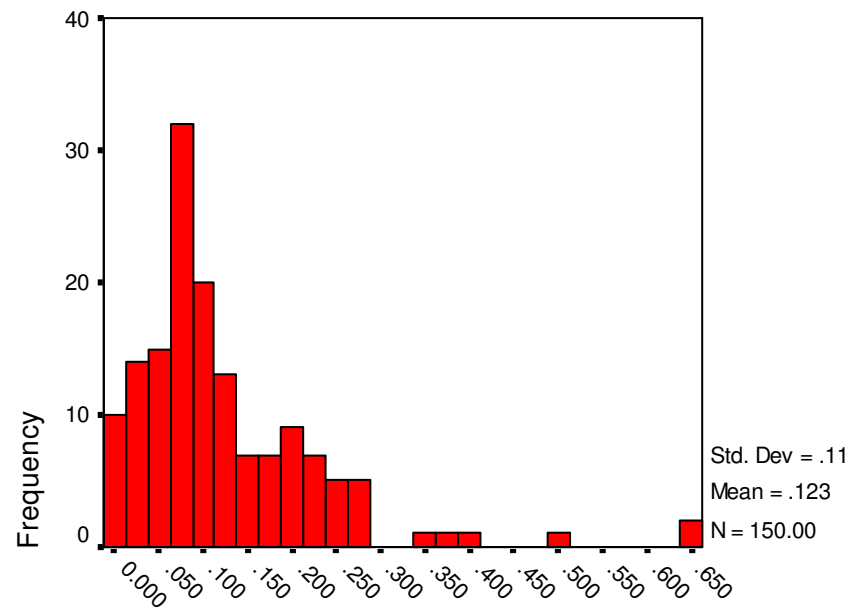
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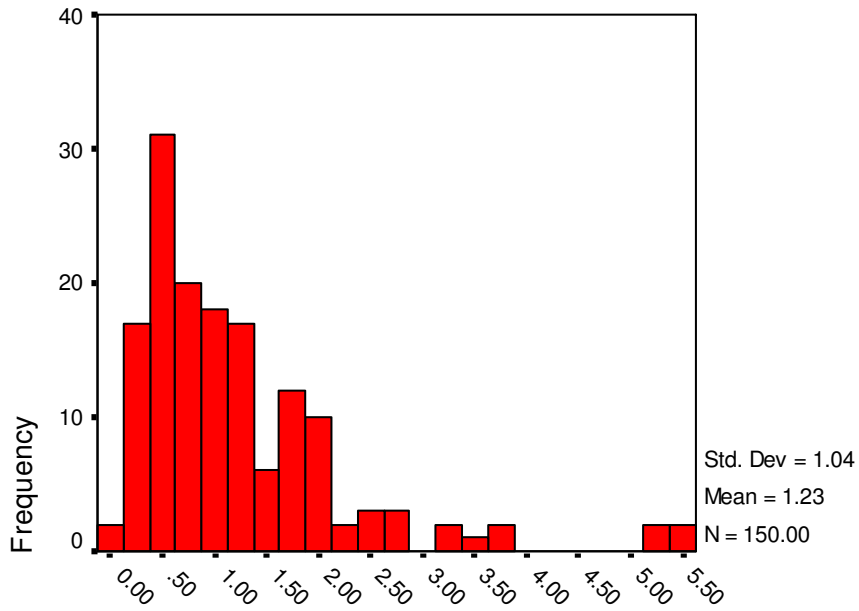
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669 **Figure 1.** Frequency distribution of percentage of birds Dead on Arrival at the slaughter
670 plant recorded at the flock level.
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view Only

Figure 2. Frequency distribution of percentage of birds rejected for human consumption recorded at the flock level.



727 **Table 1.** *Classification of carcase pathologies by slaughter plant personnel and how*
 728 *they relate to summary categories.*
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Ascites	Birds with a sufficient volume of clear fluid in the peritoneal cavity as to be readily noticeable. These are classified as 'ascites'
Abnormal colour/smell	Birds easily distinguishable from the majority of birds on the line due to discolouration of the skin over most of the carcase. These are classified as 'septicaemia' (diagnosed at the whole bird inspection point), 'fevered', 'toxaemia', 'poorly bled', 'badly bled' 'abnormal smell', jaundice' or 'abnormal colour'.
Skin Condition/abscess	Birds with skin damage of any type which is readily noticeable (excluding damage that is clearly post mortem due to plant machinery or contamination) plus birds with accumulations of purulent material at any anatomical location visible to the naked eye. These are classified as 'skin lesions' 'breast blisters', 'staphylococcal cellulitis', 'abscess', 'septic lesions' or 'pus'.
Bruising	Birds with bruising, either old or new, over an area exceeding a quarter of the area of the breast or leg. These are classified as 'bruising' or 'green leg'.
Acute internal pathology	Birds with purulent or fibrinous adhesions to the heart, liver or intestines, or with such adhesions in the air sacs These are birds classified as 'pericarditis', 'perihepatitis', 'air sacculitis', 'respiratory disease', 'peritonitis', 'septicaemia' (diagnosed at the evisceration inspection point) 'E. coli', 'enteritis' or 'bacterial necrosis'.
Small/emaciated birds.	Birds clearly much smaller or less covered in muscle than the majority of birds on the line, so that they are unfit for human consumption. These are classified as 'runts, 'emaciated birds' or 'cachexia'
Dead on Arrival	Number of birds found dead in the transport crate on arrival at the slaughterhouse or culled as unloaded from the transport crate. These are classified as 'DoAs'
Chronic Pathology	Birds with abnormal growths in one or more anatomical location, which are readily seen with the naked eye. These are classified as 'tumour' or 'Mareks'

Table 2. Frequency, mean, median, standard error and range of standard carcass reject categories and total carcass rejects (N=150).

	%Ascites	%Abnormal colour	%Skin condition /abscess	%Bruising	%Acute internal pathology	%Small/ Emaciated	%Chronic pathology	%Dead on Arrival	%Total reject
Mean	0.182	0.112	0.180	0.025	0.441	0.207	0.004	0.123	1.229
Median	0.094	0.023	0.089	0.000	0.245	0.064	0.002	0.093	0.962
Std. Error of Mean	0.020	0.017	0.022	0.004	0.057	0.028	0.001	0.009	0.085
Range	1.457	1.066	1.620	0.274	5.028	2.154	0.042	0.644	5.438
Minimum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.073
Maximum	1.457	1.066	1.620	0.274	5.028	2.154	0.042	0.644	5.511

Table 3. Significant bivariate correlations between average weight and age at slaughter with individual reject categories and total carcass rejects.

Variable 1	Variable 2	Spearman's rho	Significance
Average weight at slaughter	Ascites	0.422	0.01
Average weight at slaughter	Abnormal colour	0.182	0.05
Average weight at slaughter	Skin lesions	0.183	0.05
Average weight at slaughter	Bruising	0.193	0.05
Average weight at slaughter	Acute internal pathology	0.188	0.05
Average weight at slaughter	Chronic pathology	0.510	0.01
Average weight at slaughter	DoAs	0.281	0.01
Average weight at slaughter	Total carcass rejects	0.328	0.01
Average age at slaughter	Ascites	0.356	0.01
Average age at slaughter	Acute internal pathology	0.190	0.05
Average age at slaughter	Chronic pathology	0.446	0.01
Average age at slaughter	DoAs	0.245	0.01
Average age at slaughter	Total carcass rejects	0.323	0.01

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Table 4. Significant bivariate correlations between mortality, gait score, measures of stocking density on farm and contact dermatitis with individual reject categories and total carcass rejects.

Variable 1	Variable 2	Spearman's rho	Significance
DoAs	Percentage mortality on farm	0.400	0.01
Total carcass rejects	Percentage mortality on farm	0.216	0.01
Ascites	Percentage mortality on farm	0.330	0.01
Chronic pathology	Percentage mortality on farm	0.352	0.01
DoAs	Average gait score	0.317	0.05
Total carcass rejects	Average gait score	0.253	0.01
DoAs	Hock burn score	0.376	0.01
Total carcass rejects	Hock burn score	0.190	0.05
Ascites	Hock burn score	0.300	0.01
Small/emaciated birds	Hock burn score	-0.237	0.01
Chronic pathology	Hock burn score	0.349	0.01
Bruising	Foot burn score	-0.251	0.01
Total carcass rejects	Stocking rate at placement x Weight at kill (BLI)	0.344	0.01
Total carcass rejects	Stocking density using average pm weight at inspection	-0.171	0.05
Total carcass rejects	Stocking density using weight at slaughter	-0.255	0.01
Total carcass rejects	Average stocking density prior to thinning	-0.193	0.01

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758 **Table 5.** *Parameter estimates for univariate model accounting for variability in DoAs*
 759 *(birds dead on arrival at the slaughter plant).*

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Dependent Variable: VAR: DoAs

Parameters	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	.151	.040	3.782	.000	.072	.230
SMLLRCTS	.155	.038	4.096	.000	.080	.229
WHEATDIET4	-.003	.001	-3.154	.002	-.006	-.001
TNVAC	-.029	.010	-2.950	.004	-.049	-.010
LVEWTATSLTER	0.000043	.000	3.924	.000	2.12E-005	6.42E-005
GENOTYPAPC	-0.000401	.000	-1.822	.071	-.001	3.47E-005
MORTPC	0.000044	.000	2.224	.028	4.83E-006	8.29E-005
SIN	.018	.010	1.775	.078	-.002	.037

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764 DoAs = percentage of birds dead on arrival at the slaughterhouse
 765 SMLLRCTS = percentage of birds rejected due to small size or emaciation
 766 WHEATDIET4 = percentage of whole or cracked wheat in diet 4
 767 TNVAC = total number of vaccinations administered to the flock
 768 LVEWTATSLTER = mean live weight at slaughter
 769 GENOTYPAPC = percentage of birds in the flock which were genotype A
 770 MORTPC = percentage of birds dying on farm during the flock cycle
 771 SIN = sinusoidal curve accounting for seasonal effect

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Table 6. *Parameter estimates for univariate model accounting for variability in total carcass rejects (excluding machine damage and contamination on plant).*

Parameters	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept	.194	.563	.344	.731	-.919	1.307
WHEATDIET3	-.053	.018	-3.012	.003	-.088	-.018
GENOTYPAPC	-.009	.003	-3.494	.001	-.014	-.004
CULLPC	.030	.015	1.966	.051	.000	.060
ANYDISEASE	.390	.162	2.408	.017	.070	.711
AGE AT SLAUGHTER	.046	.012	3.823	.000	.022	.070

REJECTPC = total percentage of carcasses rejects for human consumption at the slaughter plant

WHEATDIET3 = percentage of whole or cracked wheat in diet 3

GENOTYPAPC = percentage of Ross birds in flock

ANYDISEASE = disease recorded in the live birds during the flock cycle at any time

CULLPC = percentage of birds culled for any reason during the flock cycle