The broiler's last day of life

Influences of feed withdrawal, catching and transport on physiology and losses of broilers

Edwin Nijdam

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Abstract

Before slaughter, broilers are subjected to several preslaughter management events such as feed withdrawal, catching, crating, transport, and lairage. The aim of this study was to gain insight into factors which influence mortality, stress, energy metabolism, and meat quality of the broilers on the last day of their life.

The mean percentage of broilers that arrived dead at the conveyer belt of the slaughterhouse (DOA) was 0.46. Factors associated with DOA percentage were ambient temperature, moment of transport, catching company, breed, flock size, mean body weight, mean compartment stocking density, transport time, lairage time, and the interaction term transport time x ambient temperature. The most important factors that influence DOA percentage, and which could be reduced relatively easily, were compartment stocking density (Odds Ratio (OR) = 1.09 for each additional bird in a compartment), transport time (OR = 1.06 for each additional 15 min), and lairage time (OR = 1.03 for each additional 15 min).

Moreover, the mean percentage of bruises was 2.20. Factors associated with corrected bruises percentage were season, moment of transport, and ambient temperature.

To establish predisposing factors for DOA broilers a gross post mortem investigation was done. Macroscopic lesions were found in 89.4% of DOA broilers. Signs of infectious diseases appeared to be most frequent (64.9%), followed by heart and circulation disorders (42.4%), and trauma (29.5%). The right ventricle mass to the total ventricle mass (RV:TV) was significantly higher in DOA broilers than in slaughtered broilers.

Manual catching of broilers leads to stress in the birds and is backbreaking for the workers. Therefore, mechanical catching of broilers was investigated. Mechanical catching was associated with higher DOA percentages than manual catching. However, the catching method did not influence the percentages of bruises, meat quality, and corticosterone (CORT) levels.

Feed is normally withdrawn for several hours before catching in order to reduce the danger of carcass contamination. Feed withdrawn broilers showed higher thyroxine and lower triiodothyronine, triglyceride, glucose, and lactate concentrations compared to broilers that had access to feed before the transport intervention. These findings indicate a negative energy balance, and, accordingly, BW losses occurred. BW losses further increase during transport.

To reduce the negative effects of feed withdrawal semisynthetic diets were investigated. After transport the BW loss of broilers fed semisynthetic diets was 0.24% / h less than of feed withdrawn broilers. BW loss of broilers fed conventional diets was 0.28% / h less than of feed withdrawn broilers. Moreover, the digestive tract mass was lower in broilers fed a semisynthetic diet than in broilers fed a conventional diet, which can lead to a lesser degree of contamination during evisceration. Beside that, no increase of CORT was found due to transport in broilers fed a semisynthetic diet, whereas CORT significantly increased during this period in broilers fed a conventional diet. Consequently, semisynthetic feed is a promising alternative for feed withdrawal in the period before catching and crating.

Contents

Chapter 1

General introduction

Background and Scope

Poultry Meat Production

Worldwide, poultry meat consumption is increasing. Per capita consumption between 1994 and 2005 increased by 40%, from 9.0 to 12.6 kg. Poultry is the fastest growing meat sector in the world (anonymous, 2005). As a consequence, the number of broilers, the main supplier of poultry meat, is also increasing enormously.

To fulfill the increasing demand of broiler meat, the birds are usually produced under industrialized production systems. The major exporting countries, Brazil and the USA, are two very efficient producers due to low feed costs, large-scale production and a high level of vertical integration (Nunes, 2004). After a period of approximately 6 weeks of growth in the poultry house, the broilers are transported to processing plants, where often more than a million broilers a week are slaughtered. Before the birds are hung on the shackle line in the processing plant, they have been already exposed to an array of events on the last day of life such as feed withdrawal, catching, crating, transportation and lairage at the processing plant.

Preslaughter Events

Feed Withdrawal. Before catching, broilers are subjected to a feed withdrawal period. According to recommendations by the Dutch Product Boards for Livestock, Meat and Eggs, this period should be at least 5 h (PVE, 1992). For good processing it is essential that the digestive tract is not full of feed, because a full digestive tract is more difficult to remove and breakage can occur (Smidt et al., 1964). Therefore, fecal cross contamination during evisceration will increase if an insufficient feed withdrawal period is applied (Wabeck, 1972; Lyon et al., 1991). However, extended feed withdrawal periods lead to body weight (BW) losses between 0.22 and 0.56% / h (Veerkamp, 1978; Chen et al., 1983; Veerkamp, 1986; Rasmussen and Mast, 1987; Lyon et al., 1991; Knowles et al., 1995; Warriss et al., 2004). Feed withdrawal also leads to alterations in energy metabolism. In generating energy, the carbohydrate metabolism plays an important role. First, glycogen is broken down into glucose, which might be transformed via the glycolytic pathway to pyruvate and finally to adenosine triphosphate (ATP). At high energy demands ATP will also be formed anaerobic, resulting in the formation of lactate (Stryer, 1981), which influences muscle pH. Feed withdrawal increases the pH ultimate in the biceps muscle (Warriss et al., 1993), whereas physical exercise just before slaughter might cause a decrease in muscle pH in vivo (Sjöblom and Lundström, 1989). Muscle pH is an important parameter for meat quality.

Apart from glucose production from glycogen, glucose can also be formed by the degradation of triglycerides in adipose tissue and in muscle protein (Hazelwood, 1994). Decrease in concentration of glucose results in an increase of NEFA and uric acid concentrations. These changes are due to lipolysis and catabolism and are aimed to fulfill energy demands (Langslow et al., 1970). Also the thyroid hormones play an important role in the regulation of the energy balance. Thyroid activity is suppressed during feed withdrawal to reduce metabolic processes (Kok, 2003).

Beside changes in energy metabolism and BW, feed withdrawal provokes behavioral and physiological responses, such as a glucagon-mediated response, indicating that broilers probably suffer from stress (Freeman, 1980). An increase of corticosterone (CORT), which is a reliable indicator of stress in chickens (Thaxton and Puvadolpirod, 2000), has been shown by Scott et al. (1983) and Knowles et al. (1995) in broilers after a feed withdrawal period of 10 h and 24 h. However, Freeman (1983) reported two studies in which CORT did not increase after feed withdrawal.

Catching and Crating. Catching and placement into crates or containers cause severe stress to broilers (Knowles and Broom, 1990; Von Borrell, 2001). This is shown by increased CORT values (Kannan and Mench, 1996) and prolonged tonic immobility reactions (Jones, 1992) found in broilers after catching and crating. In addition, based on histological examination of bruised tissue, Griffiths (1985) concluded that 40% of the bruises recorded at the processing plant originated from catching and crating.

Broilers are currently caught almost entirely by hand; they are grasped by the leg, inverted and carried by a catcher with 3 or 4 birds in each hand (Bayliss and Hinton, 1990). During an average working night or day, a catcher may lift 5 to 10 tons of broilers (Kettlewell and Turner, 1985). In addition, during the last decades studies have been performed to investigate mechanical harvesting as an alternative for manual catching (Farsaie et al., 1983; Duncan et al., 1986; Ekstrand, 1998; Knierim and Gocke, 2003).

Transport and Lairage. After catching and crating the broilers are transported to the processing plant where they have to wait in the lairage before being slaughtered. After transport increased CORT values are present (Freeman et al., 1984), and tonic immobility is prolonged by increased transport times (Cashman et al., 1989). During lairage the body temperature of broilers increases and the liver glycogen stores become depleted, indicating significant periods of negative energy balance (Warriss et al., 1999).

The Broiler's Last Day of Life

The preslaughter management practices (feed withdrawal, catching, crating, transport, and lairage) cause stress, BW reduction and a negative energy balance, and affect meat quality. These practices can even lead to bruises and mortality of broilers between catching and slaughter, the so called dead on arrival (DOA). Data of the levels of bruises vary greatly from 0.022 to 25 % (Taylor and Helbacka, 1968; Mayes, 1980; Farsaie et al., 1983; Griffiths and Nairn, 1984; Ekstrand, 1998; Knierim and Gocke, 2003). Published mean percentages of DOA birds range from 0.05% to 0.57% (Bingham, 1986; Bayliss and Hinton, 1990; Gregory and Austin, 1992; Warriss et al., 1992; Ekstrand, 1998). These findings indicate that the welfare of broilers during the last day of life is strongly diminished.

Objectives of the Study

The general objective of this study is to gain insight in factors, which influence mortality, stress, energy metabolism, and meat quality of the birds on the last day of the broiler's life. The following questions will be addressed in this research:

- Which factors are associated with mortality and injury rate occurring between catching and slaughtering of broiler flocks and what is their quantitative effect?
- Which disorders are frequently seen at postmortem examination of DOA broilers?
- Is mechanical catching of broilers an improvement for manual catching in respect of mortality, welfare, and meat quality?
- How do blood parameters of broilers change between catching and processing?
- What is the effect of feed withdrawal in combination with catching and transport on stress levels and energy metabolism?
- Is providing semisynthetic feed to broilers in their last phase of life a good alternative to reduce the negative effects of feed withdrawal and transport?

Outline of the Study

In chapter 2 an observational study is described to identify and quantify factors associated with mortality and bruises occurring between catching and processing. Data of 1,907 broilers flocks, collected in 2000 and 2001 at a Dutch processing plant, were analyzed by using a multilevel model.

In chapter 3 the results of a gross postmortem investigation of 302 DOA broilers are presented. Pathological features of infectious diseases, trauma, some miscellaneous disorders, and heart and circulation disorders were studied. Extra attention was paid to hypertrophy of the right ventricle of hearts of DOA broilers.

In the next chapter (4) a field experiment describes a comparison between mechanical catching and manual catching of broilers. The incidence of bruises and DOA, meat quality characteristics, and blood parameters were investigated in respect to catching method. Beside that, blood samples were taken before catching, during catching and at processing to examine the changes of blood parameters between catching and processing.

In chapter 5 a study is described of two experiments to examine the combined effects of feed withdrawal and the catching and transport process on stress and energy metabolism. Before the birds were caught, crated, transported, and lairaged, they were withdrawn from feed or had full access to conventional feed.

In chapter 6 two replicate experiments are described that were done to investigate if special diets, such as semisynthetic diets with high carbohydrate levels that were provided to broilers in their last phase of life, could reduce the negative effects of feed withdrawal and transport without an increased content of the digestive tract.

The thesis is finalized with a summarizing discussion in chapter 7, where also suggestions are given for future research to improve the last day of the broiler’s life.

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Chapter 2

Factors influencing bruises and mortality of broilers during catching, transport, and lairage

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Abstract

A multilevel analysis was performed to identify and quantify risk factors associated with mortality and bruises rates occurring between catching and slaughter of broiler flocks. The effect of each factor in the final model was expressed as an odds ratio (OR). Data included 1,907 Dutch and German broiler flocks slaughtered in 2000 and 2001 at a Dutch processing plant. The mean dead on arrival (DOA) percentage was 0.46. Percentage of bruises was corrected for economic value. The mean corrected bruises percentage was 2.20.

Factors associated with corrected bruises percentage were season, moment of transport, and ambient temperature. Unfortunately, these factors are quite difficult to manipulate.

Factors associated with DOA percentage were ambient temperature, moment of transport, catching company, breed, flock size, mean body weight, mean compartment stocking density, transport time, lairage time, and the interaction term transport time x ambient temperature. The most important factors that influence DOA percentage, and which can be reduced relatively easily, were compartment stocking density (OR = 1.09 for each additional bird in a compartment), transport time (OR = 1.06 for each additional 15 min), and lairage time (OR = 1.03 for each additional 15 min). In particular, reduction of transport and lairage times might have a major influence due to their large variations. Reducing or removing these factors will reduce DOA percentage. Consequently, profitability and animal welfare will increase.

Introduction

Worldwide, tens of billions of broilers are slaughtered annually. Before they are slaughtered, the broilers are subjected to an array of events on the last day of their life. The birds are feed withdrawn to reduce fecal contamination, and then they are caught and put into crates or containers. After being transported to the processing plant, they have to wait in the lairage of the processing plant before they are slaughtered. Birds that have died between catching and the moment of slaughter are termed "dead on arrival" (DOA). Published mean percentage ranges from 0.05% to 0.57% (Löliger and Torges, 1977; Bingham, 1986; Bayliss and Hinton, 1990; Gregory, 1992; Warriss et al., 1992; Ekstrand, 1998). The reported mean percentages of birds that arrive at the processing plant with bruises ranges from 0.022 to 25% (Farsaie et al., 1983; Ekstrand, 1998). The latter range is difficult to interpret, because it may be biased by differences in the methods of meat inspection and carcass grading (Knowles and Broom, 1990). Nevertheless, given the huge numbers of broilers that are slaughtered worldwide, financial losses due to these mortality and injury rates are enormous. Moreover, it implies that the welfare of broilers during this phase of their life is threatened.

The variability within published mortality and injury rates suggests the existence of multiple risk factors. Broilers exposed to such factors are more likely to die or get injured than unexposed birds. According to the literature, factors that influence DOA percentage are catching crew or method (Bayliss and Hinton, 1990; Ekstrand, 1998), transport time (Bayliss and Hinton, 1990; Warriss et al., 1992), lairage time (Bayliss and Hinton, 1990), type of transport crates (Stuart, 1985), time of the day at catching and transport (Bayliss and Hinton, 1990), stocking density per crate (Bayliss and Hinton, 1990), age, and sex of the birds (Bayliss and Hinton, 1990). Catching method (Farsaie et al., 1983; Lacy and Czarick, 1994; Ekstrand, 1998), transport time (Scholtyssek and Ehinger, 1976), ambient temperature (Mayes, 1980), stocking density per crate (Scholtyssek and Ehinger, 1976), age at slaughter (Bingham, 1986), mean body weight (BW; Mayes, 1980; Griffiths and Nairn, 1984) and sex of the broilers (Mayes, 1980) have been reported to influence bruising.

Thus, the main risk factors are known from previous research; however, in most of the studies referred to above, only one or a few factors for DOA or bruising percentage were investigated. Moreover, the effect of the factors was established using a univariate analysis. Therefore, because these were observational studies, confounding may have occurred (Noordhuizen et al., 1997). As a result, the effect of risk factors may have been overestimated, underestimated, or risk factors may have been missed completely. To take confounding into account, all potential risk factors have to be analyzed at the same time in a multivariate model.

The aim of this study was to identify factors associated with the mortality and injury rate occurring between catching and slaughtering of broiler flocks slaughtered at a Dutch processing plant, and to quantify their effect by using multilevel analysis. Such knowledge may be helpful to indicate measures to reduce the number of DOA birds and bruises. Therefore, profitability and bird welfare could increase.

Materials and Methods

Study Population, Data Collection and Variable Description

The study population comprised 1,907 Dutch and German broiler flocks, originating from 149 broiler farms. These flocks had been slaughtered at one Dutch processing plant in 2000 and 2001. Professional catching companies caught all broiler flocks, and the birds were transported in transport vehicles with container modules. The container modules were of a metal frame type containing 8 compartments. After transport, the vehicles were unloaded and the containers with the broilers were laired in a waiting area with fans and sprinkler systems. After lairage, the containers were tipped over automatically and so the broilers were dropped onto a conveyor. The broilers were conveyed onto a carousel table where they were hung on a shackle line. Dead broilers were removed at the carousel table.

The bruises of each flock were recorded according to the legislative standards of The Dutch Product Boards for Livestock, Meat and Eggs (PVE, 2001). According to that standard, a bruise is a discoloration of the skin or under the skin due to the presence of blood that is larger then 1 cm^2 for breast and leg and larger then 2 cm^2 for the wing. Each individual leg and wing can contribute to the total number of bruises in a flock (PVE, 2001).

From each flock the following data were recorded:

1) The numbers of DOA birds;
2) The percentage of bruises on wings, legs and breast;
3) Age at slaughter (d);
4) Mean BW (g);

5) Breed (A, B and C) [broiler flocks of mixed breeds were excluded];
6) Flock size (number of broilers / flock);
7) Catching company (A, B, C, D, and E) [flocks caught by other catching companies or by untrained persons were excluded because of the small number of observations];
8) Loading time (min) of the first transport vehicle;
9) Mean compartment stocking density (birds / compartment);
10) Moment of transport (1 = last load departed from farm before 0800 h.; 2 = intermediate; 3 = first load departed from farm after 0800 h);
11) The transport time (min) of the first transport vehicle from the broiler farm to the processing plant;
12) Lairage time (min) of the broilers transported with the first transport vehicle;
13) Season;
14) Ambient temperature (if moment of transport = 1, then minimum temperature at a neighboring meteorological center was used; if moment of transport = 3, then maximum temperature at the center was used; if moment of transport = 2, then the mean of minimum and maximum temperature at the center was used).

Statistical Analyses

The statistical analyses were performed in the SAS-PC System Version 8.1 for Windows (SAS Institute, 2000) using broiler flock as the statistical unit. PROC FREQ and PROC MEANS procedures were used for the descriptive analyses. PROC MIXED was used for the multilevel analyses. The dependent variable DOA was calculated as a percentage, with the total number of dead broilers per flock counted at the processing plant as numerator and the total number of transported broilers per flock as denominator. The assumption of normality of the outcomes was assessed using stem-and-leaf plots and normal probability plots. The distribution of the DOA percentage was skewed, and therefore a logarithmic transformation was applied.

Because, the economic value of breast, wings and legs is not equal, this processing plant gives 5, 3 and 6 credit points to the broiler farmer if no bruises are seen on breast, wings and legs, respectively. Consequently, corrected bruises percentage was calculated with the formula: (5/14 x percentage breast bruises) + (3/14 x percentage wing bruises) + (6/14 x percentage leg bruises). The distribution of the corrected bruises percentage was also skewed. To correct this, a logarithmic transformation was applied.

The 2-tailed partial F-test (type III) was used as the elimination criterion for the model building and the fit of the models was assessed by the -2log likelihood. The flock size was used as weight variable to include each flock proportional to the number of broilers. Poultry farm was used as random effect in the model to take into account that most farms occurred in the data set more than once. All independent variables and biological meaningful 2-way interaction terms were included in the preliminary multivariable model. Categorical variables were expressed as dummy variables. Next, the independent variables and 2-way interaction terms were removed manually one by one from the model if $P > 0,10$ (backward selection).

The effect of each factor in the final model was expressed as an odds ratio (OR). In essence, this value is the equivalent to the relative risk, assessing each specific factor relative to its reference class. Hence, a 95% confidence interval excluding 1.0 indicates statistical significance at the $P < 0.05$ levels. The fit of the final model was analyzed by assessing normal probability plots.

Results

Descriptive Results

The 1,907 flocks included in this study were kept on 149 broiler farms. The number of flocks delivered to the processing plant per farm ranged from 1 to 47, with a median of 11. The descriptive results of the 1,907 broiler flocks are given in Table 1. The mean DOA percentage was 0.46 with minimum and maximum values of 0.00 and 16.61%, respectively. The mean corrected bruises percentage was 2.20 with minimum and maximum values of 0.25 and 5.75%, respectively.

Multivariate Analysis for DOA Percentage

In the multivariate model for DOA percentage 9 variables were associated with the log transformed DOA percentage (Table 2), in addition to one interaction term. A significantly increased percentage of DOA birds were associated with high (>15ºC) and low (≤5ºC) ambient temperatures. Moreover, a significantly increased percentage of DOA birds were found if the broilers had been transported during the morning (OR = 1.28), or daytime (OR = 1.46) compared with the night.

Table 1. Summary statistics of technical characteristics of the 1,907 broiler flocks in the data set included in the study.

Factor	Mean	SD	Minimum	Maximum
Flock size	20,433	8,872	1,001	59,431
Age (d)	48.3	1.4	41	57
Body weight (g)	2,437	144	1,836	3,065
Ambient temperature (ºC)	10.8	7.3	-10	34
Stocking density (birds / compartment)	34.5	2.2	25.9	42.7
Loading time (min)	55	17	20	210
Transport time (min)	134	49	15	315
Lairage time (min)	150	84	0	955

In addition, the percentage of DOA birds increased with increasing BW (OR = 1.10, for each 100-g increase of BW), increasing number of birds per compartment (OR = 1.09 for each additional bird in a compartment), increasing flock size (OR = 1.04 for each additional 10,000 broilers), increasing transport time (OR = 1.06 for each additional 15 min) and an increasing lairage time (OR = 1.03 for each additional 15 min). Furthermore, one of the catching companies showed a significantly higher percentage of DOA birds (OR = 1.63) compared to the reference catching company. Breeds B and C showed a significantly lower percentage of DOA birds (OR = 0.67 and OR = 0.76, respectively) in comparison with the reference breed. Finally, the interaction term between ambient temperature and transport time indicated a decreased percentage of DOA birds when the temperature during transport was above 15ºC and lower or equal to 20ºC with an OR of 0.96 (95% confidence interval: 0.92, 0.99), and when the temperature is above 20ºC and lower or equal to 25ºC with an OR of 0.94 (95% confidence interval: 0.91, 0.98).

Multivariate Analysis for Corrected Bruises Percentage

In the multivariate model for corrected bruises percentage, 3 variables were shown to be associated with the dependent variable (Table 3). The corrected percentage of bruises percentage was lower in autumn (OR = 0.37) and spring (OR = 0.49) than in summer. Moreover, transporting the broilers at daytime resulted in a significantly higher (OR = 1.07) percentage of corrected bruises as compared with transporting them at night.

Table 2. Factors associated with the percentage of dead on arrival (DOA) birds in 1,907 broiler flocks slaughtered at a Dutch processing plant in 2000 and 2001.

Variable	Percentage of flocks	Odds ratio[1]	95% Confidence interval	
Moment of transport[2]				
Night	42.3	1		
Morning	9.8	1.28***	1.14	1.43
Daytime	48.0	1.46***	1.33	1.61
Ambient Temperature[3]				
≤5ºC	23.7	1.45*	1.04	2.03
>5ºC - ≤10ºC	28.6	1.23	0.92	1.65
>10ºC - ≤15ºC	20.9	1[2]		
>15ºC - ≤20ºC	16.3	1.54*	1.10	2.14
>20ºC - ≤25ºC	7.3	2.78***	1.91	4.06
>25ºC	3.2	2.52**	1.43	4.45
Catching company				
A	32.0	1[2]		
B	28.4	0.78	0.75	1.00
C	19.9	1.63***	1.44	1.84
D	9.2	0.85	0.72	1.02
E	10.5	0.97	0.80	1.18
Breed				
A	77.1	1[2]		
B	12.3	0.67***	0.59	0.75
C	10.6	0.76***	0.67	0.87
Flock size				
Per 10,000 increase	-	1.04*	1.00	1.09
Body weight				
Per 100 g increase	-	1.10***	1.07	1.14
Compartment stocking density				
Per bird increase	-	1.09***	1.07	1.11
Transport time				
Per 15 min increase	-	1.06***	1.02	1.08
Lairage time				
Per 15 min increase	-	1.03***	1.02	1.03

[1]Odds ratio of 1 = reference value for that variable.
[2]Moment of transport: Night = last load departed from farm before 0800 h; morning = intermediate; daytime = first load departed from farm after 0800 h.
[3]Ambient temperature: If moment of transport = night, then minimum temperature at a neighboring meteorological center was used; if moment of transport = daytime, then maximum temperature at the meteorological center was used; if moment of transport = morning, then the mean of minimum and maximum temperature at the meteorological center was used.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 3. Factors associated with the percentage of corrected bruises in 1,907 broiler flocks slaughtered at a Dutch processing plant (2000 and 2001).

Variable	Percentage of flocks	Odds ratio[1]	95% Confidence interval	
Season				
Summer	26.5	1		
Autumn	26.1	0.37**	0.20	0.68
Winter	24.2	1.12	0.59	2.12
Spring	23.2	0.49*	0.25	0.94
Moment of transport[2]				
Night	42.3	1[1]		
Morning	9.8	1.04	1.00	1.08
Daytime	48.0	1.07***	1.03	1.11
Ambient Temperature[3]				
≤5ºC	23.7	1.26**	1.06	1.50
>5ºC - ≤10ºC	28.6	1.15	0.99	1.33
>10ºC - ≤15ºC	20.9	1[1]		
>15ºC - ≤20ºC	16.3	0.98	0.83	1.16
>20ºC - ≤25ºC	7.3	0.72**	0.57	0.90
>25ºC	3.2	0.85	0.62	1.17

[1]Odds ratio of 1 = reference value for that variable.
[2]Moment of transport: Night = last load departed from farm before 0800 h; morning = intermediate; daytime = first load departed from farm after 0800 h.
[3]Ambient temperature: If moment of transport = night, then minimum temperature at a neighboring meteorological center was used; if moment of transport = daytime, then maximum temperature at the meteorological center was used; if moment of transport = morning, then the mean of minimum and maximum temperature at the meteorological center was used.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Furthermore, ambient temperatures of 5ºC and lower increased the risk for bruises (OR = 1.26), whereas ambient temperatures between 20 and 25ºC reduce this risk (OR = 0.72) in comparison with the reference category (10 to15ºC). None of the interaction terms in the preliminary model appeared to be significantly associated with the corrected percentage of bruises.

Discussion

In this study, we identified factors associated with DOA and bruises percentages of broilers per flock at a Dutch processing plant and we quantified their effects by a multivariate analysis. Ambient temperature, catching company, number of broilers in the flock, mean BW, mean compartment stocking density, transport time and lairage time were all associated with the DOA percentage of broilers. Season, moment of transport and ambient temperature were associated with the bruises percentage of broilers.

During the last decades several studies have been published on the relation between broiler catching and transport and the mortality, bruises, or both (Scholtyssek and Ehinger, 1976; Mayes 1980; Farsaie et al., 1983; Griffiths and Nairn, 1984; Stuart, 1985; Bingham, 1986; Bayliss and Hinton, 1990; Warriss et al., 1992; Lacy and Czarick, 1994; Ekstrand, 1998). However, in these studies risk factors were only identified, and the sizes of their effects were not quantified. Knowledge of this magnitude of effects is necessary in order to establish the reduction of DOA birds or bruises percentage of broilers that could be obtained by removing or reducing these risk factors. In contrast to our study, the studies above were not analyzed by a multivariate statistical model and consequently, were unable to deal with confounding and interaction (Noordhuizen et al., 1997). Finally, our analysis took into account that some flocks originated from the same farm, whereas other studies did not (Scholtyssek and Ehinger, 1976; Mayes 1980; Farsaie et al., 1983; Griffiths and Nairn, 1984; Stuart, 1985; Bingham, 1986; Bayliss and Hinton, 1990; Warriss et al., 1992; Lacy and Czarick, 1994; Ekstrand, 1998). Consequently, the variance of the parameters estimated in those studies may have been underestimated and, as a result, the statistical tests may have been too liberal (SAS Institute, 2000). Warriss et al. (1992) found that the mean DOA percentage was 1.81 times higher when broilers had been transported for more than 4 h compared with transports of shorter duration. In this study, transport time was taken into account as a continuous variable, which gives more detailed information, so a real comparison is not possible. In the present study an OR of 1.04 per 15 min increase transport time was found. For a transport time of 4 h the OR will be 1.87. In our study the maximum transport time was 315 minutes, which will give an OR of 2.27.

In the present study the maximum lairage time was 955 minutes. Per 15 min increasing lairage time the OR was 1.03, which means an OR of 6.57 for a lairage time of 955 minutes. These results show that the risk of death during transport or lairage increases enormous as time increases. Improvement in logistics and in planning at the lairage area at the processing plant will lead to a decrease of mortality; for example, by accepting only broilers of farms within 2 h of transport of the processing plant and keeping lairage time as short as possible.

Handling (Knowles and Broom, 1990), crating (Kannan and Mench, 1996) and transport (Freeman et al., 1984) are known stressors. Apart from stress caused by these factors, broilers suffer metabolic exhaustion due to feed and water withdrawal during a large part of the last day of their life. Broilers will lose live weight (Veerkamp, 1986), glycogen stores may be depleted (Warriss et al., 1988), and hyperthermia can occur during lairage (Warriss et al*.,* 1999). The stress and metabolic exhaustion as mentioned above could probably be a reason for mortality during transport and lairage.

For DOA and corrected bruises percentages, catching and transporting during daytime was found to be a risk factor. Duncan and Kite (1987) found increased tonic immobility, which is an indicator of increased fear, when broilers where handled in bright light (88 lx) compared with handling in the dark (0.35 lx). This phenomenon might form an explanation for the higher DOA percentage in broilers caught and transported during daytime. Moreover, the increased percentage of bruises may have resulted from higher activity of broilers during daytime.

Both low and high temperatures increase the DOA percentage. A good explanation for this increase might be thermal stress. Mitchell and Kettlewell (1998) linked physiological stress to thermal microenvironment during transport with a combined index called "apparent equivalent temperature" (AET). This parameter combines the dry-bulb temperature and vapor density, which can be calibrated by physiological indicators to give a measure of stress. An AET values <50ºC is considered safe for the transport of poultry. Apparent equivalent temperature values between 50 and 70ºC are potentially stressful if maintained for prolonged periods and may lead to some mortality. AET values >70ºC are considered to be stressful with a high risk of mortality. During a normal summer journey of 3 h, with an ambient temperature around 21ºC, the AET value can be 62.3ºC. However, AET may also become too high when the curtains of transport vehicles are closed at low ambient temperatures. Mitchell and Kettlewell (1998) found a maximum AET value of 81.7ºC during winter journeys of 3 h with closed curtains, with an ambient temperature around 10ºC. At an AET value of 80ºC or more, hyperthermia (>1.5ºC) is profound and may become life threatening (Mitchell and Kettlewell, 1998). A high AET may be a part of the explanation for mortality both at high and low temperatures. Another part of the explanation may be high temperatures in the broiler house during catching.

The interaction between ambient temperature and transport time resulted in a smaller increase of DOA percentage then would have been expected from the separate effects of ambient temperature between 15 and 25 ºC and transport time. This is in accordance with data produced by Webster et al. (1992), who observed that broilers transported in an open transport vehicle would be thermally comfortable when the ambient temperature varies from 18ºC to 26ºC. So longer transport times are more severe outside this zone.

An increase of the compartment stocking density likely results in an increase of the environmental humidity due to water evaporation from the respiratory tract, skin and excreta. Under these circumstances heat loss will be more difficult, which can lead to hyperthermia. A heavier BW makes it also more difficult to lose heat (Dawson and Whittow, 1994).

It is unclear why fewer bruises were observed during spring and autumn. Other factors not included in our dataset, like rain or wind could have an effect. Bruises may originate in the broiler house several days before slaughter.

A member of a catching company has to load between 1,000 and 1,500 birds / h. Larger flocks mean an increased catching time. For a member of a catching team it could be difficult to maintain concentration and exercise care throughout a longer catching time. To do the job optimal the size of a catching crew would need to be increased, which increases labor costs. Bayliss and Hinton (1990) reported that 35% of the mortality in DOA broilers could be accounted for by catching and transport injuries. Besides the human factor, which influences the mortality in large flocks, also the longer feed withdrawal time might have an influence on mortality.

In conclusion, changing management at the processing plant can reduce the effects of some of the factors that impact mortality or corrected bruises. Percentage of mortality can be reduced by reducing transport and lairage time. The effect of low ambient temperatures on mortality probably can be reduced by not using the curtains of the transport vehicle too soon. Finally, processing plants can change the time at which they slaughter the birds. To reduce DOA broilers, it is recommended that processing begin around midnight rather than at 0500 h. Changing the processing time may also reduce the corrected bruises percentage.

Better insight in the influence of these risk factors on the physiology of broilers is necessary to reduce stress and suffocation and thereby reduce DOA percentage; such changes would improve the welfare of the broilers during the last day of life.

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Chapter 3

Pathological features in dead on arrival broilers with special reference to heart disorders

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Submitted

Abstract

A gross post mortem investigation was done on 302 broilers, which died between catching and slaughter (DOA broilers), to establish predisposing factors for dying in this period. Special attention was paid to heart disorders, which were established by determining the ratio of the right ventricle mass to the total ventricle mass (RV:TV), and to post mortem changes in hearts and lungs of DOA broilers.

Macroscopic pathologic lesions were found in 89.4% of DOA broilers. Signs of infectious diseases appeared to be most frequent (64.9%), followed by heart and circulation disorders (42.4%), and trauma (29.5%). The RV:TV was significantly higher for DOA broilers in comparison with slaughtered broilers. The prevalence of hearts with an abnormal RV:TV in DOA broilers was 34.4% versus 4.1% in slaughtered broilers. DOA broilers with an abnormal heart ratio showed more frequently ascites and hydropericardium.

Post mortem changes in lungs depend on the position of the carcass the first several hours after death. Broilers, which remain in dorsal recumbancy for several hours after death, developed engorged lungs.

A good health status as well as more attention for the catching and crating process is crucial in decreasing the percentage of DOA broilers. Prevention of an increased heart ratio and of ascites will not only improve the livability in the broiler house and also decrease the DOA rate enormously.

Introduction

Mortality of broilers between catching and the moment of slaughter is of great economic significance. Estimates of the percentage of these so-called dead on arrival (DOA) vary from 0.05% to 0.57% (Bingham, 1986; Bayliss and Hinton, 1990; Gregory and Austin, 1992; Warriss et al., 1992; Ekstrand, 1998; Nijdam et al., 2004). Moreover, some events on the last day of the broilers life cause severe stress as indicated by high corticosterone values (Freeman et al., 1984; Kannan and Mench, 1996; Nijdam et al. 2005), prolonged tonic immobility (Cashman et al., 1989; Jones, 1992), or increased heart rate and increased body temperature (Duncan et al., 1986; Warriss et al., 1999). Consequently, the welfare of broilers obviously is diminished during this last phase of their lives.

To reduce the fraction of DOA broilers it is necessary to gain insight into the risk factors. Nijdam et al. (2004) found that factors that contribute to high mortality rates are moment of transport, ambient temperature, catching company, breed, flock size, BW, compartment stocking density, transport time, and lairage time. On the other hand it is also important to gain insight into the pathological features of DOA broilers. However, publications about the results of gross postmortem examination to identify such features are limited and often not easy to interpret.

Trauma is one of the most common features found at postmortem examination. Bayliss (1986) and Gregory and Austin (1992) found signs of trauma in 35% of the DOA. Dislocated or broken hip is the most common type of trauma (Gregory and Austin, 1992), especially when the broilers suffer from femoral head necrosis (Binstead, 1986). Trauma may be caused by rough handling at catching, loading, and unloading (Stuart 1980). Gregory and Austin (1992) also reported acute heart failure and congestive heart failure as causes of death in 4% and 47% of DOA broilers respectively. However, they diagnosed congestive heart failure indirectly by the presence of engorged lungs and they did not report their diagnostic criteria for acute heart failure. In addition, Bayliss (1986) pointed out that 40% of the DOA was due to stress and suffocation. However, also their findings are difficult to interpret, as their method of diagnosing was not given.

A number of conditions, such as housing environment, rapid growth rates, high basal metabolic rate, and high energy rates (Scheele et al., 1991; Julian 1993) can create oxygen deficit in broilers, resulting in hypertrophy of the right heart ventricle possibly followed by right-sided congestive heart failure and ascites (Witzel et al., 1990). Although the ratio of the right ventricle to the total ventricle mass as a gross indicator of ascites has been determined previously under several experimental conditions (McGovern et al., 1999; Gonzales et al., 1998), no published data are available on this parameter for heart hypertrophy and heart failure in DOA broilers.

In this study we investigated DOA broilers for signs of infectious diseases, trauma, some miscellaneous disorders, and heart and circulation disorders by gross postmortem examination. Special attention was paid to heart disorders, which were established by determining the ratio of the right ventricle mass to the total ventricle mass in DOA broilers and, for reasons of comparison, also in slaughtered broilers originating from the same flock.

We performed also an experiment to exclude misinterpretation. Postmortem examination of one group of broilers was performed immediately after death, while another group was examined 24 h postmortem. This experiment was done to establish normal postmortem changes in hearts and lungs of broilers. Both the investigation and experiment must gain insight in predisposing factors of DOA broilers. Such knowledge may be helpful to reduce the amount of DOA broilers.

Materials and Methods

Experimental Design

Investigation of DOA broilers. The study population comprised 21 flocks, which had been slaughtered at a single Dutch processing plant between July and September 2002. The flocks, Ross and Hybro stocks, contained between 9,836 and 45,199 broilers, and were between 46 and 50 days of age at slaughter. Two flocks were male flocks the others were mixed flocks. Out of these flocks, per flock approximately 15 (with a minimum of 13 and a maximum of 20) DOA broilers were taken randomly and from the slaughtered broilers 60 hearts were taken randomly.

The DOA broilers and the hearts of the slaughtered broilers were transported to the Veterinary Faculty of Utrecht University, The Netherlands. In total 316 DOA broilers were collected, of which 14 carcasses were autolytic to such a degree that these broilers most likely already died before catching and were therefore not examined. The remaining 302 DOA broilers were dissected at the day of slaughter of the flock. Out of the collected hearts of slaughtered broilers 152 hearts originating from six flocks were not suitable for examination due to an incorrect fine-tuning of the heart separator in the processing plant. So, in total 1108 hearts were suitable for examination.

The carcasses were weighed and gross postmortem examination was performed. Each carcass was examined for signs of trauma: head trauma, broken bones, dislocated bones (tibia in the knee joint, humerus in the shoulder joint, and femur in the hip joint), and ruptured liver. Furthermore, they were examined for signs of infectious diseases: fibrinous polyserositis, purulent arthritis, tracheitis (petechiae present in the trachea; but mostly diffuse red trachea mucosa with muco- to mucopurulent exudate), and laryngitis (petechiae present in the larynx). Also pale and yellowish liver, femur head necrosis, detachment at the articular cartilage of the femur on manual abduction of the legs, and sex were reported.

In addition we investigated whether signs of heart and circulation disorders as hydropericardium (marked distention of the pericardial sac with clear yellow, strawlike fluid), and ascites were present. Moreover, as a parameter for heart condition of DOA, the ratio of the right ventricle mass to the total ventricle mass of the heart was assessed (RV:TV). Atria were removed from the heart, and thereafter the right ventricular wall was separated from the left ventricle (Julian et al., 1986; McGovern, 1999). Both the right ventricular wall including the muscular right atrio-ventricular valve as well as the left ventricle were weighed with a Sartorius (BL610) weighing balances.

The RV:TV was also determined of hearts of slaughtered broilers from the same flocks from which DOA broilers originated. The RV:TV of slaughtered broilers was compared with the RV:TV of DOA broilers.

Experiment for Postmortem Changes. To exclude significant effects on our results caused by postmortem changes in lungs and heart, an experiment was done with 57 Ross broilers of 59 days of age, which were reared together. Thirteen female and 16 male broilers were electrocuted, debleeded and immediately examined for RV:TV and engorged lungs. These observations were compared with another group of 9 female and 19 male broilers that were electrocuted, not debleeded, and examined for RV:TV and engorged lungs 24 h postmortem. Of these broilers 50% was placed on the dorsal side, while the others were placed on the ventral side immediately after electrocution. Gross postmortem was done as described above.

Statistical Analysis

The statistical analyses were performed in the SAS-PC System® Version 8.1 for Windows (SAS Institute, Cary, NC, 2000). PROC FREQ and PROC MEANS were used for the descriptive analyses. The distribution of RV:TV was skewed, and therefore a logarithmic transformation was applied to become normally distributed. Analysis of RV:TV was done by using a generalized linear model performed by PROC GLM. Significant differences between treatments, sex, and moment of examination were separated using least squares means procedures of SAS. An analysis of BW was done by ANOVA comparing flock means with mean BW of DOA broilers. All statements of significance are based on the probability level of 0.05, unless otherwise stated.

For judgment of individual hearts, a RV:TV value below mean value of slaughtered broilers minus 2 * SD or above mean value plus 2 * SD was considered as abnormal. The strength of association between ascites, hydropericardium, and RV:TV was analyzed by Chi-square test.

Results

Experiment for Postmortem Changes

The RV:TV of broilers that were examined directly after electrocution was not significantly different from broilers investigated 24 h postmortem. However, significant sex difference was observed: female broilers had a significantly lower RV:TV then male broilers (Table 1, experimental broilers).

All broilers that were placed on the ventral side had 24 h postmortem dark red colored breast musculature. In contrast, all broilers placed on the dorsal side showed 24 h postmortem a pale appearance of this area (Figure 1). The lungs of the broilers placed on the ventral side were of normal appearance: slightly collapsed and pink colored. The lungs of the broilers placed on the dorsal side were engorged: dark red colored, a very wet appearance, and a firm consistency with no tendency to collapse (Figure 2). Of all broilers used in the experiment 86% showed detachment at the articular cartilage of the femur on manual abduction of the legs.

Table 1. Means (±SD) of the right ventricle mass to the total ventricle mass of the heart of broilers of the field investigation and of broilers of the postmortem experiment.

Sex	RV:TV[1] in experimental broilers		RV:TV in field broilers	
	Examined 0 h postmortem	Examined 24 h postmortem	Slaughtered	Dead on arrival
Both sexes	$0.20^{a} \pm 0.020$ (n = 29)	$0.21^{a} \pm 0.028$ (n = 28)	$0.19^{b} \pm 0.027$ (n = 1104)	$0.24^{a} \pm 0.058$ (n = 302)
Female	$0.19^{b} \pm 0.020$ (n = 13)	$0.20^{b} \pm 0.025$ (n = 9)	-	$0.23^{b} \pm 0.053$ (n = 84)
Male	$0.21^{a,b} \pm 0.029$ (n = 16)	$0.22^{a} \pm 0.029$ (n = 19)	-	$0.24^{a} \pm 0.060$ (n = 218)

[1]RV:TV = Ratio of the right ventricle mass to the total ventricle mass of the heart.
[a,b] Statistical analyses was not performed between field broilers and experimental broilers; furthermore, data of both sexes were compared only within the row, while data referring to female and male were compared mutually. Means with different superscript differ significantly ($P \leq 0.05$).

Table 2. Pathological signs in dead on arrival (DOA) broilers.[1]

Pathological signs	Number	Percentage
Heart and circulation disorders		
Abnormal RV:TV[2] (> 0.24)	104	
Ascites or Hydropericardium or both		
with abnormal RV:TV	22	
with normal RV:TV	24	
Total	128	42.4%
Trauma		
Broken bones	34	
Dislocated bones	28	
Ruptured liver	41	
Head trauma	9	
Total	89	29.5%
Signs of infectious diseases		
Laryngitis or tracheitis or both	130	
Fibrinous polyserositis or purulent arthritis	66	
Total	196	64.9%
Miscellaneous disorders		
Pale and yellowish liver	11	
Femur head necrosis	2	
Total	13	4.3%
DOA broilers without macroscopic lesions	32	10.6%

[1] n = 302.
[2] RV:TV = Ratio of the right ventricle mass to the total ventricle mass of the heart.

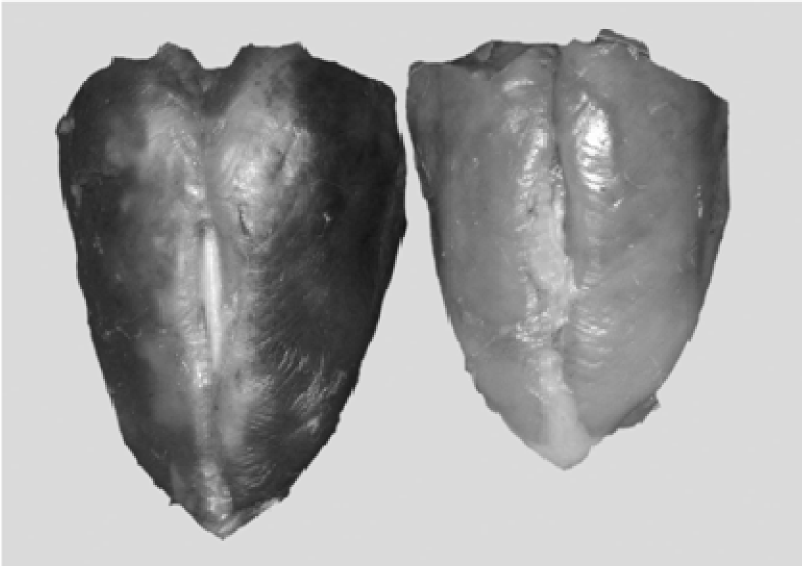

Figure 1. Breast musculature originating from broilers, which were placed on the dorsal side (right) and on the ventral side (left) immediately after death. Photographs were taken 24 h postmortem. Dark red colored appearance of left breast musculature, a pale appearance of the right breast musculature.

A **B**

Figure 2. Lungs originating from broilers, which were placed on the dorsal side (2A) and on the ventral side (2B) immediately after death. Lungs were taken out of the carcasses 24 h post mortem. Dark and wet appearance of the lung in figure 2A, costal incisures well visible due to firm consistency as compared to the lung in figure 2B.

Investigation of DOA broilers

Characteristics. The mean ± SD DOA percentage of the 21 flocks was 0.59 ± 1.53, with minimum and maximum values of 0.07 and 7.33%, respectively. The mean ± SD rejection rate was 0.88 ± 0.59, with minimum and maximum values of 0.4 and 2.9%, respectively. The mean BW of slaughtered broilers was 2457 g. The mean BW of DOA broilers was significantly lower, namely 2337 g. Of the DOA broilers that originated from mixed flocks 69.7% was male and 30.3% was female.

Heart Ratio**.** The RV:TV is significantly higher for DOA broilers than for slaughtered broilers. Moreover, the RV:TV for DOA males is significantly higher then for DOA females (Table 1, field broilers).
Figure 3 shows the distribution of RV:TV of slaughtered broilers and DOA broilers. Abnormal hearts had a RV:TV ratio of < 0.14 or > 0.24. The percentage of slaughtered broilers with an abnormal RV:TV was 4.1%, while the percentage of DOA broilers with an abnormal RV:TV was 34.4%. Only four abnormal hearts (all of slaughtered broilers) had RV:TV values < 0.14.

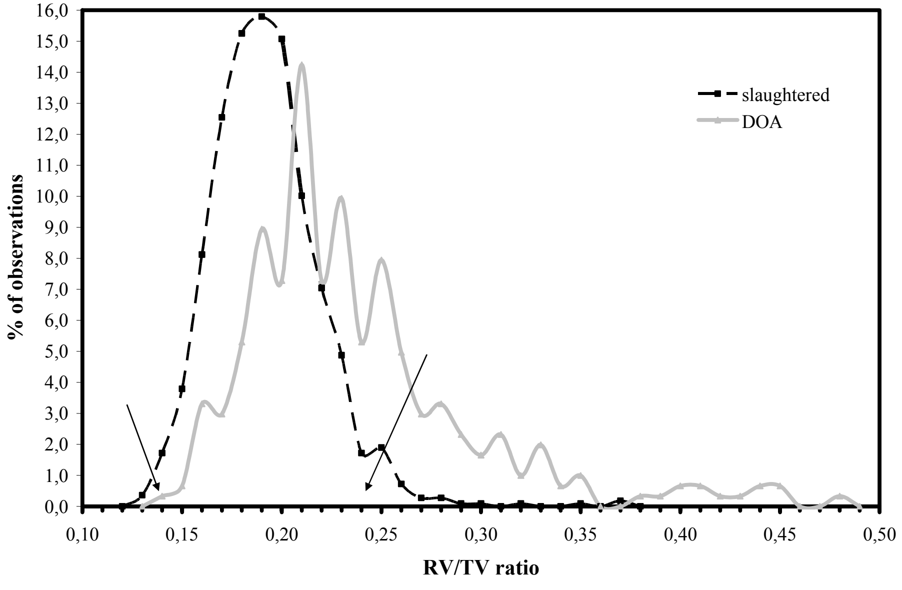

Figure 3. Distribution of the right ventricle mass to the total ventricle mass ratio of slaughtered- and of DOA broilers.
Arrows indicate low and high cutoff point.

Macroscopic Pathology. Table 2 shows the pathological signs of DOA broilers. Some broilers showed signs of more than one type of disorder. In 10.6% of the DOA broilers no macroscopic lesions were detected at all. Thus, almost 90% of the DOA broilers showed gross pathological signs. Most frequently observed were laryngitis or tracheitis or both, abnormal RV:TV, and fibrinous polyserositis or purulent arthritis. Two DOA broilers had femur head necrosis, while 88.7% of the DOA broilers showed detachment at the articular cartilage of the femur on manual abduction of the legs.

In total, 46 DOA broilers had ascites or hydropericardium or both, of which 94% were male broilers. Table 3 shows the percentages of ascites and hydropericardium in DOA broilers with abnormal and with normal RV:TV. Both the prevalence of ascites and of hydropericardium tended to be higher in DOA broilers with hearts with abnormal RV:TV. However, none of these findings were significant. However, heart and circulation disorders (ascites or hydropericardium or both) were observed significant more frequently in DOA broilers with an abnormal RV:TV. Moreover, there was also a significant association between ascites and hydropericardium.

Table 3. Percentage of ascites and hydropericardium in DOA broilers with abnormal RV:TV[1] and normal RV:TV.

Heart and circulation disorders	Percentage of DOA broilers with	
	Normal RV:TV[2]	Abnormal RV:TV (> 0.24)[3]
Only ascites	2.0	3.8
Only hydropericardium	7.6	11.5
Ascites and hydroperidcardium	2.5	5.8
Ascites, hydroperidcardium or both	12.1[a]	21.2[b]

[1] RV:TV = Ratio of the right ventricle mass to the total ventricle mass of the heart.
[2] n = 198.
[3] n = 104.
[a,b] Means within a row with no common superscript differ significantly ($P \leq 0.05$).

Discussion

In this study we observed macroscopic pathologic lesions in 89.4% of the DOA broilers. Signs of infectious diseases appeared to be most frequent, followed by heart and circulation disorders, and trauma. With respect to heart and circulation disorders RV:TV was significantly higher in DOA broilers than in slaughtered broilers.

Besides the hearts of slaughtered broilers, our study did not include a control group. As a consequence, we cannot formally establish whether the observed pathological findings, the RV:TV excluded, are associated with the risk of becoming a DOA. However, broilers or parts of broilers that are not fit for human consumption are rejected at the processing plant. Consequently we can use the rejection rate as a reference point for the observed pathological findings in this study. The mean rejection rate of the flocks examined, which was determined at the processing plant, was 0.88%. In DOA broilers the prevalence of ascites (6.3%), and fibrinous polyserositis (21.9%) by far exceeded the rejection rate of slaughtered broilers, therefore these conditions probably predispose for DOA.

The prevalence of trauma in DOA broilers was 29.5%. In cases of head trauma, and ruptured liver it is clear that this is the cause of death. In slaughtered birds the prevalence of broken and dislocated bones was unknown, because only the traumatized part of a slaughtered broiler will be condemned, not the whole carcass is rejected. However, the rejection rate was far below the percentage of trauma in DOA broilers. Therefore, this condition probably also predisposes broilers to become DOA.

Most of the trauma-induced conditions we found in DOA broilers probably occurred during catching and crating. Careful handling can thus reduce the amount of DOA broilers enormously. In several reports (Bayliss and Hinton, 1990; Kettlewell and Mitchell, 1994; Metheringham, 1996) it is concluded that more attention must be paid to the catching and crating process to reduce mortality, injuries, and stress. The percentage of broilers with trauma found in this study is in agreement with results already presented in 1986 (Bayliss; 1986) and 1992 (Gregory and Austin; 1992). Obviously, still no improvement is achieved in the field.

Pale and yellowish livers will neither contribute to the rejection rate of slaughtered birds nor to DOA broilers, as variation in color of the liver may be attributed to physiological influences e.g. post prandial processing of fat.

The prevalence of laryngitis and tracheitis in slaughtered broilers is unknown. Broilers with tracheitis and laryngitis might have problems with respiration moreover as these broilers also might possess lung damage. It is likely that the oxygen uptake of some of these broilers is insufficient to cope with the severe stress occurring on the last day of life. So, the prevalence of laryngitis and tracheitis in DOA broilers might be higher than in slaughtered broilers, making it a pathological condition that also may predisposes broilers to become DOA.

Ascites in broilers may result from pulmonary hypertension. Pulmonary hypertension can induce myocardial hypertrophy and dilatation of the right cardiac ventricle (Decuypere et al., 2000). Right ventricle hypertrophy may be indexed by the ratio RV:TV (Julian et al., 1986; Gonzales et al., 1998). In this study a significant relation was found between hypertrophy of the right ventricle and ascites and hydropericardium. Moreover, dependence between ascites and hydropericardium was demonstrated. These findings underline results found earlier under experimental conditions (Decuypere et al., 2000).

Based on engorgement of lungs, Gregory and Austin (1992) concluded that 47% of DOA broilers had died of congestive heart failure. This conclusion might be doubtful as we demonstrated that engorged lungs occur when broilers remain in dorsal recumbancy for several hours after death, rendering this lung condition useless in diagnosing congestive heart failure in broilers, which are already dead for some time.

Bayliss (1986) found no pathological lesions or injuries in 40% of DOA broilers and concluded that these birds had died due to stress and suffocation. In our study only 10.6% of DOA broilers lacked macroscopical disorders. Discrepancy between these results can be explained assuming that at least a part of the DOA broilers in the study of Bayliss (1986) had abnormal RV:TV.

In conclusion, our observations indicate that infectious diseases, heart and circulation disorders, and trauma play an important role in the incidence of DOA broilers. Therefore, both a good health status as well as more attention for the catching and crating process is crucial in decreasing the percentage of DOA broilers. More research directed to prevention of increased RV:TV and of ascites is needed as prevention of these conditions will both improve the livability in the broiler house but also decrease the DOA rate.

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Chapter 4

Comparison of bruises and mortality, stress parameters, and meat quality in manually and mechanically caught broilers

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Abstract

A field trial was conducted to compare manual catching of broilers with a mechanical catching method. Both methods were compared with respect to the incidence of bruises and dead on arrival, stress parameters and meat quality. Also the dynamics of corticosterone, glucose and lactate were investigated on the day broilers were killed.

The broilers originated from eight commercial broiler farms; visits were made on the day of catching during spring and autumn of 2001. Broilers of one house were caught manually and those of the second house were caught mechanically.

Plasma samples were taken before catching started, 30 min after the start of catching, 30 min before the end of catching and at exsanguination of broilers from the first- and last- loaded transport vehicles. Postmortem measurements of the pH, temperature and water holding capacity were made.

Mechanical catching was associated with higher DOA percentages than manual catching in spring, although the difference was not significant in autumn. Catching method did not influence the percentages of bruises or meat quality. Moreover, CORT levels indicated that both methods induce the same amount of stress. The dynamics of CORT, glucose and lactate levels show a similar pattern. The plasma levels increase at the start of catching and they further increase during transport, shackling and stunning. However during catching itself, no large changes were observed. Our findings indicate that attempts to reduce stress in broilers during the last day of life can better be focused on factors other than catching.

Introduction

During the last day of a broilers life broilers may get bruised or even die. Data of the levels of bruises vary greatly from 0.022% to 25% (Taylor and Helbacka, 1968; Mayes, 1980; Farsaie et al., 1983; Griffith and Nairn, 1984; Ekstrand, 1998; Knierim and Gocke, 2003). Based on histological research of bruised tissue Griffith (1985) concluded that 40% of the bruises recorded at the processing plant originated from catching and crating, whereas other bruises occur at the broiler house before catching or at the processing plant. Besides bruises, catching and crating can lead to dead broilers on arrival (DOA). Mean percentages of DOA birds range from 0.05% to 0.57% (Bingham, 1986; Bayliss and Hinton, 1990; Gregory and Austin, 1992; Warriss et al., 1992; Ekstrand, 1998; Nijdam et al., 2004). Consequently, the welfare of broilers during this phase of their life is diminished.

Currently, broilers are caught almost entirely by hand; they are grasped by the leg, inverted and carried by a catcher with 3 or 4 birds in each hand (Bayliss and Hinton, 1990). During an average working night or day a catcher may lift 5 to 10 tons of broilers (Kettlewell and Turner, 1985). This work has to be done in a very dusty and dirty environment (Bayliss and Hinton, 1990), and working under these circumstances may lead to injuries, such as bruises, to the broilers.

Catching and crating will cause severe stress. Handling of broilers in inverted position leads to an increase in plasma corticosterone (CORT) (Kannan and Mench, 1996) and prolonged tonic immobility reactions (Jones, 1992); crating leads to an increase of CORT in broilers (Kannan and Mench, 1996). This preslaughter stress can cause increased production and use of epinephrine and glucocorticoids, which can negatively affect meat quality (Lawrie, 1966). Broilers that are caught mechanically are pulled upright and gently by rubber fingered rotors on a conveyer belt such that the birds are not inverted, which may reduce preslaughter stress.

To reduce preslaughter stress and improve product quality and the welfare of humans and broilers, studies have been performed to compare manual and mechanical harvesting over the last 20 yr. Duncan et al. (1986) reported that mechanical harvesting was less stressful to broilers than manual harvesting, as measured by heart rate and duration of tonic immobility. Farsaie et al. (1983) observed fewer bruises on mechanically caught broilers, as did by Lacy and Czarick (1994). However in both studies neither the speed of catching nor the flock size was representative for practical circumstances.

Conflicting conclusions were reached in large-scale observational studies of injuries and DOA. Ekstrand (1998) reported higher frequencies of injuries and DOA after mechanical catching, whereas Knierim and Gocke (2003) found significantly reduced injury rates after mechanical catching and no differences concerning the number of DOA birds between the 2 harvesting methods. Because these studies were observational studies, confounding may have occurred (Noordhuizen et. al, 1997). These studies did not investigate if there was any difference in preslaughter stress and meat quality of the carcasses caused by catching method. However, these factors are important in a view of animal welfare and economic profitability.

The aim of the present investigation was to compare manual catching with a mechanical catching method under practical conditions in a field trial. Both methods were compared with respect to the incidence of bruises and DOA, meat quality characteristics, and the blood parameters, CORT, lactate, and glucose. We also investigated the changes of blood parameters between catching and processing.

Materials and Methods

Data Collection

The broilers originated from 8 commercial broiler farms with 2 broiler houses, each. The farms were visited at the day of catching, both during spring and autumn of 2001. During the first visit, in spring, we determined by random allocation at which broiler house the birds would be caught manually and at which one they would be mechanically. During the visit in autumn the order was reversed; thus both methods were applied in both houses, and both methods were applied once as first and once as second. The broiler houses selected were suitable for mechanical catching (without disturbing obstacles) and contained flocks of between 10,462 and 25,695 broilers. The flocks used in this study were Cobb, Ross and Hybro stocks, were between 46 and 50 days of age, and had mean weights varying from 2,345 g to 2,780 g. After catching, the broilers were transported to a processing plant in The Netherlands where further examination was performed and where the following data were collected: flock size, age at slaughter, BW at slaughter, rejection rate, uniformity, stocking density, ambient temperature, loading time, transport time, and lairage time. Uniformity is defined as the percentage of broilers with a slaughter weight of less then 65% of the mean slaughter weight. Broilers and organs which were damaged are referred to as rejects. Rejection rate was defined as the percentage of rejected birds and organs in kilograms of total slaughter weight.

Mechanical Catching

The catching machine (Chicken cat harvester of JTT ApS, Bredsten, Denmark) used in the field trial possessed a collecting unit in the front that contained 3 rotating, hydraulically driven cylinders. The surface of the cylinders was covered with long flexible rubber fingers, which forced the broilers onto a conveyor belt that was adjustable in length (up to 20 m) that moved sideways over a distance of 24 m. At the end of the conveyor belt broilers ended up on a smaller belt, which could be varied in height by hand, that put the broilers into the transport containers (Figure 1).

Figure 1. The catching machine ‘Chicken cat harvester’ used in the field trial.

The containers were standing on a loading platform attached to the rear of the catching machine. The machine was suitable for the use of containers with eight compartments. Each compartment has a surface of 1.25 m^2, and could contain a maximum of 85 kg of broilers. In practice a drawer is filled with 32 to 36 broilers, depending on the mean weight of the birds and environmental temperature. A forklift truck removed the loaded containers and replaced them with empty ones. The capacity of the catching machine during this field trial was approximately 7,000 broilers per hour.

Manual Catching

Professional catching teams did the manual catching. Six to nine catchers and one forklift truck driver formed a team. A catcher would grasp a broiler by the leg and inverted the bird. After catching 6 to 8 birds this way, the catcher carried them to the nearest container with 3 to 4 birds in each hand, and placed them into a compartment. The containers were placed within 10 m distance of the catching place. The amount of broilers put into a compartment was the same for both houses and methods within each farm.

Plasma Samples

Forty-five minutes before catching started, 30 broilers were chosen at random, and blood samples were collected by puncturing the vena ulnaris. Thirty minutes after the start of the catching process, blood samples were taken from 15 randomly chosen broilers that had just been caught, and approximately 30 minutes before the end of the catching process, when the chicken house was almost empty, again blood samples were collected from 15 randomly chosen broilers that had just been caught. No bird was sampled more than once. Blood samples (about 2 mL) were collected into tubes containing sodium fluoride.

After transport, and lairage the broilers were dumped on a conveyer belt, hung upside down at the slaughter line, electrical stunned, and killed by automated neck cutting equipment. During bleeding, blood samples were collected from 15 broilers of the first loaded transport vehicle and 15 of the last loaded transport vehicle. The time between the first and the last loaded vehicle was dependent on the number of broilers per broiler house. The processing plant slaughtered 7,000 broilers per hour, which was approximately the number of broilers on one vehicle. In total, blood was taken from 90 broilers per house, for a total of 180 blood samples per farm and

1,440 for round 1 from the 8 farms in spring 2001 and another 1,440 samples for round 2 from the 8 farms in the autumn 2001.

Analysis of Plasma Samples. Blood samples were kept on ice until plasma was separated by centrifugation for 10 min at 1,500 rpm. Plasma samples were stored at –20ºC until assayed. Plasma was examined for CORT, glucose and lactate concentrations.

Plasma CORT concentration was measured using a specific radioimmunoassay kit (IDS, Inc., Boldon, UK), with a sensitivity of 0.39 ng / mL, with low cross-reactions with aldosterone (0.20%), cortisol (0.40%) and deoxycorticosterone (3.30%). The intraassay variability was 3.9%. Lactate concentration was determined after deproteinization using a commercial kit (procedure 826-UV, Sigma Diagnostics, Steinheim, Germany) modified to use with the Monarch Chemistry System (Monarch Chemistry System, Instrumentation. Laboratories, Zaventem, Belgium). Glucose concentrations were measured spectrophotometrically by using an IL Test Glucose also developed for the Monarch 2000 system.

Meat Quality

The broilers that were blood sampled at the slaughter line were also used for postmortem measurement of the pH, temperature, and water holding capacity (WHC) of the pectoralis major muscle. The pH was measured at 0.25 (initiate), 2.0, 5.0 and 24 h (ultimate) postmortem with a pH meter with a Xerolyt pH electrode (Schott CG 818, Schott-Gerate GmbH, Hofheim, Germany). For 10 sec the electrode was inserted approximately 2.5 cm below the surface of the anterior portion of the muscle. To exclude differences in pH values due to differences in temperature, also the temperature of the pectoralis major muscle was measured in the same way, and at the same time as the pH. The temperature was measured with an Ebro TFN 1093 SK thermometer (Electronic GmbH, Ingolstad, Germany). The development of temperature of the muscle was for both methods almost similar, namely from 41.6 ± 2.0ºC to 4.7 ± 1.8ºC to 1.4 ± 1.4ºC to 1.8 ± 1.1ºC at 24 h postmortem for manual caught flocks, and from 41.6 ± 1.1ºC to 4.7 ± 1.8ºC to 1.3 ± 1.1ºC to 1.7 ± 1.0ºC at 24 h PM for mechanical caught flocks.

At 24 h postmortem WHC was measured with a filter paper absorption method. An incision was made in the pectoralis major muscle. A filter paper (589/3 rundfilter blauband, Schleicher & Schuel, Dassel, Germany) with a diameter of 45 mm was placed into the incision during 30 s, after which the increase in weight of the paper was measured (Kauffman et al., 1986).

Bruises and Mortality

The percentage of bruises at breast, wings and legs of each flock was recorded according to the legislative standards of The Dutch Product Board for Poultry and Eggs (PVE, 2001). According to that standard, a bruise is a discoloration of the skin or under the skin due to the presence of blood that is larger then 1 cm^2 for breast and leg and larger then 2 cm^2 for the wing. Each leg and each wing can contribute to the total number of bruises in a flock (PVE, 2001). Employees of the processing plant remove dead broilers at the carousel table, where broilers are hung on a shackle line. The variable DOA percentage was calculated using the total number of dead broilers per flock counted at the processing plant as numerator and the total number of transported broilers per flock as denominator.

Statistical Analyses

The statistical analyses were performed with SAS software (SAS Institute, 2000) using broiler flock as the statistical unit. PROC FREQ and PROC MEANS were used for the descriptive analyses. The assumption of normality of the outcomes was assessed applying stem-and-leaf plots and normal–probability plots. The distribution of the plasma CORT concentrations was skewed, and therefore a logarithmic transformation was applied so that the data would be normally distributed.

Nonparametric tests (Wilcoxon 2-sample test) were used to analyze the background data and rate of injuries and DOA because they were not normally distributed. Main effects (round, method and time effect) and their interactions were determined using ANOVA performed by PROC MIXED procedures on plasma concentrations and meat quality. Flock was included as a random effect, to take into account that there is dependency between birds in the same flock. Due to the missing CORT values of round 2, all results are presented for both rounds separately.

Results

Background Data

Background data are shown in Table 1. During round 2 (October to December 2001) the mean age of slaughter was significantly higher then during round 1 (May to July 2001).

Table 1. Means ± SEM of general characteristics of the flocks included in the study for spring and autumn 2001, for mechanical and manual catching.

	Round 1 (spring 2001)		Round 2 (autumn 2001)	
Factor	Mechanical catching (n=8)	Manual catching (n=8)	Mechanical catching (n=8)	Manual catching (n=8)
Flock size	19,302 ± 1793	18,677 ± 1788	19,493 ± 1832	19,855 ± 1679
Age[1] (d)	47.8 ± 0.5	47.8 ± 0.5	48.9 ± 0.5	48.9 ± 0.5
Body weight (g)	2,472 ± 48	2,448 ± 39	2,497 ± 49	2,533 ± 56
Rejection rate (%)	0.61 ± 0.20	0.89 ± 0.36	3.00 ± 2.08	3.00 ± 2.17
Uniformity (%)	0.51 ± 0.16	0.55 ± 0.11	0.53 ± 0.06	0.40 ± 0.05
Stocking density (birds/compartment)	33.1 ± 0.89	32.6 ± 0.66	32.3 ± 0.75	34.5 ± 1.24
Ambient temperature[1] (ºC)	17.3 ± 2.4	17.0 ± 2.2	7.9 ± 1.5	8.8 ± 2.0
Loading time (min)	52 ± 4	47 ± 4	56 ± 4	51 ± 2
Transport time (min)	136 ± 18	134 ± 19	143 ± 19	144 ± 18
Lairage time (min)	133 ± 7	115 ± 17	101 ± 19	131 ± 21

[1]Significant difference between rounds ($P < 0.05$).

The ambient temperature was significantly higher during round 1. Moreover, as expected during random allocation there were no significant differences between mechanical and manual catching relating to flock size, age at slaughter, BW at slaughter, rejection rate, uniformity, stocking density, ambient temperature, loading time, transport time, or lairage time for flocks caught during round 1 or 2.

Mechanical versus Manual Catching

DOA and Bruises Percentages. During the first round DOA percentage was higher ($P \leq 0.05$) for flocks caught mechanically vs. manually (Table 2). Mechanical catching resulted in 0.38 ± 0.1% DOA, whereas this percentage was 0.13 ± 0.02 after manual catching. The second round did not show a significant difference of DOA percentage, but the trend was similar between mechanical and manual catching. Looking at the results of bruises for each round separately, catching method did not affect leg, wing and breast bruising (Table 2). Leg bruises were more frequently observed during round 1.

Table 2. Mean percentages ± SEM of dead on arrival (DOA) and bruises on legs, breast and wings for mechanical and manual catching.

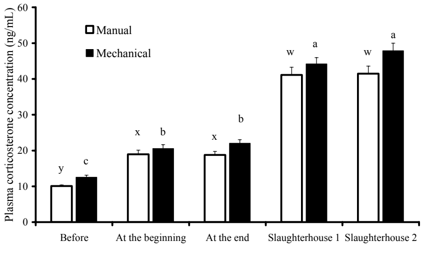
	Round 1 (spring 2001)		Round 2 (autumn 2001)	
	Mechanical catching (n=8)	Manual catching (n=8)	Mechanical catching (n=8)	Manual catching (n=8)
DOA (%)	$0.38^{a} \pm 0.10$	$0.13^{b} \pm 0.02$	0.32 ± 0.10	0.17 ± 0.04
Leg bruises[1] (%)	0.69 ± 0.09	0.74 ± 0.05	0.54 ± 0.05	0.51 ± 0.07
Wing bruises (%)	7.8 ± 0.89	8.4 ± 1.20	7.8 ± 1.54	6.7 ± 0.55
Breast bruises (%)	0.23 ± 0.05	0.25 ± 0.05	0.18 ± 0.05	0.23 ± 0.04

[a, b]Means within a row and for each round with no common superscript differ significantly ($P \leq 0.05$).
[1]Significant difference between rounds ($P < 0.05$).

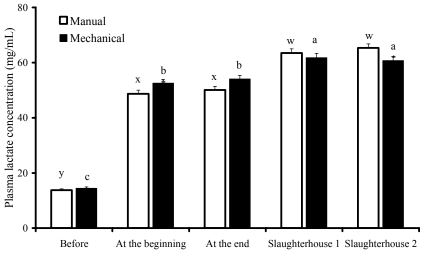
Plasma Concentrations. Plasma CORT levels are shown in Figure 2A. Catching method did not affect these levels. However, catching method was associated with plasma lactate concentrations of round 1 (Figure 2B). Thirty minutes after the start of the catching process plasma lactate levels were significantly higher for mechanically (52.62 ± 1.12 mg / dL) vs. manually (48.70 ± 1.31 mg / dL) caught flocks. Catching method also influenced plasma lactate levels for broilers transported to the processing plant on the last transport vehicle. Plasma lactate concentrations at the shackling line for manual and mechanical catching were 65.37 ± 1.45 mg / dL and 60.78 ± 1.42 mg / dL respectively. Round 2 did not show a catching method effect at all (Figure 2C). Also a catching method effect was found for plasma glucose concentrations.

Figure 2. Mean concentration of plasma cortiocosterone (A), lactate (B, C), and glucose (D, E) in manually and mechanically caught broilers during spring and autumn of 2001 at 5 different moments during the last day of life [30 min before catching (before), 30 min after the beginning of the catching process (at the beginning), 30 min before the end of catching (at the end), at exsanguination of broilers from the first loaded transport vehicle (slaughterhouse 1), and from the last loaded transport vehicle (slaughterhouse 2)]. Bars are standard errors of the mean.
[a-d] Values with different letters are significantly different for the mechanical catching process ($P < 0.05$).
[w-z] Values with different letters are significantly different for the manual catching process ($P < 0.05$).
* Significant difference between catching methods ($P < 0.05$).

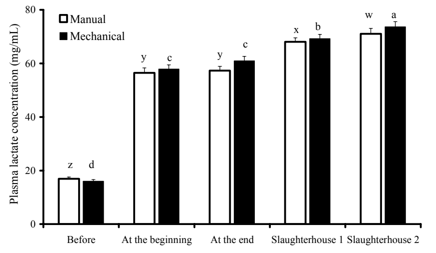
A Corticosterone



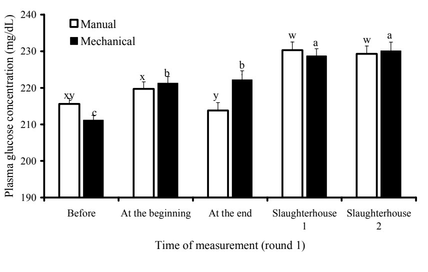
B Lactate



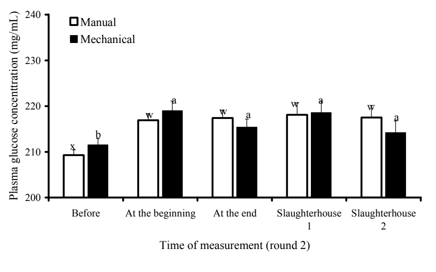
C Lactate



D Glucose



E Glucose



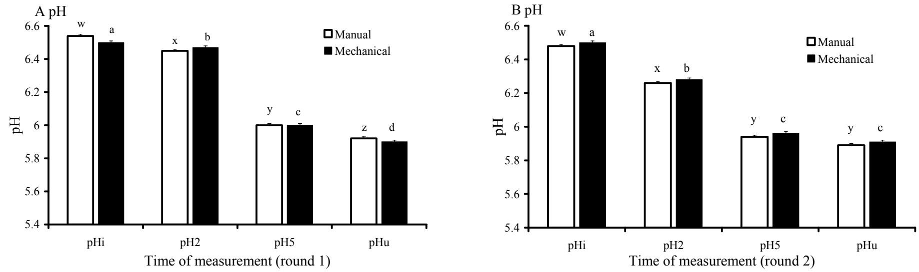


Figure 3. Mean pH of the pectoralis muscle for mechanically and manually caught broilers, during spring (A) and autumn (B) of 2001, at 25 min postmortem (intitial pH = pHi), at 2.0 h postmortem (pH 2), at 5.0 h postmortem (pH 5) and at 24 h postmortem (ultimate pH = pHu). Bars indicate standard errors of the mean.
$^{a\text{-}d}$ Values with different letters are significantly different for the mechanical catching process (P < 0.05).
$^{w\text{-}z}$ Values with different letters are significantly different for the manual catching process (P < 0.05).

Table 3. Effects of different catching methods before slaughter on the water-holding capacity of the pectoralis muscle for spring and autumn 2001.

	Mean fluid weight (±SEM) in filter paper[1] (g)	
Method	Round 1 (spring 2001)	Round 2 (autumn 2001)
Manual	0.0564 ± 0.001^{A}	0.0294 ± 0.0006^{aB}
Mechanical	0.0555 ± 0.001^{A}	0.0278 ± 0.0005^{bB}

^{a,b}Means within a column with no common superscript differ significantly ($P \leq 0.05$).
^{A,B}Means within a row with no common superscript differ significantly ($P \leq 0.001$).
[1]Filter paper diameter = 45 mm.

Thirty minutes before the end of the catching process plasma glucose levels were significantly higher for mechanically vs. manually caught flocks during round 1 (222.2 ± 2.45 mg / dL vs. 213.8 ± 2.13 mg / dL) (Figure 2D). Round 2 showed no catching method effect (Figure 2E).

Meat Quality. For rounds 1 and 2 there was no difference in pH due to catching method at any of the sampling times (Figure 3). Also, the pH decline was similar for both catching methods. However there was a round effect, round 1 showed a decrease of pH between 3.5 h postmortem and 24 h postmortem, which was not observed in round 2.

For round 2 a significant catching method effect on WHC was found (Table 3). For manual catching the WHC was 0.0294 ± 0.0006 g, whereas for mechanical catching it was 0.0278 ± 0.0005 g, but this catching method effect was not found during round 1. Also a round effect ($P \leq 0.001$) was present.

Dynamics of Plasma Concentrations During the Last Day

Plasma concentrations for CORT, lactate and glucose showed a dynamic pattern throughout the last day of life (Figure 2). During both rounds and for all plasma concentrations, a poultry farm effect ($P \leq 0.001$) was found.

Corticosterone. The mean plasma CORT level of broilers before catching was 11.31 ± 0.34 ng / mL, and increased to 19.77 ± 0.78 ng / mL after the start of the catching process ($P \leq 0.001$). During catching no further increase was observed; only the transportation of the broilers caused an increase of plasma CORT concentrations ($P \leq 0.001$). At the shackling line no difference of CORT levels was measured between broilers transported on the first transport vehicle and on the last transport vehicle (Figure 2A).

Lactate. During round 1 the same pattern for time effect as for CORT is shown for lactate (Figure 2B). The plasma lactate level increased significantly ($P \leq 0.001$) once catching was started and a further significant increase ($P \leq 0.001$) was observed after transportation at the shackling line in the slaughterhouse. During the catching process there was no significant increase. And there was also no difference of lactate levels measured at the shackling line between broilers transported on the first transport vehicle and on the last transport vehicle. During round 2 the plasma lactate level showed a slightly different pattern than for round 1. During catching there was a significant increase in lactate between 30 minutes after the start of the catching process and 30 minutes before the end of the process (57.18 ± 1.21 mg / dL vs. 59.18 ± 1.17 mg / dL). Now there was no increasing after transport of the first broilers to the slaughterhouse but only an increase for broilers transported on the last transport vehicle.

Glucose. Plasma glucose concentrations for round 1 are shown in Figure 2D and for round 2 are shown in Figure 2E. During round 1 the glucose concentration of the mechanically caught flocks showed the same time effect pattern as CORT and lactate (round 1). Manually caught flocks show a slightly different pattern. No increase was found from before catching to 30 min after the start of the catching process, and 30 min before the end of the manual catching process the plasma glucose concentration was significantly lower compared with 30 min after the start of the catching process. The second round had an increase only from before catching to 30 min after the start of catching (from 210.42 ± 0.9 mg / dL to 218.0 ± 1.27 mg / dL, respectively).

Discussion

In this study manual catching with a mechanical catching method under practical conditions were compared, taking the incidence of bruises and DOA percentages, stress parameters and meat characteristics as the outcomes of interest. Moreover, we investigated the dynamics of the blood parameters, CORT, lactate and glucose during the last day.

Mechanical catching was associated with higher DOA percentages in the first round of this study. Round 2 of this study showed the same trend, although the difference was not significant. Higher mortality rates were probably due to construction errors of the machine. In the observational studies of Ekstrand (1998) and Knierim and Gocke (2003) no significant differences were found between DOA percentages of mechanically and manually caught broilers. In both studies, however, the mean DOA percentages of mechanically caught flocks tended to be higher than those of manually caught flocks, which is in agreement with results shown in this study. In the present study both mechanical and manual catching gave similar bruises percentages. Ekstrand (1998), however, found higher percentages of bruises in mechanically caught broilers in contrast to Knierim and Gocke (2003) who found lower percentages of bruises in mechanically caught broilers. However, because the studies mentioned above were observational studies, the causality of the observed associations may be questioned due to possible confounding (Noordhuizen et al., 1997). To prevent confounding, the catching method was randomly allocated to a broiler house and both methods were tested on the same day. The broiler houses were located at the same poultry farm and therefore the flocks of the 2 houses were more related to from each other then arbitrarily chosen flocks. Besides that also other factors like feed withdrawal times and transportation times were the same for the 2 houses of 1 farm. The results of the parameter CORT indicated that both catching methods induced the same amount of stress. Moreover, although plasma lactate and glucose concentrations were different in both rounds, no significant catching method effect was found. Duncan et al (1986) concluded, based on heartbeats per minute and tonic immobility, less fear for mechanically caught broilers. In addition, Kannan and Mench (1996) found after two hours higher CORT values for broilers carried by the leg and inverted. In the present study, however, no lower CORT values were found, possibly due to the fact that blood collection took place immediately after catching. Before catching CORT values tended to be higher for mechanically caught broilers. The reason for this was unclear; however, the noise that is made by the catching machine could play a role. The engine of this machine often was started outside the house long before catching before the first blood collection (before catching) was finished.

Catching method did not influence pH of the meat. Factors that can influence pH are feed withdrawal, transport, shackling and stunning (Warriss et al., 1993; Kannan et al., 1997). However, in round 2, the Pectoralis muscle of mechanically caught broilers had lost less fluid compared with the Pectoralis muscle of manually caught broilers. These results cannot be explained because normally decline of postmortem pH and temperature influence the degree of protein denaturation and, hence, WHC (Hillebrand, 1993). As mentioned earlier, no differences were found in decline of pH and temperature between the catching methods. However, WHC measurements during round 2 were done by another person than in round 1, which is the most likely explanation for the difference between the values of WHC in rounds 1 and 2. But also factors such as season and water withdrawal times could have influenced WHC (Monin and Ouali, 1992).

This field study showed that in spite of feed withdrawal and stress, which led to high CORT, lactate and glucose values as found at the processing plant, the ultimate pH, was not negatively influenced.

The dynamics of plasma CORT, glucose and lactate were roughly the same. The plasma levels increased at the start of the catching process and they further increased during transport and shackling and stunning at the processing plant. From the beginning to the end of the catching process no dramatic changes occurred for CORT, glucose and lactate, in spite of the fact that the catching crew was present in the broiler house all the time, and that the feed and water withdrawal period was prolonged for broilers caught at the end of the catching process. The relative large increase of lactate after the start of the catching process was remarkable. At that moment the broilers are generally off of feed for over 5 h, which causes depletion of the glycogen stores in the liver, the primary accessible store for maintaining blood glucose levels (Warriss et al., 1988). Furthermore, the elevated CORT level would exhaust aerobic capacity of the broiler. Therefore, anaerobe energy must be formed by producing lactate out of pyruvate. Glucose levels are less variable, probably due to a balance between the decrease due to feed withdrawal and an increase due to stress that causes a release of glucagon and CORT that stimulates glycogenolysis and glyconeogenesis (Hazelwood, 1994).

The mean plasma CORT value increases with 75% at the start of catching, however the increase after transport, shackling and stunning is 115%. These factors offer probably more possibilities to reduce stress compared with the catching method. However, due to the limited number of sampling moments, it was not possible to identify which stressors are more important than others. For that purpose more frequent sample collection is needed, or equipment of a number of birds with an automatic sampling device.

In conclusion, in this study was observed that mechanical catching with this type of machine tended to cause slightly higher mortality rates. Postmortem research will give insights in underlying causes of mortality and so mechanical catching can be improved.

For meat quality and stress, no differences were found between mechanically and manually caught broilers. Thus, attempts to reduce stress in broilers could better be focused on other factors during the last day of life (e.g. transport and shackling).

Acknowledgments

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Chapter 5

Feed withdrawal of broilers before transport changes plasma hormone and metabolite concentrations

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Abstract

Two experiments were completed to observe the combined effects of feed withdrawal and the catching and transport process on stress and energy metabolism. During one experiment 192 male broilers (46 d of age) were used and in the other we used 240 male broilers (49 d of age). The experiments consisted of two interventions: feed intervention and transport intervention. The feed intervention took 10 h, in which broilers had full access to feed or feed was withdrawn, and thereafter, had a transport intervention that took 3 h, in which broilers were caught, crated, loaded, transported, and thereafter had to wait in the crates for 1 h or remained in the pens. After the transport intervention, blood samples were taken to determine plasma corticosterone, triiodothyronine, thyroxine, glucose, lactate, uric acid, nonesterified fatty acid, and triglyceride concentrations. Changes in BW were also assessed.

Broilers from which feed was withdrawn before the transport intervention showed higher thyroxine and lower triiodothyronine, triglyceride, glucose, and lactate concentrations compared to the broilers that had access to feed before the transport intervention. These findings indicate a negative energy balance and stress. Broilers that were transported after feed withdrawal had BW losses of approximately 0.42% per h that is approximately 0.30% per h more than those that had full access to feed.

To continue feeding the broilers until catching resulted in higher BW at the slaughterhouse and less stress, as shown by a negative energy balance, and might improve meat quality.

Introduction

Before broilers are slaughtered, they are exposed to an array of events on the last day of life. These events include feed withdrawal, catching and placement into crates or containers. Subsequently, the broilers are transported to the processing plant, and finally they have to wait in the lairage of the processing plant before being slaughtered.

Various studies show that catching, placement into crates or containers and transport cause severe stress to the broilers (Knowles and Broom, 1990; Von Borell, 2001). This is shown by an increase in plasma corticosterone (CORT) that occurs during catching, crating (Kannan and Mench, 1996) and transport (Freeman et al., 1984). Moreover, catching prolongs tonic immobility (Jones, 1992) which is further prolonged by increased transport times (Cashman et al., 1989). Furthermore, during lairage the body temperature of the broilers increases and the liver glycogen stores become depleted, indicating significant periods of negative energy balance (Warriss et al., 1999). However, the results of studies on the effects of transport on plasma glucose levels are in conflict with each other. Both Halliday et al. (1977) and Freeman et al. (1984) observed a reduction of the plasma glucose concentrations after transport, whereas Warriss et al. (1993) and Savenije et al. (2002) claimed that no significant differences are observed in plasma glucose and lactate concentrations of transported broilers.

Feed is normally withdrawn for several hours before catching in order to reduce the danger of carcass contamination. Total feed withdrawal times prior to slaughter of 8 to 10 h prior to slaughter are recommended (Wabeck, 1972), although in practice longer periods sometimes occur. In the Netherlands, feed is withdrawn from broilers for at least 5 h before catching starts, as recommended by the Dutch Product Boards for Livestock, Meat and Eggs (PVE, 1992). In addition, the loading time for one transport vehicle with a capacity of approximately 6,500 broilers is about 55 min. The catching and loading process for an average house with 20,000 broilers will take about 3 h but can take up to 9 h for a house of 60,000 birds. Transportation takes 134 min on average but can take up to 210 min, and finally birds have to wait in the lairage at the processing plant for 150 min on average, but this can increase to 955 min (Nijdam et al., 2004). Therefore, total feed withdrawal time will take about 12 h and 45 min; however in a worst-case scenario, feed withdrawal time can be 33 h and 30 min. Consequently, feed withdrawal causes BW loss between 0.22% / h and 0.56% / h (Veerkamp, 1978; Chen et al., 1983;

Veerkamp, 1986; Rasmussen and Mast, 1989; Lyon et al., 1991; Knowles et al., 1995; Warriss et al., 2004) and in reductions in carcass yields (Wabeck, 1972).

Feed withdrawal affects a lot of metabolic processes. Feed deprivation causes a shift from anabolism to catabolism, from lipogenesis to lipolysis, and a reduced metabolic rate. A study by Murray and Rosenberg (1953) revealed that the plasma glucose concentration of fasted chickens dropped rapidly until a new equilibrium was reached and became stabilized after 3 h of fasting for at least 16 h. Furthermore, the amount of nonesterified fatty acid (NEFA) is increased at feed withdrawal (Langslow et al., 1970; Van der Wal et al., 1999) and circulating triiodothyronine (T_3) concentrations are decreased (Buyse et al., 2000). Furthermore, liver glycogen will become depleted to negligible amounts after feed withdrawal of 6 h (Warriss et al., 1988). Moreover, feed withdrawal induces behavioral and physiological responses, indicating that broilers probably suffer from stress (Freeman, 1980). An increase of CORT concentrations has been shown in broilers after a feed and water withdrawal of 24 h (Knowles et al., 1995). Also in growing broiler breeders, feed restriction leads to plasma CORT increases (De Jong et al., 2003). Withdrawal of feed in broilers before catching is likely to increase CORT as well.

Despite the general acceptance of the need for feed and water deprivation, the consequences of feed withdrawal in combination with catching and transport for stress levels and energy metabolism of broilers have not been investigated. Therefore, we experimentally examined the combined effects of feed withdrawal and a transport intervention (including catching, crating, transport of approximately 1.5 h, and lairage of approximately 1 h) on stress and energy metabolism. For this purpose, plasma concentrations of CORT, T_3, thyroxine (T_4), glucose, lactate, uric acid, NEFA, and triglyceride (TG) and changes in BW were assessed.

Materials and Methods

Birds and Housing

Two experiments were performed with commercial Ross 308 male broilers.

For the first experiment, in spring 2002, 192 male broilers (38 d of age) were obtained from a commercial broiler farm. At the Farm Animal Health Research Farm of the Utrecht University, The Netherlands, these broilers were kept in 24 floor pens (8 birds / pen), of approximately 1 m^2, on wood shavings. The light schedule was 24 h light per day. Water and a grower diet (21% crude protein and 2,940 kcal ME / kg) were provided ad libitum. Due to respiratory distress the birds were treated with Baytril (Bayer, Mijdrecht, The Netherlands) in a dose of 20 mg / kg from d 41 up to and including d 43. The experimental interventions were done at 46 d of age, when the broilers had a mean BW of 2,770 g.

For the second experiment, in autumn 2003, 240 Ross 308 male broilers of 21 d of age were obtained from the same commercial broiler farm. The broilers were kept in the same 24 floor pens (10 birds / pen) under the same conditions as in the first experiment. Due to respiratory distress the birds were treated with Baytril in a dose of 20 mg / kg from d 24 up to and including d 27. The experimental interventions were done at an age of 49 d, when the broilers had a mean BW of 3,930 g.

Approval for carrying out both experiments was obtained from the Animal Experimental Committee of the Veterinary Faculty of Utrecht University, The Netherlands.

Experimental Design

Experiment 1 and experiment 2 included 4 and 5 treatments, respectively. For experiment 1 the treatments were as follows:

Treatment (TR) 1: feed was available and the broilers were not transported.

TR 2: feed withdrawal during the whole experiment (about 13 h).

TR 3: feed withdrawal for 10 h, and the broilers were caught and transported.

TR 4: feed was available until the moment that the broilers were caught and transported.

Experiment 2 consisted of an extra treatment to give more insight in the consequences of transport stress:

TR 5: feed was available during the feed procedure but removed during the transport intervention.

The transport intervention was performed on 96 broilers (12 pens) for experiment 1 and 120 broilers (12 pens) for experiment 2. The intervention started with grasping a bird by the leg and inverting the bird. After catching 4 to 6 birds in this way, the catcher carried them for 10 m to a crate with a surface of 0.53 m^2. Birds of one pen were placed together into one crate. The crates were loaded into a ventilated van (approximately 0.5 h). Thereafter the birds were transported for approximately 1.5 h. After transport the birds remained in the crates for approximately 1 h. During these activities there was no access to feed and water.

The transport intervention had a total duration of 3 h and 20 min for experiment 1 and 3 h for experiment 2. The birds that were not transported remained in the pens.

In experiment 1 six pens per treatment were involved, in experiment 2 for TR 2, TR 3, and TR 4 six pens were involved and for TR 1 and TR 5, three pens were involved.

Measurements

In both experiments the broilers were weighed before the start of the different treatments. In experiment 1 the broilers were weighed again just before euthanasia by electrocution. The period between the first weighing and the second weighing of the birds was 16 h and 40 min. In experiment 2 the second weighing was done immediately after the end of the treatments, and the period between the first and second weighing was 13 h and 20 min.

Blood sampling started immediately after the end of the treatments. Birds were taken out of the pen or crates, depending on the treatment, and blood was collected by puncturing the vena ulnaris. About 4 mL blood was taken and stored on ice in tubes containing sodium fluoride.

Analysis of Plasma Samples

Blood samples were kept on ice until plasma was separated by centrifugation for 10 min at 1,500 rpm. Plasma samples were stored at -20°C until assayed. CORT, T_3, T_4, glucose, lactate, uric acid, TG, and NEFA concentrations were determined.

Plasma CORT, T_3 and T_4 concentrations were measured using a sensitive and highly specific radioimmunoassay kit (IDS, Inc., Boldon, UK) with a sensitivity of 0.39 ng / mL, cross-reactions with aldosterone (0.20%), cortisol (0.40%) and deoxycorticosterone (3.30%). Samples were added in duplicate to check intraassay variability. Plasma CORT, T_3 and T_4 concentrations had intraassay variability of 3.9, 4.5 and 5.4% respectively. Plasma metabolite concentrations of glucose, lactate, uric acid, TG, and NEFA were determined using a commercial kit validated for chicken plasma (Procedure 826-UV, Sigma Diagnostics, Steinheim, Germany) modified for use in the Monarch Chemistry System (Monarch Chemistry System, Instrumentation. Laboratories, Zaventem, Belgium). All measurements for each variable were run in the same assay in order to avoid interassay variability.

Statistical Analyses

The statistical analyses were performed in the SAS-PC System (SAS Institute, 2000). PROC FREQ and PROC MEANS were used for the descriptive analyses. The assumption of normality of the outcomes was assessed applying stem-and-leaf plots and normal probability plots. The distribution of the plasma CORT concentrations was skewed, and therefore a logarithmic transformation was applied.

Broiler was taken as statistical unit, but pen was included as a random effect in the model to account for dependency between birds in the same pen (SAS Institute, 2000). Therefore standard errors and probabilities were calculated using the type III MS for pen as an error term. Experiment, treatment and the interaction term experiment x treatment were analyzed using a generalized linear model performed by PROC GLM on plasma concentrations and BW. The experiment effect was highly significant (P = 0.0002), and therefore the results are presented separately for both experiments. Significant differences between treatments were separated using least squares means procedures of the software (SAS Institute, 2000). All statements of significance were based on a probability level of 0.05.

Results

Plasma Concentrations and Hormones

In experiment 1, no significant differences in CORT were found; however in experiment 2 average plasma CORT concentrations of broilers that were transported (TR 3 and 4) were significantly higher than those of broilers exposed to other treatments (Figure 1A). For plasma T_3 concentration both experiments gave similar results. Treatments with long feed withdrawal times (TR 2 and TR 3) induced decreased T_3 values. For TR 4, experiment 2 gave significantly lower values as compared with TR 5. Both treatments had a similar feed withdrawal period, but TR 4 birds were also transported (Figure 1B). In experiment 1 significantly higher plasma T_4 levels were found for TR 2 and 3, which included feed withdrawal (Figure 1C). For TR 2, experiment 2 gave an increased T_4 level compared with TR 1, 3, and 4. Plasma T_4 levels of TR 5 were significantly higher then TR 4.

Plasma Concentrations and Metabolites

Plasma uric acid concentrations in experiment 1 were significantly decreased for broilers on feed withdrawal in TR 2. Broilers that were on feed withdrawal and transported (TR 3) had higher uric acid values than TR 2 birds. In experiment 2, TR 3 and 4 had significantly higher concentrations than treatments that did not include transport (TR 1, 2, and 5; Figure 2A). In both experiments the concentrations of TG found in TR 2, 3, 4, and 5 were significantly lower than the concentration of TG in TR 1. Feed withdrawal during the whole experiment (TR 2) resulted in the greatest decrease (Figure 2B).

Plasma NEFA concentrations in experiment 1 were significantly higher for TR 2, 3, and 4 birds than for fed birds (TR 1). In experiment 2 roughly similar results were obtained. TR 2, 3, and 4 showed significantly higher plasma NEFA concentrations than TR 1 and 5. Feed withdrawal and transport (TR 3) induced the highest values (Figure 2C).

Plasma glucose concentrations found in experiments 1 and 2, for birds on feed withdrawal in TR 2 and 3 were significantly decreased. TR 4 gave significantly higher glucose values then TR 5 (Figure 2D). In both experiments birds of TR 2, and 3 gave the lowest lactate concentrations (Figure 2E).

Body Weight

Table 1 shows the growth (in % / h) per experiment and treatment. TR 3 led to a decrease in BW of 0.47 ± 0.02% / h for experiment 1 and 0.35 ± 0.02% / h for experiment 2. TR 2 produced a mean decrease in BW of 0.30% / h. The transport procedure obviously led to an extra decrease in BW of approximately 0.05 to 0.17% / h. When the broilers had access to feed until the moment of transport (TR 4) the mean decrease in final BW was 0.12% / h. At the start of both experiments 1 and 2, BW did not differ significantly for any treatment groups.

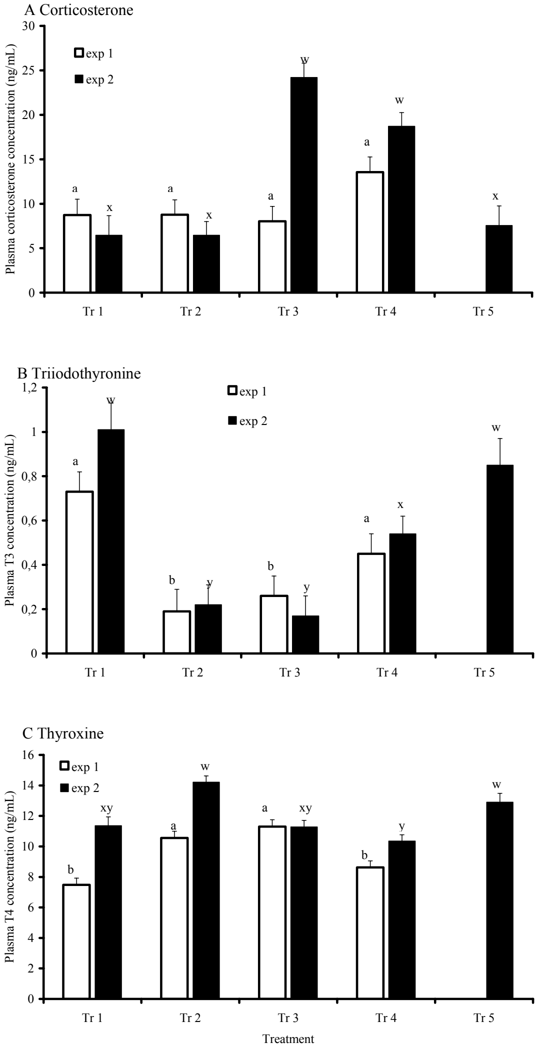

Figure 1. Mean concentration of plasma corticosterone (A), triiodothyronine (B), and thyroxine (C) for experiments 1 and 2 per treatment. Tr 1 = Feed was available and the broilers were not transported; Tr 2 = Feed withdrawal during the whole experiment; Tr 3 = Feed withdrawal for 10 h, and the broilers were caught and transported; Tr 4 = Feed was available until the moment that the broilers were caught and transported; Tr 5 = Feed was available during the feed procedure but removed during the transport intervention. Bars show standard errors of the mean.

$^{a\text{-}c}$ Values with different letters are significantly different for experiment 1 ($P < 0.05$).

$^{w\text{-}y}$ Values with different letters are significantly different for experiment 2 ($P < 0.05$).

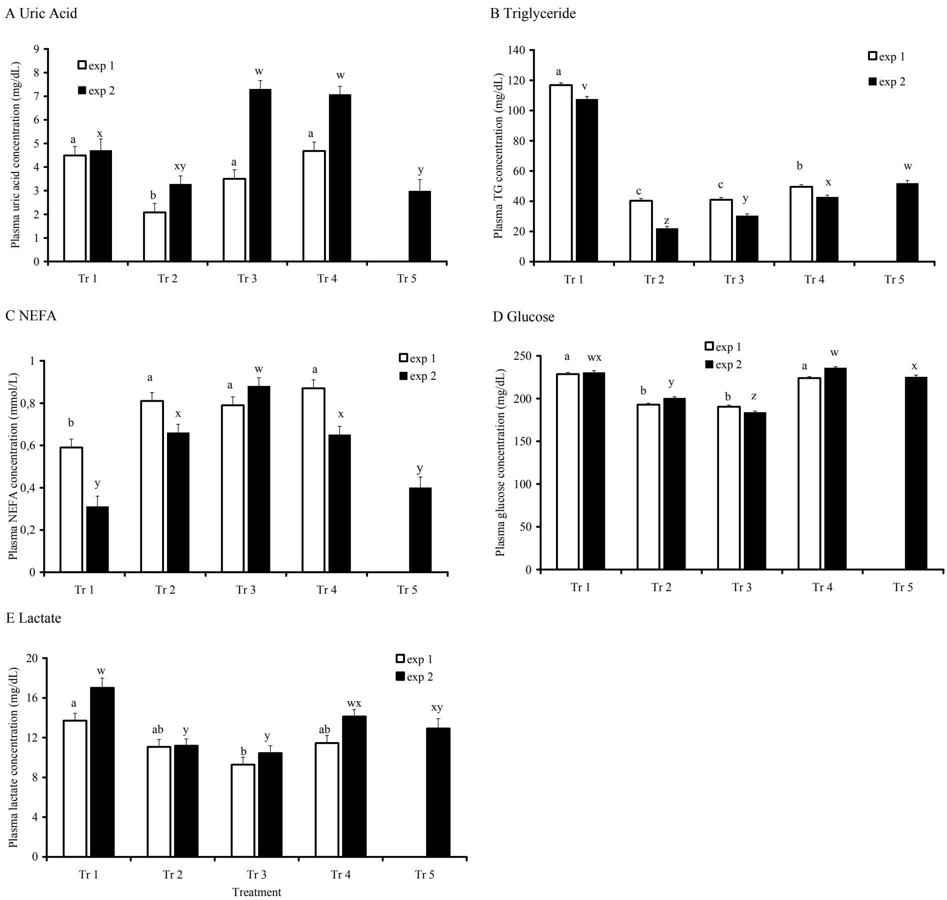

Figure 2. Mean concentration of plasma uric acid (A), triglyceride (B), nonesterified fatty acid (NEFA) (C), glucose (D), and lactate (E) for experiment 1 and 2 per treatment. Tr 1 = Feed was available and the broilers were not transported; Tr 2 = Feed withdrawal during the whole experiment; Tr 3 = Feed withdrawal for 10 h, and the broilers were caught and transported; Tr 4 = Feed was available until the moment that the broilers were caught and transported; Tr 5 = Feed was available during the feed procedure but removed during the transport intervention. Bars show standard errors of the mean.

[a-c] Values with different letters are significantly different for experiment 1 ($P < 0.05$).

[w-z] Values with different letters are significantly different for experiment 2 ($P < 0.05$).

Table 1. Mean percentages ± SEM of growth per hour by percentage of BW per treatment for experiments 1 and 2.

	Experiment 1		Experiment 2	
Treatment[1]	n[2]	Mean ± SEM	n[2]	Mean ± SEM
TR 1	48	$0.04^{a} \pm 0.02$	30	$0.09^{a} \pm 0.02$
TR 2	48	$-0.37^{c} \pm 0.02$	58	$-0.23^{c} \pm 0.02$
TR 3	48	$-0.47^{d} \pm 0.02$	56	$-0.35^{d} \pm 0.02$
TR 4	47	$-0.19^{b} \pm 0.02$	58	$-0.05^{b} \pm 0.02$
TR 5	-	-	29	$0.01^{ab} \pm 0.02$

[a,d] Means within a column and for each experiment without a common superscript differ significantly ($P < 0.05$).
[1] TR 1 = Feed was available during the whole experiment; TR 2 = Feed withdrawal during the whole experiment; TR 3 = Feed withdrawal for 10 h, and the broilers were caught and transported; TR 4 = Feed was available till the moment that the broilers were caught and transported; TR 5 = Feed was available during the feed intervention but removed during the transport intervention.
[2] Number of observations per mean.

Discussion

Broilers that had no access to feed before being caught, loaded, and transported had higher T_4, and lower T_3, TG, glucose, and lactate concentrations compared with broilers that had access to feed before catching, loading and transport, which indicated the combined effect of both actions. Besides that, the separate effect of feed withdrawal and transport intervention on hormones, except for CORT, and metabolites was in accordance with results obtained in previous studies (Buyse et al., 2000; Puvadolpirod and Thaxton, 2000).

CORT had different patterns in both experiments. A striking difference was found for transport. The higher CORT levels found in the second experiment might express more severe physical stress. Roughly, the broilers used in each experiment were distinct with respect to disease history, medication history, food intake and final BW. The broilers in experiment 1 were subjected to transport stress a few days after respiratory infection occurred. Broilers in experiment 2, however, were submitted to transport stress 3 wk after respiratory infection had occurred. It is possible that respiratory infections of the broilers in experiment 1 caused a lower response to transport stress. In humans cortisol-binding globulin, which binds free cortisol and reduces its biological activity, is down-regulated by the acute phase response from respiratory infections. Down-regulation of cortisol-binding globulin results in a negative adrenocorticotropin feedback. Although, recovery from respiratory infection may result in up-regulation of cortisol-binding globulin, resulting in a decrease of free cortisol in the plasma, and therefore, enhancement of adrenocorticotropin secretion (Garrel, 1996), it is unlikely that this phenomenon still occurs 3 wk after the infection.

The significant increase of the CORT concentration due to transport in experiment 2 is in agreement with the results of Freeman et al. (1984), Kannan and Mench (1996), and Carlisle et al. (1998), but in literature (Freeman et al., 1984; Kannan and Mench, 1996) it is not always clear whether the broilers were fed ad libitum, on restricted feeding or feed was withdrawn before they were exposed to handling, crating or transport. In this study feed withdrawal did not result in higher CORT values, which contradicts with findings of Knowles et al. (1995) and De Jong et al. (2003). Duration of feed withdrawal in our experiment might have been too short to induce a significant increase of CORT concentration. Feed was withdrawn from broilers 13 h only, whereas the broilers in the experiment of Knowles et al. (1995) experienced feed withdrawal for 24 h, and the broiler breeders in the experiment of De Jong et al. (2003) were limited in feed consumption for 35 d.

Broilers subjected to transport intervention had lower concentrations of $T_{3;}$ however, this decrease was only obvious in chickens that were fed before being caught and transported. If the period of food deprivation was followed by transport intervention, no further reduction of T_3 was observed. The reason for this finding was probably that after feed was withdrawn for approximately 13 h, the birds were already experiencing hypothyroidism, and so a further decrease of T_3 was not detectable (Buyse et al., 200).

The source for the serum TG was dietary lipids or de novo synthesis from carbohydrates or amino acids (i.e., lipogenesis). Both sources that form TG are absent or are present only to a small extent if broilers are fasted. This explains the significantly lower concentrations of TG in these animals. There is an effect of feeding or fasting only; no significant changes were observed after the broilers were exposed to stress.

A possible explanation for the significantly lower glucose and lactate concentrations in broilers that had feed withdrawn before transport compared with the levels in broilers that had access to feed before transport may be that the transport intervention demands more energy obtained by the oxidation of glucose than the additional neoglucogenetic effect of CORT increase by combining stress and feed withdrawal. Oxidation of glucose is possibly the preferred initial energy source. However, the high concentrations of NEFA also indicate increased lipolysis. Therefore, further research is needed to examine to what extent glucose and lipids are used to fulfill the energy needs of feed withdrawn and stressed broilers.

Feed withdrawal and transport led to a decreased BW. Broilers that were transported after a feed withdrawal period of 10 h had weight losses of approximately 0.42% / h, which is approximately 0.30% / h more than for broilers that had full access to feed until the moment of transport. Other studies (Veerkamp, 1978; Chen et al., 1983; Veerkamp, 1986; Rasmussen and Mast, 1989; Lyon et al., 1991; Knowles et al., 1995; Warriss et al., 2004) showed losses in BW between 0.22 and 0.56% / h, which are in agreement with our results. However, the range in BW losses is great because in some studies broilers had feed withdrawn, and in others they were also transported before slaughter. At high ambient temperatures BW, losses will be greater (Chen et al., 1983). Moreover, in some studies the birds were also water withdrawn, and the total withdrawal times differed. A large amount of the BW reduction is due to the clearance of the gastrointestinal tract (Warriss et al., 2004). However, there will also be loss of edible parts due to dehydration (Kamus and Farr, 1981; Knowles et al., 1995) and losses of fat and protein (Knowles et al., 1995). These changes can influence meat quality by affecting muscle glycogen content at slaughtering and, therefore, reduce the rate of rigor as well as the ultimate pH (Fletcher, 2002).

In conclusion, to continue feeding the broilers until they are caught results in higher BW at the slaughterhouse and less stress and may improve the meat quality compared with broilers that have no access to feed before they are caught. Feed withdrawal of broilers before the transport procedure had a negative effect not only from an economical point of view but maybe also in the light of animal welfare. Therefore, research to apply some energydelivering supplement during the last day of broilers' lives to cope with stressors, such as catching and transport, would be worthwhile.

Acknowledgements

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Chapter 6

Influence of feeding conventional and semisynthetic diets until catching on weight gain, digestive tract mass, and plasma hormone and metabolite concentrations of broilers related to transport

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Submitted

Abstract

Two replicate experiments were done to investigate if special diets that were provided to broilers in their last phase of life could reduce the negative effects of feed withdrawal and transport without an increased content of the digestive tract. In each experiment 240 broilers were used. The experiments consisted of two interventions, the feed intervention and the transport intervention.

The feed intervention took 72 h, where broilers had full access to conventional grower diet, conventional grower diet with increased carbohydrate level, conventional grower diet with increased fat level, semisynthetic diet, or semisynthetic diet with increased carbohydrate level. The diets differed remarkably in carbohydrate content; approximately 67% in the semisynthetic diets and 42% on average in the conventional diets. Beside that, all of the carbohydrates in semisynthetic diets were highly soluble and digestible. The diets were compared with a feed withdrawal period of 24 h before transport.

The transport intervention took 3 h, broilers were caught, crated, loaded, transported for 1.5 h, and thereafter had to wait in the crates for 1 h, or remained in the pens. After the transport intervention blood samples were taken to determine plasma corticosterone, triiodothyronine, glucose, lactate, uric acid, nonesterified fatty acid, and triglyceride concentrations. Also changes in BW and digestive tract mass (DTM) were assessed.

The BW losses of broilers fed with semisynthetic diets after transport was 0.24% / h less then of feed withdrawn broilers. Moreover, intake of semisynthetic diets was approximately 200 g while the intake of conventional diets was approximately 300 g. Therefore, the DTM in % of BW was lower for semisynthetic fed broilers in comparison with conventional fed broilers, which can lead to a lesser degree of contamination during evisceration. Beside that, no increase of corticosterone was found due to transport in semisynthetic fed broilers. Semisynthetic feed with high carbohydrate concentration could be a good alternative for the feed withdrawal period held before transportation to the processing plant.

Introduction

Withdrawal of feed from broilers before slaughter is common practice. An important reason to do so is to reduce fecal contamination of carcasses during evisceration. For that purpose, feed withdrawal times varying from 4 h to 12 h have been recommended (Wabeck, 1972; Warriss et al., 1988; Warriss et al., 2004). However, longer total withdrawal times can occur due to extended catching, transport or lairage times. For example, in the Netherlands total feed withdrawal time last on average 12 h and 45 min; however, in a worst-case scenario, feed withdrawal times can be as much as 33 h and 30 min (Nijdam et al., 2004).

Feed withdrawal leads to changes in shear strengths of the intestines (Bilgilli, 1988; Northcutt et al., 1997), viscera weight (Buhr et al., 1998; Warriss et al., 2004), and reduction of BW ranging from 0.22% per h to 0.56% per h (Chen et al., 1983; Veerkamp, 1986; Lyon et al., 1991; Knowles et al., 1995; Buhr et al., 1998; Warriss et al., 2004; Nijdam et al., 2005). This loss of BW is highest during the first 6 hours, due to evacuation of the gastrointestinal tract (Veerkamp, 1986; Buhr et al., 1998). BW is also significantly affected by transport. Nijdam et al. (2005) showed that losses of BW in broilers that were feed withdrawn and transported exceeded those of broilers that were only withdrawn of feed for the same period of time. Other studies about the relation between feed withdrawal and BW losses did not include a transport intervention (Veerkamp, 1986; Knowles et al., 1995; Buhr et al., 1998; Warriss et al., 2004).

Feed withdrawal and long transport times cause exhaustion, shown by depletion of glycogen stores in the liver (Warriss et al., 1988). Beside that, feed withdrawal followed by transport influences metabolic processes. Triiodothyronine (T_3) values decrease after feed withdrawal (Buyse et al., 2000; Nijdam et al., 2005). Corticosterone (CORT) values are increased by feed deprivation (Scott et al., 1983; Knowles et al., 1995) and transport (Freeman et al., 1984; Nijdam et al., 2005). Uric acid values are also increased due to transport (Nijdam et al., 2005). Both transport and feed withdrawal decrease triglyceride (TG) and increase nonesterified fatty acid (NEFA) values (Langslow et al., 1970; Van der Wal et al., 1999; Nijdam et al., 2005). Moreover, lactate and glucose values decrease following feed withdrawal. These findings show that the last day of the broiler's life is associated with a negative energy balance and stress (Nijdam et al., 2005).

A limited number of studies were done to investigate the effects of feed withdrawal supplements as an alternative to a feed withdrawal period. Young et al. (2004) supplemented broilers with glucose combined with either pyruvate or creatine via the drinking water to examine the effect on meat quality. BW losses were investigated by Farhat et al. (2002), and Northcutt et al. (2003). In each of these studies diets, based upon a commercial carbohydrate source, which were highly soluble and digestible were used. These diets reduced BW losses in comparison with broilers that had no access to feed (Farhat et al., 2002), or broilers that received normal feed (Northcutt et al., 2003). However, no transport intervention was applied in any of these studies, nor were metabolic changes investigated.

In this study we investigated a number of diets with high energy content, different macronutrient composition, and low crude fiber content, which can be provided during the last phase of life to reduce the negative effects of feed withdrawal and transport, such as stress and BW losses, without an increased content of the digestive tract.

Therefore, we compared 5 different diets that were provided to broilers in their last phase of life, with feed withdrawal during the last day. To mimic practical procedures, a transport intervention (including catching, crating, transport of 1.5 h and lairage of 1 h) was included in the study. We used weight gain, digestive tract mass (DTM), and plasma concentrations of CORT, T_3, glucose, lactate, uric acid, NEFA, and TG to assess the effect of the interventions.

Materials and Methods

Animals and Housing

Two replicate experiments were performed with commercial Ross 308 (Aviagen, Newbridge, Scotland) broilers. For each experiment 240 broilers of 3 wk of age were obtained from a commercial broiler farm. At the Farm Animal Health Research Farm of Utrecht University, The Netherlands, these broilers were kept in 24 floor pens (10 birds / pen), of approximately 1 m^2, on wood shavings. The broilers were maintained on a commercial grower diet (20% crude protein, 2975 kcal ME / kg) and fresh water ad libitum and exposed to a light cycle of 24L. Broilers were slaughtered at 49 d of age in the first experiment and at 46 d in the second experiment.

Approval for carrying out both experiments was obtained from the Animal Experimental Committee of the Veterinary Faculty of Utrecht University, The Netherlands.

Experimental Design

In the experiments a 6 x 2 factorial design was used. The treatments consisted of 6 feed regimens: conventional grower diet (Con), conventional grower diet with increased carbohydrate level (Con-starch), conventional grower diet with increased fat level (Con-fat), semisynthetic diet (SS), semisynthetic diet with increased carbohydrate level (SS-starch) (Table 1), or a feed withdrawal period of 24 h before transport (FW).

Con, Con-starch, and Con-fat are the conventional ingredient diets (further referred to as conventional diets), whereas SS, and SS-starch are the semisynthetic ingredient diets (further referred to as semisynthetic diets). The 5 diets were provided the last 3 days before transport and slaughter, so the broilers could get used to the new diet before the last day. Our measurements only include the last day of life.

Table 1. Analyzed composition of the experimental diets (%).

	Diets[1]				
	Con	Con-fat	Con-starch	SS	SS-starch
Dry matter	88.2	90.3	84.2	88.7	90.3
Crude protein	20.1	16.0	15.1	18.9	9.7
Crude Fat	6.6	24.8	4.8	4.9	5.6
Crude Fiber	2.3	2.0	2.0	1.7	0.1
Ash content	4.4	3.5	3.2	3.8	0.2
Sugar / Starch	40.5	33.2	51.3	58.1	74.9
Metabolizable energy (kcal / kg)[2]	2,975	4,004	3,016	3,286	3,514

[1] Con = conventional feed; Con-fat = conventional feed with increased percentage of fat; Con-starch = conventional feed with increased percentage of starch; SS = semisynthetic feed; SS-starch = semisynthetic feed with increased percentage of starch.
[2] Calculated values.

Before slaughter, half of the groups were subjected to a transport intervention. However, due to a mistake during experiment 2 an extra pen with Con broilers was subjected to the transport intervention whereas for the Con-fat group one pen less was exposed.

To mimic field circumstances, the transport intervention of 3 h began with grasping the bird by the leg and inverting the animal. After catching 4 to 6 birds in this manner, the catcher carried them for a distance of 10 m to a crate with a surface of 0.53 m^2. Birds of one pen were placed together into one crate. The crates were then loaded into a ventilated van (0.5 h). Subsequently, the birds were transported during 1.5 h. After transport, the birds remained in the crates for 1 h. During these activities, the broilers did not have access to feed and water. The birds that were not transported remained in the pens and also had no access to feed and water. Finally, it took 4 h on average between the end of the transport intervention and slaughter.

Measurements and variables

Broilers were weighed 24 h before transport (BW1), and also just before euthanasia (BW2). The period between BW1 and BW2 was 31 h (24 h feed regimen, 3 h transport intervention, 4 h average waiting time until slaughter). Weight gain (g) in % / h was calculated by ((BW2 – BW1) / BW2) x 100 / 31. During slaughter, the crop, the proventriculus together with the gizzard, and the intestines were removed from the carcass and weighed. The sum of these parts was defined as digestive tract mass (DTM). DTM in % of BW was calculated by (DTM / BW2) x 100.

Blood sampling started immediately after the end of the transport intervention. Broilers were taken out of the pens or crates, depending on the treatment, and blood was collected by puncturing the vena ulnaris. Approximately 4 mL blood per broiler was taken and stored on ice in tubes containing sodium fluoride. In plasma, concentrations of CORT, T_3, glucose, lactate, uric acid, TG, and NEFA were determined. Due to errors at storage immediately after blood sampling in experiment 1, only 133 samples were suitable for analyzing.

Analysis of Plasma Samples

Blood samples were kept on ice until plasma was separated by centrifugation for 10 min. Plasma samples were stored at -20°C until assayed. Plasma CORT and T_3 concentrations were measured using a sensitive and highly specific radioimmunoassay kit (IDS, Inc., Boldon, UK) with a sensitivity of 0.39 ng / mL and cross-reactions with aldosterone (0.20%), cortisol (0.40%) and deoxycorticosterone (3.30%). Samples were added in duplicate to check intraassay variability. Plasma CORT and T_3 concentrations had intraassay variability of 3.9

and 4.5 respectively. Plasma metabolite concentrations of glucose, lactate, uric acid, TG, and NEFA were determined using a commercial kit validated for chicken plasma (procedure 826-UV, Sigma Diagnostics, Steinheim, Germany) modified for use in the Monarch Chemistry System (Monarch Chemistry System, Instrumentation. Laboratories, Zaventem, Belgium). All measurements for each variable were run in the same assay in order to avoid interassay variability.

Statistical Analyses

The statistical analyses were performed in the SAS-PC System (SAS Institute, 2000). PROC FREQ and PROC MEANS were used for the descriptive analyses. The assumption of normality of the outcomes was assessed applying stem-and-leaf plots and normal probability plots. The distribution of the plasma CORT, lactate, uric acid, and triglyceride concentrations was skewed, and therefore a logarithmic transformation was applied.

Broiler was taken as statistical unit, but pen was included as a random effect in the model to account for dependency between birds in the same pen (SAS Institute, 2000). Therefore standard errors and probabilities were calculated using the type III MS for pen as an error term. Experiment, feed regimen, transport intervention and interaction term feed regimen x transport intervention were analyzed using a generalized linear model performed by PROC GLM on the plasma concentration variables and growth yield. An experiment effect was found for NEFA, lactate, TG, and DTM in % of BW. Significant differences between treatments were separated using least squares means procedures of SAS. All statements of significance are based on the probability level of 0.05.

Results

BW and Feed Intake

Feed intake during the last 24 h before transport is shown in Table 2. At the start of the experiments mean BW was 2,819 g, and no significant differences were observed between groups. Feed intake of SS and SS-starch diets was significantly lower in comparison to the other diets. Broilers that had no access to feed from 31 h before slaughter showed significantly lower weight gain (-219 g) than broilers, which were fed until 7 h before slaughter.

Table 2. Feed intake during the last 24 h before transport and growth in the last 31 h before slaughter per feed regimen.

Feed regimen[1]	Feed intake (g)		Growth (g)	
	n[2]	Mean ± SEM	n[3]	Mean ± SEM
Con	8	$304^{a} \pm 43$	77	$-17^{a} \pm 8$
Con-fat	8	$294^{a} \pm 33$	79	$49^{a} \pm 5$
Con-starch	8	$298^{a} \pm 31$	80	$13^{a} \pm 7$
SS	8	$200^{b} \pm 38$	80	$-17^{a} \pm 5$
SS-starch	8	$196^{b} \pm 27$	80	$-21^{a} \pm 5$
Feed withdrawal	8	-	78	$-219^{b} \pm 7$

[1] Con = conventional feed; Con-fat = conventional feed with increased percentage of fat; Con-starch = conventional feed with increased percentage of starch; SS = semisynthetic feed; SS-starch = semisynthetic feed with increased percentage of starch. See Table 1 for contents.
[2] n = number of pens.
[3] n = number of broilers.
[a,b]Means without a common superscript within the same column differ significantly ($P < 0.05$).

Tables 3 and 4 show that within groups of broilers that were fed the same diet, a significant transport effect was only observed in DTM in % of BW for SS and FW groups. However, in all of the feed regimens, except for the Con groups (Table 3), there was a tendency that transport decreased weight gain, DTM, and DTM in % of BW. Non-transported Con-fat broilers had the highest weight gain in % / h, but also the highest DTM. Overall, no significant difference was found between conventional diets and semisynthetic diets fed groups for weight gain in % / h. Both groups had a higher weight gain in % per h than FW broilers. The conventional diets fed groups showed a higher DTM in % of BW compared with both semisynthetic diets and FW groups (Table 4).

Plasma Concentrations

In Tables 5 and 6 mean plasma concentrations of CORT, T_3, glucose, lactate, uric acid, NEFA, and TG are given. Transported Con-fat, Con-starch, and Con fed broilers had higher CORT values compared to transported SS and non-transported SS-starch fed broilers. In almost all of the cases, the tendency was observed that transport increased CORT. A significant effect was found for groups fed conventional diets. Broilers fed with a conventional diet had higher CORT values as compared to broilers fed semisynthetic diets. No feed withdrawal effect on CORT was found.

Table 3. Effects of diets on weight gain, digestive tract mass (DTM), and DTM by percentage of BW of broilers related to transport. Data refer to the period from 31 h before slaughter.

	Transport[1]	Diets[2] provided until 7 h before slaughter										Feed Withdrawal	
		Con		Con-fat		Con-starch		SS		SS-starch			
		n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM
Weight gain (g) in % /h.	Yes	47	$0.004^{ab} \pm 0.009$	30	$0.03^{ab} \pm 0.01$	40	$-0.02^{ab} \pm 0.01$	40	$-0.04^{ab} \pm 0.007$	40	$-0.04^{b} \pm 0.008$	39	$-0.28^{c} \pm 0.01$
	No	30	$-0.06^{b} \pm 0.02$	49	0.07^{a} 0.006	40	$0.04^{ab} \pm 0.01$	40	$-0.004^{ab} \pm 0.009$	40	$-0.008^{ab} \pm 0.009$	39	$-0.24^{c} \pm 0.01$
DTM (g)	Yes	46	$206^{ab} \pm 4.4$	30	$201^{ab} \pm 3.6$	40	$189^{ab} \pm 5.0$	39	$172^{ab} \pm 4.1$	40	$176^{ab} \pm 4.2$	37	$164^{b} \pm 3.7$
	No	30	$190^{ab} \pm 5.8$	48	$212^{a} \pm 3.8$	39	$196^{ab} \pm 4.0$	40	$173^{ab} \pm 3.5$	40	$187^{ab} \pm 4.3$	38	$176^{ab} \pm 2.8$
DTM in % of BW	Yes	46	$6.96^{abcd} \pm 0.14$	30	$7.14^{ab} \pm 0.15$	40	$6.70^{abcd} \pm 0.15$	39	$6.40^{c} \pm 0.15$	40	$6.79^{abcd} \pm 0.16$	37	$6.29^{d} \pm 0.12$
	No	30	$6.89^{abcd} \pm 0.20$	48	$7.31^{a} \pm 0.11$	39	$6.80^{abcd} \pm 0.11$	40	$6.51^{b} \pm 0.12$	40	$7.06^{abc} \pm 0.13$	38	$6.44^{b} \pm 0.11$

[1] The transport intervention included catching and crating (0.5 h), transport (1.5 h), and lairage (1 h).
[2] Con = conventional feed; Con-fat = conventional feed with increased percentage of fat; Con-starch = conventional feed with increased percentage of starch; SS = semisynthetic feed; SS-starch = semisynthetic feed with increased percentage of starch. See Table 1 for contents.
[a-d] Means without a common superscript per parameter differ significantly ($P < 0.05$).

Table 4. Effects of feed composition on weight gain, digestive tract mass (DTM), and DTM by percentage of BW of broilers related to transport. Data refer to the period from 31 h before slaughter.

	Transport[1]	Diets provided until 7 h before slaughter and composed of						Feed withdrawal		
		Conventional ingredients			Semisynthetic ingredients					
		n	Mean ± SEM		n	Mean ± SEM		n	Mean ± SEM	
Weight gain (g) in % /h.	Yes	117	$0.004^{a} \pm 0.006$	A	80	$-0.04^{a} \pm 0.006$	A	39	$-0.28^{b} \pm 0.01$	B
	No	119	$0.03^{a} \pm 0.008$		80	$-0.006^{a} \pm 0.006$		39	$-0.24^{b} \pm 0.01$	
DTM (g)	Yes	116	199 ± 2.7		79	174 ± 2.9		37	164 ± 3.7	
	No	117	201 ± 2.7		80	180 ± 2.8		38	176 ± 2.8	
DTM in % of BW	Yes	116	$6.91^{ab} \pm 0.09$	A	79	$6.60^{b} \pm 0.11$	B	37	$6.29^{c} \pm 0.12$	B
	No	117	$7.03^{a} \pm 0.08$		80	$6.79^{ab} \pm 0.10$		38	$6.44^{b} \pm 0.11$	

[1] The transport intervention included catching and crating (0.5 h), transport (1.5 h), and lairage (1 h).

[a-c] Means without a common superscript per parameter differ significantly ($P < 0.05$).

[A,B] Significant difference for feed treatment if no common capital is present ($P < 0.05$).

Table 5. Effects of diets on mean plasma concentrations of corticosterone, triiodothyronine, glucose, lactate, uric acid, nonesterified fatty acid, and triglyceride of broilers related to transport. Plasma values were determined directly after transport intervention.

	Transport[1]	Diets[2] provided from 72 h before transport										Feed withdrawal from 24 h before transport	
		Con		Con-fat		Con-starch		SS		SS-starch			
		n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM	n	Mean ± SEM
Corticosterone (ng/mL)	Yes	41	$11.5^{a} \pm 1.3$	20	$15.1^{a} \pm 2.3$	35	$12.7^{a} \pm 1.4$	32	$5.3^{b} \pm 0.7$	32	$7.1^{ab} \pm 0.8$	33	$8.4^{ab} \pm 1.0$
	No	18	$7.0^{ab} \pm 0.9$	42	$6.7^{ab} \pm 0.7$	29	$7.0^{ab} \pm 1.1$	32	$6.0^{ab} \pm 0.6$	33	$4.7^{b} \pm 0.6$	28	$7.1^{ab} \pm 0.9$
Triiodothyronine (ng/mL)	Yes	30	0.34 ± 0.05	17	0.42 ± 0.07	30	0.37 ± 0.05	32	0.69 ± 0.06	31	0.57 ± 0.07	24	0.33 ± 0.08
	No	18	0.48 ± 0.06	34	0.46 ± 0.06	24	0.28 ± 0.05	32	0.58 ± 0.05	32	0.56 ± 0.07	13	0.20 ± 0.07
Glucose (mg/dL)	Yes	41	259 ± 8.5	19	218 ± 18.4	36	241 ± 10.3	31	264 ± 10.9	31	277 ± 15.5	31	222 ± 9.7
	No	18	260 ± 14.3	42	243 ± 8.1	29	254 ± 9.2	31	244 ± 11.3	33	248 ± 6.9	28	223 ± 9.6
Lactate (mg/dL)	Yes	41	$10.9^{bcd} \pm 0.8$	18	$8.7^{cd} \pm 0.8$	36	$11.1^{abc} \pm 0.9$	32	$10.2^{bcd} \pm 0.7$	32	$13.1^{abc} \pm 1.0$	29	$7.3^{d} \pm 0.6$
	No	18	$12.2^{abc} \pm 1.4$	42	$12.9^{abc} \pm 0.9$	26	$17.1^{ab} \pm 1.7$	31	$12.4^{abc} \pm 1.0$	32	$17.2^{a} \pm 1.5$	28	$15.3^{abc} \pm 1.2$
Uric Acid (mg/dL)	Yes	40	4.9 ± 0.3	20	3.5 ± 0.4	36	4.9 ± 0.3	32	5.6 ± 0.3	32	4.6 ± 0.2	33	3.7 ± 0.2
	No	18	3.9 ± 0.4	42	2.6 ± 0.1	29	2.4 ± 0.2	31	4.9 ± 0.4	33	2.9 ± 0.2	27	2.7 ± 0.2
Nonesterified fatty acid (mmol/L)	Yes	40	$0.60^{bc} \pm 0.04$	20	$0.63^{ab} \pm 0.05$	35	$0.72^{a} \pm 0.05$	32	$0.53^{cde} \pm 0.03$	32	$0.58^{bcd} \pm 0.04$	33	$0.59^{bc} \pm 0.02$
	No	18	$0.46^{efg} \pm 0.05$	41	$0.51^{def} \pm 0.04$	29	$0.43^{fg} \pm 0.03$	32	$0.41^{g} \pm 0.03$	33	$0.38^{g} \pm 0.02$	28	$0.47^{efg} \pm 0.02$
Triglyceride (mg/dL)	Yes	41	51.6 ± 3.5	18	34.6 ± 4.1	36	44.6 ± 3.1	32	39.3 ± 2.5	32	55.0 ± 4.6	33	25.4 ± 1.5
	No	18	46.4 ± 5.9	42	39.8 ± 3.3	28	59.3 ± 4.0	32	38.4 ± 3.9	32	61.3 ± 5.3	28	29.8 ± 1.8

[1] The transport intervention included catching and crating (0.5 h), transport (1.5 h), and lairage (1 h).
[2] Con = conventional feed; Con-fat = conventional feed with increased percentage of fat; Con-starch = conventional feed with increased percentage of starch; SS = semisynthetic feed; SS-starch = semisynthetic feed with increased percentage of starch. See Table 1 for contents.
[a-g] Means without a common superscript per parameter differ significantly ($P < 0.05$).

Table 6. Effects of feed composition on mean plasma concentrations of corticosterone, triiodothyronine, glucose, lactate, uric acid, nonesterified fatty acid, and triglyceride of broilers related to transport. Plasma values were determined directly after transport intervention.

	Transport[1]	Diets provided from 72 h before transport and composed of						Feed withdrawal from 24 h before transport		
		Conventional ingredients			Semisynthetic ingredients					
		n	Mean ± SEM		n	Mean ± SEM		n	Mean ± SEM	
Corticosterone (ng/mL)	Yes	96	$12.7^{a} \pm 0.9$	A	64	$6.2^{b} \pm 0.5$	B	33	$8.4^{ab} \pm 1.0$	AB
	No	89	$6.9^{b} \pm 0.5$		65	$5.3^{b} \pm 0.4$		28	$7.1^{ab} \pm 0.9$	
Triiodothyronine (ng/mL)	Yes	77	0.37 ± 0.03		63	0.63 ± 0.04		24	0.33 ± 0.08	
	No	76	0.41 ± 0.04		64	0.57 ± 0.04		13	0.20 ± 0.07	
Glucose(mg/dL)	Yes	96	244 ± 6.5		62	271 ± 9.4		31	222 ± 9.7	
	No	89	250 ± 5.6		64	246 ± 6.5		28	223 ± 9.6	
Lactate (mg/dL)*	Yes	95	$10.5^{b} \pm 0.5$	AB	64	$11.7^{ab} \pm 0.6$	A	29	$7.3^{c} \pm 0.6$	B
	No	86	$14.0^{ab} \pm 0.8$		63	$14.8^{a} \pm 0.9$		28	$15.3^{a} \pm 1.2$	
Uric acid (mg/dL)	Yes	96	4.6 ± 0.2		64	5.1 ± 0.2		33	3.7 ± 0.2	
	No	89	2.8 ± 0.1		64	3.9 ± 0.2		27	2.7 ± 0.2	
Nonesterified fatty acid (mmol/L)*	Yes	95	$0.65^{a} \pm 0.03$	A	64	$0.55^{b} \pm 0.02$	B	33	$0.59^{ab} \pm 0.02$	A
	No	88	$0.48^{c} \pm 0.02$		65	$0.40^{d} \pm 0.02$		28	$0.47^{cd} \pm 0.02$	
Triglyceride (mg/dL)	Yes	95	45.7 ± 2.1		64	47.2 ± 2.8		33	25.4 ± 1.5	
	No	88	47.4 ± 2.5		64	49.8 ± 3.6		28	29.8 ± 1.8	

[1] The transport intervention included catching and crating (0.5 h), transport (1.5 h), and lairage (1 h).
[a-d] Means without a common superscript within the same plasma concentrations differ significantly ($P < 0.05$).
[A,B] Significant difference for feed treatment if no common capital is present ($P < 0.05$).
[*] Significant difference for transport within the same plasma concentrations ($P < 0.05$).

Neither plasma T_3 concentration nor glucose was influenced by transport or feed regimen. However, both of them showed a tendency for lower values for feed withdrawn broilers (Table 5).

In FW broilers transport decreased plasma lactate values significantly. Also, an overall transport effect was found for lactate. Beside that, broilers fed with semisynthetic diets showed higher lactate values as compared to FW broilers. Neither transport nor feed regimen influenced uric acid values.

Plasma NEFA was increased in all transported groups. Non-transported SS-starch groups showed the lowest value (0.38 mmol / L). NEFA values in conventional ingredients fed groups and in FW groups were higher than in semisynthetic ingredients fed groups. Plasma TG concentrations showed a tendency for lower values for feed withdrawn broilers. However, significant effects for transport of feed regimen were not observed.

Discussion

In this study we investigated the influences of a number of diets, which were provided before transport to the processing plant, on stress, energy balance, and BW of broilers. And if these diets could be a possible alternative for feed withdrawal before catching and transport of broilers. Semisynthetic diets showed less BW losses as FW broilers and feed intake of semisynthetic feed was lower compared to conventional feed. Therefore, the DTM in % of BW was lower for semisynthetic fed broilers in comparison with conventional fed broilers, which can lead to a lesser degree of contamination during evisceration. Beside that, no increase of CORT was found due to transport in semisynthetic fed broilers.

Transport is an essential factor in studies on the effects of FW before slaughter. In this study a transport effect was found for DTM in % of BW in FW broilers. Apparently, catching, crating, and transport stimulate clearance of the digestive tract. Nijdam et al. (2005) showed that losses of BW in broilers that were feed withdrawn and transported exceeded those of broilers that were only withdrawn of feed for the same period of time. This could partly be caused by the clearance of the digestive tract during transport. Furthermore, transport influenced plasma NEFA and lactate values, and CORT values of broilers fed with conventional diets. At least one of these transport effects was also shown in earlier studies of Freeman et al. (1984), Kannan and Mench (1996) and Nijdam et al. (2005).

We did not observe that stress or transport influences plasma glucose, uric acid, and TG values as was reported in other studies (Puvadolpirod and Thaxton, 2000; Nijdam et al., 2005). An important reason for this could be the percentage of missing values in experiment 1 (45%) due to errors during storage of blood samples. Beside that, Lin et al. (2004) showed changes in uric acid and glucose values occur within 3 h after CORT supplementation due to enhanced gluconeogenesis and protein catabolism. In this investigation no significant increase of CORT occurred after transport, and therefore it is likely that no significant changes in uric acid and glucose values were found either. Nevertheless, the plasma uric acid values tended to be higher after transport.

No feed withdrawal effects on plasma concentrations were found, whereas other studies showed a feed withdrawal effect on T_3 (Buyse et al., 2000; Nijdam et al., 2005), glucose (Langslow et al., 1970; Van der Wal et al., 1999; Knowles et al., 1995; Nijdam et al., 2005), NEFA (Langslow et al., 1970; Van der Wal et al., 1999), and TG (Nijdam et al., 2005). Nevertheless, average values of T_3, glucose, lactate, uric acid, and TG were the lowest for FW groups.
Beside that, CORT values for FW groups did not increase. Studies about the relation between feed withdrawal and CORT concentration are very contradictory.

This study clearly showed that a feed withdrawal period of 27 h did not increase CORT. Nijdam et al. (2005) found the same results for a feed withdrawal period of 13 h. The results are similar to studies of Freeman (1983), who reported two studies in which CORT was not increased after feed withdrawal. However, Scott et al. (1983) and Knowles et al. (1995) showed an increase in CORT after a feed withdrawal period of 10 h and 24 h, respectively. Because CORT is known as the most reliable indicator of stress in chickens (Thaxton and Puvadolpirod, 2000), one can conclude that standard feed withdrawal times before catching are not likely to lead to excessive stress.

Differences in diet composition with regard to macronutrients might lead to metabolic changes (Collin et al., 2003; Machin et al., 2004). In this study metabolic changes were already present after a supplementation period of only 3 days. Semisynthetic ingredients led to changes in CORT, lactate and NEFA values. The semisynthetic diets consisted of an average of approximately 67 % of carbohydrates, whereas the conventional diets consisted of 42% carbohydrates on average. Moreover, all carbohydrates in semisynthetic feed are highly soluble and digestible. The other macronutrients and ME doe not substantially differ among the diets.

The decreased NEFA values that were found in semisynthetic fed broilers are not due to a decreased feed intake, or to a possible dependency on CORT. The high NEFA values in conventional fed groups and FW groups indicate an increased lipolysis (Nijdam et al., 2005). However, in broilers fed with high carbohydrate concentrated feed, glucose is probably more sufficient to fulfill the energy needs instead of lipids. A tendency for higher glucose values after transport was shown for semisynthetic fed groups, possibly due to the high carbohydrate intake. In contrary, the conventional and FW groups showed a slight decrease of glucose concentration after transport. This might be the reason for significantly higher lactate values for semisynthetic groups compared to FW groups.

In conclusion, semisynthetic feed with high carbohydrate concentration could be a good alternative for the feed withdrawal period held before catching and transport. Semisynthetic feed reduces BW losses and does not result into an increase of CORT after transport. Nevertheless, more research is necessary to investigate the consequences of feeding semisynthetic feed on shear strength of the intestines. This parameter can be used to predict the risk of condemnation during evisceration. Beside that, changes in metabolism as a consequence of diet composition were shown. The effects of these changes in plasma metabolites on meat quality must be investigated as well as the ideal duration of the supplementation period before catching and slaughter.

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Chapter 7

Summarizing discussion

Introduction

On the last day of their lives the physiology and yield of broilers is influenced by several events: feed withdrawal, catching and crating, transport and lairage, dumping on the conveyer belt at the processing plant, hanging on the shackle line, electrical stunning and exsanguination (further referred to as slaughter procedure). In our experiments the effects of these events on stress, energy metabolism, body weight (BW), and meat quality were examined. Moreover, mechanical catching and adding semisynthetic feed to the broilers just before catching were investigated as possible methods to reduce the effect of preslaughter management practices on the physiology and yield of the broilers.

After catching, 0.46% of the broilers died. Factors which increased this percentage were both high (>15°C) and low (≤5°C) ambient temperatures, catching and transporting the birds during daytime, increased flock size, increased mean BW, increased mean compartment stocking density, increased transport time, and increased lairage time. Also one catching company and one breed increased the DOA percentage. Of all DOA broilers 30% showed signs of trauma, most likely caused by catching, crating or during transport. Beside that, another 30% had heart disorders.

Energy metabolism was influenced by feed withdrawal, catching and crating, transport and lairage, and the slaughter procedure. A negative energy balance was shown by higher thyroxine and lower triiodothyronine (T_3), triglyceride (TG), glucose, and lactate concentrations. An increase of plasma corticosterone (CORT) concentration was caused by catching and crating, transport and lairage, and the slaughter procedure. Moreover, BW was reduced by both feed withdrawal and transportation. Broilers that were given semisynthetic feed in the period before catching showed an increased lactate and a decreased nonesterified fatty acid (NEFA) concentration and a smaller reduction of BW compared with feed withdrawn broilers.

Preslaughter Events

Feed Withdrawal

In chapter 5 and 6 it was shown that feed withdrawal periods of 13 h and 27 h did not have a noticeable effect on CORT concentrations of boilers. For both feed withdrawn and fed broilers mean CORT values of approximately 7 ng / mL to 8 ng / mL were found.

Thaxton and Puvadolpirod (2000) reported that CORT is the most reliable indicator of stress in chickens. Consequently, the results described in this thesis suggest that feed withdrawal is not a cause of stress in broilers. This conclusion is in accordance with the results of two studies cited by Freeman (1983), but in contradiction with those obtained by Scott et al. (1983) and Knowles et al. (1995). The latter showed increased levels of CORT after a feed withdrawal period of 10 h and 24 h, respectively. An explanation for the differences is possibly that Scott et al. (1983) and Knowles et al. (1995) not only withdrew their broilers from feed, but also from water, which may have contributed to extra stress. Moreover, Scott et al. (1983) withdrew their broilers from feed and water by placing them into holding coops instead of keeping them in the floor pens and remove the feeders. On the other hand one should be careful in concluding that feed withdrawal is not a stressor in broilers nowadays. The reason is that other parameters, such as heart rate (Duncan et al. 1986), tonic immobility reactions (Jones, 1992), and glucagon (Freeman, 1980), may also be important factors. However, these have not been measured in this study.

Feed withdrawal led to an increase in plasma glucose, lactate, TG, and T_3 concentrations. These findings are indicative for a negative energy balance, which was associated with a BW reduction of 0.37% / h and 0.24% / h after a feed withdrawal time of 17 h and 31 h, respectively. However, Veerkamp (1978) did not find any effect of withdrawal time on BW reduction in % / h between 4 and 28 h of feed withdrawal. The BW reduction that Veerkamp (1978) found was 0.353% / h. However, the first 4 h were excluded in the equation. The difference in BW reduction found in the experiments described in this thesis is possibly caused by the clearance of the digestive tract, which mainly occurs during the first several hours of feed withdrawal, and therefore, BW reduction in percent per h is higher after a period of 17 h than after 31 h. This is confirmed by the results presented in chapter 6. The digestive tract mass in percentage of BW was 7.03 in broilers that were feed withdrawn for 7 h, whereas the percentage of BW dropped to 6.44 after a feed withdrawal period of 31 h.

To reduce the negative effect of feed withdrawal on BW it is possible to provide conventional feed to the broilers until they are caught. However, as presented in chapter 6, broilers fed with conventional feed showed increased levels of CORT after transport. Moreover, they had a higher digestive tract mass in % of BW compared to feed withdrawn broilers, which might increase the risk of fecal contamination. However, broilers fed semisynthetic feed in the period before catching did not show increased levels of CORT. In addition, the BW losses during the preslaughter period were less than those of feed withdrawn broilers. Finally, semisynthetic fed broilers had less digestive tract content compared to conventional fed broilers.

Catching and Crating

Catching company, container compartment stocking density and flock size were associated with an increased DOA percentage in this study. The numbers of birds that are placed into one compartment depends on the accuracy of the members of the catching crew. Enlargement of the compartment stocking density is likely to result in both a rise in temperature and humidity in the container. Consequently, heat loss will be more difficult which may lead to hyperthermia (Dawson and Whittow, 1994). As a rule increasing the flock size results into an increased catching time. A member of a catching company usually loads between 1,000 and 1,500 birds per hour. For a member of a catching team it may be difficult to maintain concentration and exercise care. Consequently, errors in stocking density may occur. Postmortem examination of DOA broilers revealed a prevalence of traumata of 29.5%. It is likely that a substantial part of trauma, such as head trauma, and ruptured livers occurred during catching and crating. Therefore, manual catching must be improved. In studies of Bayliss and Hinton (1990), Kettlewell and Mitchell (1994) and Metheringham (1996) it was already concluded that more attention had to be paid to the catching and crating process to reduce mortality, injuries, and stress. Obviously, almost a decade later, no improvement has been achieved in the field yet.

The reason that catching company was found to be a risk factor was due to one catching company, that caught the broilers by machine, whereas all other companies caught the broilers by hand and therefore showed lower DOA percentages.

Beside mortality, catching and crating will cause severe stress. Handling of broilers in inverted position leads to an increase in CORT concentrations (Kannan and Mench, 1996), prolonged tonic immobility reactions (Jones, 1992), and an increased heart rate (Duncan et al., 1986) In chapter 4 an increase of CORT of 75% was found between the moment immediately before catching and the moment immediately after crating.

Also metabolic changes occurred during catching and crating. The relatively large increase of lactate after the start of the catching process is remarkable. The broiler probably uses a lot of energy during catching. At that time the broilers have been feed withdrawn for over five hours already. This causes depletion of the glycogen stores in the liver, which is the primary accessible store for maintaining blood glucose levels (Warris et al., 1988). Furthermore, the elevated CORT level will exhaust aerobic capacity of the broiler. Therefore, energy must be formed anaerobe by producing lactate out of pyruvate (Hazelwood, 1994).

In the period before the bird itself has been caught, but when the catching of the flock is in progress, a period that may take about 2 to 5 hours, no major alterations of CORT, glucose and lactate were observed. This, in spite of the fact that the catching crew is present in the broiler house all the time, and the fact that the feed and water withdrawal period is prolonged for the broilers that are caught at the end of the catching process. Obviously, only direct handling induced changes of plasma concentrations and not the presence of the catching crew and machines. This is in contradiction with the findings found 30 min before the start of catching. The noise of the catching machine which was standing outside the broiler house gave an increase of CORT compared to broilers that were caught by hand, and where consequently no noise of a machine was present outside the house 30 min before catching.

In chapter 4, the effect of catching methods on physiology and yield was investigated. Mechanical catching was associated with higher DOA percentages. Beside that, both manual and mechanical catching gave the same increase in CORT, and differences in ultimate pH of the pectoralis muscle were not found. With respect to mortality, these findings contradict with other studies. Ekstrand (1998) and Knierim and Gocke (2003) did not found different DOA percentages between mechanical and manual caught flocks. However, because the studies mentioned above were observational studies, the causality of the observed associations may be questioned due to possible confounding (Noordhuizen et al., 1997). After 20 yr of developing different types of catching machines for broilers, still no machine is found that results in less mortality than manual catching. Perhaps more attention has been paid on catching speed, and working conditions for the catching crew, than on mortality of broilers.

In our study no differences in CORT concentration were found between mechanical and manual caught broilers. However, based on heartbeats per minute and duration of tonic immobility, Duncan et al. (1986) concluded that mechanically caught broilers had less fear than manually caught broilers. To investigate if mechanical catching could increase bird welfare, more parameters should be used.

Transport, Lairage and Slaughter

In the transport and lairage period also factors were found associated with mortality and bruising of broilers. Risk factors were: the moment of the day that the broilers are transported, the ambient temperature, prolonged transport and lairage times. The experiments described in this thesis showed that BW losses of broilers during transport were approximately 0.11% / h more than those of broilers that were not transported. Moreover, glycogen stores will be depleted (Warriss et al., 1988), and during lairage hyperthermia can occur (Warriss et al., 1999).

Stress and metabolic exhaustion, are a likely cause of mortality during transport and lairage. Moreover, at postmortem examination of DOA broilers, macroscopic lesions were found in 89.4% of the DOA broilers; 42.4% of the DOA broilers had signs of heart and circulation disorders. RV:TV was significantly higher in DOA broilers than in slaughtered broilers. In chapter 2 an association is described between mortality and breed. Heart and circulation disorders may play a role in this association.

Breeding companies often use data of health status and mortality in the broiler house. The type of postmortem research as described in chapter 3 could give necessary information. This information should be added to their data collected in the broiler house to improve their research. Metabolic exhaustion could increase mortality in broilers with pathological conditions such as an increased RV:TV, ascites and fibrinous polyserositis in comparison to broilers without any of these pathological signs.

When combining the results of chapter 4, 5, and 6 it is possible to indicate the influence on CORT concentrations of each event. Catching, crating, transport and lairage formed the so-called transport procedure in chapter 5 and 6. Due to this procedure an average increase of CORT of approximately 85% (117% in chapter 5 and 53% in chapter 6) can be estimated. This difference between the CORT values of chapter 5 and those of chapter 6 may be caused by the inclusion of groups of broilers fed with semisynthetic diets, because they did not show an increase of CORT after transport. In chapter 4, an increase of CORT was found of 75% due to catching and crating. Therefore, transport and lairage alone may only increase CORT concentrations by approximately 10% (85% - 75%).

In chapter 4, the increase in CORT caused by the combined effect of transport, lairage and the slaughter procedure was estimated at 115%. Consequently, one could argue that the slaughter procedure caused an increase of 105% (115% minus 10% for transport and lairage). During this procedure the birds were dumped on a conveyer belt, hung upside down at the slaughter line, electrically stunned, and killed by automated neck cutting equipment, events that probably have more influence on plasma CORT concentrations than transport and lairage.

Both feed withdrawal and transport led to BW loss. In chapter 5, a difference in BW reduction between non transported and transported feed withdrawn broilers of approximately 0.11% / h was found. In chapter 6 the reduction in BW due to transport was remarkably lower, namely 0.04% / h. During catching, crating and transport it is possible that broilers will have more droppings in comparison with broilers who remain in their pens. Therefore, this difference in BW reduction can be explained by the clearance of the digestive tract. In chapter 6, the broilers were transported after a feed withdrawal period of 24 h, and in chapter 5 this period was only 10 h. After 24 h of feed withdrawal the digestive tract is probably empty, while after a feed withdrawal period of 10 h some content can still be present in the digestive tract, which could be removed during the transport procedure.

Other explanations of higher BW loss during transport than during feed withdrawal are high ambient temperatures during transport (Chen et al., 1983), and the negative energy balance, which was indicated by an increased NEFA and decreased T_3 concentration during the transport intervention. However, TG was not influenced by the transport intervention, and lactate showed reduced values after transport.

Main Conclusions, Recommendations and Needs for Further Research

Preslaughter management practices have a large influence on the physiology and yield of broilers. Approximately 0.46% of the broilers die during this period. Slaughter procedure, catching and crating and transport markedly increased CORT. Feed withdrawal, on the other hand, did not influence CORT concentrations. However, feed withdrawal, together with transport, led to alterations in plasma concentrations of glucose, lactate, NEFA, uric acid, TG, and T_3. These finding indicate a negative energy balance, and consequently, BW reductions occurred. Feeding the broilers semisynthetic diets reduced these negative effects significantly. Mechanical catching, however, could not reduce the negative effects of catching

Poultry farmers and integrations can reduce the negative effects of feed withdrawal by introducing a new type of diet, made of semisynthetic ingredients, which should be given to the broilers on the last 3 days of life. Nevertheless, more research is necessary to investigate the risk of condemnation during evisceration after feeding semisynthetic diets. Beside that, the consequences for meat quality of feeding such a diet until catching is not clear, and therefore must be investigated before practical implementation of semisynthetic diets.

One should realize however that the effects of catching and crating, transport and lairage and the slaughter process are the major stress causing factors. Members of catching crews should handle the birds with more care, more attention should be paid to the number of broilers which are put in crates or containers, and at large poultry houses extra people should be added to the catching crew.

Mechanical catching is still not a good alternative for manual catching with respect to CORT, bruises and especially mortality. However, research to improve (especially mortality rates) catching machines must continue, because, it cannot be excluded that the current way of manual catching will be banned in the future, due to the bad working conditions of the catching crews.

Processing plants can use the information obtained from the multilevel analysis to reduce the number of DOA and bruises. Transport and lairage times must be reduced where possible, and processing plants should consider start processing around midnight instead of approximately five o'clock (which is common in the Netherlands). The effect of low ambient temperatures on mortality could probably be reduced by restricted use of the curtains of the transport vehicle. Further research should be carried out to investigate how the climate on the transport vehicle can be improved to reduce mortality.

Finally, to further improve the conditions of broilers during preslaughter management practices more in-depth knowledge of the physiology of broilers during each of the separate events that take place is needed. One can think of studies in which broilers are equipped with an automatic sampling device to continuous measuring of CORT, blood metabolites, and heart rate. At present, these devices are still too large to be used without interfering in the study results. In addition, more stress parameters should be taken into account.

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Samenvatting

Wereldwijd neemt de pluimveevleesconsumptie sterk toe. In 2005 was de consumptie 12,6 kg per hoofd van de bevolking; 40% meer dan in 1994. Het gevolg van deze toename is dat het aantal vleeskuikens eveneens enorm toeneemt. Na een mestperiode van ongeveer 6 weken worden de vleeskuikens vervoerd naar het slachthuis waar tegenwoordig soms tot een miljoen kuikens per week worden geslacht. Tijdens de laatste levensdag worden de dieren blootgesteld aan een reeks gebeurtenissen zoals: voeronthouding, vangen, kratten, transport naar het slachthuis en wachten in de wachtruimte van het slachthuis alvorens de containers met kuikens op een lopende band geleegd worden, aan de slachtlijn opgehangen worden en verdoofd en verbloed worden.

In hoofdstuk 2 is een multifactoriële analyse beschreven over factoren die van invloed zijn op sterfte tussen het moment van het vangen en het slachten (DOA) en op bloeduitstortingen. Factoren die het DOA percentage verhogen zijn onder andere: het overdag vangen en vervoeren van de kuikens, zowel lage (≤5°C) als hoge (>15°C) omgevingstemperaturen, grotere koppels, hoger lichaamsgewicht, meer kuikens in een krat, langere transport- en wachttijden. Ook kan de vangploeg en het ras vleeskuikens van invloed zijn op het DOA percentage. Factoren die het percentage bloeduitstortingen kunnen beïnvloeden zijn het seizoen, maar ook het moment van vangen en de omgevingstemperatuur.

In hoofdstuk 3 is een postmortaal onderzoek bij dood aangevoerde kuikens beschreven om meer inzicht te krijgen in de onderliggende doodsoorzaken. In 89,4% van de DOA zijn macroscopische afwijkingen gevonden. Veelvoorkomende kenmerken waren die van infectieuze aandoeningen (89,4%), hart- en circulatieafwijkingen (42,4%) en trauma (breuken en bloedingen; 29,5%). Zeer opvallend was dat het aantal kuikens met een vergrote rechter hartventrikel significant hoger was in de dood aangevoerde kuikens dan in geslachte kuikens.

In hoofdstuk 4 is een vergelijking beschreven tussen het machinaal vangen en het handmatig vangen van vleeskuikens. Momenteel worden bijna alle vleeskuikens in de wereld met de hand gevangen. Het handmatig vangen van kuikens is zeer zwaar werk voor de kippenvanger en bovendien zijn er aanwijzingen dat het welzijn van de kuikens tijdens het vangen is verminderd. Om deze redenen is er gekeken of het machinaal vangen een goed alternatief kan zijn voor het handmatig vangen. De vangmethode had geen invloed op het corticosteron gehalte in het plasma. Een toename van corticosteron in het bloed wordt vaak geassocieerd met stress. Ook had de vangmethode geen grote invloed op de vleeskwaliteit. Wel bleek dat het DOA percentage hoger was in koppels die machinaal gevangen zijn.

Voordat vleeskuikens worden gevangen, is het gebruikelijk dat ongeveer 5 uur voor het vangen het voer wordt verwijderd. Dit wordt gedaan om te voorkomen dat er tijdens het slachten bezoedeling van de karkassen ontstaat, doordat de inhoud van het verteringskanaal op de karkassen terecht komt. In hoofdstuk 5 is het effect van voeronthouding voor transport op het energiemetabolisme, het lichaamsgewicht en corticosteron beschreven. Er was geen effect van voeronthouding op het corticosteron gehalte. Als kuikens werden getransporteerd vond wel een stijging van corticosteron plaats. Na voeronthouding hebben kuikens een hogere thyroxine concentratie en lagere triiodothyronine, triglyceride, glucose en lactaat concentraties in het plasma in vergelijking met kuikens die voer gehad hebben tot het moment van vangen en transport. Deze veranderingen wijzen op een negatieve energiebalans. Hierdoor nam het lichaamsgewicht van de kuikens ook af. Overigens zorgde het transporteren nog voor een verdere afname van het lichaamsgewicht.

Om de negatieve effecten van voeronthouding te verminderen, is onderzocht of het verstrekken van semisynthetische voeders gedurende de laatste 3 dagen voor het vangen een oplossing kan zijn (hoofdstuk 6). Na het vangen en transport was de gewichtsafname van kuikens die semisynthetisch voer hebben gehad 0,04% per uur, voor gevaste vleeskuikens was deze afname 0,28% per uur. Overigens was er gewichtstoename bij kuikens die conventioneel voer hebben gehad (0,004% per uur). Het gewicht van het verteringskanaal was echter hoger voor conventioneel gevoerde kuikens in vergelijking met de semisynthetisch gevoerde kuikens. Een zwaarder verteringskanaal duidt vermoedelijk op meer voerresten, en daardoor op een extra risico op contaminatie. Bovendien trad er bij de conventioneel gevoerde kuikens na transport een stijging op van het corticosterongehalte. Deze stijging vond niet plaats bij semisynthetisch gevoerde en gevaste kuikens.

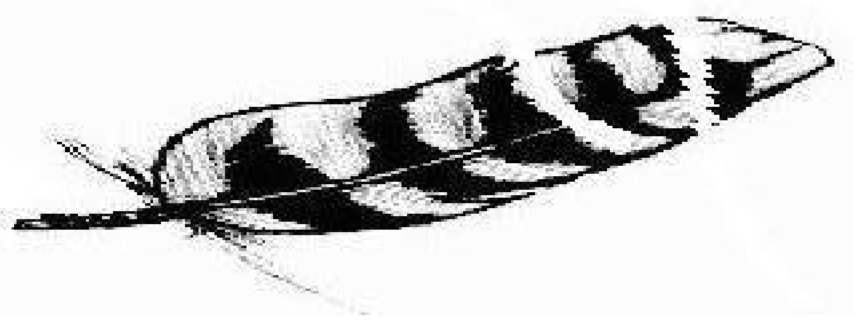
Tussen het vangen en slachten sterft 0,46% van de vleeskuikens. De periode tussen het legen van de kratten en het verbloeden op het slachthuis, het transporteren en wachten en het vangen en kratten zorgen alle voor een stijging van corticosteron. Het onthouden van voer zorgt echter niet voor een stijging van corticosteron. Voeronthouding en transport leiden wel tot een negatieve energiebalans en daarmee tot een gewichtsafname.

Om deze negatieve effecten te voorkomen moeten lange transport- en wachttijden voorkomen worden. Bovendien kunnen slachthuizen het slachtproces beter rond middernacht beginnen in plaats van 5 uur ’s ochtends, want dan is het overdag vangen en vervoeren van vleeskuikens niet meer nodig. Ook moeten vrachtwagenchauffeurs niet te vroeg de gordijnen van de volgeladen wagens met kuikens sluiten, vanwege mogelijke hittestress. Meer onderzoek is nodig naar het klimaat op de vrachtwagen tijdens het transport van kuikens.

De vangmachine was in deze studie nog geen goed alternatief voor handmatig vangen. Er moet wel onderzoek blijven plaatsvinden om de prestaties van de vangmachine op het gebied van sterfte en welzijn te verbeteren. In de toekomst valt het namelijk niet uit te sluiten dat het handmatig vangen van vleeskuikens aan banden wordt gelegd vanwege de slechte werkomstandigheden.

Het verstrekken van semisynthetisch voer bleek in deze studie een goed alternatief te zijn voor voeronthouding. Bovendien vertonen de kuikens na transport geen stijging van corticosteron. Voordat een dergelijk voer in de praktijk kan worden toegepast, moeten er experimenten op praktijkschaal plaatsvinden en dient er grondig onderzoek plaats te vinden naar de effecten op contaminatie van karkassen tijdens het slachtproces en op de uiteindelijke vleeskwaliteit.

Dankwoord



Bedankt!

Curriculum Vitae

Edwin Nijdam werd op 26 maart 1975 geboren in Groningen en groeide op in Eelde. In 1994 behaalde hij het VWO diploma aan het Zernike College in Groningen. In datzelfde jaar begon hij aan de studie Zootechniek aan de toenmalige Landbouw Universiteit Wageningen. Tijdens zijn studie heeft hij een afstudeervak bij de vakgroep veehouderij gedaan. Het afstudeervak kreeg als titel: "Newcastle disease: risicofactoren, beleid en bestrijding". Tevens heeft hij een afstudeeronderzoek naar de invloed van het opfokgewicht en de nutriëntenopname op de ontwikkeling en productie van jonge leghennen uitgevoerd bij Cehave Landbouwbelang in Veghel. Vervolgens is Edwin op stage geweest bij *Embrapa suínos e aves* in Concordia (Brazilië), waar hij de verschillen tussen de Nederlandse en Braziliaanse pluimveehouderij heeft bestudeerd. Na afronding van zijn studie in 2000 kwam hij in dienst van Nabuurs Groep te Haps om onderzoek te doen naar de laatste levensdag van het vleeskuiken. Hij werd gedetacheerd bij de Hoofdafdeling Landbouwhuisdieren van de Faculteit Diergeneeskunde van de Universiteit Utrecht, waar hij in 2001 officieel in dienst kwam. Edwin heeft bij de afdeling Pluimvee zijn promotieonderzoek uitgevoerd onder leiding van Arjan Stegeman