Ministry for Primary Industries
Manatū Ahu Matua

Survey of Lameness in New Zealand Meat Chickens

MPI Technical Paper No: 2013/45

Prepared for the Ministry for Primary Industries
by Jim Webster, Catherine Cameron and Andrea Rogers,
AgResearch, Hamilton, New Zealand

ISBN No: 978-0-478-42063-0 (online)
ISSN No: 2253-3923 (online)

October 2013

New Zealand Government

Growing and Protecting New Zealand

Disclaimer

Requests for further copies should be directed to:

Publications Logistics Officer
Ministry for Primary Industries
PO Box 2526
WELLINGTON 6140

Email: brand@mpi.govt.nz
Telephone: 0800 00 83 33
Facsimile: 04-894 0300

This publication is also available on the Ministry for Primary Industries website at
http://www.mpi.govt.nz/news-resources/publications.aspx

Contents

Page

Executive summary

The leg health of birds in the New Zealand meat chicken industry was assessed for comparison with similar measures made in 2005 and to provide recommendations to reduce lameness where possible. The main approach was to use Gait Scoring (GS) to assess leg health in 6409 Ross birds across 20 farms in the North Island. GS is a validated method of assessing leg health in poultry involving the scoring of walking ability (from 0 = normal to 5 = incapable of walking) of a subsample of birds from a flock. In addition, pathological examinations were carried out on a selection of birds with a compromised ability to move (GS of 3, 4 and 5) and birds culled for leg problems by the farmer. Farm details were surveyed and a number of other husbandry measures were recorded including mortality, culling, litter depth and light levels to examine correlative factors. To determine the effects of liveweight (LW), three categories representing different size birds were assessed LW 1=1.6-1.9kg, LW 2=2.0-2.8kg and LW 3= 2.9-3.6kg

A number of changes in the industry from 2005 were found, including an increase in shed and flock sizes, a shift to the Ross (Aviagen) breed and an increase in the average growth rate of birds. Production methods were generally consistent across the three main companies in the industry.

There is evidence from other studies that the practice of thinning a flock (removal of a sub-group of birds for slaughter at an earlier age and lower LW), which enables a higher number of birds to be initially placed in a shed than would be possible if all birds were grown to the final LW, could contribute to leg weakness and this possibility should be studied further. The highest stocking density of 35.3 ± 0.55 kg/m^2 occurred prior to the thin at an average of 32 days of age. At this time there were 19.8 ± 0.21 birds/m^2. This contrasts to 8.0 ± 0.52 birds/m^2 at final slaughter, at an average of 43 days of age. Based on the literature, this number of birds per m^2 is likely to reduce activity and contribute to an increased prevalence of leg weakness.

Mortality and culling rates had not changed significantly from 2005. Total mortality rate was 2.65 ± 0.215% of birds initially placed in a shed and the majority of these (65.0 ± 2.86%) were birds discovered dead (i.e. not assisted by the farmer through active culling). Culling rate was 0.96 ± 0.121% with 0.24 ± 0.024% culled for leg problems.

There was evidence of decreased leg health (increased GS) in heavier and older Ross birds (LW 3) in 2011 than in 2005. The flock average GS of 2.24, and the overall percentages of birds with GS 3-5 (30%) and GS 4-5 (1.7%) were not significantly different from 2005. For LW 3 birds there was a higher average GS in 2011 (2.60 vs 2.15, P=0.031), a lower percentage of GS 2 birds (42.3 vs 84.1%, P=0.023) and a higher percentage of GS 3 birds (51.8 vs 14.7%, P=0.019). The percentage of GS 3-5 birds in LW 3 was also higher in 2011 than 2005 (56 vs 15%, P=0.025) whereas the percentage in GS 4-5, despite the apparent difference in the means, was not significantly different from 2005 due to high variability (4.18 vs 0.49%, P=0.134).

The main factors influencing GS were LW and age (P<0.001). As birds got older and heavier their walking ability declined and the degree of lameness increased for each LW category (average GS = 1.96, 2.15 and 2.59 for LW 1, 2 and 3). Consequently, there was an increase in the percentage of birds with GS 3-5 and GS 4-5 with each increase in LW category (GS 3-5 = 13, 20 and 56%, LW 1 – 3 respectively and GS 4-5 = 0.12, 0.77 and 4.18%, LW 1 – 3 respectively).

As the degree of lameness increased, so did identifiable pathological causes of the lameness. For GS 3 birds, the most common leg problem was foot pad dermatitis (FPD)(23.6%) while for 64.8% of these birds no cause could be attributed. The prevalence of joint infections and twisted legs increased with each GS and septicaemia was significantly higher at GS 5. The literature suggests that the majority of the leg problems found would decrease the welfare of the birds affected by being painful and/or reducing mobility and access to food and water. With the exception of FPD which may resolve with improvements in litter quality, culling is likely to be the best option for birds with leg problems seen in GS 4 and 5. There was evidence that culling is not effectively removing all GS 4-5 birds. Leg culls (0.24%) and even total culls (0.96%) were much lower than the percentage of GS 4-5 birds (1.74%).

Introduction

Modern production of chicken meat is one of the most efficient methods of producing animal protein. In order to achieve this, the meat chicken industry uses a small genetic base of birds that have been highly selected for growth and conformation, combined with specialized nutrition and strict environmental control (Appleby *et al.*, 2004; Weeks & Butterworth, 2004). A highly controlled, fully-housed, vertically integrated system of production means that welfare issues for the industry are similar worldwide and as a consequence have been well-studied, albeit with a focus on inputs and health-related outcomes rather than the birds affective or feeling state (Robins & Phillips, 2011). While there may be compromises in terms of the natural and affective dimensions of welfare, the benefits of modern production systems in terms of reduced disease and mortality and quality of husbandry should not be discounted (Flock *et al.*, 2005). Nevertheless, there is continued interest at a public and regulatory level to assess and improve the welfare of chickens raised for meat.

The main health-related welfare issues with regard to the growing phase of meat chicken production include metabolic problems, skin lesions and leg disorders (Bessei, 2005; Bessei, 2006). A recent extensive review by an expert panel concluded that many of these problems are linked to the rapid growth rates of the birds (EFSA, 2010) and they are rare in slow-growing strains of poultry (Weeks & Butterworth, 2004). Many of these welfare problems are heritable and can be influenced by genetic selection, (Ask, 2010; Akbas *et al.*, 2009; Bennett, 2006; Haslam *et al.*, 2007). Metabolic problems, such as the failure of organ systems, can arise from rapid growth due to the increased work-load on that organ or system and include cardiovascular problems such as ascites and sudden death syndrome (Julian, 2005). Skin lesions are predominantly caused by contact dermatitis of the foot pads (FPD), hocks and breast due to prolonged contact with moist litter (Martland, 1985; Shepherd & Fairchild, 2010). The lesions may be painful and provide a route for ingress of infection (Shepherd & Fairchild, 2010). Leg disorders, outwardly exhibited as lameness, reduce welfare via detrimental effects on activity (inability to access food and water), behaviour (Weeks *et al.*, 2000) and the likelihood of associated pain (Danbury *et al.*, 2000; Naas *et al.*, 2009; McGeown *et al.*, 1999). This is considered to impinge on four of the five freedoms[1] defined by the Farm Animal Welfare Council, UK, (FAWC) as requirements for farm animals (Bradshaw *et al.*, 2002). The five freedoms form the basis for defining obligations to animals under the NZ Animal Welfare Act (1999). Lameness is therefore recognised as the single most important welfare issue in the meat chicken industry (Gregory & Grandin, 2007).

Leg disorders can be categorised as infectious, developmental or degenerative, based on the predominant underlying cause, although there is much overlap between these categories (Bradshaw *et al.*, 2002). Most of the non-infectious leg disorders such as spondylolisthesis (kinky-back), tibial dyschondroplasia (TD), valgus–varus deformity (twisted legs) and rotated tibia are related to rapid growth (Julian, 2005). Slowing growth, particularly in the first 15–20 days of life markedly reduces the incidence of twisted legs, TD and kinky back, which accounts for 65–80% of the non-infectious causes of leg deformity and lameness in meat chickens (Classen & Riddell, 1989; Julian, 2005). Infectious causes of lameness are caused by bacterial chondronecrosis of the bones and joints, viral and fungal infections (Butterworth, 1999) and may include some forms of femoral head necrosis (Bradshaw *et al.*, 2002). The effects tend to impact birds later in the growing phase and are considered to be severe due to the high incidence, painfulness and decreased ability to access food and water (Bradshaw *et al.*, 2002).

[1] Freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom to express normal behaviours.

One of the challenges when assessing welfare within the meat chicken industry is the scale of the industry. The meat chicken industry in New Zealand (NZ), in terms of animal numbers, dwarfs other production sectors in this country with around 84 million birds processed in 2011. As a result, birds are commonly raised and processed on a flock basis, whereas welfare is focussed at the level of the individual. Welfare assessment methods must be capable of identifying the welfare status for individual birds and provide recommendations for improvements at that level.

In 2003, the Ministry of Agriculture and Forestry (MAF), now the Ministry for Primary Industry (MPI), commissioned a study to identify key indicators of the welfare status of NZ meat chickens. Additional outcome information was collected to help inform discussion of current production practices and policies, and to provide recommendations to the industry and MAF. A nationwide study was carried out on 37 farms by AgResearch Ltd over 18 months between January 2004 and June 2005 and was reported to MAF in 2006 (Bagshaw *et al.*, 2006). This study will be referred to hereafter as the 2005 study, reflecting the status of the industry in that year. The main approach of the 2005 study was to measure lameness as an outcome-based indicator of leg disorders. Gait scoring (GS) was chosen as a practical on-farm method of assessing lameness as it is validated and has international benchmarks (Butterworth *et al.*, 2007; Kestin *et al.*, 1992). GS (using a reduced scale) is also highly correlated with bird movement suggesting it can provide an objective assessment of activity (Dawkins *et al.*, 2009). GS has been used successfully to assess bird welfare within meat chicken industries on a national scale in several countries including the UK, Sweden and Denmark (Knowles *et al.*, 2008; Sanotra *et al.*, 2003). One of the largest studies measured the GS of 51,000 birds, representing 4.8 million birds from 176 flocks in the UK meat chicken industry (Knowles *et al.*, 2008). While GS is a useful measure of lameness and as such an indicator of the major causes of reduced welfare, it is considered to be a lag indicator because the welfare condition is already significant by the time that visible lameness is determined (Manning *et al.*, 2007). Recommendations to improve welfare can be made in the light of the GS measures however.

The aims of this study were to survey lameness of NZ meat chickens in relation to the status found in 2005 and from these findings to provide recommendations on ways to reduce lameness where these can be made. The main approach, as in 2005, was to assess leg health in NZ meat chickens using GS; to examine the pathology of birds culled for leg problems, to survey farm details, practices and policies; and to measure litter and light levels to examine correlative factors. An additional component of this study, not carried out in 2005, was to examine potential causes of lameness. This was achieved by post mortem of birds of known GS to elucidate the pathologies underlying the different GS.

Methods

FARMS, SHEDS & BIRDS

The protocol and conduct of this study were approved by the Ruakura Animal Ethics Committee (application: 12270), under the NZ Animal Welfare Act (1999). A total of 6409 birds were gait scored and 904 birds of GS 3-5 euthanized for post-mortem.

A sample of farms from Brink's Chicken, Inghams Enterprises (NZ) Pty Ltd and Tegel Foods Ltd in the upper North Island judged to be representative of the industry were identified based on the criteria below. From this group of farms, 20 were chosen at random and within each of these farms a single shed was randomly selected to be included in the study (Table 1). The sampling was carried out between April and August 2011.

The criteria for farm qualification in the study were:

- Ross breed (strain 308)
- Fully housed birds (no free-range)
- Timing of placement (April-July 2011)
- Birds grown to a slaughter LW of 1.6-1.9, 2.0-2.8 or 2.9-3.6 kg

Table 1: The number of birds placed, date of placement and date of farm visit when welfare measures were taken for the three companies.

Company*	Number birds placed	Placement date	Farm visit
1	12756	15/04/2011	19/05/2011
2	53168	18/04/2011	03/06/2011
3	44800	29/04/2011	07/06/2011
1	41500	29/04/2011	01/06/2011
1	26400	02/05/2011	12/06/2011
2	55100	09/05/2011	22/06/2011
1	40700	09/05/2011	08/06/2011
2	29378	13/05/2011	29/06/2011
3	21700	23/05/2011	02/07/2011
1	20500	23/05/2011	04/07/2011
3	30800	27/05/2011	27/06/2011
2	40600	30/05/2011	05/07/2011
1	19420	02/06/2011	01/07/2011
2	59558	10/06/2011	11/07/2011
1	13070	16/06/2011	22/07/2011
2	29500	24/06/2011	25/07/2011
2	30200	28/06/2011	02/08/2011
1	25700	05/07/2011	03/08/2011
1	9500	08/07/2011	17/08/2011
2	33500	11/07/2011	10/08/2011

** Due to confidentiality issues, specific details for the three companies cannot be identified and have been allocated a number for reference purposes.*

MEASUREMENTS

Each shed was visited once during the growing phase, 1-3 days before a thin[2] or a terminal slaughter. The results from these farms visits are presented. All measures used in this study, apart from collection of information on shed light levels and carrying out of post-mortems on GS 3, 4 and 5 birds, were previously used in the 2005 study to allow for direct comparisons.

[2] Thinning is the practice of removal of a portion of the flock for processing at a younger age and lighter weight. It is usually used to maximise space and stocking density utilisation as it allows more birds to be placed and then birds are removed before stocking density limits are exceeded. Thinning also allows a proportion of birds to be produced at a 'lighter' slaughter weight to meet different market requirements.

Live weight categories

The farm visits were selected according to the predicted average LW at the corresponding slaughter. The LW categories used for this study (and comparable to 2005) were 1 (1.6-1.9 kg), 2 (2.0-2.8 kg) and 3 (2.9-3.6 kg). The sampling protocol in Table 2 was used which was balanced for LW categories, companies and numbers of birds placed to reflect the current industry status for these criteria.

Table 2: Number of sheds sampled in the three live weight categories and the number of birds placed.

	LW Category			
Number of birds placed	1.6-1.9 kg	2.0-2.8 kg	2.9-3.6 kg	Total
<20, 000	1	2	1	4
20 – 40, 000	5	2	4	11
> 40, 000	1	2	2	5
Total	7	6	7	20

Farm survey

A survey (similar to 2005) was used to obtain shed details, management and husbandry practices and policies for each shed/farm involved in this study. The survey was completed by the farm manager and/or owner at the completion of the growing phase/final depopulation.

Gait scoring

A minimum of 300 birds were gait scored from each shed using an internationally recognised 6 point (0-5) scoring method (Kestin *et al*., 1992). At a minimum of 10 random locations throughout each shed approximately 30 birds were penned within a 2 x 4 m area (using 0.5 m high, hinged plastic corkboard) and the GS of each bird recorded as they were individually encouraged to walk out of the pen. All birds in the study were assessed by either of two observers, who also took part in the 2005 study, to reduce variation in scoring. Techniques developed at the University of Bristol were used to train, re-calibrate and test the reliability of the observers prior to gait scoring for the study. This involved reviewing the written definitions of each gait score (see below) and viewing standardised video clips of birds of each GS. This procedure was also performed immediately before entering a shed to GS birds during the study. Reliability testing of observers was conducted prior to (n=3) and during the study (n=5). This involved independently scoring multiple video clips of birds of varying GS and scoring birds in a shed. Scores were compared and analysed as described in Statistical Analysis.

The GS was based on the following definitions (Kestin *et al*., 1992):

Gait Score 0 - Normal, dextrous and agile.

"The bird walked normally with no detectable abnormality; it was dextrous and agile. Typically the foot was picked up and put down smoothly and each foot was brought under the bird's centre of gravity as it walked (rather than the bird swaying). Often the toes were partially furled while the foot was in the air. The bird should have been capable of balancing on one leg and walking backwards easily if necessary. It should also have been in full command of where it was going, and been able to deviate its course easily to avoid other birds."

Gait Score 1 - Slight abnormality, but difficult to define.

"The bird had a slight defect which was difficult to define precisely but would have precluded its use for breeding if gait had been the sole selection criteria at the standard of a pedigree breeder. For example, the bird may have taken unduly large strides which, although the observer may not have recognised the exact cause, produced an uneven gait."

Gait Score 2 - Definite and identifiable abnormality.

"The bird had a definite and identifiable defect in its gait but the lesion did not hinder it from moving or competing for resources. For example, it may have been sufficiently lame on one leg to produce a rolling gait which did not seriously compromise its manoeuvrability, acceleration or speed."

Gait Score 3 - Obvious abnormality, affects ability to move.

"The bird had an obvious gait defect which affected its ability to move about. For example, the defect could take the form of a limp, jerky or unsteady strut, or severe splaying of one leg as it moved. The bird often preferred to squat when not coerced to move, and its manoeuvrability, acceleration and speed were affected."

Gait Score 4 - Severe abnormality, only takes a few steps.

"The bird had a severe gait defect. It was still capable of walking, but only when driven or strongly motivated. Otherwise it squatted down at the first available opportunity. Its acceleration, manoeuvrability and speed were all severely affected."

Gait Score 5 - Incapable of walking.

"The bird was incapable of sustained walking on its feet. Although it may have been able to stand, locomotion could only be achieved with the assistance of the wings or by crawling on the shanks."

Litter depth

Litter depth (cm) was recorded at each GS location by inserting a metal ruler vertically into the litter until contact was made with the permanent floor surface below.

Light levels

Light levels (LUX) within each study shed were recorded when the lights were on (according to the farmers "normal" level) using a light meter (DSE Q-1400 Lux Meter, NZ). Recordings were taken at bird height at 10 prescribed locations throughout the shed: two from directly under two different lights (brightest in the shed); one from the centre point of the shed; one in front of an open fan or vent; one in front of a closed fan or vent; two from the two darkest locations in the shed; one from near to the entry door of the shed and two from two other locations judged to be different from the rest. Two operators took the light recordings throughout the study.

Daily mortalities and culls

Daily tallies for birds found dead (unassisted by farmer through active culling), culls for leg problems and culls for other reasons throughout the growing phase for the study shed were recorded by the farmer.

Farmer leg culls

Farmers were asked to collect birds that they had specifically culled for leg problems (according to their normal farm practice and policy) on days 1, 3, 5, 7 in the first week, and thereafter once per week (e.g. day 10 in week 2, day 17 in week 3) throughout the growing phase. Birds were euthanized, labelled with age and date then frozen at -18ºC as soon as possible after death. Frozen birds were defrosted before PM.

Pathological examination

A maximum of twenty GS 3, 4 and 5 birds from each shed (60 birds in total) were identified during the GS procedure, were marked with a colour code relating to GS and held in another catching pen. Birds were euthanized by cervical dislocation prior to gross PM on the same day by a veterinarian. The same veterinarian performed all PM's for this study. Bird paint colour or age in days (for farmer leg culls), weight (kg) and sex were recorded at PM.

Each bird was examined for external signs of trauma, infection or obvious defects. This included examination of the head area, eyes, beak, mouth, vent and ventral and dorsal sides of the body and appendages. The bird was then placed on its back with feet towards the vet carrying out the post mortem. The legs were examined for any joint swelling, difference in length of legs, angular changes, and damage to the foot pads (e.g. foot pad dermatitis) or the toes.

The skin over the abdomen was tented, cut with scissors and pulled back to expose the breast muscle which was examined for decreased muscle mass, paleness (anaemia), or bruising. The abdominal muscles and the ribs on the sides of the keel bone were incised. The keel was grasped near the abdomen and pulled upwards to expose the internal organs and chest cavity.

The liver, air sacs and abdominal organs were examined for abnormal size or discoloration, thickening, white or yellow spots, abscesses, and/or tumours. The gastrointestinal (GI) tract was cut between the oesophagus and proventriculus to allow removal and inspection of the proventriculus, ventriculus (gizzard), pancreas, liver, spleen, small intestine, large intestine and caeca. The GI tract was cut at the level of the cloaca and removed. The kidneys, lungs, heart and internal body cavity were examined. The bird was cut through the throat and down towards the heart to examine for obvious signs of disease or trauma.

The stifle, hip and hock joints were exposed, opened and examined for abnormal material, blood, or excess fluid. The epiphyseal plate areas of the bones were examined for abnormal growth or infections. The legs were examined for abnormal angles, deviations or trauma. Bone strength was assessed by snapping the distal leg bones to get an estimate of calcification of the long bones.

The main pathologies diagnosed on the farms in the study were analysed and included the following categories:

- No diagnosis: no pathology was evident.
- Twisted legs: Including valgus/varus deformities and tendon problems
- Joint infection: including arthritis, viral arthritis, bacterial chondronecrosis, tenosynovitis and osteomyelitis.
- Foot pad dermatitis: lesions on the plantar surface of the feet
- Septicaemia: including colisepticaemia and septicaemia

The pathologies which were not analysed or recorded were those found in only a very small number (1-3 birds) on the farms where they occurred.

STATISTICAL ANALYSIS

All data were analysed using GenStat, 13th edition (2010). The 20 farms for the 2011 study were a random selection of farms taken from a representative range of farms from each company, from the range of number of birds placed and to include a range of predicted LW at slaughter. Since all data met the normality assumptions of the analyses, no transformations of the data were performed. Means are presented ± the corresponding standard error of the mean (sem) unless otherwise stated. For comparisons between means a standard error of the difference between the means (sed) is provided. Means were described as significantly different at P=0.05 or less and actual P values are provided.

Gait score and high gait score cull data

Previous analysis has shown that training of observers to GS is consistent and can be calibrated to international benchmarks (Butterworth *et al.*, 2007). GS reliability data was measured at three dates prior to and five dates during on-farm gait scoring. The GS reliability data were analysed using residual maximum likelihood (REML) (Patterson & Thompson, 1971) with date and scorer within date as random effects. There was some evidence that one scorer scored higher than the other when all eight reliability test data performed during validation exercises were included in the analysis (2.34 vs 2.27, sed=0.034, P=0.091). However the reliability measures taken just before and during the on-farm recording period (May-August) showed no significant difference between the two scorers (2.38 vs 2.31, sed= 0.055, P=0.274), so no adjustment for scorer was made to the on-farm GS measurements.

Only one LW group was selected from each farm for GS measurements. GS and the other data recorded during each farm visit were analysed by one-way ANOVA fitting for each LW group. The average flock GS was calculated by multiplying each GS by the number of birds in this GS category – and then dividing by the total number scored to give an 'average flock gait score'. The average flock GS is a numerical value for comparative purposes and does not reflect the real levels of lameness in the flock. Comparisons between companies were made by a regression analysis fitting both LW group and company. PM data was analysed with binomial regression fitting for LW group only, or LW group and company when comparing companies. PM diagnoses of GS 3, 4 and 5 birds were analysed as a binomial generalised mixed model (GLMM) with farm as a random effect. Only the PM diagnoses present on more than half the farms were analysed. These accounted for about 80% of all diagnoses. All the leg-related problems diagnosed by the veterinarian were also combined as total leg problems and calculated as the total of pad burn, kinky back, twisted leg, tenosynovitis and miscellaneous leg deformity diagnoses. Culling percentage at the time of GS was calculated as the sum of farm leg culls and other culls up to the date of the GS visit as a percentage of the initial number of chicks placed.

Farm mortality data

Farm mortality data was collected over the entire growing phase for each farm. This was analysed by one-way ANOVA, fitting for company. Birds culled for post-mortem at the GS visit were excluded from the calculation of farm mortality data. For two of farms in 2011 the farmer had not separated total farm deaths into other culls and mortality. In 2005 six farmers did not do this and three also did not distinguish leg culls from other culls. The data for these farms were allocated to the different categories based on the average proportions of these categories for the other farms in that year so that the overall mean for all farms was unaffected.

Survey data

Farm survey averages and standard error of the mean (sem) were calculated.

Comparison of 2005 and 2011 data

The 20 farms in 2011 were compared with the 37 farms in the 2005 study. There were differences in the study designs between 2011 and 2005. The main difference was that farms had repeated visits in 2005 compared with a single visit in 2011. This was a more efficient design in 2011 to maximise the number of farms surveyed with available resources. To be representative of the industry, the sampling was balanced across LW categories, numbers of birds placed and companies. In 2011, sampling was carried out between May to August whereas in 2005 it was spread across the year, however there was no seasonal effect on GS found in 2005. Genotype and company were not included in the analyses, as these are confounded with study year, since two companies had changed genotype of bird farmed between the two studies. The comparisons were made for all farms and repeated using farms with Ross (Aviagen) birds only (this included all farms in 2011 but only a subset from 2005; 18/37). For GS data, a REML with year, LW group and their interaction was fitted. There were significant differences between the performance of gait scorers in 2005 so the model included within-year farm and gait scorer as random effects. A binomial regression was carried out for the leg cull diagnosis data. For farm survey data, a regression analysis with year was fitted for continuous variables. For categorical survey data, contingency tables were produced and a chi-square test comparing the distribution in the two surveys was performed. Where there were only two answers to a survey question a Fishers exact 2x2 test was used instead.

Differences between the 2011 and the 2005 study are presented where relevant. Due to a change in the industry strain from 2005 when both Cobb and Ross strains were measured, differences are differentiated as either: Industry = Ross + Cobb (2005) vs Ross (2011) or Ross = Ross (2005) vs Ross (2011).

Results

SHED DETAILS

The available shed area averaged 1571 ± 122.6 m^2 which was larger (P=0.024) than the industry average in 2005 (1219 ± 90.1 m^2). Other shed details and comparisons to 2005 are shown in Table 3.

Table 3: Percentage of farms and sheds with common husbandry procedures and welfare measures in 2011 and 2005.

Measure	2011 (%)	2005 (%)
Smooth concrete floor	84	94
Wood shavings used	100	100
Air extracted	100	100
Automated lighting	100	100
Pans used to feed birds	100	100
Pan lines emptied & cleaned between flocks	100	100
Nipple drinkers	74	93
Behavioural enrichment devices provided	0	0
Bore water used as shed water supply	95	83
Chlorine added to water	90	86
Manual bird weighing system	90	94
Rodent control policy	100	100
Sheds disinfected between flocks	95	100
Disinfectant sprayed on	94	86
Replaced or laundered clothes before new flock	80	86
Replaced or cleaned boots before new flock	95	97
Feed supplied by company mill	100	100
Feed contained antibiotics	100	100
Ad libitum feed up to 7d old	95	100
Flock not vaccinated at hatchery	100	83
Flock not vaccinated at farm	100	94
Flock diagnosed with a disease during study	0	8

PLACEMENT

Placement is the start of the growth phase when the 'day old' chicks are first placed in the sheds. Chicks were placed at an average density of 20.3 ± 0.20 chicks per m^2. The numbers placed in relation to shed size are shown in Figure 1. This was lower (P<0.01) than in 2005 for the industry (21.1 ± 0.14 chicks per m^2) and Ross only (21.6 ± 0.17 chicks per m^2). The average number of chicks placed per shed in 2011(32058 ± 2520) was higher (P=0.043) than in 2005 (25575 ± 1853).

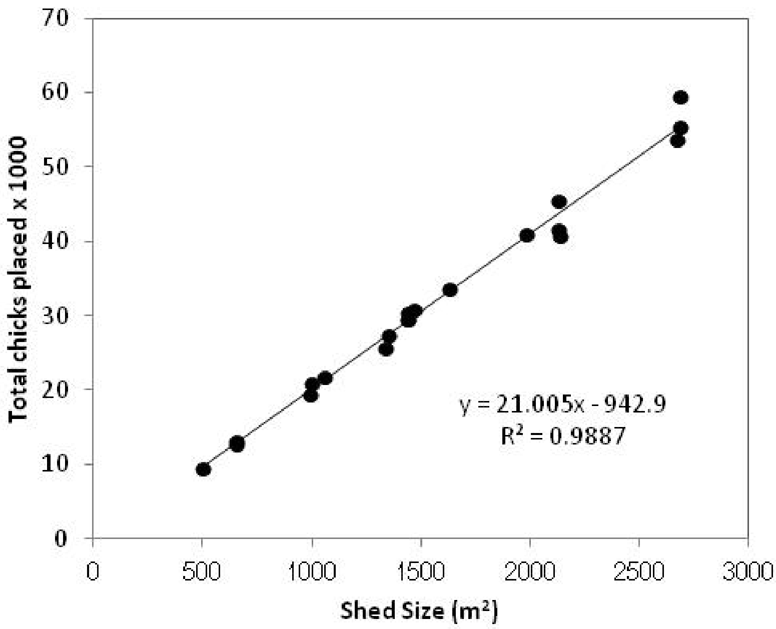
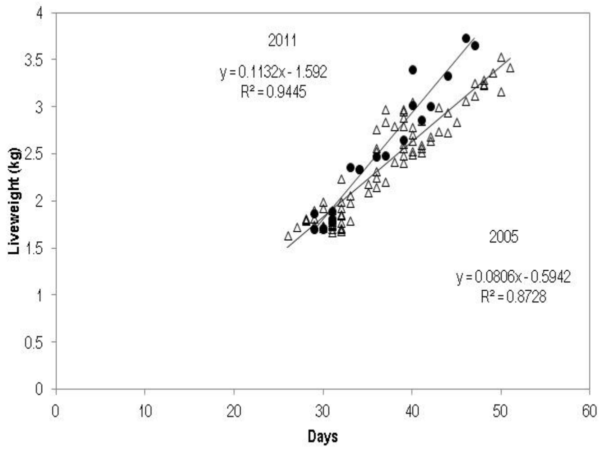


Figure 1: Number of chicks placed in relation to shed size in the 2011 study (●).

GROWING PHASE

Growth rate

Bird growth rate during the GS period (from 26 days to 51 days) was linear and averaged 113 ± 6.5g/day (Figure 2). This was significantly higher than the industry average in 2005 of 81 ± 3.5g/day ($P<0.001$). This difference is mainly due to the influence of the Cobb birds in the 2005 sample, as for Ross only in 2005, the growth rate was 102 ± 8.4g/day ($P=0.805$).



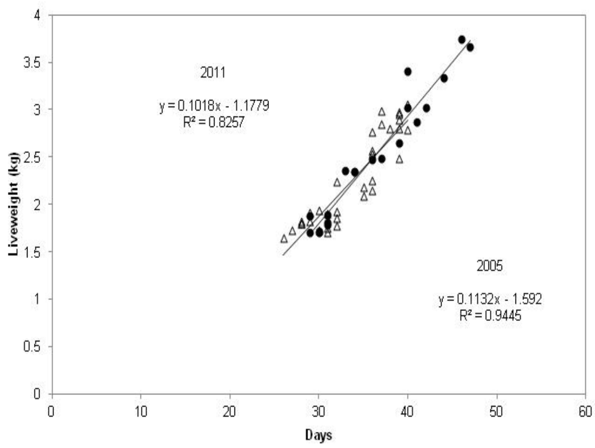


Figure 2: Mean growth rates during **the gait scoring period in 2011 (●) and 2005 (∆). The points** denote the liveweight of a flock at a given age. The left graph shows the industry in 2005 and the right graph Ross only in 2005.

Stocking density

Stocking density during the growing phase is shown in Figure 3. Maximum stocking rates occurred prior to thins, rather than at terminal slaughter. Thin 1 took place at an average age of 32 d and a LW of 1.78 ± 0.02 kg, thin 2 at 37 d and an average of 2.47 ± 0.03 kg and the terminal slaughter at 43 d and 3.19 ± 0.06 kg. The maximum mean density occurred at thin 1 of 35.3 ± 0.55 kg/m^2 with maximum and minimum values of 39.5 and 31.7 kg/m^2 respectively. At thin 2 the mean was 32.1 ± 1.55 kg/m^2 with maximum and minimum values of 39.7 and 17.7 kg/m^2 respectively. The maximum density recorded was 41.6 kg/m^2 at week 5. At thin 1 there were 19.8 ± 0.21 birds/m^2 and maximum and minimum values recorded of 18.2 and 21.8 birds/ m^2. By comparison, at final slaughter there was an average of 8.0 ± 0.52 birds/m^2.

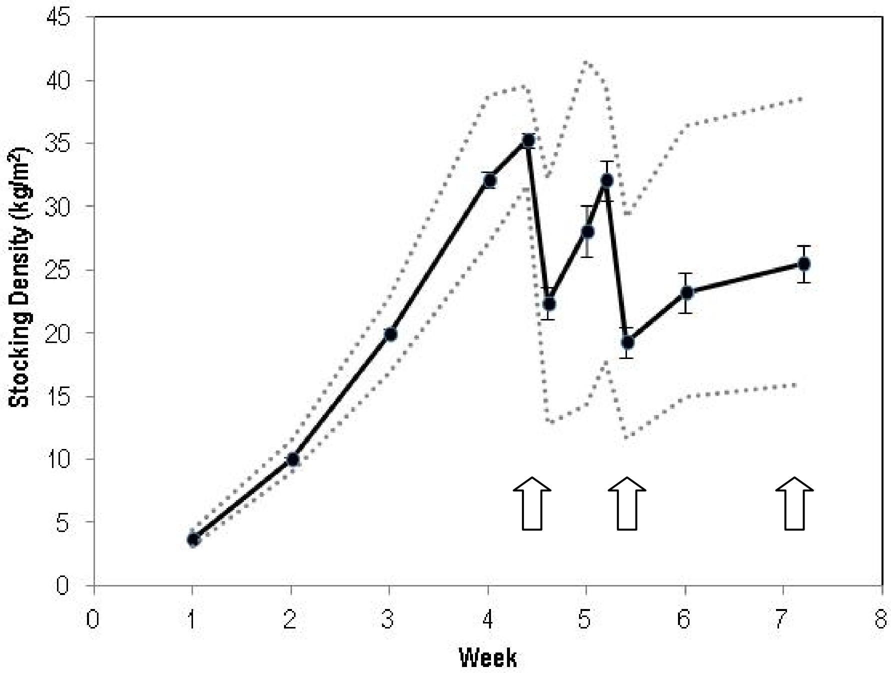


Figure 3: Mean stocking density of flocks during the growing phase in 2011. The dashed lines show the minimum and maximum values recorded. The arrows denote the times of thin 1, thin 2 and terminal slaughter from left to right, respectively. The bars denote the standard error of the mean.

Age and weight at final slaughter

The average final slaughter age at 43.8 ± 0.92 days was not significantly different from 2005 (43.7 ± 0.70, P=0.936). Due to the faster growth in 2011 described above, final slaughter weight was significantly heavier in 2011 than 2005 (3.19 ± 0.077 kg vs 2.85 ± 0.058 kg, P<0.001). Ross birds in 2005 were slaughtered at an earlier age and weight than in 2011 (39.5 ± 0.54 days and 2.64 ± 0.075 kg, P<0.001).

MORTALITY AND CULLS

Total mortality rate was 2.65 ± 0.215% of birds placed and of these 65 ± 2.86% were birds found dead, 9.2 ± 1.52% were culled for leg problems and 25.9 ± 2.41% were culled for other problems. These percentages were not significantly different from 2005 (2.79 ± 0.154%, 60.3 ± 2.32%, 12.8 ± 1.09% and 26.9 ± 1.73% for total mortality, dead birds, leg culls and other culls respectively). This equates to a total culling rate of 0.96 ± 0.121% and 0.24 ± 0.024% for leg culls. There were differences in the rates of mortality (2.31, 1.91, 3.38, sed = 0.38, P<0.01) and leg culling (0.23, 0.16, 0.32%, sed = 0.069 P<0.05) between companies. The weekly culling rate and percentage of culls for leg problems calculated on the basis of the number of chicks placed in the shed is shown in Table 4. There was a decrease in culling rate in weeks 3 and 4 and an increase in culls due to leg problems in weeks 5 and 6.

Table 4: Percentage of birds culled by the farmer in weeks 1-6 and the percentage of these recorded by the farmer as culled for leg problems on a weekly basis based on the number of birds present in the shed each week.

Week	Total culls (%)	Leg culls (% of Total)
1	0.254 ± 0.0338	17.7 ± 2.43
2	0.200 ± 0.0396	23.5 ± 2.59
3	0.101 ± 0.0104	22.6 ± 3.11
4	0.073 ± 0.0067	25.0 ± 2.80
5	0.257 ± 0.1036	38.2 ± 4.95
6	0.270 ± 0.0531	46.6 ± 4.83

LIGHT LEVELS

The average light level was 39.3 ± 6.02 lux and was not significantly different between companies. There was a significant difference between companies in the light levels in the darkest areas of the sheds (P=0.015) with average lux values for the three companies of 2.5, 7.6 and 13.7 (sed = 3.42). The light level in these areas averaged 6.5 ± 1.38 lux. Light level was not correlated with GS.

LITTER DEPTH

Litter depth averaged 4.21 ± 0.156 cm. There was an increase in litter depth (P=0.014) during the growing phase from LW 1 to LW 3 (3.76 to 4.76 cm, sed = 0.320). There was no difference between companies. There was a significant correlation between average litter depth and GS (0.534, P=0.018).

GAIT SCORE

The average flock GS was 2.24 ± 0.067.This is not significantly different from the industry in 2005 (2.18 ± 0.041) or for Ross only in 2005 (2.13± 0.060). There were no significant company differences in any of the GS categories.

GS increased (P<0.001) with age (Figure 4) and LW (Figure 5). For every day of age, GS increased by 0.0453 and for every kg heavier, GS increased by 0.3991. GS differed between the LW groups (Table 5). The average GS increased (P<0.001) with LW group.

There were no significant differences in the GS of birds within the individual LW categories on an industry basis between 2011 and 2005. For Ross birds however, there were differences between studies for the heavier and older birds (LW 3). The average GS for LW 3 was higher (P=0.031) in 2011 (2.60 ± 0.053%) than 2005 (2.15 ± 0.062%). There were lower percentages of GS 2 birds in 2011 (42.3 vs 84.1%, P=0.023) and higher percentages GS 3 birds in 2011 (51.8 vs 14.7%, P=0.019). These differences are reflected in the increased percentage of lame (GS 3-5) Ross birds in LW 3 in 2011 compared with 2005.

The percentage of birds with GS 3-5 was 30.3 ± 6.77% compared to 22.9 ± 3.30% in 2005 which was not significantly different. There was a tendency for a higher percentage of GS 3-5 birds in LW 3 category in 2011 than 2005 (55.9 vs 36.7%, P=0.064). For the LW 3 category, birds were not significantly different in weight and age between 2011 (3.29 kg and 42.8 days) and 2005 (3.16 kg and 45.6 days). For Ross birds, the percentage in GS 3-5 was higher (P=0.025) in 2011 (56.4 ± 4.69%) than 2005 (15.2 ± 5.71%). However the birds in this LW 3 category tended to be heavier and were significantly older (P=0.007) in 2011 (3.29 ± 0.105 kg and 42.9 ± 0.92 days) than Ross birds in 2005 (2.99 ± 0.138 kg and 38.8 ± 1.22 days).

The percentage of birds with GS 4-5 was 1.74 ± 0.697% compared to 1.34 ± 0.310% in 2005, which was not significantly different. There was a significant difference in the percentage of birds with GS 4-5 between LW categories (0.12, 0.77 and 4.18%; sed =1.471; P=0.024) for LW 1, 2 and 3 respectively. For Ross birds, there were no significant differences from 2005 in the percentage of GS 4-5 birds at each of the LW categories. However for LW 3 birds at GS 4-5 the difference between years in the percentage of birds tended to be the strongest (2011 = 4.18 ± 1.354% vs 2005 = 0.49 ± 1.792%, P=0.134).

In addition to age and LW, GS was correlated with litter depth (0.534) but no other factors had correlations over 0.5. There was a poor correlation between GS and stocking density (R^2 = 0.2099) and a negative relationship with a decrease of 0.021 GS for every kg increase stocking density

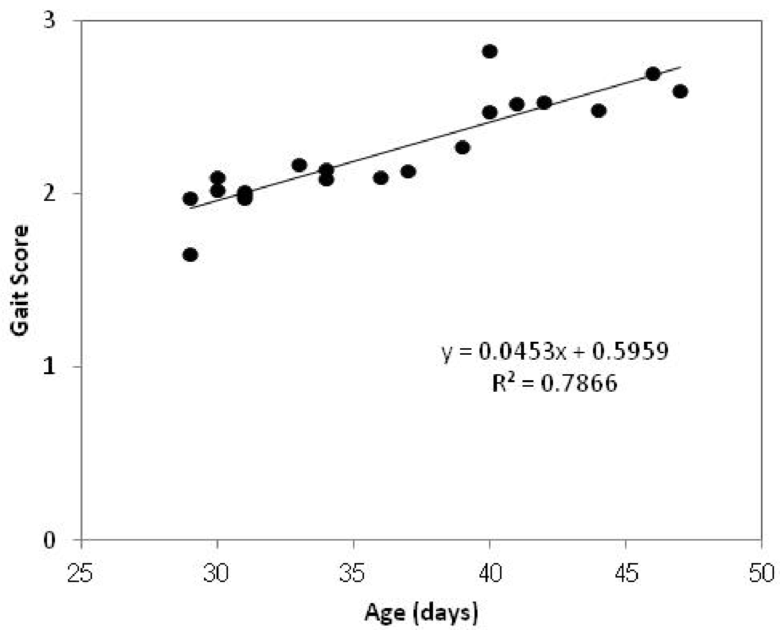


Figure 4: Mean gait score in relation to age for 2011.

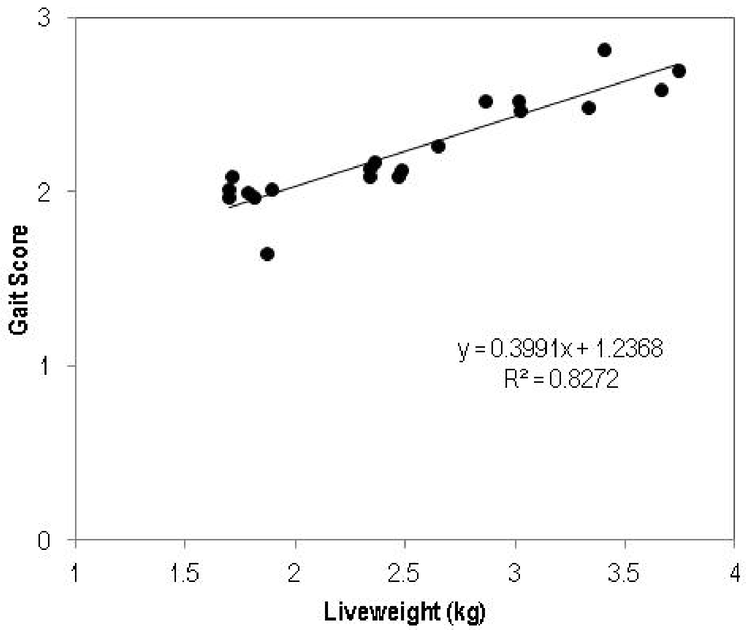


Figure 5: Mean gait score in relation to liveweight for 2011.

Table 5: Percentage of birds in each gait score by liveweight category. Included is the percentage of birds with gait score 3 and above and birds with gait score 4 and 5. The mean gait score for each live weight group is shown at the bottom of the table. The significance level is for the difference between liveweight groups. The mean percentage of birds at each gait score is shown on the right.

Gait score	LW 1 (1.6-1.9 kg)	LW 2 (2.0-2.8 kg)	LW 3 (2.9-3.6 kg)	SED	P-value	Overall Mean
0	0.17	0.0	0.0	0.110	0.227	0.06 ± 0.040
1	17.20	5.80	1.40	3.530	<0.001	8.25 ± 2.055
2	69.20	74.4	42.70	5.890	<0.001	61.49 ± 3.906
3	13.30	19.00	51.70	52.220	<0.001	28.45 ± 4.423
4	0.12	0.57	3.90	1.414	0.026	1.58 ± 0.666
5	0.00	0.20	0.28	0.122	0.075	0.16 ± 0.054
3-5	13.4	19.80	55.90	5.020	<0.001	30.20 ± 4.767
4-5	0.12	0.77	4.18	1.471	0.024	1.74 ± 0.697
Mean GS	1.96	2.15	2.59	0.067	<0.001	

PATHOLOGIES

Birds of a known GS

The post mortem diagnoses for birds with known GS is shown in Table 6. There were no significant differences in diagnoses between companies. TD was never diagnosed. The most common joint infected was the hock joint and the infection was often seen in only one joint. Bilateral infection was very uncommon. Kinky back was seen in 1% of birds and femoral head necrosis (FHN) was only seen on 8 occasions.

Joint infections and twisted legs increased with each GS ($P<0.05$). Conversely, ‘no diagnosis’ decreased with each GS ($P<0.05$). FPD occurred more in GS 3 and 4 than GS 5 ($P<0.001$).

Total leg problems (FPD, twisted leg, kinky back, tenosynovitis and leg deformities) were higher for GS 4 than GS 3 (P=0.016) and septicaemia was higher in GS 5 than GS 3 and 4 (P<0.05).

Birds culled for leg problems by the farmer

The post mortem diagnoses for birds that were culled for leg problems by the farmer are shown in Table 7. Total leg problems averaged 49.0 ± 6.11% and most of these were twisted legs 37.7 ± 6.00%. Septicaemia was found in 13.3 ± 3.33% of birds, while in 22.6 ± 4.77% no diagnosis could be found. Very few birds were diagnosed with joint infections (6.0 ± 2.2%), and these were found mainly on one particular farm, and Foot Pad Dermatitis (FPD) was also a rare cause of lameness (4.2%. ± 1.6 %). No cases of soft bones or rickets were found.

In comparison to 2005, the number of birds with no diagnosis and total leg problems were not significantly different and the level of septicaemia (P<0.001) and twisted legs were higher (P=0.047). Restricting the comparison to Ross birds in 2005, the percentage of birds with no diagnosis in the 2011 study was lower than the 2005 study (P=0.007) while septicaemia (P=0.044), twisted legs (P=0.048) and total leg problems (P=0.004) were higher in the present study.

A comparison of birds culled by the farmer, with those sampled with GS 4 and 5 during weeks 5-7 (which was when GS birds were sampled), revealed similar pathologies (Table 8).

Table 6: Percentage of birds with either no diagnosis, or diagnosed with joint infection, pad burn, septicaemia or twisted leg and the percentage of total leg problems.

Gait score	No Diagnosis	Joint Infection	Pad Burn	Septicaemia	Twisted leg	Total leg
3	64.8 ± 9.67	1.7 ± 1.27	23.6 ± 8.98	1.0 ± 0.95	1.5 ± 1.00	27.1 ± 9.59
4	35.4 ± 10.03	7.4 ± 2.54	23.2 ± 10.40	5.8 ± 2.83	12.2 ± 4.78	41.8 ± 11.87
5	5.9 ± 3.12	27.3 ± 8.18	3.2 ± 2.23	12.3 ± 4.31	27.3 ± 9.68	34.2 ± 9.47
LSD (5%)	12.57	4.58	6.10	4.85	6.33	12.85
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.05

Table 7: Percentage of birds culled by the farmer for leg problems with no diagnosis, joint infection, pad burn, septicaemia or twisted leg at post-mortem and the percentage of total leg problems.

Study	No Diagnosis	Joint Infection	Pad Burn	Septicaemia	Twisted leg	Total leg
2011	22.6 ± 4.77	6.0 ± 2.2	4.2%. ± 1.6	13.3 ± 3.33	37.7 ± 6.00	49.0 ± 6.11
2005 (Industry)	28.17 ± 3.97	n/a	n/a	3.3 ± 1.07***	24.1 ± 3.97*	35.2 ± 4.52
2005 (Ross)	43.8 ± 5.69**	n/a	n/a	5.5 ± 2.15*	22.1 ± 5.03*	24.4 ± 5.28**

(P values for comparison with 2011 are denoted by *=P<0.05, **=P<0.01 and *** = P<0.001).

Table 8: Percentage of birds culled for leg problems by the farmer in weeks 5-7 and birds euthanized due to lameness (GS 4 and 5) with no diagnosis, joint infection, pad burn, septicaemia or twisted leg at post-mortem and the percentage of total leg problems.

Study	No Diagnosis	Joint Infection	Pad Burn	Septicaemia	Twisted leg	Total leg
Farmer culls	21.6 ± 8.0	20.3 ± 15.4	16.2 ± 10.1	9.5 ± 7.2	25.7 ± 9.2	41.9 ± 11.0
GS 4 and 5	24.3 ± 4.2	14.9 ± 3.2	15.7 ± 4.8	8.2 ± 1.3	17.9 ± 2.8	39.0 ± 4.8

Discussion

There were changes in the NZ meat chicken industry between 2005 and 2011 which made direct comparisons between these years difficult in some areas. The biggest change was in bird genotype from Ross and Cobb in 2005 to Ross only in 2011. This has had some effects on the growing phase, with Ross birds tending to grow faster and being slaughtered later at a heavier weight in 2011 than in 2005. A higher GS for Cobb genotype than Ross genotype in commercial Swedish broilers (Sanotra *et al.*, 2003) suggests that a shift to Ross could have a positive effect on lameness. Other minor changes in the industry included increases in the size of the sheds and flocks and a decrease in stocking rate at initial placement.

The average GS for the industry was not significantly different from the 2005 study indicating that there is no change in the average degree of lameness. However, there was evidence that lameness is more prevalent for heavier and older birds (LW 3) in 2011 than 2005, and the industry is moving progressively to heavier bird production. This was significant for Ross birds, but the same trend was apparent for the industry as a whole. For Ross birds, there was a higher average GS for LW 3 birds and a greater percentage of these birds in the GS 3, and GS 3-5 category in 2011 than 2005. This difference in lameness could not be fully explained by the heavier weight of the Ross birds in 2011 than 2005.

In the UK meat chicken industry, 27.6% of birds had a GS of 3 and above (Knowles *et al.*, 2008). In that study it was concluded that the main risk factors for lameness and leg health were related to rapid growth. The increase in growth rate from 2005 to 2011 in the NZ industry may therefore be contributing to a detrimental effect on GS. In the present study, 30.2 ± 4.77% of birds evaluated had a GS of 3 or above which is a similar figure to that found by Knowles *et al.*, (2008) and Kestin *et al.*, (1992) of 26 - 28%. A marked effect of LW on GS was found in the present study, with the proportion of birds with GS 3-5 increasing from 13.40% at LW 1 to 55.90% at LW 3. Due to the large number of GS 3 birds in this group, the percentage of lame birds with a GS 4 and above was much lower with 1.74 ± 0.697% of birds overall and a maximum of 4.2 ± 1.04% at LW 3. These levels are similar to those for the UK of 3.3% for GS 4 and above (Knowles *et al.*, 2008). For Ross birds at LW3, the percentage of GS 4 and 5 birds (4.2%) tended to be higher than in 2005 (0.5%).

In the study of Knowles *et al.*, (2008) the age at which the birds were assessed was important in determining GS, with every extra day, across the range of 28 to 56 days, leading to an average daily deterioration (daily increase) in GS of 0.048. This is similar to the effect of age on GS found in the current study of 0.045 GS per day. A small seasonal change was found in GS by Knowles *et al.*, (2008), with lowest (best values) in winter and worst (highest values) in late summer. Based on this, our sampling during winter to early spring could be expected to give a better estimate of GS if indeed there was a seasonal effect in New Zealand, though no seasonal effect found in the 2005 study, suggesting there may not be.

Large differences in GS were reported between the five UK companies examined by Knowles *et al.*, (2008) and also between ten UK companies in a study by Dawkins *et al.*, (2004). This is different from the current study, which found no differences between the three companies in any significant GS characteristics. This perhaps indicates that the NZ companies that took part in the study are more uniform than in the UK. Knowles *et al.*, (2008) also reported bird genotype had an influence on GS. This comparison was not possible in the current study as the same Ross genotype is used exclusively throughout the NZ industry.

There is debate over the implications of different GS in terms of welfare and specifically whether birds with a significantly altered walking ability at GS 3 and above are in pain or physically unstable (Gregory & Grandin, 2007). A GS of 3 and above has been proposed as a cut-off point for lame birds (Knowles *et al.*, 2008) based on evidence of self selection of analgesics by these birds indicating they are in pain (Danbury *et al.*, 2000), alterations in behaviour in GS 3 birds (Weeks *et al.*, 2000) and the ability of analgesic administration to improve the walking ability (speed) of GS 3 birds (McGeown *et al.*, 1999). Increasing GS is associated with walking asymmetry and uneven slower walking (Naas *et al.*, 2010). In this same study there was also evidence that pain might be contributing to the lameness in birds with a GS of 3 and above as GS was improved by administration of analgesics (Naas *et al.*, 2009). Furthermore it was suggested that if standing and moving causes pain in these birds they would be less likely to perform activities such as eating and drinking and thus their welfare would be compromised (Naas *et al.*, 2009). Not all reductions in walking ability are necessarily due to pain however as heavier birds walked less and were less motivated to walk for food (Bokkers *et al.*, 2007). Morphological changes associated with rapid growth and bodyweight, including a shift in the centre of gravity due to increased breast muscle and relatively short legs, alter the gait of the birds and are proposed as an explanation for reduced activity (Corr *et al.*, 2003). It is pointed out by Bradshaw *et al.*, (2002) that even if walking ability is impaired without associated pain, it would still represent a welfare compromise due to the reduced ability to exhibit behaviours and access food and water. The aforementioned authors conclude that welfare is likely to be compromised at GS >3 (i.e. GS 4 and 5).

In addition to the major effects of age and LW, husbandry factors such as stocking density and lighting schedules may also play a role in the incidence of lameness (Butterworth & Weeks, 2010). In the present study there was a poor correlation between GS and stocking density. In a recent modelling study, a maximum density of 39.4kg/m^2 was recommended based on a reduction in certain behaviours above this, although this study did not examine movement (Bokkers *et al.*, 2011). The effects of stocking density on different welfare indicators is complex, with different factors affected at different densities (Buijs *et al.*, 2009). GS increased with stocking density in one study comparing 12, 16 and 23 birds/m^2 (Kestin *et al.*, 1994). Knowles *et al.*, (2008) also found an effect of stocking density: for every 1 kg/m^2 increase in stocking density as measured at the time of the flock assessment, across a range from 15.9 to 44.8 kg/m^2, there was a 0.013 deterioration in flock GS. In a study by Dawkins *et al.*, (2004), high stocking densities (>42 kg/m^2) increased lameness and jostling between birds although house environmental factors had a larger effect on overall bird welfare.

The highest mean stocking density in the present study occurred at around 32 days of production, just prior to the first thin, of 35.3 ± 0.55 kg/m^2 and the maximum density recorded was 41.6 kg/m^2 at week 5. The minimum standard density of 38 kg/m^2 in the NZ Code of Welfare (2003) was exceeded on 9/20 farms, 4 at the first thin, 3 at the second thin and 2 at final slaughter. While stocking density *per se* may not be the most important factor affecting bird welfare, it interacts with a number of other environmental factors such as litter quality, opportunity to perform natural behaviours and health and can negatively impact welfare at high levels (Dawkins *et al.*, 2004; Robins & Phillips, 2011).

In terms of bird numbers, there were an average of 19.8, 1.8 kg birds/m^2 at the time of this first thin. This was more than double the number of 8.0, 3.2 kg birds/m^2 at final slaughter. In a recent study, Bokkers *et al.*, (2011) noted that expressing stocking density only in terms of kg/m^2 disregards the behavioural requirements of the individual and can lead to high numbers of birds/m^2 when they are young. The inclusion of an additional production guideline of numbers of birds/m^2 would ensure adequate space while the birds are smaller. Based on measures of behavioural restriction Bokkers *et al.*, (2011) recommended a maximum of 16 birds/m^2. Given evidence that high stocking densities restrict bird activity even at what would be considered low commercial levels (Estevez, 2007) and the positive effect that activity has on leg health, it is likely that the high numbers of birds found at the first thin may be having a detrimental effect on the leg health of birds that remain.

Analysis of the activity levels of different GS birds showed that GS 3 birds had the highest activity (possibly due to feed requirements) and GS 4 and 5 birds the lowest activity (Aydin *et al.*, 2010). Activity also appears to be an important factor in increasing bone strength in fast growing meat chickens (Stojcic & Bessei, 2009). The direct effects of exercise are reported to be a reduction in bone length and cross-sectional area without impacting bone strength and the production of minor changes in tendon geometry (Foutz *et al.*, 2007b; Foutz *et al.*, 2007a). A recent study has shown that scattering feed pellets in the litter was an effective way to increase activity in meat chickens although there was a negative impact on growth rate (Jordan *et al.*, 2011). Another approach has shown that spacing feeders and drinkers at 12m apart in comparison to 2 m apart decreased leg weakness (Reiter & Bessei, 2009).

Other husbandry factors such as temperature, humidity, litter and air quality may have more influence on welfare than stocking density within the current levels used commercially (Dawkins *et al.*, 2004). Litter depth was positively correlated with GS in the present study but this is probably due to the fact that litter depth increased with age, rather than being directly causal to lameness in any way. This should not be interpreted as thinner litter will improve GS in any way. Other aspects of litter quality, such as moisture and lumpiness are more important in terms of causing FPD or hock burn but there are no generally accepted guidelines on assessment of litter quality (Spindler & Hartung, 2009). Lighting schedules can potentially influence lameness via a positive effect on activity (Blatchford *et al.*, 2009), although no influence of lighting on GS was found in the present study. The precise mechanisms for this effect are not yet clear (Bradshaw *et al.*, 2002). The average light level recorded in the present study at 39.3 ± 6.02 lux were well above the minimum standard in the NZ Code of Welfare (2003) of 10 lux. There was variability within the sheds however with darker areas falling below this level.

As GS increased there was an increase in leg problems, specifically twisted legs, joint infections, septicaemia and a decrease in FPD. This indicates that leg problems underlie increasing GS. For GS 3 birds, FPD was the most common problem at 23.6% although 65% of the GS3 birds had no diagnosed problem. The high number of GS 3 birds with no observed underlying pathology suggests that the decreased walking ability in these birds were due to factors such as weight distribution, or that the pathology was not revealed by the methodology used. Rates of 40 to 50% FPD were found in Danish and Swedish flocks (Sanotra *et al.*, 2003). A recent study has confirmed litter quality as a causative factor, susceptibility is higher at a younger age and that the severity can decrease with improvements in litter quality (Cengiz *et al.*, 2011). Some FPD is likely to be painful and results in reduced activity in affected birds (Bradshaw *et al.*, 2002). As this problem can resolve, culling for FPD alone may not be the best option, as outcomes can therefore be potentially improved by management factors. There needs to be caution on this point however as mentioned above, decreased mobility, irrespective of the underlying cause can compromise welfare. FPD rates were similar for GS 4 and GS 3 birds but total leg problems were higher in GS 4 birds, primarily due to increases in twisted legs and joint infections. For GS 5 birds, FPD had decreased, perhaps due to less time these birds spend on their feet, but infectious causes of lameness were higher. Bacterial chondronecrosis was judged to have the highest welfare impact by Bradshaw *et al.*, (2002) due to the severe pain and inability of birds to reach food and water combined with the fact that it is so common. The best outcome for GS 4 and 5 birds is proposed to be culling as there is no practicable treatment for individual birds. The speed with which these birds are recognized and culled would have an important influence on their overall welfare.

The main reasons for non-infectious leg disorders are considered to be skeletal affects resulting from genetic selection, (associated with growth rate, conformation, food conversion efficiency and deformities) and management factors (associated with nutrition, lighting, stocking density and activity) (Julian, 2004). Many non-infectious leg problems have a genetic basis and in a recent study (Akbas *et al.*, 2009), estimated heritabilities of leg problems were 0.21, 0.72, 0.17 and 0.34 for TD, valgus-varus deformity, hock burns and FPD, respectively. This indicates that genetic selection could be an effective way of reducing these problems (Akbas *et al.*, 2009). Slowing growth rate is considered to be a successful way to reduce developmental leg disorders although without genetic change this would need to be achieved by feed restriction which could be a welfare issue in its own right (Bradshaw *et al.*, 2002).

TD and twisted legs are a common cause of lameness and TD is reported to cause 5 to 25% of lameness (Julian, 2005), however the lameness and skeletal impact on the birds of TD has been reduced due to genetic selection (Gregory & Grandin, 2007). TD lesions can be difficult to diagnose by standard post-mortem and may require sectioning of the joint. TD was not seen in the current study. Twisted legs or valgus/varus angulation is characterized by deformation of the tibial bones and defects in the associated joints leading to tendon displacement and rotation of these joints (Cruickshank & Sim, 1986). Twisted legs are considered to be one of the most common causes of lameness (Julian, 2005). Affected birds are bowlegged, knock-kneed or unable to walk (Julian, 2004). A number of studies have concluded that this problem is heritable (Akbas *et al.*, 2009; Le Bihan-Duval *et al.*, 1996). Twisted legs reduce the mobility of birds affected and therefore reduce their ability to access feed and water. While the degree of deformity may not correlate with the degree of pain, it is considered to be a painful condition if there is tension on the joint or if the bird is walking on its hocks (Julian, 2004). Incidences of twisted legs of around 30 to 40% are reported in a number of studies internationally (Leterrier & Nys, 1992; Shim *et al.*, 2012; Sanotra *et al.*, 2003) which is similar to the percentages found in birds culled by the farmer and in GS 5 birds in the current study. In an Irish study, 13.6% twisted legs were found in lame birds defined as GS > 3 (McNamee *et al.*, 1998), this being similar to the incidence in GS 4 birds in the current study.

Spondylolisthesis or kinky back is a dislocation of the vertebra resulting in pinching of the spinal cord, leg weakness and paralysis (Julian, 2004). It is associated with rapid growth and genotype and while impacts on welfare are severe because of the resultant pain and immobility (Julian, 2004), it is less common than other pathologies affecting around 0.3% of birds (Butterworth, 2004). In the current study it was also very uncommon with an incidence of 1%.

Mortality rate in 2011 at 2.65% was lower than the 2005 study at 2.8% and lower than UK figures at 4.1% (Dawkins *et al.*, 2004). Natural deaths (i.e. birds found dead in the shed) were 1.7%, similar to the UK figures of 2% (Dawkins *et al.*, 2004). Culling rates in the present study were 0.96 ± 0.121% overall and 0.24 ± 0.024% for leg culls. These are lower rates than those reported for the UK of 2.1% total culling rate and 0.6% leg culls. The culling rate for leg culls is much lower (7x) than the percentage of GS 4 and 5 birds of 1.74 ± 0.697% which suggests that culling practices are not resulting in effective euthanasia and removal of these birds from the flock. The companies did differ to a small extent in the percentage of leg culls, and this may have reflected different policies on this issue between companies. The trend in the industry toward larger sheds and flocks may add to the difficulty of finding birds that require culling as soon as possible in order to minimize suffering. In the present study 65% of deaths were birds found dead in the shed. In terms of welfare outcomes it may be generally desirable as a goal to increase culling and decrease the number of natural deaths as an indicator that effective flock monitoring is occurring.

Summary and recommendations

Leg disorders are a common problem in meat chickens resulting in lameness and reduced welfare for the individuals affected. A GS method was used to assess the leg health of birds in the NZ meat chicken industry and to allow comparison with results from a similar study carried out in 2005. Pathological examinations were carried out on birds with GS 3, 4 and 5, as well as on a sample of birds culled by the farmer for leg problems, to examine the causes of lameness. Information of production factors was collected to examine correlations and risk factors for lameness, and to aid interpretation.

The average flock GS for the industry, percentages of birds at each GS and the average flock GS for each of three different LW categories was not significantly different to that found in 2005. There was an increased degree of lameness in heavier, older Ross birds, which were a subset of the 2005 study. Changes within the industry including breed, faster growth and heavier final slaughter weight may potentially underlie this change.

The highest densities in terms of kg/m^2 and particularly birds/m^2 were found at the first thin Based on the literature, the density of birds found at that time is likely to reduce activity and contribute to an increased prevalence of leg weakness.
It is recommended that the influence of thinning and stocking density, in terms of both the number of birds per m^2 and kg of birds per m^2, on behavioural activity and on subsequent leg health be studied.

The most common factors influencing the degree of lameness in the present study were LW and age. The literature is clear that growth rate is also a major factor contributing to lameness. Reducing growth rate and slaughter LW would therefore have a direct impact on lameness, although slowing the growth rate of present genotypes of birds by diet restriction may have negative welfare consequences as they have a high propensity to feed. The genetic-related leg problems identified in this study are not unique to the NZ industry and may need to be addressed at an international level.
It is recommended that the impact of changes in industry production methods such as breed, growth rate and slaughter weight on leg health should be monitored closely to help ensure that they do not result in significant worsening in lameness levels.

FPD is the most common problem associated with lameness due to its prevalence in GS 3 birds in particular and the high numbers of birds in this GS category. Twisted legs, septicaemia and joint problems were the most common diagnoses in severely lame birds (GS 4 and 5). The literature indicates that all of these leg problems are likely to negatively impact welfare due to associated pain and/or reduced mobility. FPD can resolve and has potential to be improved by management factors, and so culling may therefore not be the best option for these birds. Conversely swift culling is the best option for GS 4 and 5 birds as there are no practical treatment options for individual severely lame birds. Additionally, as some of these birds will be suffering septicaemia, it is likely to be protective of other birds in the flock to remove sick (high GS) birds to help protect other healthy birds from disease challenge. Given that GS 3 birds have an obvious walking problem and that no pathological reason for this could be found in 65% of birds, the decreased walking ability could be due to the existing skeletal and muscular conformation itself or that the reasons were not detected by the post-mortem methodology used. Decreased walking ability, irrespective of the underlying cause has the potential to compromise welfare. Due to the high numbers of GS 3 birds it is important to better understand the welfare consequences at GS 3.

It is recommended that a more detailed study be carried out on the impact of reduced walking ability of GS 3 birds (e.g. access to food and water, and the direct effects on bird behaviours of reduced mobility), the welfare outcomes for these birds (e.g. the degree that birds with GS 3 progress to GS 4) and a more detailed examination of the underlying pathologies of GS 3 birds.

Given existing industry genetics, culling is likely to be the best way to improve welfare by removing lame birds as LW increases. To be effective in this regard, culling regimes must be able to detect and euthanize birds as soon as they reach a threshold when suffering occurs and welfare is compromised. The threshold should be based upon evidence that the bird is in pain, immobile, unable or severely compromised in its ability to feed or drink, ill, moribund, and/or unlikely to recover. As GS increases with age (and LW) it could be predicted the number of birds eligible for culling and thereby culling rate would also increase with age. In the present study, culling rate did not appear to increase with age and the rate was also lower than that of the UK. Reasons for a low culling rate could be difficulty in detecting birds that require culling or thresholds for culling which are set too high. In relation to the culling threshold, industry guidelines appear to adequately describe birds requiring culling (e.g. inability to walk 1 m) and supporting this, the pathologies for farmer leg culls were similar to those birds selected as GS 4 and 5. However culling rate was still much lower than the percentage of GS 4 and 5 birds found in the present study indicating that culling is not adequately removing these birds. The problem therefore may lie in the difficulty of finding birds that require culling during shed walking routines. It is proposed that efforts should be made to improve this aspect of husbandry. Contributing to this problem could be the increase in the size of the sheds and flocks which may make detection of individual birds more difficult.
It is recommended that attention should be shown to ways to improve and monitor the effectiveness of culling GS 4 and GS 5 birds. New methods to judge the effectiveness of culling should be developed and evaluated such as the length of time that birds that have exceeded the culling threshold remain in a shed before being detected.

The effectiveness of industry protocols at improving welfare at an individual level is an important dimension of a welfare assessment of the industry and GS provides a way to achieve this. Despite the size of the industry, there should be a focus on improving outcomes on an individual bird level. Furthermore, this emphasis should be maintained and the ability to improve welfare outcomes at this level should not diminish as flock sizes get larger and the difficulty of inspecting individual birds increases.

References

GenStat for Windows. (2010). Hemel Hempstead, UK: VSN International Ltd.

Akbas, Y., Yalcin, S., Oezkan, S., Kirkpinar, F., Takma, C., Gevrekci, Y., Gueler, H.C. & Tuerkmut, L. (2009) Heritability estimates of tibial dyschondroplasia, valgus-varus, foot-pad dermatitis and hock burn in broiler. Archiv fuer Gefluegelkunde 73(1), 1-6.

Animal Welfare Act (1999). Wellington: http://www.legislation.govt.nz/act/public/1999/0142/latest/DLM49664.html?search=ts_act_Animal+Welfare+Act+1999_resel&sr=1.

Animal Welfare (Broiler Chickens: Fully Housed) Code of Welfare (2003). http://www.biosecurity.govt.nz/files/regs/animal-welfare/req/codes/broiler-chickens/broiler-chickens.pdf.

Appleby, M.C., Mench, J.A. & Hughes, B.O. (2004) Poultry behaviour and welfare. Poultry behaviour and welfare. 2004. x + 276 pp. many ref. CABI Publishing.

Ask, B. (2010) Genetic variation of contact dermatitis in broilers. Poultry Science 89(5), 866-875.

Aydin, A., Cangar, O., Ozcan, S.E., Bahr, C. & Berckmans, D. (2010) Application of a fully automatic analysis tool to assess the activity of broiler chickens with different gait scores. Computers and Electronics in Agriculture 73(2), 194-199.

Bagshaw, C., Matthews, L. & Rogers, A. (2006) Key indicators of poultry welfare in New Zealand. In Unpublished client report to MAF policy.

Bennett, A.K. (2006) Differential gene expression in the bone marrow of layer and broiler chickens : relevance to bone integrity traits Vol. M.S.: Iowa state University.

Bessei, W. (2005) Welfare of meat producing poultry - an overview. Animal Science Papers and Reports 23(Suppl. 1), 205-216.

Bessei, W. (2006) Welfare of broilers: a review. World's Poultry Science Journal 62(3), 455-466, 542, 546, 560.

Blatchford, R.A., Klasing, K.C., Shivaprasad, H.L., Wakenell, P.S., Archer, G.S. & Mench, J.A. (2009) The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens. Poultry Science 88(1), 20-28.

Bokkers, E.A.M., De Boer, I.J.M. & Koene, P. (2011) Space needs of broilers. Animal Welfare 20(4), 623-632.

Bokkers, E.A.M., Zimmerman, P.H., Rodenburg, T.B. & Koene, P. (2007) Walking behaviour of heavy and light broilers in an operant runway test with varying durations of feed deprivation and feed access. Applied Animal Behaviour Science 108(1-2), 129-142.

Bradshaw, R.H., Kirkden, R.D. & Broom, D.M. (2002) A review of the aetiology and pathology of leg weakness in broilers in relation to welfare. Avian and Poultry Biology Reviews 13(2), 45-103.

Buijs, S., Keeling, L., Rettenbacher, S., Poucke, E.v. & Tuyttens, F.A.M. (2009) Stocking density effects on broiler welfare: identifying sensitive ranges for different indicators. Poultry Science 88(8), 1536-1543.

Butterworth, A. (1999) Infectious components of broiler lameness: A review. World's Poultry Science Journal 55(4), 345-352.

Butterworth, A. (2004) Infectious disease: morbidity and mortality. In Measuring and Auditing Broiler Welfare, pp. 61-70. Edited by C.A.W.a.A. Butterworth. Wallingford: Cabi Publishing.

Butterworth, A., Knowles, T.G., Whittington, P., Matthews, L., Rogers, A. & Bagshaw, C.S. (2007) Validation of broiler chicken gait scoring training in Thailand, Brazil and New Zealand. Animal Welfare 16(2), 177-179.

Butterworth, A. & Weeks, C. (2010) The Impact of Disease on Welfare. In Welfare of Domestic Fowl and Other Captive Birds.:189-218, 2010.Edited by I.J.H.H.P. Duncan. Po Box 17, 3300 Aa Dordrecht, Netherlands: SPRINGER.

Cengiz, O., Hess, J.B. & Bilgili, S.F. (2011) Effect of bedding type and transient wetness on footpad dermatitis in broiler chickens. Journal of Applied Poultry Research 20(4), 554-560.

Classen, H.L. & Riddell, C. (1989) Photoperiodic effects on performance and leg abnormalities in broiler chickens. Poultry Science 68(7), 873-9.

Corr, S.A., Gentle, M.J., McCorquodale, C.C. & Bennett, D. (2003) The effect of morphology on walking ability in the modern broiler: A gait analysis study. Animal Welfare 12(2), 159-171.

Cruickshank, J.J. & Sim, J.S. (1986) Morphometric and radiographic characteristics of tibial bone of broiler chickens with twisted leg disorders. Avian Dis 30(4), 699-708.

Danbury, T.C., Weeks, C.A., Chambers, J.P., Waterman-Pearson, A.E. & Kestin, S.C. (2000) Self-selection of the analgesic drug carprofen by lame broiler chickens. Vet Rec 146(11), 307-11.

Dawkins, M.S., Donnelly, C.A. & Jones, T.A. (2004) Chicken welfare is influenced more by housing conditions than by stocking density. Nature 427(6972), 342-344.

Dawkins, M.S., Lee, H., Waitt, C.D. & Roberts, S.J. (2009) Optical flow patterns in broiler chicken flocks as automated measures of behaviour and gait. Applied Animal Behaviour Science 119(3/4), 203-209.

EFSA (2010) Scientific Opinion on the influence of genetic parameters on the welfare and the resistance to stress of commercial broilers. EFSA Journal 8(7), Article 1666.

Estevez, I. (2007). Density allowances for broilers: where to set the limits? Poultry Science 86: 1265-1272.

Flock, D.K., Laughlin, K.F. & Bentley, J. (2005) Minimizing losses in poultry breeding and production: how breeding companies contribute to poultry welfare. World's Poultry Science Journal 61(2), 227-237, 318, 323-324, 329, 335, 341.

Foutz, T.L., Griffin, A.K., Halper, J.T. & Rowland, G.N. (2007a) Effects of activity on avian gastrocnemius tendon. Poultry Science 86(2), 211-218.

Foutz, T.L., Griffin, A.K., Halper, J.T. & Rowland, G.N. (2007b) Effects of increased physical activity on juvenile avian bone. Transactions of the ASABE 50(1), 213-219.

Gregory, N.G. & Grandin, T. (2007) Poultry and rabbits. Edited by N.G. Gregory & T. Grandin. Animal welfare and meat production. 2007. 113-128. Cabi.

Haslam, S.M., Knowles, T.G., Brown, S.N., Wilkins, L.J., Kestin, S.C., Warriss, P.D. & Nicol, C.J. (2007) Factors affecting the prevalence of foot pad dermatitis, hock burn and breast burn in broiler chicken. British Poultry Science 48(3), 264-275.

Jordan, D., Stuhec, I. & Bessei, W. (2011) Effect of whole wheat and feed pellets distribution in the litter on broilers' activity and performance. Archiv fur Geflugelkunde 75(2), 98-103.

Julian, R.J. (2004) Evaluating the impact of metabolic disorders on the welfare of broilers. In Measuring and Auditing Broiler Welfare, pp. 51-59. Edited by C.A.W.a.A. Butterworth. Wallingford: Cabi Publishing.

Julian, R.J. (2005) Production and growth related disorders and other metabolic diseases of poultry - a review. Veterinary Journal 169(3), 350-369.

Kestin, S.C., Adams, S.J.M. & Gregory, N.G. (1994) Leg weakness in broiler chickens, a review of studies using gait scoring. In 9th European Poultry Conference, pp. 203-206.

Kestin, S.C., Knowles, T.G., Tinch, A.E. & Gregory, N.G. (1992) Prevalence of leg weakness in broiler chickens and its relationship with genotype. Veterinary Record 131(9), 190-194.

Knowles, T.G., Kestin, S.C., Haslam, S.M., Brown, S.N., Green, L.E., Butterworth, A., Pope, S.J., Pfeiffer, D. & Nicol, C.J. (2008) Leg disorders in broiler chickens: prevalence, risk factors and prevention. PLos One February, e1545.

Le Bihan-Duval, E., Beaumont, C. & Colleau, J.J. (1996) Genetic parameters of the twisted legs syndrome in broiler chickens. Genetics Selection Evolution 28(2), 177-195.

Leterrier, C. & Nys, Y. (1992) Clinical and anatomical differences in varus and valgus deformities of chick limbs suggest different aetio-pathogenesis. Avian Pathol 21(3), 429-42.

Manning, L., Chadd, S.A. & Baines, R.N. (2007) Key health and welfare indicators for broiler production. World's Poultry Science Journal 63(1), 46-62.

Martland, M.F. (1985) Ulcerative dermatitis dm broiler chickens: the effects of wet litter. Avian Pathol 14(3), 353-64.

McGeown, D., Danbury, T.C., Waterman-Pearson, A.E. & Kestin, S.C. (1999) Effect of carprofen on lameness in broiler chickens. Veterinary Record 144(24), 668-671.

McNamee, P.T., McCullagh, J.J., Thorp, B.H., Ball, H.J., Graham, D., McCullough, S.J., McConaghy, D. & Smyth, J.A. (1998) Study of leg weakness in two commercial broiler flocks. Veterinary Record 143(5), 131-135.

Naas, I.A., Paz, I.C.L.A., Baracho, M.S., Menezes, A.G., Bueno, L.G.F., Almeida, I.C.L. & Moura, D.J. (2009) Impact of lameness on broiler well-being. Journal of Applied Poultry Research 18(3), 432-439.

Naas, I.d.A., Paz, I.C.d.L.A., Baracho, M.d.S., Menezes, A.G.d., Lima, K.A.O.d., Bueno, L.G.d.F., Mollo Neto, M., Carvalho, V.C.d., Almeida, I.C.d.L. & Souza, A.L.d. (2010) Assessing locomotion deficiency in broiler chicken. Scientia Agricola 67(2), 129-135.

Reiter, K. & Bessei, W. (2009) Effect of locomotor activity on leg disorder in fattening chicken. Berliner und Munchener Tierarztliche Wochenschrift 122(7/8), 264-270.

Robins, A. & Phillips, C.J.C. (2011) International approaches to the welfare of meat chickens. World's Poultry Science Journal 67(2), 351-369.

Sanotra, G., Berg, C. & Lund, J. (2003) A comparison between leg problems in Danish and Swedish broiler production. Animal Welfare 12(4), 677-683.

Shepherd, E.M. & Fairchild, B.D. (2010) Footpad dermatitis in poultry. Poultry Science 89(10), 2043-2051.

Shim, M.Y., Karnuah, A.B., Anthony, N.B., Pesti, G.M. & Aggrey, S.E. (2012) Genetics, the effects of broiler chicken growth rate on valgus, varus, and tibial dyschondroplasia. Poultry Science 91(1), 62-65.

Spindler, B. & Hartung, J. (2009) Assessment of litter quality in broiler houses. pp. Proceedings of the 14th International Congress of the International Society for Animal Hygiene (ISAH), Vechta, Germany, 19th to 23rd July 2009. 2009. 489-492. 10 ref. Edited by A. Briese, M. Clauss, A. Springorum & J. Hartung. Sustainable animal husbandry, Tribun EU.

Stojcic, M.D. & Bessei, W. (2009) The effect of locomotor activity and weight load on bone problems in fast and slow growing chickens. Archiv fur Geflugelkunde 73(4), 242-249.

Weeks, C.A. & Butterworth, A. (2004) Measuring and auditing broiler welfare. CABI Publishing.

Weeks, C.A., Danbury, T.D., Davies, H.C., Hunt, P. & Kestin, S.C. (2000) The behaviour of broiler chickens and its modification by lameness. Appl Anim Behav Sci 67(1-2), 111-125.

Acknowledgements

We would like to thank Rose Greenfield and Suzanne Dowling for their technical expertise. To Poultry Industry Association of New Zealand for supporting the work, assisting with access to the industry and providing Kerry Mulqueen to perform all the post-mortems. Thanks to Andy Butterworth and Lindsay Matthews for their advice and constructive feedback. We appreciate the openness and helpfulness of both the companies and farmers involved in the study. This work was funded by Ministry for Primary industries.