THE EFFECT OF STOCKING DENSITY ON THE WELFARE AND BEHAVIOUR OF BROILER CHICKENS REARED COMMERCIALLY

A L Hall

Department of Zoology, South Parks Rd, University of Oxford, Oxford OX1 3PS, UK

Final Acceptance: 3 May 2000

Animal Welfare 2001, ***10:*** 23-40

Abstract

An experiment was conducted to compare the effect of two levels of house stocking density (34kg m^{-2} and 40kg m^{-2}) on broiler welfare and behaviour. The trial monitored 121 900 birds housed in eight flocks under commercial conditions and used a range of behavioural and productivity measures to assess welfare.

At the higher stocking density: i) the daily mortality was greater for part of the rearing period; ii) the incidence of leg problems, contact dermatitis and carcase bruising increased; iii) the birds' resting behaviour was increasingly disturbed; iv) locomotion and ground pecking decreased; and v) lying and preening patterns were affected, probably due to increased disruption by other birds.

Aspects of welfare were adversely affected at the higher stocking density. Further research is required to determine how stocking density affects welfare under different commercial conditions.

Keywords: *animal welfare, behaviour, broiler, commercial conditions, stocking density*

Introduction

Within the broiler industry, stocking density is believed to have important implications for both bird welfare and profitability. Many studies have been conducted to determine how stocking density influences feed efficiency, growth and monetary return (Bolton *et al* 1972; Proudfoot 1973; Proudfoot *et al* 1979; Scholtyssek & Gschwindt 1980; Weaver *et al* 1982; Quinones *et al* 1984; Shanawany 1988; Phelps 1990; Grashorn & Kutritz 1991; Cravener *et al* 1992). However, very few have addressed the effect of stocking density on bird behaviour and welfare in commercial rearing units.

There is currently no international or European legislation relating to maximum stocking densities for broiler production. Codes of practice vary considerably between countries, although the scientific basis of the different recommendations is not apparent (Bessei 1993). These limits are frequently exceeded in order to increase economic return (Ekstrand 1993). A report by the European Commission – Scientific Committee on Animal Health and Animal Welfare (2000) on the welfare of broilers, concluded that at stocking rates exceeding 30kg m^{-2} welfare problems are likely to emerge regardless of indoor climate control capacity. Within the UK, the Farm Animal Welfare Council (FAWC) and the Ministry of Agriculture, Fisheries and Food (MAFF) currently state that stocking densities of 34kg m^{-2} should not be exceeded – but have also recommended that further research into the effects of stocking density on welfare be undertaken as a matter of urgency (FAWC 1992; MAFF 1998). In practice, UK producers often stock at 40kg m^{-2}, as adhering to maximum densities of 34kg m^{-2} would be economically detrimental in the face of increasing competition from countries with higher (or no) stocking density recommendations.

Published studies on the effect of stocking density have usually involved birds housed in small groups (eg Blokhuis & Van der Haar [1990]; Cravener *et al* [1992]; Andrews *et al* [1997]). In contrast, commercial broiler farms within the UK typically rear birds in flocks of 10 000–40 000 birds. An obvious concern is that stocking density effects that are detrimental to welfare within industry are not replicated in smaller-scale experiments. Industrial trials, while involving large bird numbers, do not always control for confounding variables and tend to examine welfare indicators of commercial importance only (such as clinical disease incidence).

A preliminary survey conducted within a commercial broiler operation by Cambac JMA Research (1996) indicated that house stocking density was correlated with differential rates of carcase injury and mortality during transit. For this study, it was proposed to evaluate further the effect of stocking density on bird welfare by employing a range of behavioural and productivity indicators. Two final target levels of house stocking density with commercial relevance were compared: 34kg m^{-2} and 40kg m^{-2} (Actual final stocking densities varied slightly due to commercial constraints – see Table 1). These two densities were achieved by rearing different numbers of birds per unit area. Both stocking density treatments were present in each experimental house to reduce extraneous variables (for example, differences between houses) to a minimum.

Animals, housing and husbandry

The experiment was conducted on a commercial broiler farm (Premier Poultry Ltd) in Lincolnshire and monitored a total of 121 900 broilers. The birds (90 400 Ross 508 and 31 500 Ross PM3; Ross Breeders Ltd, Midlothian, Scotland) were placed 'as-hatched' (approximately 50% male: 50% female) in four identical houses. Each house measured 15x100 m and was 1.6m at the eaves and 4.4m at the ridge. The houses were built in 1987, with concrete floors and were insulated in the roof, walls and floor. The farm was equipped with the Flockman™© environmental and nutritional computer control system (David Filmer Ltd, Somerset, UK). Ventilation was automatically adjusted to maintain optimal airflow and temperature profile within the houses. The units were also fitted with active humidity control systems.

In order to replicate both stocking density treatments in each house, the four houses were partitioned longitudinally, using 100m-long, 90cm-high barriers (wooden frame and wire mesh), to form two identically sized areas, each of 753m^2. Birds were distributed so that the flock on one side of the barrier was reared to a target final stocking density of 34kg m^{-2} (treatment A) and that on the other to 40kg m^{-2} (treatment B). It was envisaged that all four houses would contain the same number of birds, but due to commercial constraints, one house was stocked with fewer birds than the other three. However, these birds were placed 4 days earlier and reared to a greater weight so that final stocking densities of around 34kg m^{-2} and 40kg m^{-2} were still achieved (see Table 1). The experimental design was thus four matched pairs, with birds within each pair treated identically except for being stocked at different numbers per square metre. Differences between houses were controlled for in the statistical analysis. Details of the experimental houses are summarized in Table 1.

Table 1 **Details of the experimental houses.**

Parameter	Houses 1, 2, 3	House 4
Total birds (n)	31 500	27 400
Treatment A: total birds (n)	14 500	12 600
Treatment B: total birds (n)	17 000	14 800
Treatment A: mean slaughter weight (kg)	1.82, 1.85, 1.92	2.17
Treatment B: mean slaughter weight (kg)	1.79, 1.85, 1.85	2.18
Slaughter age (days)	39, 40, 38	42
Treatment A: FSD[1] (kg m^{-2})	33.1, 33.2, 34.4	34.2
Treatment B: FSD[1] (kg m^{-2})	38.1, 38.0, 39.2	40.1

[1] Final stocking density.

The two treatments were assigned at random with respect to (left or right) side of the rearing house. At the hatchery, day-old chicks were counted into boxes of 100 which were labelled by treatment to ensure correct numbers were present in each house. Chicks were identified by batch, parent stock and strain and each type was divided equally between treatments to remove any confounding effects of these factors.

The farm was fitted with Bec™© bell drinkers (Precision Plastics Ltd, Mansfield, UK) and Roxell™© feeding pans (Vale Livestock Ltd, Horncastle, UK). Feeder and drinker space per bird was constant across treatments, with the higher stocking density side being provided with more feeders and drinkers. Birds received food and water *ad libitum* and were fed on standard (wheat-based) commercial starter, grower and withdrawal diets which were prepared by Premier Poultry Ltd. Feeders were active from 0630h to 1100h and from 1300h to 2100h (the 2h break encouraging birds to eat the finer food at the bottom of the pans).

A 14L:10D light programme, with one continuous dark period, was implemented in all houses from 4 days of age. The light period commenced at 0700h, with 7min dimming time. The light intensity was approximately 10 lux.

The same stockperson tended all the birds studied during this trial and ensured that birds from the two stocking densities were managed identically. The houses were initially bedded with Litterite™©, further processed straw (Northern Straw Co, Weatherby, UK) and were 'topped-up' if necessary using soft, white wood shavings.

Methods

Mortality

The percentage mortality, with respect to treatment and house, was recorded daily throughout the rearing period. Mortality was calculated as the number of birds which died or were culled that day, divided by the flock size from the previous day.

Leg problems

The number of birds culled for leg problems was recorded daily. Birds were humanely killed (by neck dislocation) if the stockperson considered they exhibited an obvious gait defect that was likely to compromise welfare. Birds showing only slight gait abnormalities were not culled.

Behaviour patterns

A total of 384 birds were observed between the ages of 23 and 37 days of age. Focal animal sampling and continuous recording methods were employed (Altmann 1974; Martin & Bateson 1993), with each bird being observed for 10min. On each day, observations were made in two blocks (commencing at 0930h and 1400h) during which two birds from each

https://doi.org/10.1017/S096272860002323X Published online by Cambridge University Press

treatment were observed in every house (16 birds per treatment per day). Upon entering the house, the observer allowed 5min for the birds to habituate before observation began. The observer's position and orientation within the house was randomized. A focal individual was then chosen according to the criterion that it was the nearest bird to a predetermined point (estimated to be 5m in front of the observer).

A total of 20 activities were recorded, with each occurrence of an activity being dictated into a miniature tape recorder. If the behaviour had a duration that could be determined it was classified as a 'state' (Table 2), and bout lengths were also recorded. At all times the bird was classified as exhibiting one of four, mutually exclusive, major activity states (following Murphy & Preston [1988]): eating, drinking, lying and standing. When birds were lying or standing, they also performed other behaviours (eg lying-preening or standing-running). Table 2 provides definitions of the activities recorded.

Table 2 Definitions of behavioural activities.

Activity	Description	Category
Feed	Pecking at food in feeder	State
Drink	Intake of water from bell	State
Lie	Bird has both hocks resting on ground	State
Stand	All time not occupied by eating, drinking and lying	State
Preen	Grooming of plumage with beak	State
Dustbathe	Performed with fluffed feathers while lying, head rubbed on floor, wings opened scratching at ground	State
Walk	Each step counted separately	Event
Litter peck	Peck directed at ground	Event
Peck other	Peck directed at other bird	Event
Litter scratch	Several backwards strokes with leg but not as part of a dustbathing bout	Event
Leg-wing stretch	Unilateral stretching of wing and leg, backwards and slightly to the side	Event
Body shake	Ruffling of feathers while body rotated in axial plane	Event
Head shake	Rapid side-to-side movement of head with its feathers raised	Event
Head stretch	Pronounced extension of neck	Event
Head scratch	Head area scratched by foot, the leg passing beneath the wing	Event
Run	Fast locomotion where individual steps could not be determined	State
Sparring event	Playful fighting movements, may incorporate a threat display, but without physical contact	Event
Wing flap	Bilateral up-and-down wing flaps	Event
Disturbance	Bird stops lying and stands because other birds step on or over it	Event

If a focal individual became obscured, the duration for which the bird was not visible was recorded. If a bird was lost from sight – either because it could not be reliably re-identified after becoming obscured or because it strayed too far from the observer – the observation was terminated. If the focal bird appeared to be influenced by the observer, for instance by moving closer to her and showing increased head stretching behaviour, recording was also stopped. A small pair of binoculars was used when required.

Catching and transportation

Birds were harvested by a manual catching team of five men using a fork-lift truck and a modular crating system. Hand harvesting was employed (as is common commercial practice) with each man catching and carrying 6–8 birds at a time, inverted by one leg, and loading them into a transport crate within the house. Catching occurred at night and no light sources were employed, except two blue headlights on the fork-lift.

Carcase damage can be caused by handling during catching and loading on the farm and by the subsequent transportation, unloading and slaughter at the processing plant. For this reason, all these stages were carefully controlled during this experiment to eliminate possible confounding variables. It was important to ensure that there were no treatment differences in factors, eg in the catching team personnel or time spent in lairage, which could cause differential carcase damage.

Two transporter-loads of birds were harvested from each house for the purpose of carcase assessment (a total of 48 480 birds). Birds from the two treatments in each house were caught simultaneously by the same men to prevent different effects of time of day or particular catching teams. Two men caught birds on one side of the barrier while another two caught on the other side. These pairs changed sides frequently. Birds were loaded within the house into modules labelled treatment A (low stocking density) or treatment B (high stocking density).

To prevent confounding effects of transportation on carcase damage (eg due to different journey lengths), each transporter carried equal numbers of birds from the two treatments. On each vehicle, the first half of the load consisted of modules from one treatment and the second half consisted of modules from the other treatment. This order was alternated in order to remove any confounding effect of position on the vehicle on levels of damage during transit. The mean load size was 6060 birds (3030 per treatment).

Processing

Birds were slaughtered at a large commercial processing plant employing an autoflow modular unloading system. To avoid confounding effects due to different conditions or waiting times in lairage, birds from both treatment groups in a house were processed on the same killing line, consecutively and with as little delay as possible.

As the transporters carried half a load of birds from each treatment, all the processing plant data was collected on a half-load basis. (There were a total of 16 half-loads – eight per treatment – analysed for the experiment.) Half-loads of birds were slaughtered and graded in the following way with respect to treatment (to remove order effects): ABBA or BAAB.

Records were kept of the number of 'Dead On Arrivals' (DOAs). A total of 48 091 birds were assessed immediately post-plucking for the presence or absence (for each bird) of: wing bruising, leg bruising, breast bruising, back bruising, breast blisters, hock burn (one or both hocks), back scratching, wing breakage/dislocation, and leg breakage/dislocation.

Each carcase was graded by two assessors – one observing the bird's ventral side and the other viewing its dorsal side. This grading was effectively done 'blind', as the half-loads were not identified by treatment to the assessors. Carcase damage caused by processing plant machines was discounted from the analysis.

A bruise was defined as a blemish with a diameter greater than 2.5cm caused by escape of blood into the surrounding tissue. The colour of bruises was also recorded as this allowed approximate estimation of their age. However, as the number of green (older) bruises was low, these were pooled with recent bruises. A breast blister was defined as a breast lesion of ≥ 2cm in diameter. The number of birds with multiple breaks or bruises was also low, and these were recorded as one occurrence.

Statistical analysis

Mortality, leg cull and behavioural data

Data were analysed by fitting linear mixed effects models (Vonesh & Chinchilli 1997) using S-Plus (MathSoft S-Plus 4, Programmer's Guide 1997). Density, day and house were explanatory variables in the model. Density and house were considered as categorical variables with two and four levels respectively. House was fitted as the factor defining the random effects of the model, thus controlling for the internal correlation structure within each level of house.

Day was modelled as a continuous variable with a linear term and higher order polynomials where appropriate. Interaction terms between day and density, and house and density, were also modelled. For behavioural observations, time of day was included in the model as a categorical variable with two levels (morning and afternoon).

If residual plot analysis or the coefficients of skewness and kurtosis indicated departures from the normal distribution, an appropriate transformation was applied to the response variable. The angular transformation ($Y = \text{arcsine } [y/n]^{1/2}$) was applied to mortality data. Leg cull data were fitted to the natural logarithm of the response variable. For behavioural observations, the natural logarithm was applied to the percentage of time a bird was out of sight, feeding, drinking, preening and running. All mean bout lengths were also log-transformed, except the mean lying bout length (which was square root transformed). The large number of response variables considered in the behavioural data analysis leads to problems of multiplicity of probability (*P*) values (Samuels 1991, p 500), therefore, a significance level of 1 per cent rather than 5 per cent was taken. However, where $0.05 > P > 0.01$ for a variable, this is indicated in the text and the results table. Where a *P* value is equal to (and not less than) 0.01 or 0.001, exact values are stated or the ≤ symbol used. For each linear mixed effects model the following results are given in parentheses: *z*-ratio (coefficient/standard error of coefficient) and *P* value.

Processing plant data

A generalized linear model (GLM) was fitted to the natural logarithm of response variables using S-Plus. House and density were explanatory variables. House was modelled as a random effect. Each data point represents one half-load of birds. Response variables were the percentage of birds in each half-load with a given defect, for example, the percentage with a broken wing. For each model, the following results are given in parentheses: $F\text{-ratio}_{(df)}$ and *P* value.

Results

Mortality

The daily mortality was affected by stocking density as evidenced by a significant quadratic interaction between density and day ($z = 2.194$, $P < 0.05$). Daily mortality was greater at the higher stocking density for part of the rearing period. The form of this interaction is shown in Figure 1. The total mortality over the rearing period was in the range 5.92 per cent to 8.94 per cent.

*Animal Welfare 2001, **10:*** 23-40

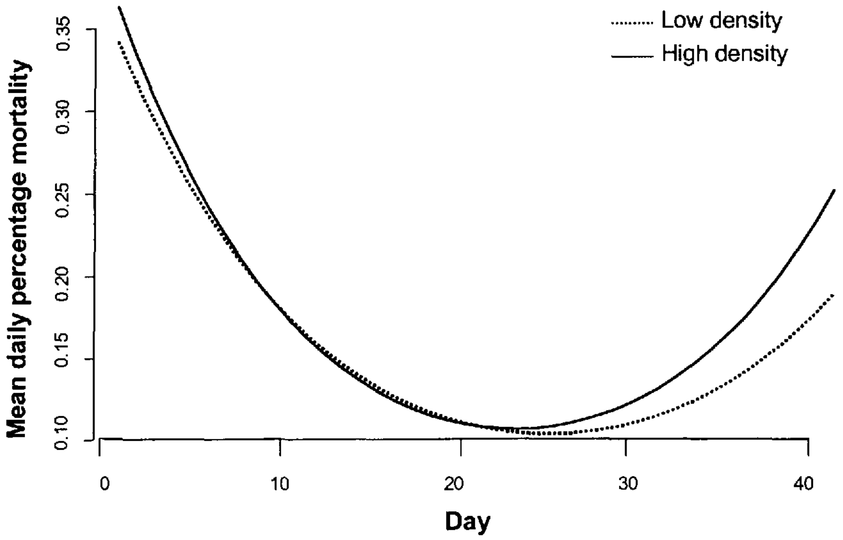

Figure 1 **Graph of the linear mixed effects model predicting the effect of age and stocking density on daily percentage mortality (using back-transformed data).**

Leg problems

The percentage of birds culled each day for leg problems was greater at the higher stocking density (z = 3.134, P < 0.01) – and this effect varied with age as shown by a significant density*day^3 interaction term (z = -3.443, P < 0.001) (see Table 3 and Figure 2).

Table 3 **Effect of stocking density on mortality and culls for leg problems. Values represent untransformed means (± SEM) per half rearing house. (**P < 0.01; *I* – effect of density only significant in interaction with day; na – not applicable due to small sample size.)**

Parameter	Low density	High density	Significance
Mean daily % mortality	0.156 ± 0.071	0.176 ± 0.014	*I*
Total % mortality	6.380 ± 0.356	6.997 ± 0.657	na
Mean daily % leg culls	0.020 ± 0.002	0.028 ± 0.003	**
Total % leg culls	0.811 ± 0.080	1.123 ± 0.100	na

Behaviour patterns

Method validation – time obscured

Before analysing the behavioural data, it was necessary to ensure that any apparent differences between the two treatments were not an artefact of the observation method. In particular, it was important that the accuracy of observation was not differentially affected by stocking density.

Tests were performed to determine whether stocking density affected the visibility of the focal bird to the observer. Stocking density did not significantly affect any of the variables measured. This suggests that the accuracy of observation method did not differ systematically between the two stocking densities and comparisons are, therefore, valid. Table 4 summarizes the behavioural data results.

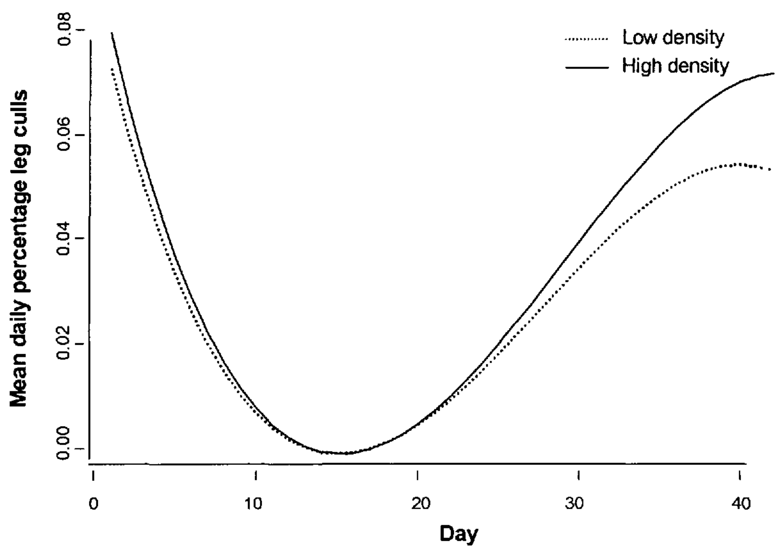

Figure 2 **Graph of the linear mixed effects model predicting the effect of age and stocking density on the percentage of birds culled for leg problems each day (using back-transformed data).**

Lying behaviour

The mean percentage of time spent lying was not significantly influenced by stocking density but increased with age (z = 4.825, P < 0.001) and was greater in the afternoon than the morning (z = 2.514, P = 0.01). The frequency of lying was, however, affected by stocking density, being greater at the higher density (z = 3.237, P = 0.001). This effect became more pronounced with age – as evidenced by a significant interaction between these two factors (z = 2.630, P < 0.01). There was some evidence that mean lying bout length was also affected by stocking density, being shorter at the higher density, although this failed to reach the 1 per cent level of statistical significance (z = -1.987, P < 0.05).

The number of disturbance events increased at the higher stocking density (z = 3.568, P < 0.001) and with age (z = 2.512, P = 0.01). The proportion of lying bouts terminated by disturbance was greater for birds housed at the higher density (z = 2.843, P < 0.01) and in the afternoon compared to the morning (z = 3.053, P < 0.01). The mean time spent lying without disturbance (time spent lying/number of disturbances) was greater at the lower stocking density (z = -3.222, P = 0.001).

Feeding behaviour

Stocking density did not have a significant effect on any of the feeding behaviour variables. There was some evidence that feeding bout frequency decreased with age, although this failed to reach the set level of statistical significance (z = -2.147, P < 0.05).

Drinking behaviour

Stocking density did not have a significant effect on any of the drinking behaviour variables. There was some evidence that an interaction between density and day influenced the percentage of time spent drinking, but this just failed to reach statistical significance (z =

Table 4 **Effect of stocking density on behaviour. Values represent untransformed means (± SEM) per 10min observation period; n = 192 per treatment. (*P < 0.05; **P ≤ 0.01; ***P < 0.001; ns – not significant.)**

Variable	Low density	High density	Significance
% time obscured	5.201 ± 0.840	6.201 ± 0.996	ns
No times obscured	2.352 ± 0.186	2.642 ± 0.212	ns
Mean length of time obscured (s)	20.46 ± 4.58	23.63 ± 5.48	ns
% time lying	65.28 ± 1.79	65.59 ± 1.71	ns
No lying bouts	4.852 ± 0.190	5.869 ± 0.251	***
Mean lying bout length (s)	98.42 ± 4.35	83.85 ± 3.57	*
No disturbances	2.460 ± 0.171	3.415 ± 0.211	***
No disturbances/No lying bouts	0.443 ± 0.0231	0.5367 ± 0.0225	**
Time spent lying/No disturbances (s)	217.9 ± 11.2	170.7 ± 9.6	***
% time spent feeding	7.441 ± 0.885	7.424 ± 0.825	ns
No feeding bouts	0.972 ± 0.120	1.040 ± 0.120	ns
Mean feeding bout length (s)	53.89 ± 4.35	47.24 ± 2.93	ns
% of time spent drinking	3.564 ± 0.465	4.548 ± 0.588	ns
No drinking bouts	0.722 ± 0.095	0.784 ± 0.114	ns
Mean drinking bout length (s)	35.56 ± 2.96	39.57 ± 3.19	ns
No steps taken	55.44 ± 4.03	42.36 ± 2.75	**
% time spent running	0.841 ± 0.113	0.566 ± 0.085	ns
No running bouts	1.000 ± 0.149	0.761 ± 0.126	ns
Mean running bout length (s)	6.015 ± 0.373	5.000 ± 0.240	ns
No sparring events	0.858 ± 0.120	0.852 ± 0.110	ns
No pecks other bird	4.119 ± 0.568	4.528 ± 0.594	ns
No ground pecks	54.14 ± 4.48	39.76 ± 3.20	**
No litter scratches	2.028 ± 0.333	1.665 ± 0.291	ns
% time spent dustbathing	0.894 ± 0.487	0.417 ± 0.301	ns
No dustbathing bouts	0.1591 ± 0.0759	0.0739 ± 0.0535	ns
Mean dustbathing bout (s)	33.29 ± 9.99	37.50 ± 16.00	ns
% time spent preening	14.837 ± 0.946	14.016 ± 0.944	ns
No preening bouts	4.739 ± 0.285	5.591 ± 0.349	*
Mean preening bout length (s)	20.197 ± 0.949	16.876 ± 0.745	**
No head stretches	1.335 ± 0.197	1.312 ± 0.217	ns
No leg-wing stretches	0.756 ± 0.109	0.875 ± 0.123	ns
No head shakes	1.523 ± 0.150	1.864 ± 0.197	ns
No feather shakes	0.744 ± 0.090	0.665 ± 0.087	ns
No wing flaps	0.489 ± 0.074	0.557 ± 0.078	ns
No head scratches	0.500 ± 0.066	0.540 ± 0.097	ns

-2.461, P = 0.014). There was also some evidence for an effect of density and day on the frequency of drinking, as shown by a nearly significant interaction term (z = -2.344, P = 0.018).

Locomotory behaviour and social interactions

There was evidence that walking (ie the number of steps taken) decreased at the higher stocking density (z = -2.782, P < 0.01) and also with age (z =-3.180, P = 0.001). There was some evidence that the mean number of steps taken was lower in the afternoon than the morning, although this was not significant (z = -2.449, P < 0.05). The effect of density on walking behaviour depended on house, as shown by a significant interaction between house and density (z =3.405, P < 0.001). The form of this interaction was that houses 2 and 4 were significantly different from each other (but neither differed significantly from the other two houses) in the effect that density had on walking. The difference between the two stocking density treatments was greater in house 4 than house 2.

None of the variables modelled had a significant effect on the percentage of time spent running, the frequency of running bouts or the mean length of running bouts. Similarly, the number of sparring events was not significantly affected by stocking density or any other variable in the model.

The frequency with which the focal bird pecked another individual was not affected by stocking density as a main effect – but there was a significant interaction between house and density (z = 3.449, P < 0.001). The form of this interaction was that house 4 differed significantly from the other three houses (which were not significantly different from one another). In house 4, pecking of other birds was greater at the higher stocking density, whereas in the other houses pecking of other birds was greater at the lower stocking density.

Dustbathing, ground pecking and ground scratching

The frequency of dustbathing was low, being observed in only 7 of the 384 focal birds. Statistical analyses were not performed due to the small sample sizes. Ground pecking decreased at the higher stocking density (z = -2.617, P < 0.01). Litter scratching was not affected by any of the factors modelled.

Preening, stretching and shaking behaviours

The percentage of time spent preening was not influenced by stocking density. There was some evidence that the rate with which preening was initiated was greater at the higher stocking density, although this just failed to reach the set level of significance (z = 2.154, P < 0.05). The mean preening bout length decreased at the higher stocking density (z = -2.520, P = 0.01).

There was a significant interaction between house and density on the number of leg-wing stretches (z = 3.177, P < 0.01). The form of this interaction was that house 4 differed from the other three houses. In house 4, the number of leg-wing stretches was greater at the higher stocking density, whereas in the other three houses the number of leg-wing stretches was greater at the lower stocking density.

Stocking density did not have a significant effect on any of the stretching or shaking movements recorded. However, the frequency of head stretching increased with age (z = 2.716, P < 0.01). The frequencies of head shaking, feather shaking, wing flapping and head scratching were not significantly affected by any of the variables in the model.

Processing plant data

Table 5 summarizes the results.

Mortality during transit and carcase damage

Stocking density did not have a significant effect on mortality during transport. Birds stocked at the higher density showed a significantly higher percentage of wing bruising ($F_{1,11}$ = 9.05, P = 0.01) and leg bruising ($F_{1,11}$ = 6.70, P < 0.05). Stocking density did not have a significant effect on the percentage of breast bruising or back bruising.

Stocking density had a significant effect on the incidence of breast blisters ($F_{1,11}$ = 10.43, P < 0.01) and hock burn ($F_{1,11}$ = 23.15, P = 0.001). Both variables increased at the higher density. The percentage of birds with back scratching was greater at the higher density ($F_{1,11}$

Table 5 Effect of stocking density on mortality during transit and carcase damage. Values represent untransformed means (± SEM) per half-load; n = 8 per treatment. (*$P < 0.05$ **$P \leq 0.01$ ***$P \leq 0.001$; ns – not significant.)

Parameter	Low density	High density	Significance
% DOA	0.074 ± 0.020	0.041 ± 0.018	ns
% birds with wing bruising	0.465 ± 0.061	0.992 ± 0.176	**
% birds with leg bruising	0.465 ± 0.060	0.743 ± 0.101	*
% birds with breast bruising	0.533 ± 0.072	0.481 ± 0.043	ns
% birds with back bruising	0.177 ± 0.030	0.254 ± 0.049	ns
% birds with breast blisters	0.248 ± 0.037	0.414 ± 0.037	**
% birds with hock burn	0.997 ± 0.197	2.350 ± 0.477	***
% birds with back scratching	0.259 ± 0.080	0.517 ± 0.110	*
% birds with wing breakage	0.287 ± 0.046	0.268 ± 0.070	ns
% birds with leg breakage	0.035 ± 0.018	0.029 ± 0.007	ns

= 6.09, $P < 0.05$). Stocking density did not significantly affect the percentage of birds with broken wings or broken legs.

Discussion

The objective assessment of farm animal welfare requires that a range of welfare indicators be used when comparing different husbandry systems (eg Broom [1986]). In this study, a range of behavioural and productivity measures were used in order to evaluate the relevant merits of two levels of stocking density commonly used in commercial rearing of broilers.

When conducting experiments in industry it is necessary to eliminate, or control for, a large number of potential extraneous variables. Care was taken in this study to reduce confounding variables to a minimum, as far as possible, at the design stage. For example, experimental animals were pseudo-randomized with respect to density, to the extent that chicks from adjacent boxes on the transporters were placed in different treatments to prevent any pre-placement effects (such as time of journey from hatchery to farm) being confounded with treatment.

Flock size was confounded with stocking density in this study. It was decided that manipulating group size was the preferable method of producing treatment densities as this would introduce fewer confounding variables than altering the area available to each treatment or slaughtering treatments at different ages (and, therefore, weights) in order to produce a greater final liveweight per unit area for the higher density treatment. Such decisions were also considered in a commercial context; for example, a major implication of higher recommended stocking densities is that more birds will be reared in a given house. Clearly, the alternative solutions to those implemented in this study (for example, achieving different densities by keeping flock size constant and varying house areas or rearing birds to different slaughter weights) are important subjects for further work.

Due to commercial constraints, one house (house 4) was stocked with fewer birds than the other three. However, these birds were reared to a greater weight in order that final stocking densities were equivalent to the other three houses. The birds in house 4 were also older than those in the other houses, so stocking densities (liveweight per m^2) were approximately equivalent between houses on each day of the behavioural observations. To address whether the effect of stocking density differed between houses, interactions between house and density were included in each model. Significant house*density interactions were only found in the case of three behaviours – walking, pecking other birds and leg-wing stretches. The reasons for these differences are not clear, but only in the case of walking was stocking density significant as a main effect.

Mortality

Mortality was significantly affected by stocking density in this experiment. The daily mortality was greater at the higher stocking density for part of the rearing period. Figure 1 shows that mortality was greatest during the first week. Early mortality (mortality occurring during the first week) is influenced by pre-hatching factors such as parent stock age (Peterson *et al* 1987). However, the pseudo-randomization of chicks between stocking densities on the farm should have removed any treatment differences in such effects on early mortality. Mortality decreased after week 1, but then began to increase again after week 4 at the higher stocking density. A sample of 25 dead birds submitted on day 35 for post-mortems indicated Sudden Death Syndrome (SDS) to be the main cause of death. (SDS is an acute heart failure condition and is an important lethal pathology of broilers [Maxwell & Robertson 1997], although whether there was an effect of stocking density on this disorder was not established in this study.)

Most investigations have found no effect of stocking density on mortality, even at levels as high as 75kg m^{-2} (eg Weaver *et al* [1973]; Proudfoot *et al* [1979]; Shanawany [1988]). However, Coenen *et al* (1996) found increased mortality in birds stocked at 38kg m^{-2} rather than 33kg m^{-2}. The lack of an effect of stocking density on mortality in other studies may be partly explained by the fact that few experiments have been conducted under conditions representative of industry. Factors which have a detrimental effect on birds housed in commercial houses may not be replicated in smaller-scale experimental designs. For example, smothering following a fear response is more likely to occur in large flocks than in pens, and becomes an increasing problem at higher stocking densities (A Hall personal observation). The opportunities for disease transmission may also be enhanced in a commercial environment. However, the relationship between stocking density and disease incidence was not examined in this study due to the possibility of infectious agent transmission between treatments within a house.

Leg problems

The percentage of birds with severe leg problems, as reflected in the number requiring culling, was greater at the higher stocking density. This is in agreement with the findings of Grashorn and Kutritz (1991), who showed that broilers suffered increased leg problems when kept at 50kg m^{-2} (23.1% of birds affected) as compared to 38kg m^{-2} (4.3% of birds affected). The percentage of birds exhibiting severe leg problems was low in this study (means of 0.8% at the low density and 1.1% at the higher density).

Leg problems have many different causes, including genetic predisposition, nutrition, exercise, environment and disease. These may interact in a complex way (FAWC 1992). In severe cases, birds show obvious signs of distress and have difficulty walking and reaching food and water (Kestin *et al* 1992). FAWC (1992) found levels of leg problems in broilers to be unacceptable and recommended that steps be taken by producers to ensure a reduction in the incidence and severity of leg problems. Suggestions include stimulation of activity to develop leg strength through lower stocking densities and intermittent lighting levels. The present study supports the use of lower stocking densities as a method of reducing leg problems. This correlation may be mediated by the increase in locomotory behaviour at the lower stocking density (Table 4).

Behaviour patterns

Focal sampling is generally the most satisfactory approach to recording time budgets, particularly for groups (Altmann 1974; Martin & Bateson 1993). The choice of sample session length usually depends upon several considerations (Altmann 1974). However, in this study, the sample period was primarily dictated by the practical limitations of the observation method. The longer a focal individual was observed, the more difficult it became to keep it in view. However, as durations of behaviours were of interest, the session length also had to be long enough to obtain an adequate estimate of the distribution of durations (Altmann 1974). This reduced the likelihood that the lengths of behavioural bouts would be underestimated due to termination of recording. Following preliminary observations, the session length of 10min was decided upon as a compromise between theoretical and practical considerations.

The percentage of time spent lying (65.4%), feeding (7.4%) and drinking (4.1%) was similar to that observed in other studies. For example, Murphy and Preston (1988) observed times of 64 per cent lying, 11 per cent feeding and 5 per cent drinking in broilers housed at 14.4 birds m^{-2} in a commercial situation. Preston *et al* (1983) found broilers spent 73 per cent of their time lying, 6 per cent eating and 2 per cent drinking when stocked at 13.8 birds m^{-2} in small pens of 165 birds. Savory (1975) noted 80 per cent of the time was spent lying and 10 per cent feeding in broilers caged in groups of four at densities of 17.4 birds m^{-2}. These results are remarkably similar given that the experimental procedures differed in numerous ways including housing conditions, genetic strain, group size and flock sex composition. Also, the studies took place over a long time, and employed different sampling methods. Rose *et al* (1986) observed considerably less resting (39%) and more eating (20%), with similar levels of drinking (5% to 10%). However, the birds in Rose *et al*'s study were housed at low densities by industry standards (7.8 birds m^{-2}) which may explain these differences.

In this study, walking (ie the number of steps taken) decreased at the higher stocking density and with increasing age. This finding is in agreement with Andrews *et al* (1997), Blockhuis and Van der Haar (1990), Lewis and Hurnik (1990) and Newberry and Hall (1990). This restriction of movement may be indicative of some physical restriction exerted by other birds under more crowded conditions (Lewis & Hurnik 1990). The decrease in movement with age results from decreased free space and, possibly, increased leg problems.

Litter pecking decreased with increasing stocking density in this experiment. This pattern was also observed by Blokhuis and Van der Haar (1990) in pens holding 9–90 birds (corresponding to 2–20 birds m^{-2}).

Red junglefowl, *Gallus gallus*, from which domestic fowl are descended, spend a high proportion of their time engaged in foraging activities. For example, Dawkins (1989) observed semi-wild junglefowl to be ground pecking in 60 per cent of all minutes of observation during the active part of the day and ground scratching in 34 per cent, despite being fed regularly. Red junglefowl and chickens are the same species (Thorpe 1965) and their behaviour is very similar (Kruijt 1964).

The reduced ground pecking found at the higher stocking density in this study may be due to the poorer litter quality at higher densities or to decreased free space to perform behaviours without disturbance. The effects of this behavioural restriction should be investigated further, for example, by performing motivational tests to establish how important foraging behaviour is to the chickens (Dawkins 1988).

The percentage of birds preening decreased with increasing stocking density in week 7 of Blokhuis and Van der Haar's study (1990). In the present study, there was some evidence that the frequency with which preening was initiated was greater ($P < 0.05$), and the mean bout length was shorter ($P = 0.01$), at the higher stocking density. This may have been due to increased disturbance by other birds at the higher density.

The increased frequency of lying and the shorter length of lying bouts at the higher stocking density indicates that birds' resting behaviour is affected by increasing stocking density, as suggested by Lewis and Hurnik (1990) and Martrenchar *et al* (1997). In concordance with this, the proportion of lying bouts which ended in disturbance was greater at the higher stocking density and the duration of undisturbed rest was shorter.

Murphy and Preston (1988) found direct disturbance accounted for the termination of 21 per cent of lying bouts – which is a lower proportion than found in this study (44% and 54% at the lower and higher density respectively). However, the stocking density at which their birds were housed (14.4 birds m^{-2}) was considerably lower than in the present study (22.2 birds m^{-2} at the higher density). Disturbances were frequently caused by birds climbing over one another, which is known to increase carcase scratching and bruising (Frakenhuis *et al* 1991).

Stocking density did not have a significant effect on feeding or drinking behaviour in this experiment. This is in agreement with other studies which have shown that stocking density has no effect on feeding and drinking behaviour, provided that feeder and drinker space per bird are constant (Blokhuis & Van der Haar 1990; Lewis & Hurnik 1990).

The results from this study indicate that certain behaviour patterns were affected by stocking at the higher density. Welfare assessments should not be made solely on the basis of behavioural differences between situations (Duncan 1981). However, these results indicate that further research is required into the effects of disruption of behaviour patterns on bird welfare.

Carcase damage

The percentage of birds exhibiting wing and leg bruising increased at the higher density. The majority of this bruising was estimated (by colour) to have occurred a few days before examination. However, the method used to age bruises was not sensitive enough to determine the causal stage with accuracy. Further research is needed to determine at which stage the increased bruising found at the higher stocking density occurred.

The incidence of contact dermatitis (breast blisters and hock burn) was higher in birds reared at 40kg m^{-2} than at 34kg m^{-2}. This is supported by other studies (eg Weaver *et al* [1973]; Proudfoot *et al* [1979]; McIlroy *et al* [1987]; Cravener *et al* [1992]) and can be partly attributed to poorer litter quality at higher stocking densities (Gordon 1992). The decrease in mobility at higher densities may also be a contributory factor, as this increases the time that breasts and hocks are in contact with the litter.

Scratching to the back increased at the higher density in our study ($P < 0.05$). This is in agreement with Elfadil *et al* (1996) who found strong evidence for an association between increases in stocking density and the incidence and severity of abdominal scratches. This scratching is caused by birds climbing over one another when moving through the house (Vertommen *et al* 1989; Frakenhuis *et al* 1991). These scratches often become infected, particularly by *Escherichia coli*, leading to Scabby Hip Syndrome (an inflammation of the skin on the back, hips and thighs) (Glunder 1990).

Economic implications

The broiler industry is by far the largest sector of UK agriculture in terms of number of animals. In 1997, the national broiler flock totalled 792 million birds placed (MAFF personal communication 1998). Where such large numbers are concerned, small changes in husbandry practice can have far-reaching effects. For example, the apparently small rise in breast blistering with increasing stocking density in this study (from 0.25% to 0.41%, see Table 5) has important welfare and economic implications.

Most studies have shown an increase in stocking density to result in a reduced monetary return per bird but an increased output per unit floor area. For example, Shanawany (1988) found that profit margin increased linearly with stocking densities up to 75kg m^{-2} (although he questioned the welfare implications of such results). However, no study has fully addressed the effect of stocking density on carcase downgrading and condemnation in broilers reared and processed commercially.

Animal welfare implications

In general, an increase in stocking density leads to a reduction in the 'margins of safety' in rearing (Ekstrand 1993). Flock monitoring and management becomes increasingly difficult. There are also corresponding increases in the levels of ammonia, carbon dioxide, heat and humidity produced – and this can lead to a deterioration in air quality (Ekstrand 1993).

High ammonia levels (over 25ppm) have been shown to reduce chicken growth and increase dermatitis, air sac inflammation and keratoconjunctivitis (Algers & Svedberg 1989). High air humidity increases the incidence and severity of dermatitis (Martland 1985). An effect of stocking density on these factors would not have been apparent in the present study because the ventilation systems distributed air throughout the house. However, even if stocking density can be increased in some circumstances without a corresponding decrease in environmental quality, the possibility that welfare may still be adversely affected (for example, due to physical restrictions on movement) should be investigated.

The detrimental effects of high temperature on broilers were not a factor in this experiment as it was conducted during the winter. However, heat-stress problems remain a cause for concern within the broiler industry (Tegethoff & Hartung 1996) and are exacerbated by high stocking densities.

Stocking density can be expressed in terms of liveweight or number of birds per unit area. This experiment was designed in relation to current recommendations which are based on maximum liveweight densities. However, the number of birds per unit area is also an important welfare consideration. When the number of birds to be stocked per house is calculated, it should be remembered that the commercial and logistical pressures on processing plants mean that slaughter does not always occur on the planned day so the projected liveweight densities may be exceeded.

In conclusion, it is important to consider the welfare implications of stocking density within a commercial context as smaller-scale experiments may not adequately replicate all aspects of this environment. The results of this preliminary study indicate that an increase in stocking density from 34kg m^{-2} to 40kg m^{-2} has an adverse effect on aspects of broiler welfare. However, stocking density interacts in a complex way with other variables such as group size, hybrid type, temperature, ventilation, litter type, lighting and feeding programme (Ekstrand 1993). Therefore, further research is required to determine how stocking density affects welfare and economic return under the range of conditions found within a commercial operation.

Acknowledgements

I thank my supervisor, Professor Marian Stamp Dawkins, for her continuous support and encouragement. I also gratefully acknowledge the assistance of Premier Poultry Ltd with this project and especially Paul Cook and John Beeching. The work was financially supported by the UK's Ministry of Agriculture, Fisheries and Food. I thank Dr Georgia Mason and two anonymous referees for helpful comments on the manuscript. Statistical advice was provided by Dr Mario Cortina Borja of the Oxford University Statistics Department.

References

Algers B and Svedberg J 1989 Effects of atmospheric ammonia and litter status on broiler health. In: Faure J M and Mills A D (eds) *Proceedings of the 3rd European Symposium on Poultry Welfare* pp 237-241. World Poultry Science Association's Working Group 9 on Poultry Welfare: Nouzilly, France

Altmann J 1974 Observational study of behaviour: sampling methods. *Behaviour 49:* 227-267

Andrews S M, Omed H M and Phillips C J C 1997 The effect of a single or repeated period of high stocking density on the behaviour and response to stimuli in broiler chickens. *Poultry Science 76:* 1655-1660

Bessei W 1993 Der Einfluß der Besatzdichte auf Leistung, Verhalten und Gesundhet von Broilern. *Archiv für Geflügelkunde 57:* 74-77

Blokhuis H J and Van der Haar J W 1990 The effect of the stocking density on the behaviour of broilers. *Archiv für Geflügelkunde 54:* 74-77

Bolton W, Dewar W A, Jones R M and Thompson R 1972 Effect of stocking density on performance of broiler chicks. *British Poultry Science 13:* 157-162

Broom D M 1986 Indicators of poor welfare. *British Veterinary Journal 124:* 524-26

Cambac JMA Research 1996 *A Welfare Audit of Conditions During Transport and Handling of Broilers.* Cambac JMA Research: Draycot Cerne, UK

Coenen M, Schulzerkersting I, Zentek J and Kamphues J 1996 Effects of different housing conditions (stocking density) on performance of broilers and the composition of litter. *Deutsche Tierarztliche Wochenschrift 103:* 79-83

Cravener T L, Roush W B and Mashaly M M 1992 Broiler production under varying population densities. *Poultry Science 71:* 427-433

Dawkins M S 1988 Behavioural deprivation: a central problem in animal welfare. *Applied Animal Behaviour Science 20:* 209-225

Dawkins M S 1989 Time budgets in Red Junglefowl as a baseline for the assessment of welfare in domestic fowl. *Applied Animal Behaviour Science 24:* 77-80

Duncan I J H 1981 Animal rights – animal welfare: a scientist's assessment. *Poultry Science 60:* 489-499

Ekstrand L 1993 *Effects of Stocking Density on the Health, Behaviour and Productivity of Broilers. A Literature Review.* (Report 32. Swedish University of Agricultural Sciences). Swedish University of Agricultural Sciences: Skara, Sweden

Elfadil A A, Vaillancourt J P and Meek A H 1996 Impact of stocking density, breed and feathering on the prevalence of abdominal skin scratches in broiler chickens. *Avian Diseases 40:* 546-552

European Commission – Scientific Committee on Animal Health and Animal Welfare (2000) *The Welfare of Chickens Kept for Meat Production (Broilers).* European Commission: Brussels, Belgium

FAWC 1992 *Report on the Welfare of Broiler Chickens.* FAWC: Tolworth, UK

Frakenhuis M T, Vertommen M H and Hemminga H 1991 Influence of claw clipping, stocking density and feeding space on the incidence of scabby hips in broilers. *British Poultry Science 32:* 227-230

Glunder G 1990 Dermatitis in broilers caused by *Escherichia coli. Journal of Veterinary Medicine 37:* 383-391

Gordon S H 1992 The effect of broiler stocking density on bird welfare and performance. *British Poultry Science 5:* 1120-1121

Grashorn M and Kutritz B 1991 Der Einfluss der Besatzdichte auf die Leistung moderner Broilerherkunfte. *Archiv für Geflügelkunde 55:* 84-90

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

Kruijt J P 1964 Ontogeny of social behaviour in Burmese Red Junglefowl. *Behaviour, Supplement 12:* 1-201

Lewis N J and Hurnik F J 1990 Locomotion of broiler chickens in floor pens. *Poultry Science 69:* 1087-1093

MAFF 1998 *Animal Health and Welfare Research Requirements Documents, 1999-2000.* MAFF: London, UK

Martin P and Bateson P P G 1993 *Measuring Behaviour: An Introductory Guide, 2nd edition.* Cambridge University Press: Cambridge, UK

Martland M F 1985 Ulcerative dermatitis in broiler chickens: the effect of wet litter. *Avian Pathology 14:* 353-364

Martrenchar A, Morisse J P, Huonnic D and Cotte J P 1997 Influence of stocking density on some behavioural, physiological and productivity traits of broilers. *Veterinary Research 28:* 473-480

MathSoft S-Plus 4, Programmer's Guide 1997. Data Analysis Products Division, MathSoft Inc: Seattle, USA

Maxwell M H and Robertson G W 1998 UK survey of broiler ascites and sudden death syndrome in 1993. *British Poultry Science 39:* 203-215

McIlroy S G, Goodall E A and McMurray C H 1987 A contact dermatitis of broilers – epidemiological findings. *Avian Pathology 16:* 93-105

Murphy L B and Preston A P 1988 Time-budgeting in meat chickens grown commercially. *British Poultry Science 29:* 571-580

Newberry R C and Hall J W 1990 Use of pen space by broiler chickens: effects of age and pen size. *Applied Animal Behaviour Science 25:* 125-136

Petersen R A, Jones W T, Ilardi R L and Carpenter G H 1987 Effect of tetracycline hydrochloride and oxytetracycline hydrochloride on early mortality of broiler chicks from twenty-eight week old dams. *Poultry Science 66:* 158

Phelps A 1990 Crowding of broilers leads to profit. *Feedstuffs 62(35):* 12

Preston A, Pamment P, McBride G and Foenander F 1983 Some activity patterns of meat chickens. *Fifth Australian Poultry and Stock Feed Convention, Adelaide: 203*-207

Proudfoot F G 1973 Response of broilers to variations in waterer, feeder and floor space under continuous and intermittent photoperiods. *Canadian Journal of Animal Science 53:* 349-354

Proudfoot F G, Hulan H W and Ramey D R 1979 The effect of four stocking densities on broiler carcase grade, the incidence of breast blisters and other performance traits. *Poultry Science 58:* 791-793

Quinones R, Polanco G and Morejon O 1984 A comparison of three housing densities for broilers reared on the floor. *Revista Aviculture 28*: 241-249

Rose S P, Burnett A and Elmajeed R A 1986 Factors affecting the diet selection of choice fed broilers. *British Poultry Science 27:* 215-224

Samuels M L 1991 *Statistics for the Life Sciences.* Dellen Publishing Company: San Fransico, USA

Savory C J 1975 A growth study of broiler and layer chicks reared in single-strain and mixed-strain groups. *British Poultry Science 16:* 315-318

Scholtyssek S and Gschwindt B 1980 Untersuchungen zu Besatzdichte und Futterplatz in der Bodenmast von Broilern. *Archiv für Geflügelkunde 44:* 220-224

Shanawany M M 1988 Broiler performance under high stocking densities. *British Poultry Science 29:* 43-52

Tegethoff V and Hartung J 1996 A field study on stocking density and air-quality in broiler production and recommendations to avoid heat stress in summer. *Deutsche Tierarztliche Wochenschrift 103:* 87-91

Thorpe W H 1965 The assessment of pain and distress in animals. In: Brambell F W R (chairman) *Report of the Technical Committee to Enquire into the Welfare of Animals Kept Under Intensive Livestock Husbandry Systems: Cmnd 2836* pp 71-79. HMSO: London, UK

Vertommen M H, Frakenhuis M T and Hemminga H 1989 Scabby hips in broilers is a space problem. *Poultry Misset 5:* 40-41

Vonesh E F and Chinchilli V M 1997 *Linear and Nonlinear Models for the Analysis of Repeated Measurements.* Marcel Dekker Inc: New York, USA

Weaver W D jr, Beane W L, and Cherry J A 1982 Effect of light, feeding space and dietary energy on broiler performance. *Poultry Science 61:* 33-37

Weaver W D jr, Beane W L and Siegel P B 1973 Methods of rearing sexes and stocking densities on broiler performance. *Poultry Science 52:* 2100-2101