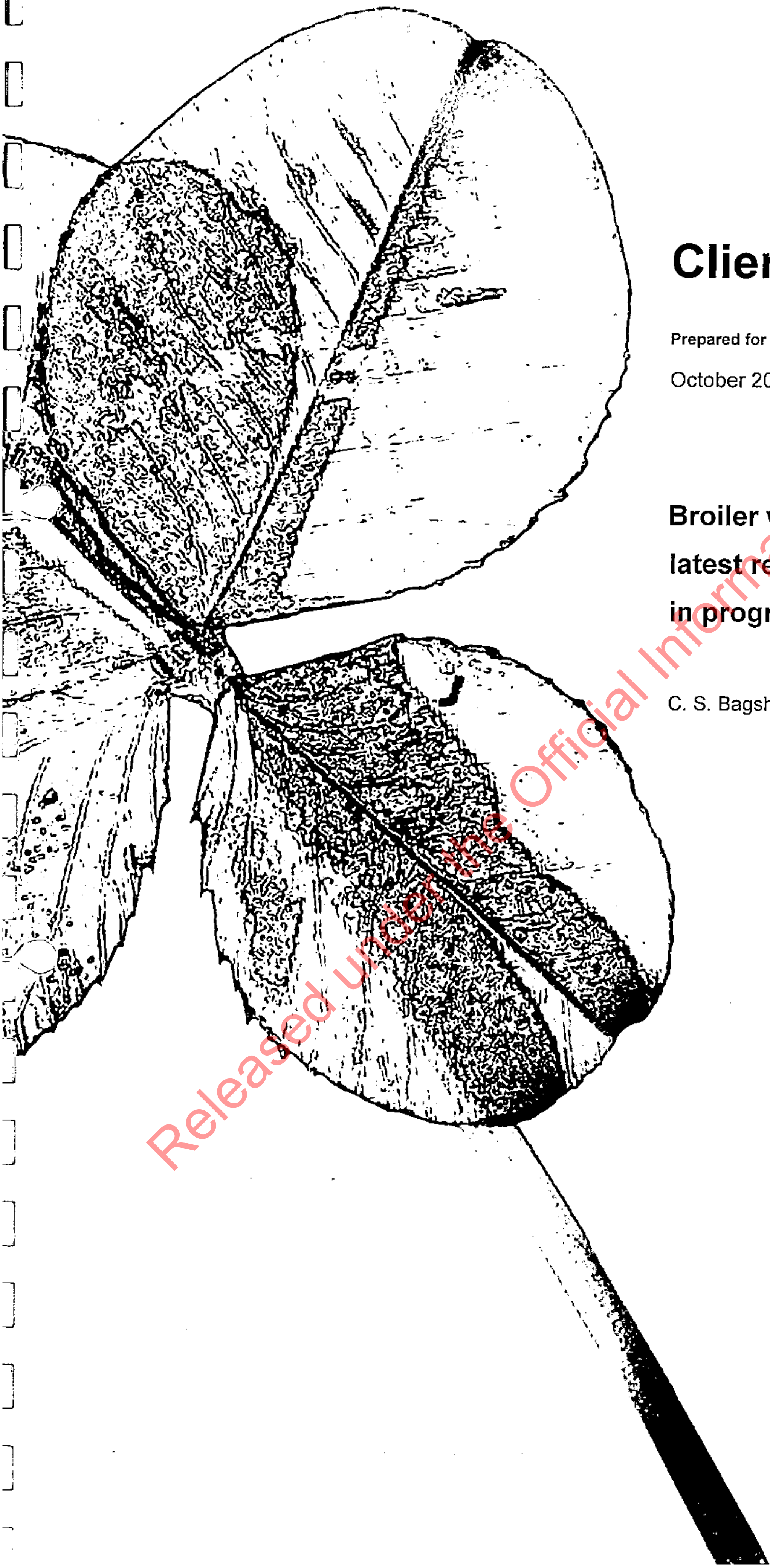

Client Report

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Broiler welfare - a review of latest research and projects in progress internationally.

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agresearch

Broiler welfare

– a review of latest research and projects in progress internationally

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EXECUTIVE SUMMARY

- The aim of this review is to survey the latest published research results and report on research projects in progress internationally, so that they can be considered in the development of welfare practices for broilers under NZ conditions. The review considers research relevant to broilers in the growing out (rearing phase).
- There is little legislation internationally to protect the welfare of broilers. Most Northern European countries have guidelines for specific broiler management practices, e.g. stocking density, but these vary considerably between nations.
- The major welfare issues include leg and mobility disorders, ascites, sudden death syndrome and lack of behavioural complexity. Each of these conditions is influenced by a wide range of genetic, health, environmental, feeding and other management related factors. Further, each health or welfare problem can influence the incidence of any or all of the other types of disorder.
- One key factor underlies most of the welfare issues: the fast growth rate of the broiler (due to intense genetic selection and nutrient supply). Many procedures have been developed to moderate the effects of fast growth on broiler health and welfare. Some of the most successful techniques reduce the rate of growth early in the rearing period; increase the level of locomotory activity; and, reduce the incidence of pathogens in the environment or incidence of diseases.
- Two management procedures that are particularly useful in stimulating locomotory activity are intermittent lighting and/or meal feeding. These techniques are not common practice in Europe or North America. This may be due to a perception (that is not supported by research) that broilers require an uninterrupted and prolonged dark phase each day. Reports from Denmark suggest that prolonged dark phases may induce other welfare concerns (e.g. increased foot-pad dermatitis).
- Leg disorders are also likely to be reduced through genetic selection.
- A new finding is that stocking density per se does not appear to be a major direct cause of most welfare problems traditionally associated with high stocking rates. Rather, it appears that factors such as poor control of litter quality and temperature, and other environmental conditions are more directly implicated.
- Behavioural restriction in broilers seems not to be influenced greatly by the lack of complexity of the rearing environment; rather, it is a by product of selection for rapid growth. Reduced scratching and walking, and disturbed resting activities are associated with high stocking densities. Research is required to determine if stocking

density or other variables e.g. litter quality/temperature are underlying causes of these behavioural changes. Such information is critical in devising appropriate management strategies to alleviate any problems.

- Since most broiler welfare issues are influenced in a complex way by a combination of genetic, environmental and management factors, it can be expected that welfare concerns will be addressed best by undertaking further research in, and implementing appropriate changes across, all of these parameters.

IMPLICATIONS FOR NEW ZEALAND BROILER INDUSTRY

- There are no published studies of the incidence of welfare problems in the New Zealand broiler industry.
- Since the New Zealand industry is free of some diseases, particularly infectious bursal disease (IBD), which is a strong immunosuppressant and has a role in the aetiology of leg disorders, and uses lighting regimes (intermittent lighting) reported to be beneficial for leg development, it would be surprising if the incidence of leg abnormalities and associated conditions (e.g. contact dermatitis) were not lower in New Zealand than elsewhere.
- There is no published information for New Zealand production on broiler behaviour, or on the status of the key environmental parameters (such as air and litter quality and temperature/humidity) which influence broiler welfare, or on the relationship of such measures to changes in stocking density.
- Details of welfare standards and performance in the New Zealand broiler industry are required so that they can be: (1) placed in an international context; and (2) used as a benchmark in the evaluation of alternative management strategies, should they be required.

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INTRODUCTION

Aim and contextual note

The aim of this review is to survey the latest published research results and report on research projects in progress internationally, so that they can be considered in the development of welfare practices for broilers under NZ conditions. The review considers research relevant to broilers in the growing out (rearing phase).

In March 2000 the European Commission (EC) published a report on the welfare of chickens kept for meat production, written by the scientific Committee on Animal Health and Animal Welfare (ECSCAHAW) (Berg et al., 2000). The report is a thorough exposition of the literature on this subject up to the year 2000. In our review, there is reference to this report and a summary of the main points where appropriate. On occasions, our interpretation of the research differs from that presented in the ECSCAHAW report. In addition, the more recent international literature is presented, including personal communications with researchers currently conducting research on broiler welfare. In particular, this review provides a context in which welfare conditions in the NZ broiler industry can be assessed. Unfortunately, there is no published information on the welfare of broilers in NZ which can be used to compare with international benchmarks of broiler welfare.

The first section describes normal behaviour of the domestic fowl, and welfare considerations and legislation or recommendations currently in place to protect poultry welfare in commercial broiler production. The second section details diseases and pathologies associated with broiler chickens, in particular the most common side effects of fast growth rate, being several types of leg weakness and other diseases such as ascites and sudden death syndrome. The third section of the review discusses the latest research on welfare issues associated with general environmental factors in broiler production system.

SECTION 1 – POULTRY BEHAVIOUR AND BROILER WELFARE

The extent of world-wide commercial broiler chicken meat production has been estimated as 20 x 10^9 which is concentrated in a few countries, with the US representing 24%, China 18.5%, and EU 14% (Berg et al., 2000). New Zealand produces an estimated 68 million (0.3% of world production) broiler chickens annually.

NORMAL BEHAVIOUR THE DOMESTIC FOWL (GALLUS GALLUS DOMESTICUS)

The domestic fowl is descended from the red jungle fowl (Gallus gallus). There are a variety of different strains of domestic fowl, some bred primarily for laying eggs and others bred primarily for meat production (in this report the terms fowl, poultry and chicken refer to G. gallus and its descendants, unless otherwise stated). An adult jungle fowl usually weighs below 1 kg, a weight reached in a few weeks by the modern broiler chicken. The growth rate of the modern broiler has increased dramatically as a consequence of genetic selection. Intense selection for growth has resulted in modern broilers growing almost three times as fast (during the period of maximum growth) as the breed they were derived from 40 years ago (Sandoe et al., 1999). Poultry have well-developed visual (visual field 330°, colour vision) and auditory systems (sensitive to frequencies in the range of 15 to 10 000 Hz). There have been few basic changes in the behaviour patterns of the domestic poultry from their ancestral stock. Jungle fowl are omnivorous, and spend up to 61% of their time ground pecking, which is similar to free range domestic chickens. Broilers show a wide range of behaviours typical of other strains of domestic fowl or ancestral stock. However, the frequencies, durations or thresholds for some activities appear to be different in broilers (for example, broilers spend more time sitting and less time walking, standing and foraging than layers (Gerken & Jaenecke, 1997). There seems to be a genetic (as well as an environmental) contribution to these differences, possibly as a result of the way that behaviour is organised. Bizeray et al. (2000) showed that behavioural differences between fast and slow growing strains were manifest within the first 3 days of age, even though the fast growing chickens were lighter at this time. The relevance of behavioural differences between poultry strains to welfare is discussed below. For further discussion on the behaviour and biology of the domestic chicken, refer to ECSCAHAW (Berg et al., 2000).

WELFARE

Welfare is clearly a characteristic of an individual animal and is concerned with the effects of all aspects of its genotype and environment on the individual (Duncan, 1981). The welfare of an animal has been defined by Broom (1986) "as the animals state as regards its attempts to cope with its environment". Welfare includes the extent of failure to cope, which may lead to disease and injury. Other researchers suggest that the welfare of farm animals can be considered in relation to the housing and management conditions (Berg et al., 2000). The welfare of the animals is good when all the needs associated with the maintenance of good health, and the need to show certain behaviours have been met (Animal Welfare Act, 1999). Such concepts are embodied in the five freedoms, which have often been used as the basis for farm animal welfare recommendations.

In conclusion, welfare assessment requires a wide range of indicators, even though a single measure may indicate that welfare is poor. There are many aspects of broiler production which may impinge on the welfare of the animals, such as the incidence of leg weakness and its consequences.

LEGISLATION OR RECOMMENDATIONS FOR THE WELFARE OF BROILERS

Berg et al. (2000) in the ECSCAHAW report stated that legal regulations for broiler rearing exist only in Sweden and Switzerland. In addition, in some countries in Europe there are official recommendations for broiler production standards (UK, Germany), but in most countries in Europe, the production follows the recommendations of breeding companies, feed manufactures or advisory services. In the US, the National Chicken Council is currently developing welfare guidelines for management of broilers, to be undertaken by producers on a voluntary basis (Estevez, 2001). Within Canada, a committee representing the poultry industry, animal welfare groups and animal scientists are currently refining 'codes of practices' for poultry producers (Duncan, 2001). Similarly in New Zealand a code of Recommendations and Minimum Standards for the Welfare of Broiler Chickens has been developed by NAWAC with representation from the poultry industry, animal science, veterinary profession, RSPCA and the public. This code is currently being refined to fit with the requirements of the new Animal Welfare Act (1999).

Stocking density is one of the contentious issues in broiler welfare and is one of the key factors that is discussed in the recommendations in ECSCAHAW (Berg et al., 2000). Table 1 lists stocking densities for a range of countries. There is considerable variation between countries in recommended maximum densities. Some researchers (Berg et al., 2000) have argued that broilers reared on litter at stocking densities equal to or exceeding 30 kg m^{-2} (approximately 20 birds m^{-2}) have a tendency for growth rate depression. We will argue later that stocking density, per se, is not necessarily the main factor influencing broiler welfare or growth.

Table 1. Legal requirements and maximum stocking density on the day before slaughter

Country	Maximum Stocking density	Legislation/recommendations
Canada	31kg m^{-2}	Codes of Practice
Denmark	25 to 29 birds m^{-2} (Up to 44kg m^{-2})	Recommendation
Switzerland	30 kg m^{-2} (20 birds m^{-2})	Legal requirement
Sweden	20 to 36 kg m^{-2}	Legal requirement
New Zealand	40 kg m^{-2}	Recommendation
United States	8 kg m^{-2} to 11kg m^{-2}	Actual stocking density in commercial situations
United Kingdom	34 kg m^{-2} to 40 kg m^{-2}	Recommendation to actual stocking density in commercial situations

In Sweden, maximum stocking densities can vary (based on welfare performance) between 20 to 36 kg m^{-2}, as set by the animal welfare programme for broilers in Sweden, which is an agreement between the production advisors, veterinarians and the Swedish National Board of Agriculture. Stocking density is lowered if welfare is not acceptable. In Switzerland, the law for animal protection limits stocking density to 30 kg m^{-2} (20 birds m^{-2}) (Berg et al., 2000). Within the UK, the Farm Animal Welfare Council (FAWC) and the Ministry of Agriculture, Fisheries and Food (MAFF) currently state that stocking densities of 34 kg m^{-2} should not be exceeded. In practice, in the UK the maximum broiler stocking density is approximately 40 kg m^{-2} (Hall, 2001). Within Canada, codes of practice for poultry producers state that the maximum stocking density be 31 kg m^{-2}, although Duncan (2001) says that in practice stocking densities are generally lower than the recommended levels. As yet, no maximum stocking densities have been set in the US, although currently stocking densities for broilers in the US are lower compared to Europe. The Codes of Recommendations and Minimum Standards in New Zealand currently state that maximum stocking density should be 36 to 38 kg m^{-2}, although in extraordinary circumstance (such as natural disaster) there is allowance for the stocking density to increase to 40 kg m^{-2} (Anon, 1999).

TYPICAL REARING (GROWING OUT) ENVIRONMENT

Berg et al. (2000) gives a full description of rearing conditions in Europe, which are not dissimilar to conditions in countries such as Canada and New Zealand. In most Northern European countries, commercial broiler houses are enclosed buildings with insulated roofs and walls, with concrete floors. The buildings are usually windowless and force ventilated. They generally have concrete floors, which are covered with litter (e.g. straw, wood-shavings, peat, and paper). However, in France the majority of houses do not have concrete floors (89%) and only 54% of them are windowless. In the US, broiler chickens are reared in conditions either similar to Northern European countries or in the so-called Louisiana system. The Louisiana system buildings are open-sided and naturally ventilated, and the ventilation rate can be controlled automatically by curtains. The floors are covered with deep litter (40cm), which is removed after 5 to 7 batches of broilers. The buildings and running costs of the Louisiana system are lower compared to the conventional system, and probably due to this, there has been an increase in the use of the Louisiana system in European Union (EU). In New Zealand, the broilers are generally reared in environmentally controlled, enclosed housing, with concrete floors and litter, which are constructed in such a way as to minimise risk of injury and disease (Anon, 1999).

Three types of lighting programmes are typically used for broiler production: (1), natural or pseudo natural rhythms; (2), continuous or near continuous illumination; (3), intermittent illumination. Full descriptions of these lighting programmes may be found in the report on the welfare of broilers (Berg et al., 2000), and a summary of the latest research on lighting regimes is given in a section below. Major welfare issues in broiler production are leg disorders, ascites, sudden death syndrome and other health issues. Other welfare concerns arise specifically from environmental factors such as heat or behavioural restriction.

SECTION 2 - DISEASES AND PATHOLOGIES OF BROILERS

Broilers have been selected for rapid growth and increased feed conversion rates (FCR). Unfortunately, these genetic improvements, and associated improved nutritional regimes, contribute to a range of welfare problems commonly seen in modern broilers when they are fed ad libitum (or close to ad libitum).

The main welfare issues associated with rapid growth are leg disorders, ascites and sudden death syndrome (SDS), metabolic and muscular disorders, and behavioural restriction. Contact dermatitis is another common disorder, which may be associated with for example behavioural inactivity, which itself is influenced by the rapid growth rate of broilers (along with other factors). There are a wide range of other potential welfare concerns in broiler production systems that, on the surface, appear to be more associated with environmental factors in the rearing facilities. Such issues relate to levels of harmful gases (e.g. ammonia), or dust, ambient temperatures and humidity, long light periods, lack of environmental and behavioural complexity, high densities of birds, and accessibility of water.

However, and not surprisingly, it is unlikely that any of the health and welfare issues that are seen commonly in broiler production systems are uniquely associated with any single causal factor. For example, the prevalence and severity of leg disorders are influenced by a wide range of genetic and environmental factors, including infectious agents, feeding regime, lighting programmes, litter quality and ventilation. An increase in the incidence of one type of disorder (leg weakness) can influence the prevalence of other disorders (e.g. sudden death syndrome or contact dermatitis).

MOBILITY AND LEG DISORDERS

Broiler lameness and leg weakness is a major cause of commercial loss through mortality, culling and reduced performance (Butterworth, 1999) and welfare concern. Lameness has been shown to be prevalent in commercial broiler chickens reared under a variety of conditions (Sorensen et al., 1999). In a recent report for the Compassion in World Farming Trust (Stevenson, 2000), lameness and leg weakness were viewed as the most serious health and welfare issue affecting broilers. The Farm Animal Welfare Council, a British Government welfare committee (FAWC, 1992 in Butterworth 1999) set up a working group to assess the welfare of broiler chickens. They found that there were large variations in the degree of severity of leg problems, from birds that were able to walk easily, to the worst cases where birds were unable to move to food and water. When animals are unable to access food and water the welfare is very poor, and Butterworth (1999) suggested that such animals ought to be humanely killed immediately. Between these extremes the FAWC working group observed many birds exhibiting varying degrees of gait abnormalities.

Another major welfare concern with leg disorders is the likelihood that the affected birds experience significant pain. This is discussed in more detail below. The Farm Animal Welfare Council (FAWC) in the UK (Anon, 2001) recently completed a seven-year survey on leg health in commercial broiler production. They found no improvements in welfare of the birds, particularly with regard to leg problems, over this time. In a letter to the parliamentary secretary for the Ministry of Agriculture the chairman of FAWC (MacArthur Clark, 2000) has expressed disappointment about the lack of progress the broiler industry has made in improving leg health in broiler production. Similarly, the Danish Animal Welfare Society and the Danish Poultry Council in 1998 launched an investigation to estimate the prevalence of leg problems in conventional broiler production in Denmark, under continuous lighting and at high stocking densities (25 to 29 birds m^{-2} or up to 44 kg m^{-2}) (Sanotra, 2000b). They found that the prevalence of leg problems was high (about 30% of birds were scored as having high to severe gait abnormalities) with leg weakness due to either a common fast growth rate pathology (tibial dyschondroplasia (TD), 57.1 %) (Sanotra, 2000b).

Causes and incidence of leg disorders

The potential causes of lameness in broilers are many faceted and have been discussed recently by Sorensen et al. (1999) and Butterworth (1999). Much of the lameness in modern genotypes of broilers is linked to pathologies and skeletal abnormalities. It has been proposed that these abnormalities are a function of the birds' rapid growth rate, which results in abnormally high loads being placed on relatively immature bones and joints (Webster 1995 cited in Kestin 2001). Rath (2000) has found that bone fragility in young birds is not only due to rapid growth, but also maturity (in terms of the architectural aspects such as collagen crosslink content of bones) and physical activity, as bone mass and strength are increased with use, genetics and nutrition. Kestin et al. (1999) found leg problems varied among different genetic lines of commercial chickens, and the causes of leg weakness was associated with a large variety of problems such as tibial dyschondroplasia, foot-pad burn, hock burn and angulation of the hock joint. Ducro and Sorensen (1994, cited in Sandoe et al. 1999) have reported that the heritability of tibial dyschondroplasia (TD) is relatively high and would appear to be improveable with genetic selection. However, after a number of years of broiler companies selecting against TD, incidence has decreased but broiler gait has not improved as much as would be predicted by the decrease in TD. This suggests that other types of leg disorders are the major cause of gait problems, or that these disorders are increasing in the broiler population. Sanotra (2000a) has suggested that much of the published literature on TD incidence in broilers is no longer relevant due to the genetic progress made in selecting against TD. Leg disorders are also related to feeding regimes. Rath et al. (2000) reported that both organic and inorganic nutritional factors are likely to be important to poultry bone strength. The most relevant inorganic factors are calcium and phosphorus, and collagen is the major constituent of the organic factors contributing to the tensile strength of bone. Whitehead (2001) has reported that supplementation with specific vitamin D metabolites can reduce, or even eliminate, TD incidence. Therefore, it is likely that diet can be changed to improve bone strength, and perhaps overall leg health. Liveweight of birds has often been thought of as contributing to lameness. Kestin et al. (2001) studied thirteen genotypes of poultry, ranging from intensive hybrids to traditional 'dual purpose' breeds. The birds were fed one of two feed rations (non-limiting or Label Rouge ration). The birds were weighed and assessed for lameness at 54 and 81 days of age. Kestin et al. (2001) found that live weight was the major determinant of lameness of the birds at both ages regardless of feeding ration. In addition, they found that younger birds were less able to walk compared with older animals, which tended to suggest that when birds are growing rapidly they tend to be lamer than slower growing broilers. In contrast, Yalcin et al. (1998) found that animals on low protein diets with resulting lower body weights had poorer walking ability at 7 weeks (49 days) of age compared to birds on medium or high protein diets with higher body weights. The reason for the results in the latter study was inconclusive.

Other management and environmental factors are also involved in the aetiology of leg disorders. These factors include stocking density, light cycles and intensity, ambient temperature and humidity, ammonia levels, litter quality and floor type (Reiter & Bessei, 1998).

The types of leg disorders their causation, and remediation strategies are presented in the following sections.

Pathologies causing leg disorders

The ranges of pathologies causing broiler lameness are bacterial, viral or fungal in origin.

Bacterial

Staphlococci bacteria appear to cause a number of infections of the joints, tendons and skin, which result in lameness. Bacterial chondronecrosis (BCN, also known as femoral head necrosis) appears to occur when staphylococci, usually S. aureus, overcomes the birds local immune response, circulate in the blood and establish themselves, forming micro-abscess. However, the entry route of the bacteria is as yet not fully understood (Butterworth, 1999). McNamee et al. (1998) found that bacterial chondronecrosis associated with S. aureus has been identified as an important cause of leg weakness in commercial broilers, but in a further study McNamee & Smyth (2000) found that BCN was highly likely to be under diagnosed. In addition, staphylococci may cause localised bone infection of the vertebrae (commonly between T3 and T7), causing bone necrosis and compression (osteomyelitis of the vertebrae - spondylitis), which results in birds performing a characteristic hunched posture, where the animal rests back on the caudal aspect of its legs (Butterworth, 1999). McNamee & Smyth (2000) reports that the exact pathogenensis of BCN is unknown, but it is thought that adherence of blood-borne bacteria to exposed cartilage at the tips of metaphyseal blood vessels is fundamentally important. In an experiment, McNamee & Smyth (2000) found that BCN incidence was increased when birds were infected with immuno-suppressive viruses such as chicken anaemia virus and infectious bursal disease (IBD) virus, while restricting feed intake reduced the incidence of the disease. In addition, they found that it is possible by good management and bio-security to at least to reduce the incidence of viruses such as chicken anaemia and bursal disease. Arthritis and tenosynovitis result from the colonisation of the synovia (sheaths) by staphylococci and result in inflammation of the hock tendons and joints. Gangrenous dermatitis and sternal bursitis may be caused by staphylococci alone or in combinations with Clostridium perfringens type A. The skin lesions may be moist and gangrenous and create changes in gait or in ability to sit.

There are a number of other bacteria, namely E.coli, Salmonella genus, Pasturella genus, and Mycoplasma genus that have all been implicated in acute and chronic lameness in broilers associated with arthritis, synovitis and tenosynovitis.

Viral

The genus Reovirus has been associated with many lameness conditions, such as tenosynovitis and tibial dyschondroplasia. Butterworth (1999) reports that the age of the birds when they are infected with the virus and food availability alter the progress of the disease. Birds inoculated with Reovirus at 1 day old had more organs infected compared to birds inoculated at 1 week old (Roessler & Rosenberger, 1989). Timms (1985) found that a combination of 125g kg^{-1} rapeseed and inoculation with Reovirus appeared to give an increase incidence of tenosynovitis and tibial dyschondroplasia when compared with inoculated but normally fed birds.

Adenoviruses have been described as a cause of, or contributory factor in, tenosynovitis, sometimes in association with Reoviruses. However, the link between adrenovirus and tenosynovitis has not been clearly demonstrated (Butterworth, 1999).

A herpesvirus such as Marek's disease (MDV) affects chickens from 6 weeks of age, and is a cause of neurological lameness. However, MDV is very low in commercial broilers as most meat birds are harvested at 42-55 days of age.

Paramyxoviridae such as Newcastle disease (NDV) has been implicated in the increased incidence of leg weakness, paralysis of the wings or legs and ataxia, however, in relation to the amount of lameness observed in most commercial broiler flocks, the link with NDV is not considered important (Butterworth, 1999).

Fungal

Fungal infections act either directly on the skeletal tissues or indirectly through the feed in the form of fungal toxins (Butterworth, 1999).

<u>Developmental leg disorders</u>

The most common form of developmental leg disorder in broilers results from dyschondroplasia, typically in the tibia (hence tibial dyschondroplasia, TD). TD is manifested in hock joint distortions of the varus or valgus type (inward or outward rotation of the feet). Genetic and nutritional factors are implicated in the development of TD. In severe cases, the growth plate may be fractured. The prevalence of TD is greatest between 2 and 5 weeks of age (Lynch et al., 1992). Angular rotations of the varus/valgus type can also occur through distortions of the long bone or stifle joint.

Leg disorders and welfare concerns

The major welfare concerns with leg disorders are derived from the likelihood that the birds experience pain or discomfort from the disorders, and to the inability of lame birds to properly carry out essential functions.

Gait analysis

In an effort to objectively assess leg disorder problems in poultry Kestin et al. (1992) developed a lameness scoring system, which has been used frequently to assess the mobility of broilers. The lameness of these birds was assessed using a lameness score of 0 to 5. Birds with a score of 0 have a normal and agile walking style and inclination. Birds scoring 1 and 2 have slight defects of varying degree that result in abnormal gait which does not seriously compromise the ability of the birds to move. In birds with a score of 3, the gait defect impairs walking ability to the extent that the bird has a limp, with a jerky or unsteady strut, and loss of manoeuvrability, acceleration and speed. The birds often prefer to squat when not forced to move. Score 4 birds have a severe gait defect and birds with score 5 are incapable of sustained walking (Kestin et al., 1992). High scores have been associated with femoral head necrosis and lower scores have been associated with TD (Bradshaw et al., 2001).

Pain and lameness

It is difficult to determine if animals experience pain. In recent times, a number of researchers have attempted to assess if pain is associated with leg problems by giving the animal analgesics, and recording the changes in behaviour when the animals cannot feel pain, thereby, indirectly indicating if some sort of pain or discomfort is experienced under normal circumstances. McGeown et al. (1999) used an analgesic, carprofen, to identify if broilers with an intermediate gait score (3) experienced pain when walking. In this study, the ability of lame (score 3) and sound (score 1) birds to traverse an obstacle course was measured after treatment with the analgesic, placebo saline injection, or after being handled (control). Birds were 4 weeks old at the beginning of the study. Sound birds negotiated the course in 11 seconds compared to lame birds who took 38 seconds. Lame birds given carprofen took 18 seconds to traverse the course, which provides evidence that birds with moderate lameness suffer pain when they walk. Weeks & Kestin (1997) observed that lame birds spent less time in activities that required them to stand. Danbury et al. (2000) trained birds to discriminate between different coloured feeds, one of which contained carprofen (analgesic drug). They found that lame birds selected more drugged feed than sound birds, and that, as the severity of the lameness increased, lame birds consumed a significantly higher proportion of the analgesic feed. Danbury et al. (2000) concluded that lame birds may have eaten more analgesic in order to reduce pain. Similarly, Hocking et al. (1999) counted the number of steps lame and sound turkeys at 54 weeks of age took over a 24 hour periods in their pens. He found that when the turkeys were given an intra-muscular injection of an analgesic (betamethazone) there was no difference in the number of steps taken by lame or sound birds. From these four studies, it appears that there is some indirect evidence that poultry feel pain or discomfort when they exhibit lameness. Gentle (2001) suggests that determining if an animal can feel pain, rather than simple nociception, depends to a large extent on being able to demonstrate a cognitive emotional response to noxious stimulation. In the latest published research, Gentle (2001) took a novel approach to understanding pain perception in chickens. He examined the response of chickens with (presumed) induced pain to changing environmental or physiological stimulation. Gentle (2001) induced tonic pain in chickens by injecting the ankle joint with sodium urate, and then subjected the birds to one of three environmental conditions; battery cage, familiar pen with another chicken, or novel pen with another chicken (both pens had wood shavings on the floor). Birds in pens showed less pain related behaviours compared with birds in cages, and birds in the novel pen the least number of pain responses. In another experiment, Gentle (2001) induced tonic pain in the ankle of laying birds 1 to 2 hours before egg laying. All birds showed normal pre-laying behaviour, and none showed any lameness. He suggested that during this period the birds were totally occupied in finding a suitable nest site, and they seemed totally unaware of the pain in their ankle. After oviposition the birds fed briefly and then showed pain-related behaviour (either standing on one-leg, or sitting). From these experiments, Gentle (2001) suggests that perception of pain may be reduced through changes in the motivational state of chickens. In another experiment, Vestergaard & Sanotra (1999) investigated whether poultry were experiencing pain or discomfort through limiting their opportunity to dustbath. They measured the duration of dustbathing after the bird had been deprived of access to a dustbath. When the lame birds had free access to the dustbath, they bathed 2.34 times less often compared with non-lame birds. However, when the lame birds were deprived of the opportunity for dustbathing, and then given free access again, the frequency of dustbathing increased by the lame birds. This was thought to be a rebound effect, and Vestergaard & Sanotra (1999) suggested that there is a trade off between the motivation to dustbathe and pain experienced by the animals.

To summarise, the expression of pain related behaviours decreases (or is absent) when chickens engage in other high priority activities (e.g. dustbathing, nesting, exploration in a novel environment). The interpretation of such changes in behaviour remains unclear. The reductions in pain related behaviours may indicate that the birds do not perceive pain (or as much pain). Repeating the types of experiment conducted by Gentle, but with the addition of analgesics to half of the birds may provide some insight into the degree of pain relief provided when performing other behaviours. Alternatively, the changes in behaviour may simply reflect the immediate needs of the animal without any change in perception of the degree of pain. Recent research with humans suggests that the perception of pain is reduced when they are distracted by other activities (e.g. viewing videos). If similar processes are operating in poultry, the human research would suggest that engaging in alternative behaviours reduces the perception of pain. Further research is required to refine models of pain perception in poultry, to determine the degree to which pain may be experienced or modified by performance of other high priority activities, and to identify appropriate (if required) pain relief strategies.
Since some behaviours, such as dustbathing, are reduced when chickens are lame, Vestergaard & Sanotra (1999) suggested that reduced dustbathing may be used as a measure of the welfare of broiler chickens.

Behavioural restriction

If lameness were to prevent birds from carrying out normal activities this would also give rise to welfare concern. There is some evidence (Vestergaard & Sanotra, 1999, Gentle, 2001) that lameness in broilers alters their normal behavioural patterns. Weeks et al. (2000) observed the behaviour of sound and lame broilers between 39 and 49 days of age, fed ad libitum and housed in pens (similar conditions to commercial production in the UK). They found that sound birds ate while standing and had 50 meals in a 24 hour period, compared to lame birds who spent half of their feeding time eating while lying down, and had 30 meals a day. There was no difference in the amount of food consumed between sound and lame birds. In contrast, research by Hall (2001) in commercial poultry units found no difference between feeding times, or number of feeding bouts between animals reared at high (40 kg m^{-2}) or low (34 kg m^{-2}) stocking densities, despite the frequency of leg problems being greater at higher stocking densities compared to lower stocking densities in this study.

However, it ought to be noted that Hall (2001) observed animals throughout their growing period whereas Weeks et al. (2000) observed birds for 10 days late in the growing period, when leg problems tend to be higher compared to earlier in the growing period. Thus, differences may have been difficult to detect in the Hall (2001) study.

Methods to improve leg disorders

As mentioned previously, the causes of leg disorders are multi-factorial in nature, although the beneficial effects of changes to all or any of the management factors implicated in the condition appear to operate through two main mechanisms only:

(1) Changes to (i.e. slowing) early growth rate

(2) Increases in locomotory activity

Even these two processes are related, in that slowing early growth can exert its effects via an increase in mobility. There are additional benefits from slowing growth and increasing activity, such as reductions in SDS and less behavioural restriction.

Slowing early growth

Earlier work on this topic has been reviewed in the ECSCAHAW report (Berg et al., 2000). Growth can be restricted by qualitative (e.g. feeding mash instead of pellets, or increasing the dark phase) or quantitative means (e.g. providing less food). To gain the benefits for leg health, it is important that the restriction (maintenance level intake) take place from around 4 days of age for periods of 5 to 6 days (Fontana et al., 1992). The greater the degree of restriction (up to 75% of growth achieved with ad libitum feeding), the lower the incidence of TD and the greater the improvement in mobility at 6 weeks of age (Su et al., 1999). These effects are primarily a function of reduced body weights, as when body weights were taken into account, there were no significant effects of feeding restriction or TD or walking. In another study, (Lippens et al., 2000), low levels of food restriction (90% of ad libitum) for short periods (4 days) had no effect on final body weights but neither was there any reduction in leg abnormalities. Of note, Lippens et al. (2000) reported a reduction in mortality on the restricted diet. One possible reason for the reduced mortality in Lippens' et al. (2000) study might be due to changes in activity of an intramuscular enzyme. Hocking et al. (1998) reported that muscle damage (such as heart muscle damage associated with ascites) is associated with increases of an intracellular muscle enzyme (creatine kinease), and he found that activity of this enzyme was reduced by food restriction in broiler turkeys.

Making food availability in distinct bouts (meals) is reported to be more effective in improving walking ability and reducing the severity of TD than restrictive feeding early in life (Su et al., 1999). Birds were offered two, three, or four meals per day or ad libitum feed. When the broilers were fed fewer meals per day they had lower body weights at 28 and 35 days of age compared to those fed more meals or fed ad libitum. Even when the data were adjusted for body weight, it was found that birds fed fewer meals had less tibial dyschondroplasia (TD), less hock burn and better walking ability than those fed more meals or ad libitum.

<u>Increasing locomotor activity</u>

The beneficial effects of meal feeding may be mediated by the (increased) levels of activity reported in broilers when they raised on intermittent feeding schedules (Haye & Simons, 1978). The birds tend to feed and be more active early and late in the meal feeding periods. Reiter & Bessei (1995) have demonstrated that additional activity on a treadmill leads to improved mobility. A convenient and effective way to schedule meals is to arrange an intermittent lighting schedule, where there are several light (L) and dark (D) cycles each day. The periods of light create distinctive meal times. Common patterns of intermittent lighting are 4L:2D (4 times per day) or 6L:2D (3 times per day). If leg problems are becoming an issue, then a schedule with a greater dark period can be helpful (e.g. 6L:6D (2 times per day) (Marks, 2001). Rose et al. (1996 cited in Bizeray, 2000) have suggested that activity in the first few days of life may be particularly beneficial for leg development, as this is an essential phase for bone development. There are likely to be many other ways to induce additional activity in broilers to improve mobility, including:

(1) increasing unpredictability of the feeding regime. Boon et al. (1999) studied the behaviour of Japanese quail chicks subjected to three feeding regimes; 17.5 h feeding, 6 h feeding with the start of feeding period at the same time each day, and 6 h feeding

with the start of feeding period at an unpredictable time every day. Growing quail subjected to predictable restricted feeding grew at the same rate as birds with unrestricted diets. Quail exposed to unpredictable feeding conditions gained less body mass than birds that received the same amount of food per day but at fixed times. Activity of quails was higher in the first two hours of food availability when the birds were on either a predictable or unpredictable 6 hour feeding regime. However, birds on the unpredictable feeding regime increased their activity level and feeding behaviour at the end of the feeding period (Boon et al., 1999).

(2) placing feeders and waterers at greater distance from each other (e.g.12 m instead of 2 m (Reiter & Bessei, 1996). Care needs to be exercised in instituting this procedure routinely, as lame animals probably experience pain while moving and may be severely disadvantaged if they are required to walk greater distances for essential nutrients.

(3) increasing light levels (Newberry et al., 1988) or intermittency of light (Haye & Simons, 1978). There is no evidence that broilers prefer to have a long period of continuous dark (Savory & Duncan, 1982). Shorter but more frequent Light: Dark cycles may better fit with normal short-term rhythmic activity patterns of broilers as described by Reiter & Bessei (1999). Very long photoperiods (22 to 24 hr) can adversely effect development of the eyes (Li et al., 1995).

(4) reducing heat stress and improving air quality (Grashorn & Kutritz, 1991). High air temperatures reduce activity levels (Reiter & Bessei, 2000b). Two important recent studies indicate that heat stress is a feature of broiler production systems, particularly for birds kept at higher densities. McLean et al. (2001) recorded the behaviour of male and female broilers at each of three stocking densities (28, 34 and 38.5 kg m^{-2}). There was no significant effect of stocking density on any class of behaviour other than deep panting, with less deep panting being shown at the lowest density (28 kgm^{-2}) late in the grow out period (5 and 6 weeks). One third of low-density birds were deep panting at this time, compared with 47% and 51% of the 34 and 38.5 kg m^{-2} birds, respectively. Interestingly, females were more likely than males to be deep panting late in the rearing period. The air temperatures in broiler houses are usually measured above the birds. Reiter & Bessei (2000b) has shown that the temperature between the birds and in the litter surface is up to 8°C higher at high (40.2 kg m^{-2}) than at lower densities (19.4 and 30.0 kg m^{-2}), even though the air

temperature at the usual site for measurement (1m above birds) is maintained in the normal range (22°C). Therefore, it would seem that the normal procedures for measuring and managing environmental temperatures are inadequate. Further, high litter and between bird temperatures at high stocking densities are a cause of heat stress and welfare concern as indicated by the high levels of deep panting measured in McLean's et al. (2001) study. Further, heat stress is likely to further inhibit activity levels (Nichelmann, 1986 cited in Reiter & Bessei 1999) in birds at 5 and 6 weeks of age, which are already very inactive, thereby exacerbating leg problems due to a lack of locomotory activity. Litter and air temperatures at high stocking densities can most likely be managed to within acceptable ranges by introducing improved temperature monitoring and air or litter cooling systems.

(5) improving litter quality

(6) developing genotypes which maintain adequate locomotory behaviour throughout the rearing period. Reiter & Kutritz (2001) have shown that there are large strains differences in walking which cannot be explained by differences in growth rate or behaviour. Reiter & Bessei (2001) have also demonstrated that weight per se is not the main factor contributing to reduced locomotory behaviour in broilers aged 4 weeks or more. Bizeray et al. (2000) observed the behaviour of two genetic types of chicken (fast and slow growing animals) in a commercial situation throughout the growing period. They found that in the first 3 days slower growing chickens spent twice as much time walking, standing and the number of steps taken, compared to the faster growing birds. This result cannot be explained in terms of live weight, as faster growing birds were lighter than slower growing birds in the first 3 days of life. It appears that there may be a genetic component to the locomotory behaviour of young chicks.

This suggests that it might be possible to develop genotypes with improved locomotory ability, and that growth rate may not necessarily be sacrificed in the process. In fact, the genetic correlation between leg problems and body weight is sufficiently low (0.25) (Le Bihan-Duval, 1995) to suggest that it may be possible to select for increased body weight at the same time as selection for decreased incidence of leg disorders. Van Kaam et al. (1999) has been undertaking experiments to enable quantitative trait loci (QTL) mapping of carcass traits (carcass weight, carcass percentage, meat colour and leg score) in the whole genome. Some of these traits cannot be measured on living animals which is thought to hamper selection, therefore utilisation of QTL marker assisted selection could aid animal breeders. In addition, this technique might have uses in selecting for better leg scores (Van Kaam et al., 1999). Van Kaam et al. (1999) had previously found a number of QTLs have an influence on feed intake in broilers. In this study, they found QTLs associated with two (carcass percentage and meat colour) of the five analysed traits, but not for leg weakness. Motivational factors may be implicated in the vastly reduced activity patterns seen later in the grow-out period. Several researchers are investigating the role of feeding motivation in broilers (Bokkers & Koene, 2001, Picard et al., 1999, Martaresche et al., 2000, Haskell et al., 2001). This work may lead to new genotypes or alternative ways to formulate or present feed to increase feeding motivation or activity levels in broilers late in the grow-out phase. Further, these studies may identify procedures to reduce the temporary suppression of feeding when dietary ingredients are altered (Haskell et al., 2001).

(7) increasing the complexity of the environment. There have been many attempts to increase activity in broilers by increasing the complexity of the housing environment (e.g. with interactive devices (string) (Jones et al., 2000) and sand (Arnould et al., 2001) or perches (Su et al., 2000). Mench et al. (2001) reported on improvement in gait score in broilers at 5 weeks of age after they had been given access to apparatus promoting climbing, perches and dustbathing from 3 weeks of age. It is not clear why this study, alone, has yielded positive benefits for mobility by increasing environmental complexity, particularly since the apparatus was introduced late in the grow-out period, and relatively few birds were observed using the device at any one time. This study requires replication with a larger number of birds raised under lighting conditions more closely resembling commercial practice (instead of 16L:8D) before drawing any firm conclusions on the effectiveness of the apparatus.

Broilers have a weakened immune response as a result of selection for rapid growth (Qureshi & Havenstein, 1994). Inappropriate feeding (Mireles, 1991) and diseases (particularly IBD) further weaken the immune system. Recent unpublished research (Mireles, 1991) indicates that there is a strong and direct relationship between the strength of immune system of broilers and bone strength. Thus, diseases and feeding regimes are likely to influence the incidence of leg disorders indirectly through their impact on immunocompetence. Minimising disease challenge is likely to be a useful strategy in reducing leg problems in broilers.

CONTACT DERMATITIS

Skin disorders resulting from contact between the bird and litter are common and increasing in broiler production systems (Hartung, 1994), reaching a prevalence of 34.5% in 1988. These disorders are typically seen on the breast ("breast blisters"), hocks ("hock burn") and feet ("foot-pad"). Although there is limited recent data available on the incidence of contact dermatitis, surveys in Ireland and Sweden indicate that hock burn and foot-pad dermatitis are the most frequently occurring forms of the condition. For example, the prevalence of severe footpad lesions in Sweden is reported to be 5-10% (Berg, 1998) but there is huge between farm variability of 0 to 100% (Ekstrand et al., 1998).

The condition is thought to be caused by a combination of moisture and chemical irritants in the litter (Ekstrand et al., 1998). The main causal factors identified on Swedish farms with a high prevalence of foot-pad dermatitis were poor management of litter, ventilation and heating systems. There was a correlation between the food-stuff manufacturer and the prevalence of foot-pad dermatitis. Ekstrand et al. (1998) thought that this might be due to some foods causing wetter faeces, which is likely to result in wetter litter and, thus, a higher prevalence of foot-pad dermatitis. Litter wetness may be reduced by increasing ventilation and using sand rather than straw on the floor, so that the birds peck and turn the sand over, thereby, reducing the amount of faeces on the litter surface (Ekstrand et al., 1998). In addition, Vestergaard & Sanotra (1999) has shown that when chickens are reared on sand they show more dustbathing compared to when they are reared on straw. Such stimulation of the bird's natural behaviour may also aid in improving the birds overall welfare.

ASCITES AND SUDDEN DEATH SYNDROME

Ascites and sudden death syndrome are two important and common (and related) lethal metabolic diseases of broilers. A full report on the effect of both ascites and sudden death syndrome may found in the ECSCAHAW report (Berg et al., 2000). In summary, ascites is a condition in which the body cavity accumulates serous fluid, due the heart being unable to pump fast enough to supply sufficient oxygen to the rapidly growing body. Subsequently, right ventricular hypertrophy and dilation as a result of increased workload results in heart failure. Sudden death syndrome (SDS) is often observed in healthy fast growing (predominately male) birds who have an acute heart failure. Fast growth rate, nutrition and environmental factors are implicated in the incidence of ascites and sudden death syndrome. Terzich et al. (1988) has demonstrated that lowering ammonia levels from 40 to 70 ppm down to 20 ppm reduces the incidence of ascites. Earlier research had indicated that SDS was not influenced by stocking density. Recently, (Imaeda, 2000) had demonstrated that there is an interaction between season and stocking density on SDS incidence, with higher rates observed in summer at the highest density (18 birds m^{-2}). In another study, McGovern (1999) examined the effect of restricted feeding (from day 7 to 16 with 18 g of feed per day) on the incidence of ascites by comparing restricted fed birds with ad libitum fed birds. They found that ascites was reduced with birds fed a restricted diet, however growth rates were also reduced (McGovern, 1999).

WELFARE ISSUES ASSOCIATED WITH

ENVIRONMENTAL FACTORS

THERMAL ENVIRONMENT

In general when broilers are exposed to high temperatures feed intake declines in order that the birds may reduce their metabolic heat, however, this also reduces growth rate (Settar et al., 1999, Whitehead, 2000). Temim et al. (2000) found that at high temperatures (32 °C) growth rate could be altered by dietary protein. Temim et al. (2000) gave chickens higher amounts (from 20 to 25%) of digestible protein in their diet at high air temperatures and found an increase in growth rate.

In addition, Brake et al. (1998) found that the ideal amino acid balance (Arginine : Lysine ratio) for broilers varies with ambient temperature. Studies showed that increasing the Arginine : Lysine ratio at high temperatures produced consistent improvements in food conversion without any loss in growth (Brake et al., 1998).

High environmental temperatures can cause heat stress and potentially death in poultry (Degen & Kam, 1998). There have been a number of studies examining ways to reduce thermal stress in the chicken, including cooling drinking water (Degen & Kam, 1998), providing suitable drinkers (waterers) (May et al., 1997), adding supplements to the water (Zhou et al., 1998), and providing ventilation (Furlan et al., 2000).

There is some evidence that drinking cool water at high temperatures may alleviate thermoregulatory stress and improve performance in chickens (van Kampen, 1981) cited in (Degen & Kam, 1998). In summer and winter, Degen & Kam (1998) offered roosters water at two different temperatures (summer, tap water 25 °C, cool water 8 °C, and in the winter tap water at 12 °C and warm water at 30 °C). The roosters showed no preference for water of different temperature in the first 2 days. On the afternoon of the 3rd day, the roosters chose cool drinking compared to warm drinking water in both summer and winter. Water was provided in insulated water containers.

In another study, when air temperatures were high, May et al. (1997) found that broilers drank less from nipple waterers compared with bell waterers. In a further study, water consumption was related to the height of the waterers. Indeed water consumption was greatest from low nipple waterers compared to high nipple waterers or bell waterers. May et al. (1997) suggests that panting broilers may have difficulty drinking from high nipple waterers. In addition, Ekstrand et al. (1997) showed that the type of water system may affect the welfare of the broilers. Birds given access to small cups to drink from rather than nipple drinkers, were found to have an increased prevalence of footpad dermatitis probably, from spillage and increased moisture in the litter.

Other researchers (Zhou et al., 1998) have studied the influence of adding a supplement (in the form of glucose) to water to reduce thermal stress. Zhou et al. (1998) found that chickens given 4% glucose water during periods of high environmental temperatures had lower mortality rates compared to broilers drinking tap water. This was thought to occur through changing the whole blood viscosity and plasma osmolality of the broiler chicken during high temperature exposure.

In hot weather, broiler drinking behaviour may be altered by the coolness of water and the type of watering system. In addition, adding glucose to the drinking water may increase survival of the birds at high temperatures. Ventilation has become an accepted means of reducing environmental heat stress in broiler chickens. After the first 2 weeks, air temperatures are maintained in the low 20s °C. Furlan et al. (2000) found that when the air temperature was 29 °C, broilers would become cooler if the incoming air temperature was lower than the bird surface temperature, since there will be a thermal gradient between the environment and the bird. The thermal equilibrium is established within the first 10 minutes of air moving at a velocity of between 1.8 to 5.7 m sec^{-1}. Rectal temperature would reduce further if the air velocity was maintained at 5.7 m sec^{-1} for 30 minutes. In addition, a report by the European Commission (ECSCAHAW) (Berg, 1998) found when adequate ventilation rates are provided, the negative effects of stocking density on growth rate are reduced. Heat stress is more profound late in the grow-out period and appears to be influenced by the litter temperature (see previous section on leg disorders). Appropriate litter temperatures remain to be defined. Susceptibility to heat stress is greater in lines selected for faster growth (Settar et al., 1999).

LIGHT

Spectral range

Birds are able to perceive radiation in the UV range (peak sensitivity of 415nm) as well as the visual range of humans (400 to 730nm with a peak sensitivity of 555nm). Bird plumage has been found to have UV reflectance with variable patterns between individuals, which are undetected by the human eye but are highly likely to be seen by another bird. It is thought that these patterns may be used by the birds to identify others (Prescott & Wathes, 1999). Prescott & Wathes (1999) found that artificial lighting contains little if any UV_A and has different spectral characteristics and light intensity compared to natural light. It has, as yet, not been determined whether the light spectrum or intensity of artificially lit poultry houses effects the welfare of the birds (Prescott & Wathes, 1999).

In recent years poultry producers have changed from incandescent (general lighting service tungsten filament, GLS) lamps to more energy efficient, longer lasting source of light such as low pressure mercury (fluorescent) lamps (Lewis & Morris, 1998). In Lewis & Morris's (1998) review of the literature, it was reported that there were no differences between types of artificial lighting sources and the occurrence of mortality. However, there was a higher incidence of angular deformities and total leg abnormalities in birds reared under incandescent (GLS) lamps, and more cases of tibial dyschondroplasia (TD) in those grown under fluorescent lighting. In a more recent study, Widowski et al. (1992 cited in Lewis & Morris, 1998) found that the UV reflectance of bird plumage may be more readily visible under fluorescent lights compared to incandescent lights and an advantage for the birds. Rozenboim et al. (1999b) found that the body weights of broilers grown under mini fluorescent lamps were higher than those reared under warm white fluorescent lamps or incandescent lamps. It is unclear whether the effect of the mini fluorescent lamps was due to a specific spectrum or lower emission frequency.

Coloured light

In a review, Picard et al. (1999) reported that feed intake of broilers is regulated by environmental factors such as light. Lewis & Morris (2000) in a summary of research on the effect of coloured light on poultry, concluded that chicken growth is enhanced under blue or green light compared to red or white light. This may be because birds reared under red light are more active and more aggressive compared to birds exposed to shorter wavelengths of radiation. For example, Rozenboim et al. (1999a) compared the effect of four light treatments (white light (mini incandescent light bulbs), blue (480 nm), green (560 nm) and red (660 nm) on developmental and growth parameters of broilers reared under a single lighting regime from day 1 until termination (day 35). They found that birds reared under green or blue light had enhanced growth rates compared to birds reared under red or white light. The difference in growth enhancement with green light could be detected when the chicks were 3 days old. Growth rate was also enhanced by blue light, however, the effect was delayed in comparison to green light. Rozenboim et al. (1999a) suggest that enhancement under green light might be due to proliferation of skeletal muscle satellite cells, while blue light enhancement may by due to elevation in plasma androgens. There are many studies mentioned in the review by Lewis & Morris (2000) in which comparisons were made between coloured light without controlling for illuminance or radiance. Consequently physiological differences observed may be confounded differences in illuminance. Indeed, it has been found that the intensity of white light affects growth. Despite the inadequacies in previous research, poultry clearly respond differently to different coloured light. They are more docile under blue light and more aggressive under red light (Lewis & Morris, 2000) although, these effects have occurred under lamps with narrow bands of emission and may not necessarily be observed under commercial lamps (Lewis & Morris, 2000).

Photoperiod

(Refer to an earlier section on increasing activity for a summary of the effects of Light:Dark cycles on behaviour and growth).

Performance

Sorensen et al. (1999) tested chicks at 3 to 21 days of age, on four lighting schedules (8, 16, 21 and 23 hours of light) and found that increased photoperiod was associated with increased body weight. Buyse et al.'s (1996) review on the effect of lighting on broiler performance and welfare found that intermittent lighting schedule could improve increase body weight gains. Ohtani & Leeson (2000) found that birds reared on an intermittent lighting schedule (1h L: 2h D), exhibited higher feed intake and produced more heat with a subsequent higher weight gain compared to birds on a continuous lighting schedule. Boon et al. (2000) reported that high feed intake by broilers was due to the length of time food was available rather than photoperiod per se. Reduced weight gain was seen when birds had 9 hours light and 15 hours dark, as birds filled their crops with food, and decreased metabolic rates in the dark phase to reduce energy expenditure, compared to birds with 12 hours light or more (Boon et al., 2000). Rozenboim et al. (1999b) has found that birds reared on a continuous lighting schedule have a higher mortality rate compared to broilers reared with intermittent light.

Welfare

When the results in the Sorensen et al. (1999) study were adjusted for increasing body weight, it was found that birds on shorter days (longer dark period) had poorer walking ability due to hock and food pad burns compared to birds on longer days. However, as day length increased, there were more birds lame due to tibial dyschondroplasia. In a review, Buyse et al. (1996) reported that intermittent lighting schedules reduce the incidence of leg disorders in broilers. Birds reared on intermittent lighting schedules (1 hr light 3 dark) (Kliger et al., 2000), or 12 hours light (Zulkifli et al., 1998) have been found to have increased immune function (Kliger et al., 2000), lower physiological stress indictors (heterophil to lymphocyte ratios), and lower fear responses (duration of tonic immobility) compared to animals on a continuous lighting schedule (23 hour (Kliger et al., 2000), or 24 hour (Zulkifli et al., 1998) light). In addition, Hammershoj (1997) reared broilers on either one of three light schedules, and found that birds reared on the shortest light schedules (16 hr light) had reducing skin tearing at the processing plant compared to birds raised on long light schedules (21 or 24 hr light).

In summary, the latest research evidence strongly suggests that the welfare of birds reared on a continuous lighting schedule (23 or 24 hours light) is compromised compared with intermittent lighting.

In some countries (e.g. Denmark), there is a view that the lighting pattern should reflect the natural photoperiod, with a single dark phase of about 8 hour duration. Unpublished reports from Denmark suggest that such a schedule has a detrimental effect on foot-pad health, possibly due to long periods of inactivity and crowding causing deterioration in litter quality. In addition, broilers have a high food intake requirement and are likely to require food during a prolonged dark period. It is not known to what degree broilers may experience hunger during such periods.

LITTER QUALITY

A range of litter materials are used to cover the floor of broiler housed, with wood shavings perhaps being the most common. Maintaining the quality of the litter is essential for protecting the welfare of the birds. Poor litter quality can influence several different aspects of broiler welfare (e.g. incidence of ascites and contact dermatitis, respiratory problems, thermal stress, and probably activity levels). Good quality litter is friable (i.e.

not wet or caked), and does not create high levels of dust, ammonia or humidity in the air. The ideal temperature for litter has not been defined, but values in the high 20s or above are probably not desirable (Reiter & Bessei, 2000b). Litter quality is influenced by a range of physical, environmental and biological parameters. An excellent up to date summary of research on litter quality is given in the ECSCAHAW report and is summarised here.

Wet litter is a major risk factor for broiler welfare, particularly, contact dermatitis (Ekstrand et al., 1997). It seems that litter 5 cm of less in depth may be easier to keep dry than depths of more that 5 cm (Ekstrand et al., 1997). There authors proposed that thinner layers of litter are more likely to be kept dry by the action of the ventilation system, and the pecking and scratching behaviour of the birds. Food composition (e.g. high levels of sodium) and type may influence litter moisture content through increasing water ingestion and excretion (Ekstrand et al., 1998). Spillage from drinkers is a common way for water to enter litter, and can be reduced by the use of nipple rather than bell type drinkers (Cholocinska, 1997 cited in Berg, 2000). Outdoor temperatures and relative humidities will influence the effectiveness of ventilation systems to control indoor temperature/humidity and, therefore, litter moisture levels. Air flow (above the birds) alone may not be sufficient to control litter moisture levels, while also providing a comfortable thermal environment for the birds. Additional cooling or heating facilities may be necessary in maintain appropriate climatic conditions. Under floor ventilation would be an additional option for controlling litter moisture and temperature.

Stocking density is the main biological factor likely to influence litter quality. There have been several published studies showing that, as stocking density increases litter quality declines (e.g. (Blokhuis & Van Der Haar, 1990) and foot-pad dermatitis incidence increases (e.g. (Martrenchar et al., 1997). As the adverse effects of density on dermatitis are most likely mediated via changes in litter quality, it would seem logical that such effects could be mitigated by improving ventilation or drying of litter.

AIR QUALITY

Air quality in broiler houses is a function of levels of dust (and micro-organisms), gases, and relative humidity, with contributions from both the biological (bird) and physical (litter, feed, water) features of the internal environment and incoming air. The main features of air quality that require specific management for broiler production are relative humidity, dust and ammonia. The ECSCAHAW report provides a good summary of the impacts of aerial pollutants on broiler welfare, and methods to control air quality (and will not be repeated here). Of note, it would seem that relative humidities should be maintained between 50 and 80% (except for the first 1 to 2 weeks). More recent research on control of dust and ammonia levels is of interest and presented below.

Dust

High dust levels in the air may contribute to respiratory problems, ascites incidence, and reduced performance in broilers (Wathes, 1998). Wathes (1998) has made recommendations for atmospheric dust levels. Limits for broilers are specified according to two sizes of particle. The larger (inspirable) fraction should be below 3.4 mg m^{-3}, while the smaller (respirable) particles should be below 1.7 mg m^{-3}. Dust levels are normally controlled by ventilation and maintaining appropriate humidities (and associated litter conditions). In a novel approach, McGovern et al. (1999) evaluated the effectiveness of biweekly additions of oil (canola) to the litter (totalling 0.8 l m^{-2}) on dust levels and ascites. Oiling reduced dust levels by an increasing amount (up to 40%) over weeks 2 to 6 of the rearing period, and improved heart morphology but did not reduce the ascites score or mortality.

Ammonia

Ammonia gas is produced during the decomposition of faecal material. The current exposure limits for ammonia in the UK of 25 parts per million (ppm) are set on the basis of human safety rather than animal welfare (Kristensen & Wathes, 2000). Kristensen & Wathes (2000) reviewed the literature on ammonia and poultry welfare, and found evidence to suggest that ammonia exposure adversely affects the physiology, production and behaviour of poultry and, hence, compromises their welfare. Numerous independent findings show an effect of ammonia on voluntary food intake, although the birds may compensate for chronic exposure by increasing their food conversion efficiency (Kristensen & Wathes, 2000). Ammonia exposure may increase their susceptibility to respiratory diseases as a result of biochemical changes in mucus viscosity altering bronchial clearance. Additionally, the behavioural responses of poultry to ammonia suggest that they can detect and avoid ammonia concentrations at or below the recommended exposure limits of 25 ppm (Kristensen & Wathes, 2000). Homidan et al. (1998) found that ammonia concentrations increased as the chickens grew from 3 to 7 weeks at a stocking density of 19 birds m^{-2}. Ferguson et al. (1997) examined the possibility of reducing the amount of nitrogen (in the form of ammonia) birds produced by reducing the amount of crude protein consumed. They found that at all ages, even when supplemented with amino acids, the feed conversion ratios were increased with reductions in crude protein content. Reducing crude protein intake from 215 g/kg to 196 g/kg caused ammonia gas concentration to decline by 31%, and litter nitrogen to decline by 16.5%. In commercial situations this method of reducing ammonia concentrations is unlikely to be embraced because of reduction in growth rate.

An alternative method to reduce ammonia concentrations in commercial poultry buildings may be made possible by treating the litter with organic acids. In a recent study, (Ivanov, 2001) found that acidifying litter (using 5 per cent citric acid, 4 per cent tartaric acid and 1.5 per cent salicylic acid creating an acid medium under pH 5) reduced ammonia content of the litter and in the air below hygiene limits (25-50 ppm). The cost of litter acidification was calculated as $0.10 per bird, with 15 birds m^{-2} with a feed consumption of 2.5 kg kg^{-1} growth. In another study, Homidan et al. (1998) found that ammonia concentrations could be reduced by using wood shavings for litter rather litterite.

In conclusion, using wood shavings, which have been treated by acidification, may be a practical method of reducing ammonia concentrations.

ENVIRONMENTAL COMPLEXITY

Environmental enrichment is thought likely to benefit chickens and farmers in many ways including, reduced fearfulness and feather pecking, and improved productivity (Jones et al., 2000). Researchers with broilers have attempted to stimulate pecking (by providing inanimate objects, altering the floor covering material, or giving birds access to the outdoors) or other activities such as dustbathing and perching.

Commercial broiler housing is a relatively barren environment, with waterers and feeders evenly spaced, on a uniform floor covering (for example straw, shavings or litterite) and no external lighting. King (2000) provided broilers reared in commercial production systems with or without plastic wrapped wood-shaving bales. Birds with the wood-shaving bales showed less aggressive head pecks, less drinking, and 30% more of their time was spent interacting with the bales, compared to birds without bales. Jones et al. (2000) gave broiler chicks in an experimental situation the choice of different coloured string, with or without shiny beads to peck at. He found that they preferred pecking at white or yellow strings without beads. In a further experiment, Jones (2001) found that chicks were particularly attracted to pecking at a bunch of non-moving white string. When the string was moved in a variety of ways, there was less pecking of the string (Jones, 2001). He suggested that such simple, practical objects may be placed in broiler chick environment to increase activity, and thereby, perhaps improve bird welfare.

Arnould et al. (2001) compared the behaviour of broilers in small pens either containing both pecking strings and a dustbath or neither. There was no difference in locomotory activity or time spent lying (75%) between treatments at 5 weeks of age.

As mentioned previously, Mench et al. (2001) provided 3 week old broilers with an apparatus which supported climbing, perching and dustbathing. Few birds were observed using the apparatus at any one time (6 to 7 %), but there was an apparent improvement in gait score by week 6. Others (e.g. LeVan et al., 2000. Martrenchar et al., 2000) have also evaluated the effects of providing perches to broilers, but perch use is usually at low levels. In addition, toys and moving lights have been used to increase environmental complexity, but without notable or consistent improvements on leg strength (and presumably behaviour) (Letterrier et al., 2001).

Other researchers, Nielsen et al. (2000) and Knierim (2000), have given broilers access to outdoor areas, as a means of stimulating their natural behaviours, and thereby improving the animals' welfare. Nielsen et al. (2000) introduced two breeds of broiler, a slow growing variety (La Bresse x L86) and a fast growing variety (Ross 208) to outdoor areas at 6 weeks of age. It was found that the slowing growing birds spent more time outside, and moved further away from the house compared to the fast growing birds. There were differences in body weight, with the slower growing also being lighter. In addition, birds were fed one of two diets, one diet with a high wheat content (60%), and the other diet comprised of more variety (30% wheat, 20% oats, 10% peas). All birds, regardless of growth rate, spent more time outside when they were being fed the high wheat diet, compared to the wheat, oat, pea diet. Knierim (2000) compared the behaviour of chickens given access to outdoor area for 12 hours daily with that of chickens reared continually indoors. By week 5 sitting was the most common activity (about 80% of time) and was not different between housing environments. There were higher levels of locomotion (5.4 % vs 2.2%) and pecking (17.3 vs 2.5 peck per bird times hour) in the free-range broilers.

To summarise, there is little evidence to suggest that increasing environmental complexity will increase the behavioural repertoire, or frequency of desirable behaviours significantly, especially in fast growing breeds. There is a particularly strong propensity in fast growers to become inactive from about 4 to 5 weeks of age. This is unlikely to be changed without modifying the genotype of the animals.

STOCKING DENSITY

Contextual Notes

In consideration of broiler welfare, stocking density is one of the most controversial topics. There has been considerable research on variations in stocking density and its effects on broiler productivity, health and behaviour (see ECSCAHAW report for a sample). There is very little consistency in the results between studies for each of the various welfare parameters investigated. It seems that there is a major reason for this lack of consistency: stocking density per se is unlikely to be the main underlying biological variable directly influencing the production, health and behavioural outcomes. Factors such as litter quality, and air and litter temperature appear to be more important determinants of performance and health. Each of these parameters is, in turn, influenced by a wide range of other animal, environmental and management factors (see elsewhere in the review).

Of all the welfare measures, the one that shows the most consistent variation with stocking rate is behaviour (or at least some behaviours). But even here, as with many of the other studies on stocking density, there have been few studies that have taken account of major confounding factors e.g. group size. Many studies have varied density by varying group size, and it is well-known that both factors influence the expression of behaviour (e.g. Reiter & Bessei, 1999), and no doubt other welfare parameters as well. Typically, the methodology sections of the reports do not mention if any procedures were invoked to eliminate variation between treatments in other parameters, such as litter and air quality, or litter temperature which can themselves have a major influence on behaviour and welfare (e.g. Reiter & Bessei, 2000b). Another environmental parameter which can have a marked influence on behaviour (e.g. activity level) is the cycle of Light:Dark schedules, with shorter Light:Dark cycles stimulating greater activity (see previous section on increasing locomotor activity). The effect of stocking density on welfare does not seem to have been evaluated under photo-periodic conditions which promote maximal activity. With these limitations noted, a summary of the research on stocking density will be presented (see ECSCAHAW report for more complete listing of studies). Note that the full range of confounding factors and the difficulties they pose for interpretation are not mentioned in the ECSCAHAW report.

Over a wide range of stocking densities (up to 40 kg m^{-2}) mortality has been reported to increase with density (e.g. Hall, 2001) or be unaffected by it (e.g. Reiter & Bessei, 1999). Interestingly, Reiter and Bessei controlled for group size but Hall did not. Others (e.g. Grashorn & Kutritz, 1991) have shown that with appropriate management (increasing ventilation rate) potential adverse effects of higher stocking rates can be avoided. Several studies have reported growth depression (e.g. Reiter & Bessei, 2000a), and increases in leg disorders, contact dermatitis (Hall, 2001), sudden death syndrome (Imaeda, 2000), with increases in stocking density. However, others have found that when confounding factors such as wet litter and ammonia levels are taken into account there is no direct link between density and the incidence of disorders (e.g. Algers, 1989).

Behavioural studies have shown that two types of activity are reasonably consistently depressed with increases in stocking density: walking and scratching. Other behaviours such as feeding, drinking and sitting are consistently reported as not being influenced by density. But, as Reiter & Bessei (2000a) have argued, the behavioural changes that are attributed to density effects are more likely to be related to increases in litter quality and temperature, rather than density per se. It has been reported that resting behaviour is more disturbed at higher densities (Hall, 2001), but this too could be explained by higher litter temperatures inducing more frequent standing behaviour to assist in thermoregulation (Reiter & Bessei, 2000a).

In small groups of birds (four), moderate increases in stocking density (from 1.7 to 14 kg m^{-2}) are associated with greater activity in the presence of humans, and longer tonic immobility responses (Andrews et al., 1997). These changes are indicative of enhanced fear. It remains to be seen if similar responses are shown in group sizes or at densities more typical of commercial enterprises.

To summarise, in some studies a range of welfare parmeters have been seen to vary with stocking density, but it is likely that most of the variation is due to factors other than stocking density. The degree to which production systems can be altered to manage the impact of the underlying variables will determine the extent to which potential adverse welfare impacts can be mitigated. Not all of the causative agents and appropriate remedial actions are known. Therefore,

(1) it would be prudent to acknowledge that higher stocking densities are associated with a greater risk to broiler welfare.

(2) a conservative approach to recommendations on stocking density should be followed, taking into account current best practice and the latest scientific information.

(3) that production techniques such as stocking density, should be based on a performance system, in which the use of, for example, high stocking rates is contingent on achieving high standards of animal welfare. Sweden uses the incidence of footpad dermatitis as a welfare performance indicator.

SUMMARY

There is little legislation internationally to protect the welfare of broilers. Most Northern European countries have guidelines for specific broiler management practices, e.g. stocking density, but these vary considerably between nations. The major welfare issues include leg and mobility disorders, ascites, sudden death syndrome and lack of behavioural complexity. Each of these conditions is influenced by a wide range of genetic, health, environmental, feeding and other management related factors. Further, each health or welfare problem can influence the incidence of any or all of the other types of disorder. However, one key factor underlies most of the welfare issues: the fast growth rate of the broiler (due to intense genetic selection and nutrient supply). Many procedures have been developed to moderate the effects of fast growth on broiler health and welfare. Some of the most successful techniques reduce the rate of growth early in the rearing period; increase the level of locomotory activity; and, reduce the incidence of pathogens in the environment or incidence of diseases. Two management procedures that are particularly useful in stimulating locomotory activity are intermittent lighting and/or meal feeding. Surprisingly, these techniques are not common practice in Europe or North America. This may be due to a perception (that is not supported by research) that broilers require an uninterrupted and prolonged dark phase each day. Reports from Denmark suggest that prolonged dark phases may induce other welfare concerns (e.g. increased foot-pad dermatitis). Leg disorders are also likely to be reduced through genetic selection. A new finding is that stocking density per se does not appear to be a major direct cause of most welfare problems traditionally associated with high stocking rates. Rather, it appears that factors such as poor control of litter quality and temperature, and other environmental conditions are more directly implicated.

Behavioural restriction in broilers seems not to be influenced greatly by the lack of complexity of the rearing environment; rather, it is a by product of selection for rapid growth. Reduced scratching and walking, and disturbed resting activities are associated with high stocking densities. Research is required to determine if stocking density or other variables e.g. litter quality/temperature are underlying causes of these behavioural changes. Such information is critical in devising appropriate management strategies to alleviate any problems.

Since most broiler welfare issues are influenced in a complex way by a combination of genetic, environmental and management factors, it can be expected that welfare concerns

will be addressed best by undertaking further research in, and implementing appropriate changes across, all of these parameters.

IMPLICATIONS FOR NEW ZEALAND BROILER INDUSTRY

There are no published studies of the incidence of welfare problems in the New Zealand broiler industry. Since the New Zealand industry is free of some diseases, particularly IBD, which is a strong immunosuppressant and has a role in the aetiology of leg disorders, and uses lighting regimes (intermittent lighting) reported to be beneficial for leg development are in common use, it would be surprising if the incidence of leg abnormalities and associated conditions (e.g. contact dermatitis) was not lower in New Zealand than elsewhere. Further, there is no published information for New Zealand production on broiler behaviour, on the status of the key environmental parameters (such as air and litter quality and temperature/humidity) which influence broiler welfare, or on the relationship of such measures to changes in stocking density. Details of welfare standards and performance in the New Zealand broiler industry are required so that they can be: (1) placed in an international context; and (2) used as a benchmark in the evaluation of alternative management strategies, should they be required.

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