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The Welfare of Chickens

Kept for Meat Production (Broilers)

Report of the

Scientific Committee on Animal Health and Animal Welfare

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1 REQUEST FOR OPINION

The EU Commission has asked its Scientific Committee on Animal Health and Animal Welfare to prepare a report on the welfare of chickens bred and kept for meat production (in the continuation referred to as ”broilers”). The Commission asked that particular attention be paid to problems arising from genetic selection for increased appetite, the space requirements for birds during the fattening period and health problems arising from rapid fattening.

2 BACKGROUND

At present there is no Community legislation on the subject of keeping and breeding poultry kept for meat production. A Recommendation on domestic fowl was, however, adopted by the Standing Committee of the European Convention on the Protection of Animals kept for Farming Purposes on November 1995. However, this Recommendation does not, sufficiently, cover all elements that could involve risk to poultry welfare.

This report covers the period from the arrival of the chicks on the farm until they leave. Thus, it does not cover transportation or hatching but does cover the catching of the birds prior to transport to the abattoir. It does not cover aspects not usually regarded as commercial broiler production such as the farming of capons.

3 WELFARE - DEFINITIONS AND MEASUREMENTS

3.1 The concept of animal welfare

Farm animals are reared for commercial purposes but are nevertheless living and sensitive creatures. In order to safeguard welfare and avoid suffering, a wide range of needs must be fulfilled. To be useful in a scientific context, the concept of welfare has to be defined in such a way that it can be scientifically assessed. This also facilitates its use in legislation and in discussions amongst farmers and consumers.

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). Broom (1986) defines it as follows: the welfare of an animal is its state as regards its attempts to cope with its environment. Welfare therefore includes the extent of failure to cope, which may lead to disease and injury, but also ease of coping or difficulty of coping and the associated disease and injury. Furthermore, welfare includes pleasurable mental states and unpleasant states such as fear and frustration. Good welfare can occur provided the individual is able to adapt to or cope with the constraints it is exposed to. Hence, welfare varies from very poor to very good and can be scientifically assessed The word stress is used by some authors when there is failure to cope (Fraser and Broom 1990), but others use it for any situation in which an organism is forced to respond to environmental challenge (Selye 1980, Zulkifli and Siegel 1995).

The welfare of a farm animal can be considered in relation to the housing and management conditions to which it is subjected (Puppe 1996, Rushen and de Passillé 1992). Welfare is good when all needs associated with the maintenance of good health and needs to show that certain behaviours are met. Health is an important part of welfare and behaviour is important in many regulatory systems. It is also clear that many needs involve the necessity for the animal to express different behaviours (Vestergaard 1996, Jensen and Toates 1993).

3.2 The assessment of farm animal welfare

Farm animal welfare is assessed by a combination of indicators of its physical and mental components. The scientific methods that are available for selecting these indicators, and establishing and interpreting scores, are detailed in several reviews (Broom 1993, Broom and Johnson 1993, Puppe 1996). In general, minimum mortality, low morbidity, little or no risk of injury, good body condition, the ability to express species-specific activities including social interactions, exploration, and play, and the lack of abnormal behaviour and of physiological signs of stress, including alterations of immune responses, indicate that there are no major animal welfare problems.

3.3 The assessment of welfare in broilers

When assessing the welfare of broilers, the following points need to be considered in detail:

3.3.1 MORTALITY AND MORBIDITY.

Deaths on farm may be due to many factors, caused for example by disease, injury, physiological system failure or unidentified causes, which shows that the welfare has been poor. Animals may also be culled for the same reasons, and in such cases, culling should be treated as a similar sign of poor welfare. Welfare is poorer if the incidence of production related diseases is higher in animals under consideration than in similarly aged animals which have not been exposed to the same management, housing or selection. In a group of animals, such as a flock, house, herd or any other population unit, the amount of poor welfare caused by disease is a function not only of its incidence but also of its severity and duration, as described by Willeberg (1991). If some inherent weakness or abnormality means that the individual would be more likely to succumb to disease or injury, etc. then the welfare is poorer than in an animal which does not have this weakness or abnormality. Health indicators of animal welfare can also be assessed indirectly based, for example, on the extent of the use of therapeutic veterinary medicines (Willeberg, 1991). Estimates of welfare using mortality and morbidity figures have to be based on comparisons between production systems since reference values on acceptable levels are rarely available.

3.3.2 BODY CONDITION AND REPRODUCTION

Welfare is poorer if body condition is worse or there is unbalanced organ function or damaging muscular hypertrophy. In general, reproduction is given high priority in the allocation of resources within an animal so, if given adequate fertilisation opportunities, individuals, which are not already involved in reproductive processes, are less likely to conceive, poor welfare may be indicated. Broilers are slaughtered long before reaching sexual maturity, and therefore reproduction can not be used as a welfare parameter for these birds. However, for breeding birds, this may be an important aspect to consider.

3.3.3 BEHAVIOUR

Animals use behaviour as one of the important means of adapting to their physical and social environment. They do so by reacting according to a genetically predisposed pattern to relevant causal factors inside and outside of the body. When the animal is in an environment that allows it to perform adequate reactions and to get adequate feedback from its behaviour, the animal is adapting. If such adaptation is prevented, welfare will be poor. Deviations from the behaviour, which is normal for the species, age and sex considered may therefore be important signs of welfare risks. Various behaviours including abnormalities of behaviour are indicators of pain, fear or other poor welfare. Among such indicators, one would also consider locomotory disturbance. Some behaviour may provide indicators of good welfare.

3.3.4 PHYSIOLOGY

Physiological indicators of welfare include measurements of the main regulatory functions, such as heart rate and adrenal hormones and immune response. Some physiological changes in brain and body may indicate good welfare. A treatment that interferes with the main physiological regulatory functions, would be regarded as associated with poor welfare.

Conclusion

- For an adequate assessment of welfare a wide range of indicators must be used, although single indicators can show that welfare is poor. Animal welfare can be assessed in a scientific way and indicators of welfare include those of physiological states, behaviour and health. Estimates of welfare using mortality and morbidity figures have to be based on comparisons between production systems since reference values on acceptable levels are rarely available.

4 BIOLOGY AND BEHAVIOUR OF FOWL/BROILER

4.1 Characteristics associated with normal behaviour of fowl

The ancestor of the domestic fowl is the red jungle fowl (*Gallus gallus*). Wild populations of these jungle fowl are still abundant today in S.E. Asia and the domesticated bird can be regarded as a subspecies (*G. gallus domesticus*). Estimates vary, but domestication is thought to have occurred about 8000 years ago, first in India and China, then spreading along trade routes. Initially birds were probably used for sacrifice in religious ceremonies or for cockfighting. It was not until the Roman times that the bird's potential as an agricultural animal was developed and laying strains, and even a poultry industry, were established (Wood-Gush, 1959). This industry collapsed with the Roman Empire and large-scale selection of birds for commercial use did not resume again until the nineteenth century. A more complete history of the domestic chicken is presented by Wood-Gush (1959) and Yamada (1988).

Several characteristics predisposed jungle fowl to domestication. They are social, living in groups of 1-2 males and 2-5 females plus young, which has allowed them to be managed in groups. They have a hierarchical structure, probably based on individual recognition. They show promiscuous sexual behaviour, which allows any male to be mated with any female and so facilitates artificial selection. Fowl have flexible dietary requirements and are adaptable to a wide range of environments. All these traits have been used to advantage in commercial poultry production (Appleby *et al.*, 1992).

Domestic poultry grow larger than jungle fowl, and in the case of broilers, the difference is striking. An adult jungle fowl usually weighs below 1 kg, a weight reached in a few weeks by modern broiler chickens. With respect to behaviour, there have been remarkably few changes in the behavioural repertoire. The behavioural changes that are apparent when comparing modern birds with older strains or feral populations seem to be in threshold of response rather than a change in behaviour per se (McBride *et al.*, 1969; Wood-Gush *et al.*, 1978).

Jungle fowl and domestic fowl are prey species and as such are well designed to detect and avoid predators. Vision is important. They have a well-developed colour vision and a visual field of about 330^{o}. Hearing is also important. They are sensitive to frequencies in the range of 15 to 10,000 Hz and have a repertoire of about 20 separate calls (Wood-Gush, 1971) including distinguishable calls for ground and aerial predators. Sight and sound are used for communication and social recognition. Sexual and aggressive displays are highly developed (Kruijt, 1964, Wood-Gush, 1971).

Jungle fowl are omnivores, spending a large portion of their day pecking and scratching in the ground for food (Collias and Collias, 1967). Studies in free ranging jungle fowl in zoos have estimated that birds spend up to 61% of their time ground pecking (Dawkins, 1989). Domestic hens also spend a large proportion of their day pecking and scratching (Hansen, 1994). The beak is the main exploratory organ for the bird. It is well innervated with a collection of touch receptors at the end which allows birds to peck accurately (Gentle and Breward, 1981; 1986).

Birds possess pain receptors and show aversion to certain stimuli, which can be interpreted as that they experience pain (Gentle, 1992b, Gentle *et al.*, 1990). They show fearful behaviour and avoid frightening situations, implying that they experience fear (Jones and Faure, 1982; Jones, 1986). They show behaviour indicative of frustration (Duncan, 1970). These would seem to be part of the "unpleasant emotional states" defined as suffering (Dawkins, 1980).

4.2 Specific aspects of broiler biology and behaviour

To understand the underlying causes of welfare issues that relate specifically to commercial broiler production, one must be aware of the differences in biology and behaviour between modern broilers and other strains of domestic fowl that have arisen as a consequence of intensive genetic selection for faster and more efficient production of chicken meat. There are also differences in biology and behaviour between male and female broilers that have implications for their respective welfare. Furthermore, there are differences between broilers and breeding birds (parent stock), because they are kept under completely different regimes.

The performance of the modern broiler represents one of the most marked increases in livestock productivity achieved by selective breeding. In the last 30 years, the time taken to produce a chicken weighing 2 kg has been halved, from more than 10 weeks to less than 6 weeks. Initially, selection was for greater growth rate and meat yield, but as excessive carcass fat became a problem the emphasis changed to improving food conversion efficiency (FCE) as well. [This measure is obtained by dividing body weight gain by food intake; the reciprocal (food intake per unit of weight gain) is referred to as food conversion ratio (FCR)]. In recent years there has also been selection against susceptibility to certain types of disease. McKay (1997) predicted that in the 30 years between 1976 and 2007, broiler weight at 42 days will have increased threefold and the age at 2 kg will have decreased by one day per year. In 1976 the amount of feed a broiler needed to eat to reach 2 kg body weight was 5 kg, in 1997 it was 3.3 kg, and in 2001 the prediction is it will be 3 kg.

In association with the continuing selection for improved production performance, there have been changes in carcass composition and conformation, in growth, metabolism, digestion, endocrine and immune system, brain function, and in behaviour. Many of these changes were reviewed in a recent OECD-Workshop on broiler production (Ellendorff *et al.*, 1995).

Selection for increased body weight gain tends to cause an increase in carcass fat, whereas selection for decreased FCR tends to reduce fat and increase the carcass water content (Pym and Solvyns, 1979; Chambers *et al.*, 1983; Soller and Eitan, 1984). Conceivably, the amount of fat in adipose deposits could influence body insulation and hence thermoregulation, while muscle hypertrophy and intramuscular water content may influence muscle function. Increasing breast muscle yield has caused broilers' centre of gravity to move forward and breasts to be broader. These changes have implications for walking ability, gait and mechanical stresses on legs and hip joints. Accelerated skeletal growth has led to an increased incidence of bone disorders, most resulting from growth plate pathologies. Stocks in which rapid growth is combined with low FCR typically show an increased disposition to low thyroid hormone concentrations, low metabolic rate, hypertrophy of the right ventricle of the heart and ascites (Scheele, 1997). These pathologies can be attributed to an insufficient oxygen supply in metabolism, due to genetically (and environmentally) induced mismatches between energy-supplying and energy-consuming organs. The same endocrine factors which exert a major influence on growth are also important regulators of immune development and function (Marsh, 1995), and concern has been expressed about possible increased susceptibility to viral and bacterial infections (Urrutia, 1997).

It has been argued that the faster growth of selected strains of broilers is associated mainly with increased appetite, characterised by an accelerated rate of voluntary intake which, in contrast to unselected strains, uses the digestive capacity of the gut almost to the full (McCarthy and Siegel, 1983). This conclusion is debatable because such differences can also be accounted for in terms of reduced FCR. Furthermore, if the "standards" of modern broiler and layer strains are compared (e.g. Ross Breeders, 1996; Ross Poultry, 1998), the FCR to 6 weeks of age is 35% lower with the female broiler than with the layer pullet, but the average food intake per day over the same period hardly differs when expressed on a body weight basis.

Scheele (1995) pointed out that there are only three possible ways in which FCR of a given diet at a given live weight can be improved:

1. Increasing the digestibility of dietary nutrients.

2. Increasing the protein-fat ratio in deposited tissue (depositing more water in lean tissue and less fat in adipose tissue saves energy).

3. Decreasing heat production and associated oxygen consumption to conserve energy (i.e. reducing maintenance costs).

Broilers show evidence of all of these strategies and, when one compares their behaviour patterns with those of other strains of fowl, it appears they conserve energy through altered activity levels as well as through altered physiological processes. The most striking difference is that broilers are much less active than layer strains. They spend less time in walking/running and scratching/pecking litter and more time in sitting/resting as they grow older (Newberry *et al.*, 1988; Blokhuis and van der Haar, 1990; Bessei, 1992; Reiter and Bessei, 1994; O'Rawe *et al.*, 1998a,b). Over the whole growing period they may spend >75% of time sitting/resting (Savory, 1975; Bessei, 1992), compared to <30% in laying strains at the same age (Savory and Mann, 1997), and this relative inactivity increases broilers' susceptibility to leg weakness and hock burn/breast blister forms of contact dermatitis (Savory, 1995). It also means that the behavioural needs of broilers are not necessarily the same as those of laying strains, especially as broilers show very little dustbathing, wing-stretching and wing-flapping (Murphy and Preston, 1988; Bessei, 1992; O'Rawe *et al.*, 1998a,b).

Little is known about the social behaviour of broilers, except that there is a tendency for them to huddle together in the first week or two of life, before they achieve complete homeothermy (O'Rawe *et al.*, 1998a). In a study on a commercial farm, no agonistic interactions were observed, and it was concluded that social factors did not restrict movement of individual birds through the flock; results indicated that they were not attached to a particular site in the house (Preston and Murphy, 1989).

Despite the fact that growing broilers eat substantially more per day than do laying strains at the same age, their rate of food consumption per minute of feeding is much greater than in laying strains and they actually spend less time feeding (Masic *et al.*, 1974; Savory, 1975). Very similar differences in behaviour have also been demonstrated between populations of laying hens selected for high and low efficiency of feed utilisation (Braastad and Katle, 1989). As the energy expenditure and heat production attributable to eating activity *per se* are considerable (Van Kampen, 1976; Macleod, 1991), this is yet another way in which broilers conserve energy. Nevertheless, the heat increment due to their greater food consumption becomes greater as their daily intake increases with age (Ross Breeders, 1996), and may well have a growing impact on their thermoregulation.

After about the first 2 weeks of life, the FCR of female broilers is greater than that of males, regardless of whether sexes are compared at the same age or the same body weight (Ross Breeders, 1996). In other words, females become less efficient than males at converting food to weight gain. Some broiler strains can be sexed at day-old because females feather faster and their wing feathering then can be distinguished from that of males (e.g. Ross Breeders, 1996). Associated with the higher FCR of females is a greater carcass fat content (Pym and Solvens, 1979; Broadbent *et al.*, 1981) and this, together with their faster feathering, may mean their body insulation is greater than that of males at an age when heat dissipation becomes more important for thermoregulation. Because males are more efficient and grow faster, some commercial producers segregate sexes at day old in adjacent halves of the same house, and either slaughter the males first, at <6 weeks of age when they weigh 1.5-2 kg, or slaughter them later at 7 or 8 weeks when they weigh >3 kg ("roasters"). Whichever sex remains has use of the whole house in the final week(s), and this provision of additional space has implications for predicted terminal stocking density.

As broiler growth rate increased through genetic selection, it became necessary to impose progressively more severe food restriction on parent stock (breeders) during rearing, in order to limit their body weight at sexual maturity. Food restriction continues in a more mild form throughout adulthood. As a consequence of this restriction and suppression of body weight gain, the behaviour and physiology of breeding birds differ markedly from those of (*ad libitum*-fed) broilers. These differences and the reasons for the food restriction are described in section 9.

Conclusion

- Most of the welfare issues that relate specifically to commercial broiler production are a direct consequence of genetic selection for faster and more efficient production of chicken meat, and associated changes in biology and behaviour. There are also differences in biology and behaviour between male and female broilers, and between broilers and breeding birds, that have implications for welfare.

5 BROILER PRODUCTION OF TODAY

5.1 Size and importance of broiler production

In the world the number of chickens involved in commercial meat production can be estimated to be $20x10^9$ broilers and $180x10^6$ breeding birds. Most of this production is concentrated in few countries with USA representing 24%, China 18.5% and EU 14% of the world production.

The number of broiler farms in Europe is generally small with regard to the overall production, and only in some countries where broiler production is less important, or, where the number of broilers per farm is regulated by law (Switzerland) there exist small farms. This applies for standard broiler production. Special broilers like "Label rouge" in France are generally produced in smaller farms. With the exception of Switzerland, there is a high concentration of broiler farming geographically in most European countries. This is considered favourable for the logistics of chick placement, slaughter and marketing. It also reduces duration of transportation from the hatchery to the farm and from the farm to the slaughter facilities. It is very difficult to have a general view of what is called a broiler in the different member states as slaughter weight can vary from less than 1 kg to more than 3 kg and slaughter age from 21 to 170 days (Table 1 and 2). The mean body weight, age, density and mortality are given in Table 1.

Table 1: Range of broiler production parameters in European countries according to Magdeleine, 1997: Lapierre , 1995: Hamon, 1995; Gauvin, 1996; Bardi *et al.*, 1997

Parameter	Typical Reported Ranges
Slaughter Weight (g)	1440 – 2310
Slaughter age (days)	36 - > 50
Stocking density	
(No./m²)	11 - 25.4
(kg/m²)	22.5 - 42.5
Mortality (%)	4.1 - 7.1

In Table 2 major types of broilers are given for France where characteristics of production are more variable than in other member states. However at least for France means do not cover the real variability as illustrated in Table 2. This table does not cover all the types of broilers and some marginal productions include animals up to 24 weeks old but represent only a fraction of a percent of the French production.

Even if taking only the means given in Table 1, the body weight at slaughter varies from 1440 to 2310 g. Age at slaughter varies more or less accordingly, but some countries only use the fastest growing crosses whereas some others use slower growing ones.

Densities in commercial broiler farms are also very variable from very low (11 birds/m^2, 22.5 kg/m^2) to very high (25.4 birds/m^2, 42.5 kg/m^2). Mortality typically varies between 0.75% per week and 1.32% per week for light birds. Results of the German random sample tests for broiler breeds and commercial feeds showed a clear tendency for the average mortality to increase during the last decades (Grashorn, 1993) (see 6.1).

Table 2: Type and performances of broiler chicken in France

	% of total production	Slaughter age (days)	Slaughter weight (g)	Strain
Cockerels	1.5 ---	21 63	950 ---	Broiler Layer
Export	33.0	30	1450	Broiler
Standard	53.0	39	1900	Broiler
Certifié	2.0	56	2100	Female Label X Male standard
Label rouge	9.0	>81	2000	Yes
Heavy	1.5	42-49	2300-3000	Broiler

Source: Magdelaine, 1997: Lapierre , 1995: Hamon, 1995; Gauvin, 1996

In some countries broiler production is carried out to higher standards of welfare or meat quality. Examples of the norms are given in Table 3. Freedom Food is more welfare orientated whereas "Label rouge" is more quality orientated but complies with most of the Freedom Food requirements. Table 3 is not complete, since other similar programs exist in other countries as well (for example in Italy almost 3.5 million birds per year are reared similar to ”Label Rouge”, and slow growing broilers with low density rearing exist under the names ”Naturi” and ”Valdarno”; Pignatelli, pers. comm.).

Table 3: Some Requirements of premium broiler production.

	Slaughter age	Density	Outdoor access	Specific strain	Food	Light	Max. Group size	Transport to slaughter
Label rouge (France) Type I	>81 days	11 birds/m^2	Not compulsory, but >95%of flocks have it. All day after 6 weeks, >2 m^2	Yes	No growth promoter. No animal food. >75% cereals	Natural	4400	<200 km <2 hours
Label rouge (France) Type II	>81 days	20 birds/m^2	Yes Unlimited	Yes	No growth promoter. No animal food. >75% cereals	Natural	1000	<200 km <2 hours
Freedom food (RSPCA, 1995)	No limit	30 kg/m^2	Not compulsory More than 8 hours	No	No growth promoter Green Brassica	>8 hours light >20 lux.	10000	Loading to unloading< 6 hours Unloading to slaughter<6 hours
Extensive indoor (Barn reared) (EU, 1991)	56 days	12 birds/m^2 25 kg/m^2	No	No				
Free range (EU, 1991)	56 days	13 birds/m^2 27.5 kg/m^2	>1m^2 bird half lifetime	No	>70% cereals			
Traditional free range (EU, 1991)	81 days	20 birds/m^2 40 kg/m^2	All day starting at 6 weeks >2m^2 bird	Yes	>70% cereals		<4800	
Free range total freedom (EU, 1991)	81 days	20 birds/m^2 40 kg/m^2	All day starting at 6 weeks Unlimited	Yes	>70% cereals		<4800	

5.2 Legal regulations for broiler production

Legal regulations for broiler rearing exist only in Sweden and Switzerland. In some other countries there are official recommendations for proper broiler production standards (Germany, UK), but in most of the other countries the production follows the recommendations of breeding companies, feed manufacturers or advisory services. Besides general instructions about proper regulation of temperature, ventilation, lighting, hygiene, etc, the main issue of the recommendations is stocking density. Stocking density is generally given as kg body weight (at slaughter age) or number of birds per m^2. In some cases the number of birds per farm is restricted. The recommendations for maximum stocking density vary considerably among countries and organisations. According to the expert Committee of the German Federal Ministry of Agriculture (BML) in 1974 the stocking density should not exceed 30 kg (plus/minus 10%) per m^2. In a more recent report of an Expert Group of the same Ministry the maximum density may vary between 30 and 37 kg/m^2 depending on the management conditions (Anon., 1993). A report of the UK's Farm Animal Welfare Council (FAWC 1992) recommended a maximum density of 34 kg/m^2. In Denmark 40 to 42 kg/m^2 are considered as upper limit (unpublished information Working Group IX WPSA).

There is an Animal Welfare Programme for broilers in Sweden, which is an agreement between the production advisors, veterinarians and the Swedish National Board of Agriculture. The procedure is to score the general standard of management, housing facilities, equipment, and stockmanship of the broiler farms and each broiler house (Ekstrand and Algers, 1997). According to the animal welfare regulations the maximum stocking density can vary between 20 and 36 kg/m^2 or 25 birds/m^2. The higher densities are subjected to a high management quality, which is scored and controlled by the authorities concerned. (Berg, 1998)

In Switzerland the law for animal protection fixes the upper limit at 30 kg/m^2, which is equivalent to 20 birds/m^2 at a common slaughter weight. It further says that natural daylight should be provided if possible. When windowless houses are used the light period should not be artificially extended beyond 16 hours and 5 lux should be the minimum light intensity. It has been noted by Scherer (1989) that these rules were not always respected in practice. The recommendation of the Federal Ministry of Agriculture of Germany requests a 24-hour day-light cycle. But no instructions are given on the duration of day and night phases because of lack of information on the welfare consequences of different light-dark rhythms. Law in Sweden requires a minimum of two hours of darkness.

A publicly acknowledged agreement, but which does not have legal force, between producers, the Ministry of Agriculture Fishery and Food and scientists of the School of Veterinary Medicine Hanover was formulated in Lower Saxony, Germany which gives advice on some standards of management, housing facilities and equipment, particularly on ventilation in summer to avoid mortality because of overheating. An energy content of 72 kJ/kg of animal house air of is seen as lethal for broilers. Therefore even broiler houses with natural ventilation have to provide a ventilation capacity of 4.5 m^3 per kg live weight and hour (5.4 kg air/kg LW/h) during hot periods by installing electric fans. In situations when the energy content of the outdoor air exceeds 67 kJ/kg of air additional measures have to be taken beside the increased ventilation rate, such as reduced feeding during the hot day, cooled drinking water as far as possible, air movement in the animal zone or water spraying as long as the relative humidity does not exceed 80 % in the animal house air. The maximum stocking density of 35 kg/m² is related to the last day before slaughter (Anon., 1997).

5.3 Rearing Conditions

The following section sets out a general description of broiler rearing in EU Member States. Broilers in the EU are kept on litter systems. Attempts to develop cages similar to layers cages were made in the 1960s and early 1970s (Scholtyssek, 1973). Although the development of body weight was satisfactory and feed conversion was better in cages than on litter cage rearing did not succeed because of the occurrence of breast blisters and leg problems and only in Eastern European countries have large units of broiler cages been established.

The standard broiler houses in Europe are window-less and force-ventilated. The walls and the roof are insulated and the floor consists of concrete. In France, however, the majority of broilers are kept in houses without concrete floor (89% of total capacity) and only about 54% of the broiler house capacity is window-less (Magdeleine and Guibert, 1997).

Under conventional production systems in Europe the used litter is usually completely removed after each batch, and the house is cleaned and disinfected. Since the beginning of the 1990s the so-called Louisiana-system, which is widespread in the US, has been introduced in some European countries. These houses originally did not have a concrete floor. The litter layer of about 40 cm is placed on the natural ground. As in most broiler enterprises in the US the litter in the Louisiana-system is removed after 5 - 7 batches, and before housing a new flock only a thin layer of fresh litter is provided regularly. However, nowadays there are Louisiana barns in operation with concrete floors because of hygienic reasons and disease control. The litter is removed after each crop. The houses are open-sided and natural ventilation is used to reduce humidity and gases. The ventilation rate is controlled automatically by a curtain system. There are no official statistics on the number of Louisiana houses in the EU. It has been estimated that in Germany about 30 percent of broiler units are Louisiana type systems and about 15 percent of the broilers are raised under these conditions. The building costs are about 30 percent lower as compared with conventional systems. This makes it highly competitive with conventional broiler houses (Hinrichs *et al.*, 1992).

All the broilers are reared on litter (straw, wood shaving, peat, paper...) and have free access to water. In order to reduce leg problems some are not fed *ad libitum* during the first weeks of age or to prevent heat stress are not fed during the day in hot conditions.

Except for litter, feeders and drinkers, the environment of broilers is usually bare.

Three types of lighting programmes are used for broiler production:

Natural or pseudo natural rhythms. In this case animals are in natural light, have natural light plus some complementary light during the night, or are in artificial light only, but always have an uninterrupted dark period for many hours. This is compulsory in some high standard productions.

Continuous or near continuous illumination. A truly continuous illumination is rarely used but lighting programmes with 23L:1D are used relatively commonly though decreasingly. This can be done with natural plus artificial light. Longer periods of darkness are required in some European Countries

Intermittent illumination. These programmes are often of the type 6x(3L:1D) and can be used only in dark buildings. These programs are thought to stimulate birds' activity and food consumption.

Day-old chicks are usually kept under continuous light for the first two or three days before the lighting programme is started.

Light intensity varies from less than 10 to over 1000 lux if natural light is provided in Louisiana-Systems (Deaton *et al.*, 1989). In windowless houses the chicks can be started at intensities of about 15 lux or higher, and light intensity is often reduced to 5 lux or less after one week. Incandescent light bulbs are most commonly used in broiler houses, but other kinds of lamps, such as fluorescent and high pressure sodium, are used (Darre, 1996). Although it cannot be excluded that type of light influences growth rate, the selection of the lighting system is usually made on the basis of the investment and operating costs rather than physiological responses.

The building's main role is to protect animals against adverse conditions. The 3 major problems encountered are cold weather, hot weather as broilers are very sensitive to excess temperature and humidity which leads to wet litter and also prevents heat dissipation in hot conditions.

Chicks need extra heat during the first weeks of life. According to the recommendations of Tüller (1999), newly hatched chicks require ambient temperatures of 32 to 35°C. When whole room heating is provided the temperature above the litter should be adjusted to 35 °C. The temperature will be reduced gradually to 32 ° at the end of the first week of age and to 26 °C in the third week. The use of whole room heating varies in EU-countries, depending in the energy input costs and the climate. Heat is usually provided by zonal brooder systems which are fuelled by gas or electricity. The temperature under the brooder should be 35°C and the room temperature not under 25 °C at time of placement. The chicks are able to select the areas of preferred temperature. The recommended figures represent only a general guideline. The final regulation of temperature is being carried out by observation of the chicks: crowding under the brooder shows that the temperature is too low while avoidance of the brooders indicates overheating. Zonal heating systems have the advantage of providing the young chick with a temperature gradient in which it can position itself according to its needs. Whole house brooding provides a more stable environment but any dysfunction is far more dangerous for the chicks' welfare and health.

There are recommendations which vary considerably from the above mentioned temperatures. According to the Ross Broiler Breeders Manual (Ross Breeders,1996) the temperature for day-old broiler chicks should be 29 °C when house brooding is provided, and 30° C at the edge of the brooder when spot brooding is practised. The recommendation of Donald (1998) is 33 °C and takes an intermediate position. This may be of welfare interest in so far as it is known that chicks raised under sub-optimal temperatures tend to develop ascites, retarded growth and increased mortality.

Because older chicks can succumb to hot temperatures it is important to protect them against this type of accident when the climate makes it likely to occur. The possible solutions are to spray water to reduce temperature by evaporative cooling, but this does not work in humid climate, and the other to have good ventilation, either static or dynamic. At the same time it is wise to reduce diurnal food intake to avoid extra-heat production during the hottest hours. In this case the animals are fed in the evening and night when the temperature is lower.

There is no special litter management under conventional broiler production systems. Litter conditioning has been shown to reduce ammonia development and to reduce mortality (Shane, 1998; Terzich *et al.*, 1988). It is not practised in Europe so far. Wet litter is a very important problem as it can be the origin of parasitic infestation and also hock burns, contact dermatitis or breast blister. To avoid wet litter it is important to have good ventilation, particularly in humid climates.

Feeder space is not considered an important welfare issue under normal *ad libitum* feeding. Feeder space for chain feeders is about 2 to 3 cm per bird (one sided). With pan feeding systems 70 to 100 broilers can share one pan of 40 cm diameter. When chain feeders or conventional round feeders are used it is recommended to provide feed on flat pans during the first days of age. This practice is not needed when flat automatic pan feeders are used.

The recommendations for feeder space are mainly based on experience from commercial broiler production. There is little scientific work available.

The traditional automatic bell drinkers of 40 cm diameter provide water for 70 to 100 broilers. Supplementary small hand-filled drinkers are required at chick placement. These types of drinkers have to be cleaned frequently. They have been replaced during recent years by nipple and cup drinkers. Depending on the flow rate and operating pressure of the systems 12 to 22 chicks are watered per nipple or cup (Tüller, 1999). Nipple and cup drinkers do not require cleaning by hand. They are flushed with disinfecting agents after each flock.

Feed and water are generally supplied automatically and on an *ad libitum* basis.

Standard broilers, which grow for 5 weeks usually receive 3 different diets: Starter (1st week) containing about 23 % crude protein (CP) and 12 - 13 MJ ME/kg; grower (2nd to 4th week) containing about 22 % CP and 13 - 13.2 MJ ME/kg, and finisher (5th week) containing 21 % CP and 13 - 13.32 MJ ME/kg. The grower diet can be provided from 2 weeks up to the end of the growing period if it does not contain coccidiostats. Standard broiler rations are usually pelleted. This enhances feed intake, and reduces food choice and feed wastes as compared with mash. The starter diet may be fed as mash when early growth rate needs to be retarded to control leg disorders.

Four different diets are recommended when the growing periods are extended up to seven or 9 weeks of age. The grower diet is split into two parts, grower 1 containing 22 and grower 2 containing 21 % CP. Since the differences in nutrient requirements for males and females become important with increasing age the sexes are being kept separately under many extended growing systems.

5.3.1 METHODS OF FEED RESTRICTION

A mild restriction of feed intake in broilers improves feed conversion and reduces leg problems (Petersen, 1988). Restriction is carried out by feeding mash instead of pellets, reducing duration of light, controlling the amount of feed per day, or controlling water consumption. Restricted birds, however develop unrest during the feeding periods and may climb over one another. This can result in damage to the skin and a high percentage of downgraded carcasses, but can also improve leg conditions. There may be other welfare consequences of this practice, particularly when water restriction is used. Feed restriction is not widely used in practical broiler farming.

Feeding whole grain in addition to pellets is used in some cases where the price for farm grown cereals is very low. Special equipment is needed to provide the correct dosage of grain and pellets. It has also to be taken into consideration that the nutrient contents of the pelleted diet must be adapted to the composition and percentage of grain supplementation.

5.3.2 BUILDINGS

Buildings differ according to climatic conditions, with very light buildings with windows, static infrared heaters and ventilation in southern countries and more sophisticated buildings in the north with good thermal insulation, dynamic ventilation, artificial light and uniform temperature inside the building. The ventilation rate is adjusted according to the stocking rate. The ventilation system should provide a minimum of 3.6 to 4 m^3 of fresh air per kg body weight and hour. This amount may not be sufficient under hot conditions, when rates of 4.5m^2 may be needed, so supplementary ventilators should kept on stand-by, or cooling systems should be installed.

An outside run can be associated with every type of building but is more likely to be used with unsophisticated buildings under extensive production systems. There is a general tendency to keep environmental conditions as uniform as possible, though this is probably not the best solution from the welfare point of view. Much research is needed before variable conditions can be applied (see chapter 7).

5.4 Selection of meat type chicken

A small number of breeding companies provides most of the world's chicks. Six companies provide 95% of the breeding birds and 3 of them 80% of the total.

The criteria each company includes in its selection index are not public knowledge but two major objectives are to reduce age at a given weight (maximise growth rate) and to reduce food conversion ratio. These two types of selection have resulted in an increased adult body weight as early growth rate and food conversion ratio are positively correlated with adult body weight (Ricard, 1978). The selection for growth rate was very efficient and between 1925 and 1998 age at 1500g body weight decreased from 120 to 33 days (Figure 1) (Albers, 1998).

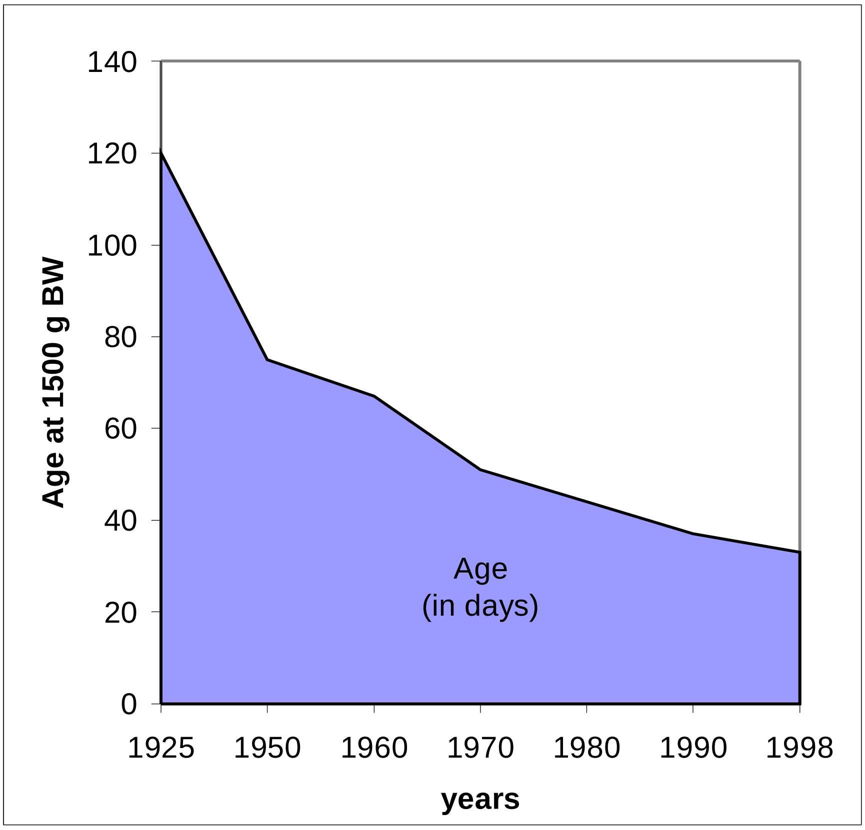


Figure 1: Age (in days) at 1500 g body weight, Albers (1998)

In all cases the production of broilers is the result of a cross between 3 or 4 strains (Figure 2).

Because of the inverse relationship between growth and reproductive abilities, selection objectives may differ for the different lines used in broiler breeding. The overall objective is to produce as cheaply as possible a commercial broiler cross with a high performance potential from parents with good reproductive abilities. Figure 2 gives the number of animals necessary to obtain 10000 broilers. It is clear that the more numerous animals are the mothers of the broiler, followed by the father. Cost of the grandparents only has a marginal influence on the final cost of the broiler chicken. The use of a 3- or 4- way cross (instead of a two-way cross) is the best way to reduce the cost of the broiler as heterosis increases reproductive capacity of the mother. For the same reason it is helpful to have higher laying rate and higher fertility for the strains represented on the left of the figure (line A) than in any other line, and to have the highest body weigh and growth rate in the strains represented on the right hand side of the figure (line C or D).

For every commercial cross line A is thus selected on its growth rate and reproductive capacity whereas line C (3- way) or D (4- way cross) are selected mostly on growth rate.

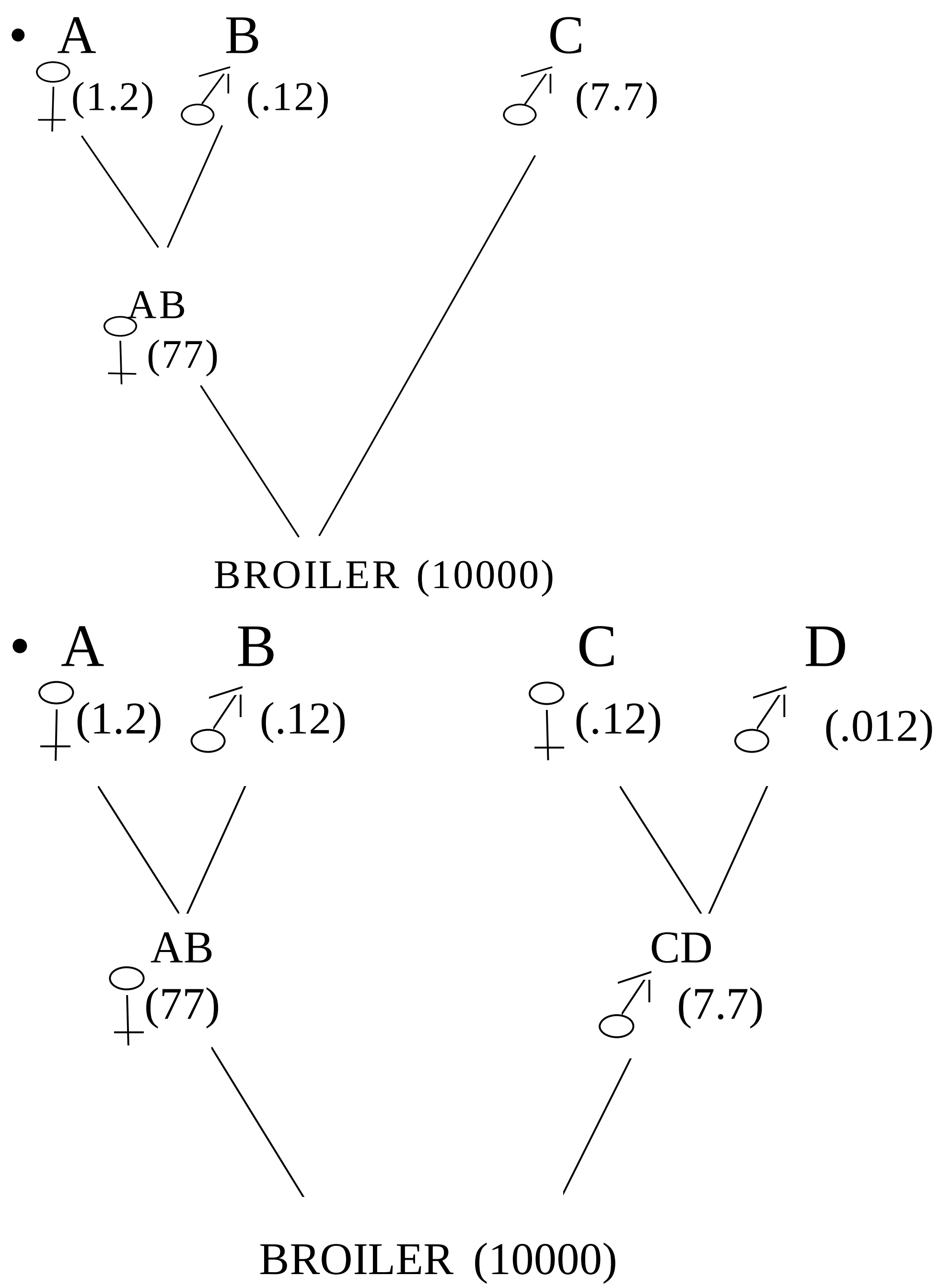


Figure 2: Schematic representation of a 3- way and a 4- way cross used to produce a broiler. (Values into brackets are an estimation of the number of animals of each strain necessary to obtain 10000 broilers)

A third approach to reducing the cost of the broiler chicken is to have dwarf mothers. Because the dwarf gene used is sex linked and recessive, if line B is dwarf, all the females AB are dwarf (whereas AB males are normal heterozygotes) and all the broilers are normal. The dwarf AB females can be kept in higher densities (their body weight is about 30% less than for normal females) (Ricard, 1972). However the dwarf gene is only partly recessive and heterozygotic male broilers are 1.4% lighter than normal broilers (Ricard, 1974). This probably explains why dwarf broiler mothers only represent less than 10% of the world market.

The two major characters selected in breeding birds are thus growth rate and reproductive capacity. However some other characters are likely to be selected by at least some of the breeding companies. Fat deposition and leg problems are also factors that can be selected against. Hardiman (1996) reported that selection against leg disorders was the ninth of 12 factors taken into account by the breeders of broilers, well behind growth rate and feed conversion efficacy.

In a review paper on leg problems Sorensen (1992) showed that heritabilities were usually rather high (0.2 to 0.5) in most of the studies and that lower values were usually found in studies where the incidence of the problems were low. The genetic correlations were rather low (0.1 to 0.3) and the author concluded that genetic correlation "*is not sufficiently high to rule out the possibility of improving* (in the same breeding programme*) growth capacity and decreasing the incidence of leg disorders"*. However the final conclusion was that there were "*several reports stating that the leg disorders problems seem to be increasing"* showing that the selection intensity devoted by breeders to the character was not high enough to counteract the effect of selection for body weight (Sorensen, 1992).

The commercial selection practices resulted in very fast growing animals (see figure 3 for growth curve in broilers, "Label rouge" and layers). As a consequence of this the breeders have to be severely food restricted and the broilers themselves tend to have frequent respiratory problems leading to ascites. They also tend to be more sensitive to heat stress and to have reduced activity leading to contact dermatitis and leg problems. A good illustration of this consequence of high growth rate selection on health is the comparison of mortality between standard broilers (1% per week), "Label rouge" rouge chickens (0.25% per week, Prin and Koehl, 1998) and pullets (0.14% per week, Guerder, *et al*, 1998). It is likely that these metabolic problems and other welfare problems will be the limiting factors to the continued heavy emphasis on selection for growth rate.

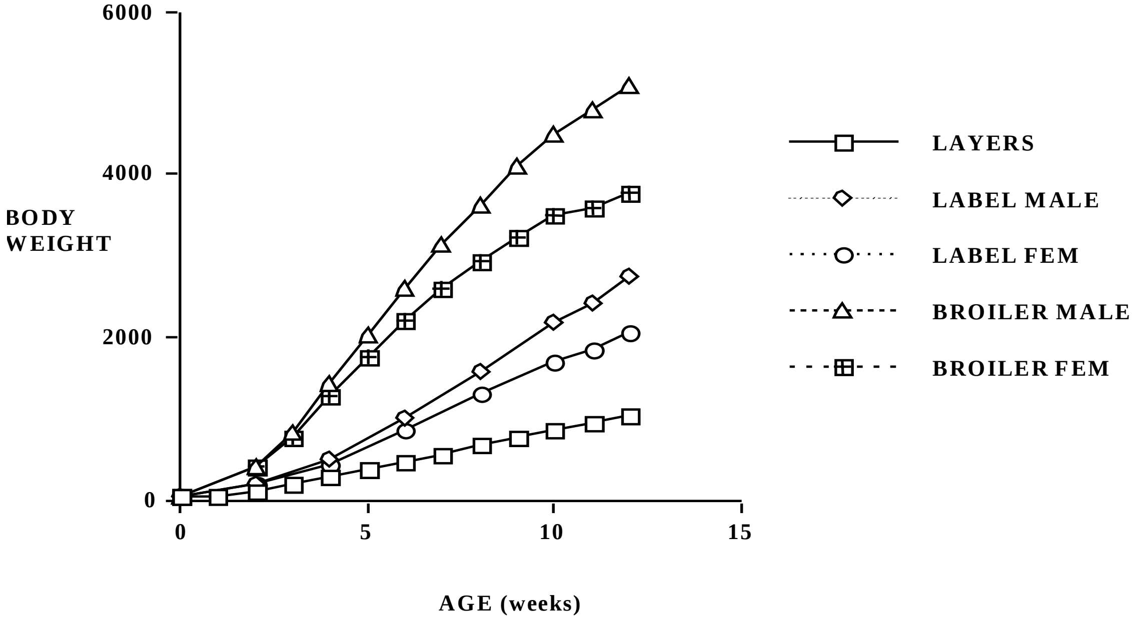


Figure 3: Growth curve of layer (female), broilers and "Label rouge" (males and females). (Prin and Koehl, 1998, Guerder, *et al*, 1998)

For "Label rouge" production the selection criteria are very different as growth rate does not need to be improved (slaughter age must be at least 81 days). In this case strains are mostly selected on their breeding capability and body composition (high breast muscle proportion, low abdominal fat content, thin skin).

To complement the selection for quantitative characteristic, the strains are also selected for some discrete characters such as skin colour (white or yellow), plumage colour (usually white under cover), leg colour (white, yellow, blue or black), comb type or naked neck (giving thinner skin and heat resistance). They can also be selected for sex-linked genes in order to have autosexing chicks (mostly K/k: feathering speed or S/s: white or brown down).

Conclusion

- Broiler chickens are mostly selected for growth rate and food conversion ratio. Other traits such as low frequency of leg disorders or resistance to pathogens are likely to be also included in the selection index by most breeders, but the importance given to such traits is often low and up to now has not improved welfare.

5.5 Consequences of Genetic Selection

The major selected traits in breeding birds are body weight and food conversion ratio. Numerous studies have been conducted to determine the consequences of this selection on other parameters. These studies either compared broilers and layers or random bred but in many cases the animals did not have the same genetic origin, or compared strains divergently selected for growth rate or leanness. Metabolic traits have been affected as well as reproduction, health and behaviour.

5.5.1 METABOLIC TRAITS

Selection for growth rate improves utilisation of energy and amino acids in growing animals. This improved food utilisation is associated with a decrease in metabolic rate, a higher rate of food passage and digestion and higher enzymatic activities in the small intestine (Dunnington and Siegel, 1996). It also decreases lipolysis and thus results in fatter animals. However this effect is probably counterbalanced in commercial breeds by selection for increased food efficiency (Pym, 1985) or for reduced body fat (Whitehead and Griffin, 1985, Leclercq, 1992). Strains selected for a high body weight (without considering FCR) also show a higher concentration of blood glucose, lipids and proteins at 25 days of age and at the endocrine level, higher levels of Insulin Growth Factor 1 in growing birds and Insulin Growth Factor 2 irrespective of age but has no effect on thyroxine 3 and thyroxine 4 levels (Dunnington and Siegel, 1996).

5.5.2 REPRODUCTION

High body weight lines show an earlier age at first egg (Siegel and Dunnington, 1985). The earlier age at first egg in a heavy line might be related to body composition and selection for lean animals can counterbalance this effect (Siegel and Dunnington, 1985).

Fast growing animals show a higher percentage of defective eggs (double yolked, extra calcified, flat sided, soft shelled and broken eggs) (Siegel and Dunnington, 1985) but this is probably partly compensated in breeding birds by restricted feeding. In heavy breeds sperm storage in female sperm gland is lower and decreases more quickly with age (Brillard, 1993).

In male sperm production there is decreased motility, increased proportion of dead or abnormal spermatozoa and lower sperm concentration in heavy birds (Siegel and Dunnington, 1985). A quicker reduction of sperm quality with age is also observed in heavy breeds (Perek and Snapir, 1963; de Reviers, 1996).

Sexual behaviour is also affected by selection for body weight, with high weight males courting 3 times less than the low weight males and showing a lower percentage of complete mating. Reproductive behaviour of females is also affected (Siegel and Dunnington, 1985).

In heavy lines chromosomal aberrations are also more frequent than in layers or light lines (Siegel and Dunnington, 1985)

The reduced egg, sperm, and embryo quality explains the lower reproductive performances observed in broiler lines but at least part of the effect is probably due to fatness of the heavy lines as fat lines have been reported to have poor reproductive performances (Leclercq, 1992). At least part of these deleterious effects are masked in breeding birds by restricted feeding.

5.5.3 HEALTH

Heavy birds show a reduced capacity for antibody production (Qureshi and Havenstein 1994). This can partly explain an increased mortality due to reduced resistance to infectious agents but most of the health problems encountered in broilers are either cardiac (ascites and sudden death) or leg (tibial dyschondroplasia) problems (see 6.1 and 6.2). These two types of metabolic diseases are far more frequent in heavy lines (Rauw *et al*. 1998) than in control or light lines of chicken but can be very variable from line to line. For example Rauw *et al*. (1998) report an incidence of tibial dyschondroplasia as high as 47.5% in one commercial line whereas this problem was far less frequent in most of the commercial crosses.

According to the strain, the type of problem studied and the method used for its calculation, heritabilities of leg problems varies from 0 to 0.5 (Le Bihan-Duval, 1995). The genetic correlation between leg problems and body weight is sufficiently low (0.25) to suggest that it should be possible to select for increased body weight and decreased incidence of leg problems.

Scheele *et al*. (1997) claimed that a primary reason for the increased incidence in ascites is the focus in selection on growth, weight and feed conversion, which has lead to some neglect of the maintenance needs of the birds. An altered protein and energy metabolism may have increased the susceptibility of broilers to ascites. Maxwell *et al*. (1998) and Grashorn *et al.* (1998) found that the heritability of cardiac-derived plasma troponin T was moderately high, and it may be possible to use this variable to select for resistance against heart damage and ascites. Shlosberg *et al*. (1998b) found a correlation between the hematocrit value and the presence of ascites in broilers, indicating that high hematocrit value is also closely related to genetic predisposition for ascites.

Significant differences between commercial lines in the occurrence of sudden death syndrome (SDS) have been reported by various authors (Riddell and Orr, 1980; Steele and Edgar, 1982; Grashorn, 1993). The estimates of heritability for SDS on the basis of paternal half- and full-sibs were 0.06 and 0.04 respectively in a sire line, and 0.01 and 0.06 in a dam line (Chambers, 1986). Comparisons of a commercial sire and dam line and commercial hybrids showed that the parent sire line was more susceptible to SDS than the hybrids (Grashorn *et al*., 1998). There was no direct within line correlation between individual growth rate and SDS. The mean body weight of the birds which died from SDS did not significantly differ from the mean group weight (Grashorn, 1993). The author suggested that SDS is not directly linked with growth rate, but selection for high growth rate has increased the risk for SDS.

All these health problems induce a weekly mortality that is 7 times higher than in pullets and 4 times higher than in slow growing meat type birds, such as "Label rouge" strains.

5.5.4 BEHAVIOUR

The feeding behaviour of broilers has been profoundly modified by selection. In a comparison between lines selected for high or low body weight Dunnington and Siegel (1996) showed that heavy lines consume more food by changing the number of meals but not meal size. Heavy lines also show a reduced detection of taste and adjust their food intake to caloric intake less efficiently than lighter birds. Broilers also show a reduced activity and reduced perching compared with layers (Faure and Jones, 1982).

Conclusions

- A wide range of metabolic and behavioural traits in broilers has been changed by selection practices. Major concerns for animal welfare are the metabolic disorders resulting in leg problems, ascites and sudden death syndrome and other health problems.

6 WELFARE PROBLEMS IN BROILERS

6.1 Mortality

6.1.1 GENERAL REMARKS

Mortality in broiler flocks as reported in the literature cannot be compared easily because the definitions and the way they are calculated differ considerably. In most cases mortality is confounded with culling and hence different criteria for culling influence the levels of mortality. The causes of culling in broiler flocks differ among regions and farms. There are no general rules on culling procedures.

Mortality figures from experimental work are more accurate than those from field studies. But in the experimental groups small numbers of birds depress the reliability of data. In field studies containing large numbers of broilers, the mortality rate is often calculated as the difference of the number of placed chicks and birds delivered to the slaughterhouses. Care must be taken in this case that the number of extra chicks which are usually delivered for placement are taken into account.

In most cases one mortality figure is given for the whole period from placement to slaughter. This has to be taken into account when comparisons of mortality rate are reported from production systems that differ in growing duration.

The total mortality from day-old to slaughter age has been relatively high in the past. A mortality of 18% was not unusual in the 1920s), compared with 2-3 % mortality reported in the 1970s (Gordy, 1974). Comparison of such data is difficult because there has been a dramatic change not only in the growing period but also in breeds, management conditions and disease control.

6.1.2 EARLY MORTALITY

Mortality, which occurs during the first week of chicks' placement, is usually categorised as early mortality. Separate recording of early mortality is justified in so far as problems with the parent stocks, storage of hatchery eggs and hatching techniques may influence mortality in the first days of life. Higher early mortality occurs in chicks which are hatched from young rather than from older parent stocks (McNaughton *et al.*, 1978; Petersen *et al.*, 1987), probably as a consequence of better egg size and shell quality in the latter. It is known that chicks hatched from extremely small or large eggs, or eggs with poor shell quality have poor liveability. This means that the selection of hatching eggs can influence early mortality. For economical reasons, however, appropriate screening of hatching eggs is not often practised. Deviation from optimum hatching temperatures increases early mortality in the chicks (Michels *et al.*, 1974). Cloacal sexing of broiler chicks for separate growing of male and female broilers and extended delay from hatch to placement are also causes of early mortality.

6.1.3 MORTALITY IN OLDER BROILERS

It is obvious that rapid growth which is the result of genetic selection and intensive feeding and management systems is the main cause of various skeletal disorders and metabolic diseases (Julian, 1998) that have become important causes of mortality. Gardiner *et al.* (1988) found a clear relationship between body weight and mortality, in particular to mortality caused by the Sudden Death Syndrome (SDS). Differences between breeds in mortality have also been reported by many authors (Tarrago and Puchal, 1977; Neupert and Hartfiel, 1978; Proudfoot *et al.*, 1979; Seemann, 1981; Ehinger, 1982; Sailer, 1985; Grashorn, 1987; Bergmann *et al.*, 1988). It is also well documented that in male broiler (which grow faster than females) the mortality is about twice as high as in females (Cassidy *et al.*, 1975; Seemann, 1981; Proudfoot *et al.*, 1982; Bergmann *et al.*, 1988; Greenless *et al.*, 1989; Hulan *et al.*, 1989). One of the most important causes of mortality in modern broilers is SDS, and in some countries ascites. The peak of both mortality from SDS and ascites is usually after the second week of age (see 6.6).

Slow growing breeds, such as "Label rouge" show lower mortalities as compared to standard broilers when reared under similar conditions (Bauer *et al.*, 1996). Various management and feeding measures, which reduce early growth, obviously reduce the level of mortality in standard broilers. This effect has been reported for

- feed restriction
- lighting programmes
- mash vs. pellet feeding
- low protein and energy diet

(Gardiner, 1971; Hulan and Proudfoot, 1981; Scholtyssek, 1987; Mollison *et al.*, 1984; Tiller, 1984; Petersen, 1988).

More detailed information on mortality will be provided in the relevant chapters on management, stocking density, ascites and sudden death syndrome.

Conclusion

- Mortality rate is a rather complex measurement. In most cases, it comprises birds that have been culled as well as those dying naturally. Pre-hatching factors related to egg size and shell quality influence early mortality and can be reduced by appropriate screening of hatching eggs. Mortality in older birds is often related to metabolic disorders caused by rapid growth.

6.2 Skeletal disorders

Skeletal problems in broilers affect predominantly the locomotor system and are often referred to under the general term "leg weakness". Many pathologies have been described but, despite much research, problems are still widespread. Research has been successful in identifying and eliminating some causes, such as chondrodystrophies caused by simple nutrient deficiencies. However, the more intractable types of problem that remain have grown in importance and are major causes of poor welfare for birds. Infectious, developmental and degenerative causes all contribute to the skeletal problems currently affecting broilers and breeding birds.

6.2.1 INFECTIOUS DISORDERS

6.2.1.1 Femoral head necrosis

Femoral head necrosis (FHN), more correctly known as proximal femoral degeneration, is a very severe degenerative disorder. It frequently affects broilers towards the end of the growing period and gives rise to characteristic signs. Birds do not show any outward signs of leg deformity but are reluctant to walk, and when they do, they place their wing tips on the ground to support themselves. On post mortem examination, the cartilaginous epiphyseal plate can be found to separate easily from the bone metaphysis or, alternatively, the femoral head can have disintegrated completely. A study of FHN cases has shown that it is a bacterial osteomyelitis in which coagulase-positive Staphylococci are the main infective organisms present within epiphyseal cartilage (Thorp *et al.*, 1993) and lead to necrosis and degeneration of cartilage and adjacent bone tissue. Immunosuppression, perhaps associated with challenge from infectious bursal disease' may be a contributory factor in the development of infection. Other nutritional and developmental factors may also be involved. The particular vulnerability of the femoral head to osteomyelitis may arise from a sluggish circulation in metaphyseal vessels contributing to a localisation of bacteria. Pre-existing pathologies including disruption of physeal vasculature and small cracks and clefts commonly seen in broiler femoral head cartilage (Thorp, 1988) may then act as foci for bacterial invasion. Likewise, defects in cartilage mineralisation such as those arising from rickets or dyschondroplasia may further enhance the problem.

6.2.1.2 Synovitis

A range of problems characterised by arthritis/tenosynovitis in joints has bacterial and viral causes. The lesions can include swollen joints and tendons, with occasional rupture of the gastrocnemius tendon, thickened capsules, purulent exudate, pitted articular surface. Bacteria that have been identified include *Staphylococcus*, *Salmonella*, *Pseudomonas* and *E. coli* (Reece, 1992). These bacteria may not all be primary causes of the whole range of pathologies, but may complicate lesions brought about by primary infections by reovirus or mycoplasma (especially *M. synoviae*).

6.2.1.3 Infectious stunting

An infectious stunting syndrome (ISS) has been reported in young chicks from most countries with intensive broiler production. Conditions variously named as runting and stunting syndrome, malabsorption, pale bird syndrome, 'helicopter disease' may all be manifestations of the same problem and picornavirus-like particles have been implicated as a cause (Reece and Frazier, 1990). The conditions are characterised by poor, uneven growth, sometimes accompanied by signs of enteritis. Lameness and reluctance to move are explained by signs of calcium or phosphorus deficiency rickets in leg bones. Impaired digestion and nutrient absorption caused by the infection, rather than dietary deficiency, appear to be primary causes of these bone lesions.

6.2.2 DEVELOPMENTAL DISORDERS

The main developmental disorders are characterised by angular and rotational deformities of the leg bones. They are most commonly seen as hock joint distortions of the varus or valgus type, although the original deformity may have arisen at another location such as the femur or proximal tibia. The main primary deformities may involve defective formation of bone (osteodystrophy) or cartilage (dyschondroplasia). These defects in the long bones and the joints may, in turn, lead to secondary soft tissue pathologies. These deformities seem to affect all types of modern broiler, though the incidences of specific abnormalities and their impacts on lameness can vary between current commercial strains (Kestin *et al*., 1999).

6.2.2.1. Bone deformity

Angular limb deformity of the valgus/varus type is the most common long bone distortion seen in broilers. It involves either outward or inward angulation of the limb at the intertarsal joint. Deformity can also arise in the stifle joint and can be quantified by measurement of the plateau angle of the proximal tibia. Values of up to 20^0 may be considered normal, but can almost double in deformity (Lynch *et al.,* 1992).

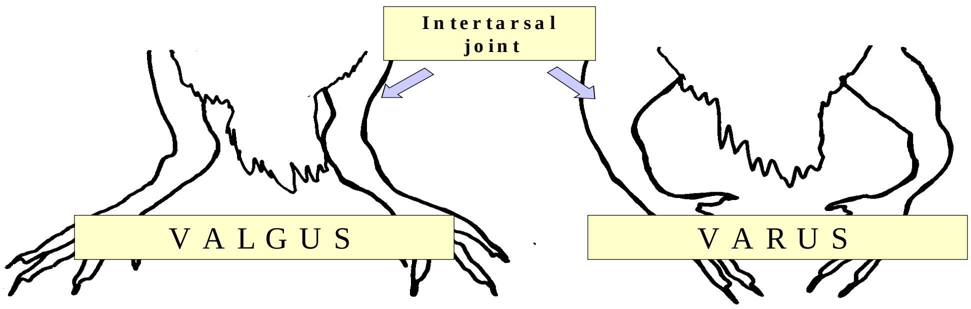


Figure 4. Valgus and varus deformity of the intertarsal joint is the commonest form of long bone distortion in broiler chickens and refers simply to either outward or inward rotation.

Rotational deformity is less common in broilers. It involves a rotation of the shaft of the tibia, often by up to 90° and sometimes even 180° and is often reported as twisted leg. It is usually unilateral, though both legs can be affected on occasions.

Both of these deformities can occur in leg bones without any signs of lesions, which may have caused them. Long bones are subject to biomechanical forces, which result in tension and compression and influence the development of normal bone torsion or angulation (Lanyon and Baggott, 1975). Pressure on the bone growth plate may affect the columnar orientation of chondrocytes and thus influence directional or angular growth. Normal application of biomechanical loads through degree and nature of exercise are required for proper bone development and restricting movement, such as by keeping growing birds in cages, is thought to cause a higher incidence of twisted legs (Haye and Simons, 1978).

Angular limb deformities are also a cause of considerable interest in rapidly growing horses (Brauer *et al.,* 1999). Both congenital factors (Auer *et al.,* 1982) and developmental factors have been associated with the condition in foals (Auer *et al.*, 1983).

6.2.2.2. Dyschondroplasia

Dyschondroplasia is the most common lesion seen in broiler leg bones. It is characterised by the build up in the bone growth plate of an avascular mass of prehypertrophic chondrocytes. These are chondrocytes, which have not fully matured and hence do not allow the normal process of bone calcification to occur. The lesion can occur in distal and proximal femur and tibia but are largest in the last and is hence usually referred to as tibial dyschondroplasia (TD). It develops usually between 2 and 5 weeks of age (Lynch *et al.*, 1992) before regressing. The size of the lesion can range from a small focal accumulation of chondrocytes to a large mass extending over the whole width of the growth plate. The lesion can lead to two types of problem. If the lesion is large, a fracture may develop through the growth plate. The more usual consequence of TD is the development of an abnormal tibial plateau angle (Lynch *et al.*, 1992) leading to deformity of the valgus/varus type.

TD has a strong genetic component and divergent selection for low and high incidence has been carried out experimentally using a hand-held X-ray fluoroscope (Lixiscope). In practice, it has proved easier to increase the incidence of TD than to reduce it to low levels (Wong-Valle *et al.*, 1993), partly because of the difficulty in detecting smaller TD lesions with the Lixiscope.

TD is also heavily influenced by nutrition (see also section 8.2). Dietary calcium/phosphorus (Edwards and Veltmann, 1983) and ionic balance (Hulan *et al.*, 1986) can affect TD incidence, though optimisation of these factors does not prevent TD. The most effective nutritional means of combating TD involves dietary supplementation with vitamin D metabolites. Dietary supplementation with vitamin D itself is ineffective but adding 1-hydroxylated metabolites to diets markedly reduces TD incidence. The metabolite studied most extensively is 1,25-dihydroxyvitamin D3 which has been shown to prevent TD completely (Edwards, 1990; Rennie *et al.*, 1993). This compound is not available commercially but its metabolic precursor, 25-hydroxyvitamin D, is available as a commercial feed additive. 25-Hydroxyvitamin D is less effective than 1,25-dihydroxyvitamin D but has also been shown to decrease the occurrence of TD (Rennie and Whitehead, 1996), though there has been variability in the response. The mechanism of action of vitamin D metabolites in preventing TD has not yet been established and more information on this subject would help the establishment of a more effective and consistent nutritional strategy for preventing TD.

6.2.2.3. Rickets

Rickets has some similarities to TD in that it also involves accumulations of growth plate cartilage and is affected by dietary calcium and phosphorus contents and balance. However, rickets differs histologically from TD and no aetiological link has been established between TD and rickets. There are two types of rickets. Calcium deficiency rickets is characterised by an increased thickness of the zone of proliferating chondrocytes whereas an increase in the thickness of the hypertrophic zone is seen in phosphorus deficiency rickets. Provision of adequate dietary calcium, phosphorus and vitamin D will prevent rickets under normal conditions, in the absence of malabsorption syndromes.

6.2.2.4. Bone strength

Most of the musculoskeletal problems affect the function of the locomotor system. The term "leg weakness" does not specifically imply bone weakness. However, cases of bone fracture do occur in broiler production, during catching of birds and when they are hung on shackles before slaughter. The fractures can result from weak bones or from forcing deformed limbs into the shackle. Though broilers rarely suffer from osteoporosis, maintenance of bone strength is nonetheless important in broiler production. Evidence has been obtained recently that a modern broiler strain has been showing decreased bone mineralisation and increased porosity of cortical bone that could result in more fragile and easily broken bones (Williams *et al.*, 2000). This finding may indicate that continued genetic selection for fast growth is resulting in poorer bone quality.

In a pathomorphological study on a total of 360 broiler chicken which had been random-sampled on day 22 and day 35 of the fattening period from several flocks, about 90% of the animals showed bending of the vertebral column by 20° at the height of the 6^{th} thoracic vertebra. The L6 and L7 vertebrae were particularly affected. In numerous birds the 6^{th} vertebra was dislocated and slightly rotated causing encroachment of the vertebral canal. Löhnert *et al*. (1996) assume that these abnormalities in the spine of the birds together with other disorders such as plantar pododermatitis may cause pain resulting in decreasing movements and activities.

6.2.3 DEGENERATIVE DISORDERS

Degenerative disorders of joints occur in broilers but are usually more prevalent in birds grown to greater ages and weights for breeding purposes. In older birds, destructive cartilage loss or osteoarthrosis in the hip joint, particularly the antitrochanter, can be widespread (Hocking *et al.*, 1996b). These problems are less apparent in feed-restricted birds. Ruptured tendons and ligaments can occur, particularly in male breeding birds (Duff and Hocking, 1986). These degenerative disorders in older birds may represent the progression of abnormalities occurring at earlier ages, or may be the consequences of loadbearing or trauma through life but arthritic lesions in younger broilers can also result from viral infections.

6.2.4 WELFARE IMPLICATIONS OF LEG DISORDERS

The welfare impacts of musculoskeletal disorders in poultry are the pain or discomfort experienced by affected birds and the consequences of impaired locomotion. Innervation in the joints of chickens is similar in many ways to that in mammals (Gentle, 1992a) and joint pathologies that are painful to humans and other mammals are also likely to be painful in chickens. Some welfare assessments can be made easily. Birds with extreme abnormalities, such as severe femoral head necrosis, show overt pain responses. Birds that have high lameness scores negotiated an obstacle course faster after the administration of a non-steroidal anti-inflammatory drug. Furthermore, lame birds selectively significantly more drugged feed than sound birds and as the severity of the lameness increased so they at significantly more of the drugged feed. (McGeown *et al*., 1999, Danbury *et al.*, 2000).

Likewise, welfare is obviously compromised in birds that are unable to reach food and water and die from starvation and dehydration. However, the degree to which welfare is poor in other types or degrees of lameness is less easy to categorise.

Gait analysis has been used to characterise the walking ability of birds and a subjective scoring system has been developed (Kestin *et al.*, 1992) with scores ranging from 0 to 5. Birds with score 0 have normal and agile walking style and inclination. Birds scoring 1 and 2 have slight defects of varying degree that result in abnormal gait, but the defects do not seriously compromise the ability of the bird to move. In birds with score 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 on their feet. Dissection studies have confirmed that birds with poorer gait have more skeletal deformities. A high proportion of birds with gait scores 4 or 5 are generally affected with FHN. In birds with lower scores, there is an association between lameness and the occurrence of TD (Vestergaard and Sanotra, 1999).

Abnormalities resulting in degeneration or inflammation are likely to be directly painful. Cartilage does not have nerves so conditions affecting the growth plate are probably not directly painful, though pain may arise because of the presence of receptors in the synovial membrane. This is likely to be the case in TD but the situation with rickets is less clear cut since pain may result from a general calcium deficiency rather than from a specific bone lesion. However, regardless of the inherent painfulness of lesions, if growth plate or other conditions result in a deformity causing pronounced lameness, this is likely to produce abnormal strains on tendons and muscles leading to inflammation in these structures and consequent pain. These conclusions are supported by observations of McGeown *et al*. (1999) who reported that the walking ability of broilers with moderate lameness (gait score 3) was improved considerably following administration of carprofen, a drug with both analgesic and anti-inflammatory properties. In contrast, Hocking (1994) found that administering an anti-inflammatory drug did not improve the walking ability of broiler breeder males with mild cartilage degeneration in the hip joint.

The welfare of birds with different walking abilities has been judged by a number of criteria. Birds with gait scores 4 and 5 show considerable difficulty in walking or are unable to walk and obviously have very poor welfare. The welfare of birds with gait scores 1, 2 and 3 has been more difficult to judge. Behavioural studies have shown that lame birds spend more time lying and sleeping and less time on activities such as standing, running, preening or dust bathing (Vestergaard and Sanotra, 1999). There is good evidence that welfare is poor in birds with gait score 3 or higher (Kestin *et al*., 1992; McGeown *et al*., 1999).

Surveys have been carried out to assess the distribution of gait scores in commercial broiler flocks. During their development of the gait scoring method, Kestin *et al.* (1992) also studied the distribution of scores in some small groups of broilers in the UK. The mean proportion of birds over four intensively reared flocks (1127 birds examined) with gait score 3 or higher was 10%. A comparison of commercial strains showed that one strain had a particularly poor gait score, with 27% of birds having gait score 3 or above. A more recent, much larger survey of UK broiler flocks commissioned by the British Chicken Association, at the request of the Farm Animal Welfare Council, has found that the proportion of birds with gait scores of 3 and above was nearer to 3% (25000 birds examined). Assessors for this latter survey tried to use the same scoring system as Kestin *et al.* (1992). These results are not published and factors such as the age of the birds, the actual scoring procedures and culling procedures prior to gait assessment are not known. Care is needed in comparing the results of these surveys. Firstly, the number of birds studied in the initial Kestin *et al.* (1992) survey was rather low to give an indication of the overall state of leg health in the UK broiler flock. Secondly, the gait scoring system is subjective and the results depend on the age of the birds and the ways in which the subjects were selected. The reasons for the differences between these studies need to be elucidated especially in the light of the recent study in Denmark which used birds of a type widespread in Europe and which reported that that 30% of birds sampled had gait score 3 or higher (Sanotra, 1999).

Conclusions

- Leg disorders are a major cause of poor welfare in broilers. Gait scoring surveys have shown that large numbers of broilers have impaired walking abilities and there is evidence that birds with score 3 or higher experience pain or discomfort. However, the subjective nature of the scoring system leads to difficulties in making direct comparisons between different studies and there is a strong need to develop objective measurement systems and to carry out systematic epidemiological studies. Femoral head necrosis is an important cause of poor welfare. Developmental disorders resulting from dyschondroplasia or other bone growth abnormalities represent less severe but more widespread problems. Continued effort is needed to improve genetic, nutritional and management methods of minimising these problems.

6.3 Muscle disorders

Avian muscle is similar in structure to the mammalian tissue. The circulating activities of a number of enzymes are raised in muscle damage or myopathy. These enzymes include lactate dehydrogenase, aspartate aminotransferase (AST) and aldolase but creatine kinase (CK) is most commonly used for the diagnosis of muscle damage because of its very high activity in and high specificity for muscle. This enzyme has been widely used in the diagnostic interpretation of various avian pathologies (Siller *et al.*, 1978; Hollands *et al.*, 1980; Tripp and Schmitz *et al.*, 1983), acute heat stress (Ostrowski-Meissner, 1981) and transportation stress (Mitchell *et al.*, 1992). Elevation in the circulating concentration of troponin T is taken to be specific for heart muscle damage.

6.3.1 MUSCLE ABNORMALITIES

Deep pectoral myopathy (DPM), Oregon disease or green muscle disease is a degenerative myopathy of the deep pectoral muscle in broilers and turkeys. The muscle is inflamed and oedematous with localised haemorrhages, pigmented green and contains large amounts of necrotic tissue. The problem is caused by ischaemia during exercise caused by raised intramuscular pressure. It is accompanied by large increases in plasma CK and AST activities (Siller *et al.*, 1978).

Muscular dystrophies in broilers can have either genetic (Hudecki *et al.*, 1995) or nutritional causes. Nutritional muscular dystrophy is caused by deficiencies of antioxidants, particularly vitamin E and selenium (Cheville, 1966; Hassan *et al.*, 1990). Affected muscles show degenerative changes including calcium deposits, vascular lesions and haemorrhages.

A number of agents can cause toxic myopathies in poultry, with monensin toxicity perhaps being the most frequently described. Monensin is a sodium ionophore coccidiostat which in excess disrupts sodium-potassium balance leading to an increase in intracellular calcium concentration.

Focal and stress induced myopathies are also seen in poultry and may have a strong genetic component, with elevated levels of muscle damage being associated with genetic selection for high growth rate. Using plasma CK activity as an indicator of muscle cell membrane integrity, it has been demonstrated that the degree of myopathy increases with age in commercial broilers (Mitchell and Sandercock, 1994). There are also greater signs of muscle damage in modern lines selected for rapid growth than in slower growing lines. Moreover, faster growing birds show signs of more severe muscle damage when exposed to acute heat stress (Mitchell and Sandercock, 1995). The evidence thus suggests that genetic selection for production traits predisposes birds to spontaneous or stress induced muscle damage, probably through a mechanism involving impaired muscle cell calcium homeostasis.

Parallels may be drawn with pigs, where susceptibility to myopathies associated with porcine stress syndrome and pale, soft, exudative (PSE) meat have strong genetic components. In poultry, muscle activity, metabolism and bird survival may be affected by undesirable changes in calcium regulation and transport. It has been suggested that such effects in cardiac muscle may underlie Sudden Death Syndrome (Reiner *et al.*, 1995). The full impact on the welfare of the bird of these genetic effects is not well established and should be the subject of further research.

Conclusions

- Myopathies and biochemical indices of muscle damage have been identified in modern broilers. A better understanding is needed of whether or how changes in muscle physiology resulting from modern breeding practices have an impact on bird welfare.

6.4 Contact dermatitis

Skin diseases are the disorders in broilers that have increased most over the last 30 years, increasing from 1.4% in 1969 to 34.5% in 1988 (Hartung 1994b). They are usually characterised by conditions or lesions of the skin on the breast, hocks and feet of the birds. The different forms can also involve the subcutis and the muscle fascia. The lesions are commonly referred to as 'breast blisters', 'hock burns' and 'ammonia burns' respectively, and are all believed to have a similar background (Nairn and Watson, 1972; Harms and Simpson, 1975; Greene *et al.*, 1985; Martland, 1985; Bruce *et al.*, 1990). The lesions on breast and hocks usually develop more slowly and are less frequent than lesions on the feet (Stephenson *et al.*, 1960).

In an early stage, discoloration of the skin is seen. Hyperkeratosis and necrosis of the epidermis can be seen histologically. The histopathological changes observed in the skin are similar to those described in many other types of dermatitis, and no lesions specific for the disease have been observed (Greene *et al.*, 1985; Martland, 1985). In severe cases, the erosions are developed into ulcerations with inflammatory reactions of the subcutaneous tissue (Greene *et al.*, 1985). The ulcerations are often covered by crusts formed by exudate, litter and faecal material. Although not primarily caused by any particular microbial agent, the lesions often become infected by a variety of bacteria and fungi (Greene *et al.*, 1985), especially *Staphylococcus spp.* (Hester, 1994). The lesions may heal (Greene *et al.*, 1985).The healing is quicker if the litter quality is substantially improved (Martland, 1985). For broilers, this rarely happens under commercial conditions, except when flocks are thinned as a portion of the flock is removed for slaughter.

The lesions are thought to be caused by a combination of wet litter and unspecified chemical factors in the litter (Nairn and Watson, 1972; Harms *et al.*, 1977; Greene *et al.*, 1985; Martland, 1985; McIlroy *et al.*, 1987; Schulze Kersting, 1996). Such lesions can cause pain, which together with a deteriorated state of health constitutes a welfare issue. Apart from animal welfare aspects, contact dermatitis is relevant to the poultry meat industry for several reasons. For example, it has been indicated that broilers with severe foot-pad dermatitis show slower weight gain (Martland, 1985; Ekstrand and Algers, 1997), which has been suggested to be a result of pain-induced inappetance (Martland, 1985). As flocks with a high incidence of foot-pad dermatitis often also show a high prevalence of other types of contact dermatitis, such as breast blisters and hock burns (Greene *et al.*, 1985; Martland, 1985), in addition to lower body weights, downgrading may adversely affect the profitability of these flocks (Wise, 1978; Cravener *et al.*, 1992). Finally, the lesions can be a gateway for bacteria, which may spread through the blood stream and cause joint inflammations and impaired product quality in other ways (Schulze Kersting, 1996).

Earlier research aiming at identifying factors influencing the incidence of contact dermatitis, and especially foot-pad lesions, has been directed mainly towards the effect of different feed compositions (Patrick *et al.*, 1942), such as biotin, riboflavin and methionine deficiencies. Seasonal effects, mainly related to variations in relative air humidity influencing litter quality, have been shown to be related to the prevalence of contact dermatitis (McIlroy *et al.*, 1987; Bruce *et al.*, 1990), also in flocks reared in so-called 'climate controlled' houses (Ekstrand and Carpenter, 1998b). For a more thorough discussion on risk factor for wet litter, see chapter 5.2.

A frequent form of latent skin damage is the so called deep dermatitis (Bergmann and Scheer 1979). This is an infection of the subcutis, especially on the caudal back, thighs and around the cloaca. The skin is slightly swollen at sites of inflammation. The skin does usually not show any lesions. The affected areas have a slightly pale colour in comparison to normal skin. Some show faint but bright yellow discoloration of the skin surface (Randall *et al.* 1984). No clinical signs are visible in the living flock but the disease causes economical losses because of degrading and rejection of carcasses (Glünder 1989). Usually the bigger birds are affected. The disease is caused by *Escherichia coli* (strain penetrating through the skin into the subcutis by scratching wounds in the skin or by sharp litter particles penetrating through the skin (Valentin 1987, Valentin and Willsch 1987). The infected area contains masses of fibrinand is only seen at meat inspection where the whole carcass has to be condemned. Losses in broiler herds can reach up to 5 %. It is assumed that high animal densities, poor hygiene, particularly insufficient ventilation rates support the development of the disease. By improving litter management and ventilation/air quality conditions deep dermatitis can be kept below 2%. It is not known whether or how much the animals suffer from the disease.

Stephenson *et al.* (1960) and Bruce *et al.*(1990) have reported associations between the age and sex of broiler chickens and the prevalence of hock and breast lesions. In some studies, higher incidence of foot-pad lesions have been reported in male birds compared to females (Harms and Simpson, 1975; Cravener *et al.*, 1992), but other studies have not been able to reproduce these results, possibly due to lower age and weight at slaughter (Berg, 1998). No biologically significant differences between different commercially available hybrids have been identified (Ekstrand and Carpenter, 1998c).

There is only limited information available on the actual incidence of the different types of contact dermatitis in European broilers. The few internationally reported surveys have been concentrated on estimating the point prevalence at time of slaughter. In studies carried out in Northern Ireland in the late 1980s, the prevalence of hock burn was found to be approximately 20 % and the prevalence of breast blisters 0.2-0.3 % (McIlroy *et al.*, 1987; Bruce *et al.*, 1990). In another study, also from Northern Ireland, the flock prevalence of contact dermatitis in general was reported to be up to 90 % (Greene *et al.*, 1985). Swedish studies on broiler foot-pad dermatitis have shown that the average flock prevalence of severe foot-pad lesions was 5-10 % (Elwinger, 1995; Berg, 1998), with a range from 0-100 % in different flocks (Ekstrand *et al.*, 1998c).

Conclusions

- Contact dermatitis is a relatively widespread problem in the European broiler production. The problem cannot easily be handled by breeding efforts or by changes in age or weight at slaughter within commercial ranges. Management practices seem to be the most important factor in preventing the occurrence of wet litter which, together with feed composition, is believed to be the main underlying factor of the disease.

6.5 Ascites and Sudden Death Syndrome

Ascites and Sudden Death syndrome (SDS) are two important, lethal diseases of broilers. They are closely related, although their pathologies differ, in that they are both metabolic in origin, and both affect the faster growing males more than females (Maxwell and Robertson, 1998). Although the clinical signs of ascites and Sudden Death Syndrome differ considerably they share a wide range of common risk factors and causes. It is generally assumed that the central problem for both diseases is a lack of oxygen caused either by shortage of supply or by too high demand.

Therefore, both pathologies are both treated in the following sections.

6.5.1 ASCITES

Ascites in broilers is characterised by a dilatation and hypertrophy of the right side of the heart, affecting both the atrium and the ventricle. It develops rapidly, and typical signs are cardiac failure and several changes in liver function, causing an accumulation of ascitic fluid, with or without fibrin, in the abdominal cavity (Riddell, 1991). It mainly affects fast growing broiler chickens, and it is known to be the primary cause of death in birds reared at high altitude (Maxwell and Robertson, 1998). Maxwell and Robertson (1998), in a world wide survey in 1996, estimated the incidence of ascites to 4.7 %, which makes it one of the major causes of death in broilers.

At high altitudes, hypoxia may increase pulmonary artery blood pressure, causing a subsequent dilatation and hypertrophy of the right side of the heart and associated valve lesions (Julian 1987, 1993; Julian *et al.* 1986, 1989a,b, 1993, Julian and Goryo 1990, Julian and Wilson 1992, Julian and Squires 1994). However, ascites may also be the consequence of a circulatory insufficiency associated with a progressive bradycardia rather than the result of pulmonary insufficiency. Pulmonary hypertension may be a secondary effect (Olkowski *et al.*, 1998). According to Maxwell *et al.* (1992a) reduced pO_2 and resulting hypoxemia are the most important factors in the aetiology of ascites at high altitude. Owen *et al.* (1990; 1995a,b), in a series of experiments, reared broilers in hypobaric chambers simulating altitudes of 3000, 3500 and 5000 meters. Their results confirmed the importance of altitude as a causative factor for the syndrome. Julian and Squires (1994), using the hypobaric chamber, found that the relationship between right ventricular hypertrophy and duration of hypoxia was greater than that between polycythaemia and duration of hypoxia.

Today ascites is a world wide problem, and is readily found in broilers reared at all altitudes. At lower altitudes, increased myocardial intracellular concentrations of calcium, and general cellular activity of lactate-dehydrogenase (LDH) may be the more important aetiological factors. Although Jimenez *et al.* (1998) found that males showed higher levels of ascites than females, Shlosberg *et al*. (1992) observed no connection between sex and packed cell volume or ascites heart index, in ascitic birds, and therefore the effect of the sex of the birds is still somewhat unclear.

Ascites may develop secondarily to some infections and intoxications. Hepatotoxins usually increase the susceptibility; Shlosberg *et al.* (1997) found increased ascites in birds with ocratoxin intoxication. Hatayde *et al*. (1997) observed that ascites could arise after consumption of *Crotalaria spectabilis* hepatoxic seeds. Viral respiratory diseases like IB with or without *E. coli* or *Mycoplasma* infections, can lead to ascites (Tottori *et al.,* 1997).

Several different diagnostic methods have been used for the detection of ascites in a broiler flock. The most common practical method is to use autopsies or simplified post-mortem examinations (Shlosberg *et al.*, 1998b). In addition, there have been some methods developed on an experimental scale, but they are not in common use in practical farming. These include: hematocrit level and saturation of the arterial blood with oxygen (PaO_2) (Shlosberg *et al.*, 1998b); polycythemia and Cardiac Index (CI) (Jimenez *et al.*, 1998); PNN (Probabilistic Neural Network), the PNN index ranges between 0 and 2 in blood, and includes body weight, the hematocrit value, S wave, electrocardiogram and cardiac rhythm in specimens (Roush *et al.*, 1997); measurement of plasma levels of troponin-T, a cardiac-specific protein that forms part of contractile apparatus of striated muscle - hypoxic broilers have an increased troponin-T value (Maxwell *et al.*, 1995a,b); Electrocardiography (Wideman *et al.*, 1998).

Ascites develops faster in low ambient temperatures (Shlosberg *et al.,* 1992; Olkowski and Classen, 1998b; Yahav and Hurwitz 1996, Yahav *et al*, 1997). It appears that there is an interaction between temperature and oxygen pressure, so that ascites develops more often in low oxygen pressure, even when temperature is high (Vanhooser *et al.*, 1995).

6.5.2 SUDDEN DEATH SYNDROME

The Sudden Death Syndrome (SDS), a major cause of mortality in broilers, was first described in the early 1980s and in Europe its reported incidence is between 0.1 and 3%, with large differences between the various countries (Maxwell and Robertson, 1997).

A concise description of SDS has been given by Newberry *et al.* (1987). It is characterised by sudden vigorous wing flapping, muscle contractions and obvious loss of balance. Vocalisation can be heard in some cases. In the final phase the birds fall on their back or to the side and die. The duration from the first unrest until death was found by Newberry *et al* (1987) to range from 37 to 69 seconds. Because of the rapidity of the death and the typical posture of the dead birds (80 % are found lying on their backs; Bowes and Julian, 1986), SDS has also been called ”sudden death” or “flip-over-syndrome”.

Using electrocardiography it was demonstrated that aberrations of the cardiogram occurred in birds which were susceptible to SDS (Grashorn, 1993). Post-mortem necropsy of birds which died from SDS show that the individuals are generally in good body condition, the digestive tract is filled, heart ventricles are contracted and lungs are congested. Olkowski and Classen (1997) concluded that SDS is associated with an acute cardiovascular failure caused by lethal cardiac arrhythmia and ventricular fibrillation. Reiner *et al.* (1995) found that SDS is a disease of well developed, predominantly male broiler chickens where death appears to occur because of cardiovascular failure, which can be caused by a deficient calcium regulation which may lead to hyperactivation of skeletal muscles, followed by elevated lactic acid concentrations and cardiovascular failure. Itoh et. al (1997) found that the heart damage that produces SDS can be associated with the increase of serum creatine kinase levels (CK). The incidence of SDS during the growing period of commercial broilers shows highest levels between the 3rd and the 5th week of age (Summers *et al.*, 1987; Riddel and Springer, 1985; Ononiwu *et al.*, 1979; Grashorn, 1993). In one study of a single cross sire line, the maximum mortality by SDS was in the 5th and 6th week of age, and males were generally more affected than females (Grashorn *et al.*, 1998). Selection for high growth rate may increase the risk (see chapter 5.5).

Handling (weekly weighing and blood collection) and high stocking density did not increase the levels of SDS (Grashorn, 1993). This was explained by the habituation of the birds to the procedure when it was started at early age. A sudden manipulation (catching and pushing), however, may cause mortality in unprepared chicks (Freeman and Manning, 1979; Jones and Hughes, 1981).

Increased troponin-T levels may be an indicator of the risk of dying from SDS. High troponin-T levels were found in a line known to develop high levels of SDS: the heritability estimates for troponin-T level on the basis of the animal model (REML) were 0.23 (Grashorn *et al.*, 1998). However, the relations between troponin-T levels and the susceptibility to SDS are not quite clear. For the time being the use of troponin-T levels for selection against ascites seems to be more promising than for selection against SDS.

Recently Imaeda (1999), suggested that an elevation in serum LDH (lactate dehydrogenase) and GOT (glutamic oxaloacetic transaminase) activities occur in association with SDS, and may be used as a characteristic sign of birds that are prone to die from SDS. Grashorn and Classen (1993) did not find correlations between levels of calcium and potassium in the heart muscle and SDS incidence.

Conclusions

- Ascites has a serious negative effect on broiler welfare. There are direct correlations between high growth rate, hypoxia and ascites. The problem has increased in recent years. The hematocrit and troponin-T levels, are valuable tools to predict and diagnose ascites under experimental conditions, and might be used together with selection under reduced pressure in breeding for increased resistance. Air quality, light conditions, temperature, and nutrition are important managemental factors that may affect risk of ascites.

- Sudden-Death-Syndrome (SDS) is an acute heart failure condition that affects mainly fast growing male birds, otherwise in generally good condition. Even though the apparent time from onset of the syndrome until death occurs is only a matter of minutes, it may still have an important impact on bird welfare. Genetics, nutrition and environmental conditions can influence the incidence of ascites and SDS. Fast growth rates increase the risk of ascites and SDS by increased oxygen demand of the broilers, which intensifies the activity of the cardio-pulmonary system. Since growth rate and oxygen demand coincides with other physiological challenges in the young chick (e.g. change in the thermoregulation), this may lead to failure of cardiac function.

6.6 Respiratory and mucous membrane problems

Health problems relating to respiration and mucous membranes are of great economical significance in broiler production. In particular chronic states and those diseases that cause high mortality are of considerable significance for broiler welfare. There are both infectious and non-infectious disorders. Some of the key infections and respiratory disorders are mentioned below.

6.6.1 INFECTIOUS RESPIRATORY DISEASES THAT CAN AFFECT THE WELFARE OF BROILERS

In this report, we will not consider acute viral infections which are in the A list of the OIE, for example Newcastle Disease (ND) and Avian Influenza (AI), which are subject to vaccination in some EU member states (ND), or to eradication programs (AI).

6.6.1.1 Infectious Bronchitis (IB)

This viral disease is characterised by lesions in the respiratory system (trachea, bronchi, lungs and air sacs), and can infect kidneys, and the ovaries in adults, producing intense respiratory symptoms (King and Cavanagh, 1991). It can be controlled by good management (including all in all out systems) and by vaccination. However, some virus variants will be insensitive to vaccination protection (Capua et. al., 1994; Raj and Jones, 1997; Gelb et. al., 1991; Case et. al., 1997).

6.6.1.2 Avian Pneumovirus infection in broilers

Although first described in turkeys, in broilers this pneumovirus infection is associated with the so called Swollen Head Syndrome with sinus inflammation and blindness, and sometimes signs of nervous dysfunction with twisted necks. It is aggravated by poor ventilation, poor hygiene, high stocking densities and mixing of birds of different ages (Alexander, 1991a).

6.6.1.3 Mycoplasmosis

Mycoplasmosis is one of the most common chronic diseases among broilers in some countries. According to Yoder (1991), *Mycoplasma gallisepticum* is the predominant mycoplasma infection in the complex syndrome Chronic Respiratory Disease (CRD), which affects bronchi, lungs and air sacs. It also affects several production parameters, and makes the birds more susceptible to other diseases and infections, such as IB, Avian Pneumovirus infection and *E. coli* (Stipkovits *et al.*, 1993).

Mycoplasmosis, alone or associated with *E. coli* infection, is a slow and chronic disease, with an insidious respiratory symptomatology that affects the whole respiratory system, including eyes, sinus cavities, air sacs and perihepatic and peritoneum membranes. It often occurs as a mixed infection with severe and general respiratory disease signs (Nakamura *et al*., 1992). In this form it can cause blindness, loss of appetite with subsequent weight loss, and finally death.

M. synoviae causes a sub-clinical infection of the articular synovial membranes, but can also cause chronic respiratory infections, with clinical manifestations similar to *M. gallisepticum* (Kleven *et al.*1991).

Mycoplasmosis can be controlled by chemotherapy, vaccination and by eradication programmes.

6.6.1.4 Colibacillosis

The endogenous colibacillosis, produced by *E. coli* of intestinal origin, (Gross 1991), is a generalised infection that can be localised in the respiratory or digestive system. It affects organs such as the liver, and usually occurs in broilers as a consequence of mixed viral infections (Nakamura *et al* 1992).

6.6.2 VACCINE REACTIONS

Some strains of vaccine virus (IB or ND) can produce tissue reactions of the respiratory organs and mucous membranes, which may develop into a chronic respiratory disease (Alexander, 1991b; King and Cavanagh, 1991). Vaccines, especially live vaccines, may also have more generalised detrimental effects depending on a) the vaccine, b) the method of dispensing the vaccine c) interactions with other vaccines and combinations of these points. Properly licensed vaccines should result in minimal side effects if administered correctly. It is an imperative part of good flock husbandry that vaccine regimens are carefully planned and their application supervised. General reactions on some vaccines may also affect the welfare of the birds in a negative way, but this is not further considered in this report.

6.6.3 IMMUNOSUPPRESSIVE EFFECTS OF RESPIRATORY AND MUCOUS MEMBRANE DISEASES.

Lymphoid tissues are present in the trachea and bronchi and offer immune protection to the respiratory tract (Rusell, 1996). Factors affecting the respiratory lymphoid tissues will therefore also affect the development of respiratory infections. The most obvious effects of lymphoid tissue damage include an observed increase in susceptibility to infection, resulting in poor performance, often accompanied by decreased antibody responses, which may be seen as suboptimal vaccine responses or vaccine failure. Viruses that produce immunosuppression are those causing Marek's disease (MD), chicken anaemia (CA) and infectious bursal disease (IBD) (Adair, 1996), because they infect and kill lymphocytes or their precursor cells.

Allan *et al* (1972) described how infection of the Bursa Fabricius by the infectious bursal disease virus(IBDV) may cause immunosuppression. Other immunosuppressive infections are CA (von Bülow, 1991), aflatoxicosis (Hoerr, 1991) and MD (Calnek and Witter, 1991). All these infections can cause chronic airsacculitis.

6.6.4 PREVENTION OF INFECTIOUS DISEASE OUTBREAKS

In order to prevent outbreaks of contagious diseases that may cause welfare problems to the birds, such as respiratory diseases, the level of biosecurity on broiler farms should be high. All-in-all-out procedure is recommended, rodent control is essential and the houses should be properly cleaned between batches. The number of visitors should be restricted to a minimum, and the staff should be educated in hygiene measures used to minimise the risk of introducing contagious diseases on the farm. When there is a disease risk, vaccination should be considered when available/practicable.

6.6.5 NON INFECTIOUS RESPIRATORY DISORDERS.

Non infectious respiratory problems are mostly caused by poor air quality conditions and will be dealt with in later chapters. Air composition, dust and ammonia concentrations are the main causal factors of non infectious respiratory disorders.

Respiratory disease may be important in the aetiology of ascites (see chapter 6.5).

Conclusions

- Infectious Bronchitis, Avian Pneumovirus infection and chronic respiratory disease are currently the main infectious respiratory diseases affecting the welfare of broilers, because of their effects on trachea, bronchi, lungs, mucous membranes and whole body functions. The incidence of these diseases varies substantially between different EU member states. The respiratory pathology can be a good indicator of the hygienic state of the environment and the success of preventive treatments given to broiler chickens. Respiratory diseases may contribute to the appearance of ascites.

6.7 Stress Indicators

6.7.1 THE RANGE OF INDICATORS

The physiological indices of broiler welfare, which have been commonly used include: body temperature, heart rate, blood cell counts, corticosterone and other hormones in plasma and enzymes in plasma. Behavioural indices include: panic, violent escape, freezing, panting, supression of normal behaviour, and various abnormalities of sound, maintenance and locomotor behaviour. Such measures are described in detail by various authors including Duncan and Wood-Gush (1972), Faure (1981), Gross and Siegel (1983), Hocking *et al.* (1993, 1996a), Broom and Johnson (1993), and Mitchell and Kettlewell (1998). Combinations of measures give better information than single measures.

Considerable efforts have been made to establish welfare indices to give qualitative or quantitative indications of the extent of the effects of stressors on a bird's welfare. Changes in behavioural patterns can provide information, but these characteristics can be dependent upon the type of environment in which the bird is housed or the genetic make-up of the bird. Physiological indices have been widely used to give quantitative data. The indices most commonly used include body temperature, blood concentrations of electrolytes, hormones and enzymes and leucocyte composition. However, changes in these characteristics may vary depending upon the nature of the stressor. Measurement of short-term responses may also be complicated by the effects of the method such as collection of a blood sample. Nevertheless, despite these drawbacks, physiological indices are widely used to provide information on welfare.

6.7.2 HAEMATOLOGICAL RESPONSES

The main haematological response is a change in the heterophil/lymphocyte ratio (H/L) in leucocytes. The number of heterophils per unit of blood increases and the number of lymphocytes decreases in birds under stress but the ratio of these cell types is less variable and thus a better measure than individual cell numbers (Gross and Siegel, 1983). A normal ratio is about 0.4 but this can rise to 8 in birds under severe stress. Changes in H/L have been observed in response to thermal stress and treatment with corticosterone. An increase in H/L has also been reported as an initial response to feed restriction but the change is not necessarily maintained throughout a prolonged period of feed restriction (Maxwell *et al.*, 1991; Maxwell *et al.*, 1990a) and may be influenced by diurnal factors. Basophil numbers can also be increased during stress, but the rise is more rapid than the increase in H/L and is associated with acute stress of life-threatening magnitude.

6.7.3 HORMONAL RESPONSES

Corticosterone is the main hormone associated with stress in chickens. Its concentration in plasma rises under stressful conditions and administration of corticosterone is used experimentally as a means if inducing other stress responses. Plasma corticosterone concentration is widely used as a criterion of stress, though care must be taken in interpretation of results. For instance, a rise in concentration is a normal response to fasting and is thus an indicator of physiological state which may or may not be indicative of stress. Changes in corticosterone may have secondary effects on other hormone systems, such as the conversion of noradrenaline into adrenaline or the production of thyroid hormones. Whilst these changes may be related to the mediation of stress responses, it is also important to distinguish between hormonal changes resulting from normal homeostatic mechanisms and those associated specifically with stress responses. Elevated corticosterone levels can also have wider effects, such as immunosuppression.

6.7.4 ENZYME RESPONSES

The plasma enzymes that have been widely used as indicators of stress include creatine kinase (CK), aspartate transaminase (AST), lactate dehydrogenase (LDH) and alkaline phosphatase (ALP). These are intracellular enzymes and elevation of plasma concentrations reflect alterations in tissue function or are indicative of cell damage or necrosis and may be diagnostic of the organ system involved (Hocking *et al.*, 1993). ALP can be released from liver and bone whereas LDH may be released from liver and muscle and is also a good indicator of haemolysis. Increases in plasma CK and AST indicate muscle damage. CK is a particularly good indicator of heat stress.

6.7.5 BEHAVIOURAL RESPONSES

Several behaviours have been associated with stress. Fearfulness induced by severe stress is characterised by a freezing response, or tonic immobility (Jones and Faure, 1981b). Other fear reactions include panic and violent and continued attempts to escape. Where the environment precludes escape, physical injuries such as cuts, scratches and broken bones can result from collisions with obstacles and trampling. Suffocation may occur if birds pile on top of each other (Jones, 1996). Less extreme behaviours have been associated with milder forms of stress. For instance, feed restricted birds show an increase in spot pecking, litter scratching and pecking and preening (Hocking *et al.*, 1996a). These behaviours have been taken as indicators of frustrated eating behaviour (Duncan and Wood-Gush, 1972). Increased drinking is also a behavioural response to feed restriction. Panting is an indication that the birds may be under heat stress.

6.7.6 GENETIC RELATIONSHIPS

Genetic influences have been established in the relationships between physiological and behavioural responses to stress. A line of chickens selected for higher activity in an open field were less fearful and showed lower resting and stress-induced plasma corticosterone concentrations than their less active counterparts (Faure, 1981). Experimental studies on chickens (Gross and Siegel, 1985), turkeys (Brown and Nestor, 1974) and quail (Satterlee and Johnson, 1988) have confirmed the principle that selection for lower plasma corticosterone response will result in birds that are less fearful and show more subdued physiological and behavioural responses to stressors (Jones, 1996).

Conclusion

- A range of behavioural and physiological changes has been used to identify and quantify stress. These changes may differ qualitatively or quantitatively depending on the stressor so that a range of indices should be used in order to assess the extent of the stress or welfare.

6.8 Thermal discomfort

Well feathered broilers may experience thermal comfort over only a narrow range of ambient temperatures (Webster *et al.*, 1993). Depending on the ambient temperature in broiler houses, young chicks may huddle together in groups in the first week or two of life, in order to conserve heat before they achieve complete homeothermy. Thereafter, the risk of thermal discomfort increases as birds get bigger and better insulated, eat more food and generate more heat, and as declining space between them allows less room for dissipating heat. A slaughter weight (2 kg) bird’s metabolic heat production has been estimated to be 10-15 watts (Mitchell and Kettlewell, 1998), so in a 30000-bird house this is equivalent to the heat production from 300-450 one-kilowatt heaters.

The effects of heat are exacerbated by any rise in atmospheric relative humidity (RH), which increases the "apparent equivalent temperature" (AET, derived from absolute temperature, water vapour pressure, and a psychrometric constant). This is the true index of thermal load because vapour density gradients determine evaporative heat loss from birds (Mitchell and Kettlewell, 1993). In hot conditions, increases in RH can result from evaporative water loss due to panting, from compensatory drinking leading to wetter droppings and moist litter, and from air cooling systems which rely on "misting" or passage of inlet air over wetted pads. The efficacy of such cooling systems depends largely on outside climatic conditions. Laboratory studies have indicated that physiological stress effects are minimal at AET values less than 40^{o}C, moderate at 40 to 65 ^{o}C, and severe and potentially lethal above 65^{o}C (Mitchell and Kettlewell, 1993).

A diagram indicating how the relationship between ambient temperature and relative humidity affects broiler welfare is shown in Figure 5.

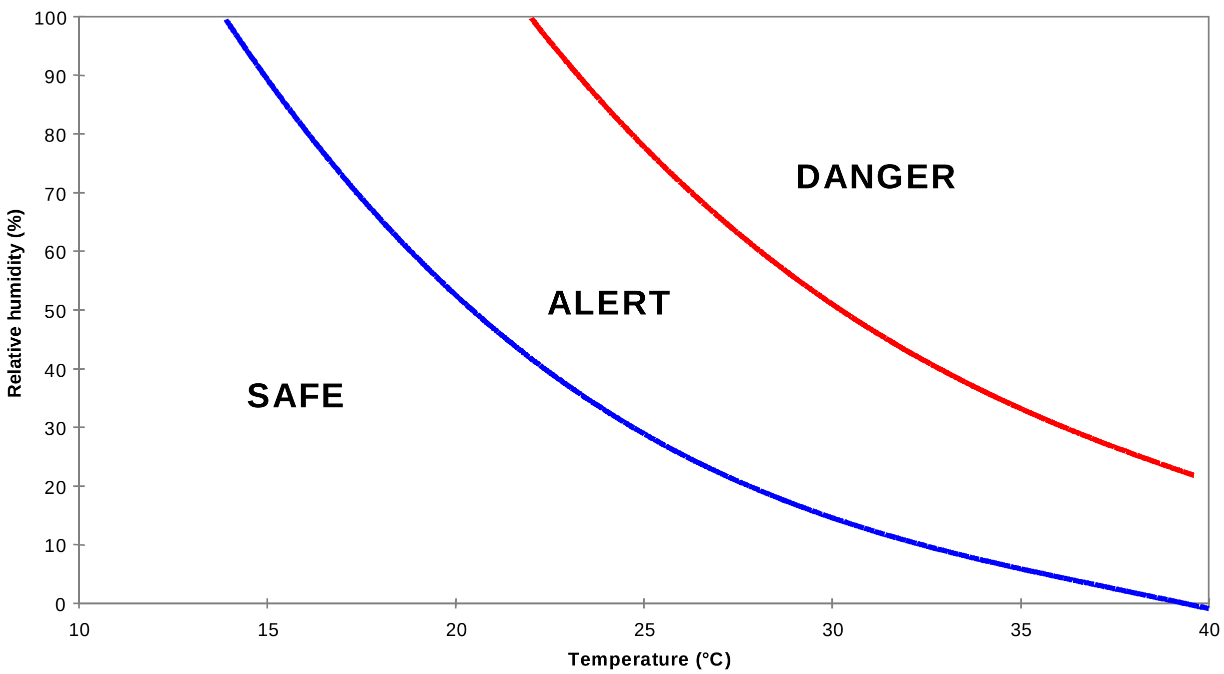


Figure 5: "Thermal comfort zones" for six-week-old (2-2.5 kg) broiler chickens, derived from AETs. (Reprinted from Cockram and Mitchell, 1999). The two isotherms shown represent AETs of 40 ^{o}C (separating "safe" and "alert") and 65 ^{o}C (separating "alert" and "danger").

Every effort should therefore be made to keep the AET below 40 ^{o}C with five- to six-week-old birds (younger birds will tolerate higher AETs), by prevention of overstocking and moist litter, appropriate environmental monitoring, and adjustment of ventilation rate. Control over ambient temperature, humidity and air circulation is usually better in modern broiler houses than in older ("traditional") ones, and this means that birds can often be stocked at higher densities in modern housing without increasing the risk of heat stress and poor litter quality. Such control systems are highly dependent on electricity, and an auxiliary back-up supply must always be provided in case of mains power failure.

In conditions where AETs exceeding 40 ^{o}C are sometimes inevitable, there is evidence that fowls may benefit from receiving dietary or drinking water supplements of antioxidants like vitamin C (ascorbic acid), vitamin E (α-tocopherol) and selenium (Pardue and Thaxton, 1986). Heat-stressed broiler chicks have even been reported to select ascorbic acid-supplemented food in a dietary choice situation (Kutlu and Forbes, 1993). In countries where outside temperatures are high for all or part of the year, access to food is withheld during the hottest part of the day to reduce heat production (associated with eating at that time) then.

In recent (unpublished) trials in a modern house investigating effects of different stocking density (28-40 kg/m^2) treatments on broiler welfare (O'Rawe *et al.*, 1998a,b; McLean *et al.*, submitted), it was found that birds started to pant regularly in the third or fourth week of life (younger birds pant only when house temperatures are high), and thereafter time spent panting increased consistently. Panting was mostly shallow to start with, but mostly deep later on. It also increased with increasing stocking density, presumably because radiant transfer from bird to bird is then greater, stagnant hot air is trapped between birds, and heat in the floor litter due to contact with birds and bacterial fermentation is less easily dissipated (Reiter and Bessei, 2000). In trials where sexes were grown separately, males and females spent about the same total amount of time panting, but females panted more while standing, possibly reflecting a greater need to dissipate heat (cf. Savory and Maros, 1993). Females also showed more shallow panting than males in weeks 2, 3 and 4 of life, and more deep panting than males in week 5 (McLean *et al.*, submitted). Despite their lower food intake and body weight than males of the same age, the faster feather growth (Ross Breeders, 1996) and greater carcass fat content (Pym and Solvens, 1979; Broadbent *et al.*, 1981) of females may cause increases in both their body insulation and their need to dissipate heat through behavioural thermoregulation. Hence, if thermal discomfort becomes a problem at higher stocking densities later in the growing period, it may do so earlier in females.

When ambient temperatures are within the thermoneutral zone, the risk of thermal discomfort is reduced in breeding birds because of the levels of food restriction to which they are subjected (Savory and Maros, 1993), and because their tendency to overdrink and cause wet litter (and hence a higher AET) is usually prevented by removal of the water supply soon after feeding. However, this cannot be done when outside temperatures are high, and any overdrinking then is likely to exacerbate the situation.

Conclusion

- The risk of thermal discomfort increases with age, and may be greater in females than in males. A useful index of thermal load is the "apparent equivalent temperature", derived from absolute temperature, water vapour pressure, and a psychrometric constant.

•

6.9 Behavioural restriction

In a flock of broilers, the space available to each bird depends on stocking density, which is usually expressed as the total weight of birds per unit of floor area. Recommended maximum (terminal) stocking densities for commercial broiler production in European countries vary from <30 to >40 kg/m^2. Density expressed in this way increases as birds grow older/bigger, and the space available to each declines accordingly. Thus, any restriction of behavioural expression due to lack of space is most likely to occur in the last week of life.

It is possible that the increasing immobility of broilers seen as they grow older (Newberry *et al*., 1988; Blokhuis and van der Haar, 1990; Bessei, 1992; Reiter and Bessei, 1994; O'Rawe *et al*., 1998a,b) could be a consequence of diminishing space to move about. Another possibility, however, is that it could be due to increased difficulty in walking, associated with age-related increases in both body weight/size and the incidence of leg weakness/gait problems (Kestin *et al*., 1994). Weeks *et al*. (1994) proposed that genetic selection for high growth rate may prevent broilers from performing certain behaviours even if they are motivated to do so, and that their limited mobility may be accompanied by some behavioural thwarting. Yet another reason for increasing inactivity/sitting with age could be that it is a direct consequence of genetic selection for reduced FCR, and associated reduction in energy expenditure (cf. Van Kampen, 1976). As yet, there is insufficient evidence to establish the primary cause of older birds' inactivity. All one can say is that behavioural restriction is likely to be greatest when birds are least active.

In an experiment where locomotor behaviour of 5-week-old broilers was compared at different stocking densities, the mean distance travelled per bird per hour was significantly less when density was (commercially) "normal" (15.2 birds/m^2) than when it was only half (7.6 birds/m^2) as great (Lewis and Hurnik, 1990). In the same study, there was no effect of density on frequencies of visits to feeders and water cups, and birds spent less time resting at the high density because of increased disturbance. A similar increase in disturbance of resting birds, at the highest density, was observed in another study comparing 12, 16 and 20 birds/m^2 (27, 35 and 43 kg/m^2) (Martrenchar *et al*., 1997a,b). Preston and Murphy (1989) followed movements of 4- to 6-week-old broilers in a commercial flock where density was 14 birds/m^2. They concluded that birds moved further than was necessary simply to reach food and water, and there was no evidence that movement was constrained by crowding. In a comparison of behavioural "time budgets" of broilers stocked at 34 and 40 kg/m^2, the only activity that was significantly less frequent at the higher density was pecking and scratching at litter (O'Rawe *et al*., 1998a,b). Similar suppression of pecking and scratching, walking, and also preening, at higher densities has been reported by Blokhuis and van der Haar (1990) and Reiter and Bessei (1994), with densities ranging from 2 to 20 birds/m^2. Bessei (1992) found little difference in behaviour between densities ranging from 10 to 30 birds/m^2, though there was some evidence of increased activity at the lower density early in the growing period.

Reported effects of stocking density on behavioural expression are thus inconsistent, and this is due at least partly to variation in the densities and ages of birds tested. It does seem likely, however, that locomotor and litter directed activities may become increasingly constrained at densities above about 30 kg/m^2 (15 birds/m^2), and this has implications for the aetiology of leg weakness, poor litter quality and associated contact dermatitis. These problems have all been found to increase with increasing stocking density (Grashorn and Kutritz, 1991; Kestin *et al*., 1994; O'Rawe *et al*., 1998a,b; Sanotra *et al*., 1995). Activities such as dustbathing, wing-stretching and wing-flapping are seen only infrequently in broilers (Murphy and Preston, 1988; Bessei, 1992; O'Rawe *et al*., 1998a,b) and it has yet to be determined whether their expression is limited by bird density.

Crowding in commercial flocks is often prevented by "thinning" (removal of birds), particularly when males and females are segregated in adjacent areas of the same house. Perches are not usually provided in broiler houses, but they have the theoretical potential for reducing bird density at floor level, though broilers rarely perch (Hughes and Elson, 1977). In a comparison of broiler behaviour in free-range and deep litter conditions, it was found that birds on free-range were initially more active, but made little use of their extra space, and otherwise behaved just like those on deep litter (Weeks *et al*., 1994).

However, a barren environment, very low light levels and poor litter quality may contribute to low activity levels and thus this low stimulation may be a cause of behavioural restriction. Recent experimental results show the high preference of broilers kept on usual littered floor for specific scratching areas, which provide sand bathing.

In broiler breeder flocks, normal feeding behaviour is restricted severely during the rearing period and more mildly in adulthood, drinking behaviour may also be limited, motivation to feed may conflict with motivation to lay an egg, and sexual behaviour may become increasingly restricted in adulthood. These points are covered in more detail in section 9.

Conclusion

- The greatest threat to broiler welfare due to behavioural restriction would appear to be likely constraints on locomotor and litter directed activities caused by high stocking densities, and consequences for leg weakness, poor litter quality and contact dermatitis

7 ENVIRONMENTAL FACTORS LINKED TO WELFARE PROBLEMS

7.1 Air quality

The indoor environment of intensively kept broilers is composed of physical, chemical and biological factors which include the aerial environment (air quality), light and the building components. Air quality is a composite variable of air constituents such as gases, dust and micro-organisms. These components, polluting the air in livestock buildings, are widely considered to be principal risk factors for respiratory diseases in farm animals (Versteegen *et al*. 1994, Hartung 1994a). Temperature and the humidity of the air are influencing the thermal comfort of the animals. The air contaminants originate from birds, feed, litter and a smaller part is entering the animal house together with the incoming ventilation air. Pollution of the air depends strongly on stocking density, age of the animals, litter quality and management as well as of the activity of the animals. Feed composition and ventilation rate are other factors which interact with all other in a complex manner to create what we here will call 'air quality'.

Poor air quality affects health and welfare of both birds and stockpersons, and constitutes a risk for environmental pollution (Hartung 1998). Air contaminants may carry specific pathogens, or alter the virulence of other pathogens, and they may depress the growth of the birds (Wathes, 1998). In addition, some air contaminants may alter the commensal respiratory microflora, something which can sometimes be used in diagnosis of respiratory diseases (Wathes, 1998).

7.1.1 HUMIDITY

The humidity depends mainly on factors within the building but also on outside humidity. Examples of important factors in the building are stocking density, liveweight of the birds, ventilation rate, indoor temperature, type and management of drinkers, water consumption and occurrence of diseases among the animals

There are two aspects to moisture control: the litter moisture produced by the birds; and the enviromental humidity.

It is difficult to give a figure for appropriate litter moisture, but for chickens (1-4 weeks) it should be between 20-50 %, and 10-30 % in the last 2-3 weeks of growing period. The poultry house moisture is reflected in environmental relative humidity and is affected by: temperature; ventilation and water consumption (North, 1972).

If environmental relative humidity is very low (below 50 %), there is a higher production of dust and an increase in the number of airborne microorganisms, which may increase susceptibility to respiratory diseases. However, with the exception of the first or the second week of life of the chicks, this situation is not very common.

In practical circumstances, high humidity in a broiler house can be a problem in winter when ventilation rate is reduced to maintain temperature. Under high stocking densities and with relatively heavy animals, humidity may occasionally reach as high as 80% or more. Conversely, in summer, a problem could arise with broilers ready for slaughter if the temperature is very high and ventilation systems fail in the poultry house. In this case, after a short time relative humidity can increase to 90% or more, which may lead to animals dying from hyperthermia or and hypoxia, (North, 1972) (see chapter 6.8).

7.1.2 GASES AND AIR CONTAMINANTS

7.1.2.1. Carbon Dioxide.

CO_2 is an odourless gas heavier than air and produced as a byproduct of metabolism. The amount produced is proportional to the heat production of the animal (1 liter CO_2 for every 24.6 kJ of total heat produced; Albright, 1990). This corresponds approximately to 1.5 liter/hour/kg liveweight (Le Ménec, 1987).

Under commercial conditions, CO_2 in poultry houses does not raise to dangerous concentrations since minimum ventilation rate is usually adjusted to the removal of the moisture production of the birds and the ventilation rate which is required to remove moisture exceeds the ventilation rate to remove CO_2 production of the birds and the litter. CO_2 accumulation only occurs when additional CO_2 is produced by direct heating systems (where the exhaust gases remain inside the broiler house) and when the ventilation rate is operated at extremely low level.

When CO_2 levels have been experimentally raised to levels over about 1.2% (in various studies up to more than 17% has been used), negative effects on chicks and broilers such as panting, gasping, reduced feed intake and reduced growth have been recorded (Wilson and Edwards, 1950; Helbacka *et al.*, 1963; Romijn and Lockhorst, 1964; Reece and Lott, 1980).

7.1.2.2. Ammonia.

Ammonia has a sharp and pungent odour and can irritate eyes, throat and mucous membranes in humans and farm animals. Ammonia is formed during decomposition of uric acid. Although it is lighter than air, it rises slowly through the building, but is eventually removed through the ventilation system.

Ammonia levels are affected by a number of factors, such as temperature, ventilation rate, humidity, stocking rate, litter quality, and feed composition (Homidan *et al.*, 1998). Ferguson *et al* (1998) found that a reduction of crude protein and lysine in the diet, and supplementation with amino acids, significantly reduced ammonia levels. Approximately 18% of the feed contents of nitrogen is released into the atmosphere as ammonia (Patterson *et al.*, 1998). Wathes *et al.* (1997) in a survey of broiler houses in the UK, found ammonia concentrations ranging from approximately 10 to 50 ppm, with a mean of 24.2 ppm.

Several detrimental effects on broiler welfare of high ammonia levels have been documented. For example, Terzich *et al*. (1998) found that the occurrence of ascites appeared to be correlated to ammonia levels. The literature has been reviewed by Castelló (1993) In general, respiratory diseases increase with increasing levels of ammonia, and Reece *et al.* (1980) found that growth rate decreases with ammonia levels above 50 ppm. At even higher levels, 60-70 ppm, increased levels of keratoconjunctivitis and tracheitis have been observed (Valentine, 1964).

High levels of ammonia are only likely to occur in the later stages of broiler growth. The effects of ammonia are highly dependent on the exposure time. Three days of exposure to 30 ppm has been shown to increase respiratory problems (Le Ménec, 1987). It should therefore be remembered that any effect demonstrated at rather high concentrations is likely to be present at much lower concentrations with longer exposure times. Wathes (1998) proposed a maximum level of ammonia of 20 ppm.

In this context, it should also be borne in mind that many countries have regulations for human exposure, which set upper limits for the acceptable ammonia concentration in working environments. For example, in the UK the limit is 25 ppm (Charles, 1980) and in Sweden and Germany (DFG 1999), it is 25 ppm and 20 ppm respectively for an 8 h working day. Sweden also has a limit of 50 ppm for a maximum of 5 min exposure. It may be reasonable to adjust to similar levels for any recommendation regarding broiler houses.

7.1.2.3. Other gases:

Detrimental CO and CO_2 concentrations only occur when heating systems are used where the fuel is burned inside the brooder room and when the room is not sufficiently preheated. In this case heat production is run at full capacity and ventilation rate is reduced so as to keep the temperature high. Preheating of the broiler houses of 24 hours before the cicks arrive is essential to avoid damages through elevated CO and CO_2 concentrations. Bocquier *et al.* (1999) found in a survey, that CO ranged up to 50 ppm, depending on the type of ventilation and heating system. The authors considered that under good management conditions CO levels between 14 to 35 ppm can be tolerated, but this is a ratrher high figure in comparison to other species.

The risk for hazardous levels can be kept at a minimum by using a ventilation rate of a minimum of 0.8 m^3/hour/kg liveweight (Le Ménec, 1987).

A number of different gases may potentially affect the risk for disease and poor welfare in broilers, for example Hydrogen Sulfide (H_2S), Nitrous Oxide (N_2O), Dimethylamine ($HN(CH_3)_{2)}$ and Methane ($CH_{4)}$. Tegethoff and Hartung (1996) did not find any strong improvements on the levels of these gases or CO_2 by a reduction of bird density from 43 to 30 kg/m^2. Whilst the levels were never considered detrimental to bird welfare, the highest concentrations of N_2O were found in Louisiana-type broiler houses. Wathes *et al.* (1997), in a survey of UK broiler houses, found that concentrations of methane and nitrous oxide were mostly close to ambient levels.

7.1.2.4. Dust

Dust irritates the respiratory tract of broilers, thereby lowering their resistance to diseases, and it plays an important role in the transmission of many infections (*Salmonella*, *E. coli*, Marek's virus, bursal disease virus, etc; Maurer *et al.*, 1998; Davies *et al*., 1997). It can also cause a direct inflammation of bronchi, in particular in houses with low humidity and high temperature (Riddell *et al*., 1998).

Homidan *et al.* (1998) found that keeping the temperature at 25.8 °C, from 3 to 7 weeks, resulted in dust levels that were significatly higher than at 23.8 °C.

Dust in broiler houses arises from several sources. A large proportion comes from small pieces of feathers and feather follicles, as well as small pieces of skin scales from the birds. There are also small particles of feed dispersed into the air. Litter particles and dried small pieces of manure are other sources.

Dust is made up of fractions of particles with different sizes. According to (Gastaldo and Samoggia, 1992), the largest particles (>5 μm; the so called inspirable fraction) are largely stopped in the nostrils, but can produce irritation and infections in the nose and throat. Of the smaller particles (the so called respirable fraction), the larger of them can reach the trachea, and produce damage in the mucous membranes, irritation and reduced feed intake. The smallest respirable particles can enter all the way down to the lungs and can bring bacterias and viruses to the deeper lung tissue, thereby causing infections, as well as lowering respiratory capacity and oxygen intake.

In a UK survey by Wathes *et al.* (1997), concentrations of dust ranged from 2-10 mg/m^3 for the inspirable fraction and from 0.3-1.2 mg/m^3 for the respirable fraction. Production of dust in the inspirable fraction ranged from 0.86 to 8.24 g/h/500 kg live weight. Wathes (1998) recommends the following exposure limits for birds: 3.4 mg/m^3 of inspirable dust and 1.7 mg/m^3 of respirable dust. In the survey it was concluded that higher dust concentrations were associated with a decreased bird performance.

Dust in broiler houses can be minimised through the use of proper ventilation and by keeping relative humidity at recommended levels.

Conclusions

- Air quality in a broiler house is determined by a complex interaction between many factors including ventilation, stocking rate, litter quality, health status of the birds.

- Air humidity is largely dependent on factors within the broiler house, and can increase because of malfunction of technical equipment, poor ventilation or disease. When levels increase to 80% or more, serious welfare problems may occur, and animals may die from hyperthermia or hypoxia if such humidity levels are combined with high temperatures.

- Levels of CO_2 of 1% do not, by itself, cause any harm for animals. However, an increase in CO_2 levels is usually accompanied by increased levels of other detrimental air pollutants such as ammonia, dust and micro-organisms. Therefore CO_2 is used as an air quality indicator by which the ventilation can be calculated.

- Concentrations of ammonia having detrimental effects on broiler welfare are regularly observed in practice. The effects result from a combination of concentration and exposure time, and at exposures for three days, detrimental effects can be found at concentrations of 30 ppm.

- N_2O and CH_4 do not occur in concentrations in animal housing which may influence health or welfare of animals. Other gases, such as CO, H_2S, and $HN(CH_3)_2$, are potential risk factors, but there are little data available on the commonly occuring concentrations or on risk levels.

- Dust is a potentially harmful air contaminant, mainly in combination with ammonia and other gases and may directly affect the respiratory tracts of the broilers, as well as act in the transmission of bacterial and viral infections. Dust levels can be kept to a minimum by appropriate ventilation and by maintaining recommended humidity levels.

7.2 Litter quality

Litter quality is of great importance for the welfare of broiler chickens, as they generally spend their entire life in contact with litter. Poor litter quality is recognised as a welfare problem in modern broiler production (Savory, 1995). Litter quality will affect the environmental situation of the birds by influencing, for example, dust levels, air humidity levels and ammonia levels, factors which influence the birds' risk of developing respiratory problems.

Terzich *et al.*(1998) studied the effect of litter moisture, litter nitrogen, and atmospheric ammonia on mortality due to ascites. They found that reduction of the ammonia levels from 40-70 ppm to 20 ppm significantly reduced the incidence of ascites (see chapter 6.6.1).

Litter quality also has a direct influence on the skin condition of the birds, wet litter being a major risk factor for contact dermatitis (see chapter 6.5).

A number of risk factors for wet litter have been suggested. Litter material and texture is regarded to be of importance. Litter materials with a high water-holding capacity, such as wood shavings from coniferous trees, are believed to result in better litter quality than litter materials with poorer absorption capacity, such as straw. For example, Shanawany (1992) has shown that broilers raised on litter with high water-holding capacity had lower incidence of breast blisters than birds raised on litter with lower water-holding capacity. Peat moss or sawdust, which has a high water-holding capacity (Shanawany, 1992), can also be used as litter material for broilers but often result in a dusty environment. Coarse litter texture can increase the incidence of contact dermatitis compared to fine, soft quality litter. The litter depth also seems to be of importance, thin layers of litter (<5 cm) resulting in lower levels of foot-pad dermatitis than thicker layers (Ekstrand *et al.*, 1997). A possible explanation could be that the chickens are less prone to peck, scratch and turn the litter particles over, and thereby help to ventilate the litter, if the layer of litter is thick and compact. A thin layer may also be more thoroughly ventilated by air streams from the fans (Ekstrand *et al.,* 1997).

It has been described how nutritional factors, such as excessive sodium or potassium levels, can lead to over-drinking and result in wet litter (Appleby *et al.,* 1992; Tucker and Walker, 1992). Other researchers have shown an effect of the quality of the dietary fat and energy and protein levels on litter quality, and found an association with the incidence of hock burn in broilers (Bray and Lynn, 1986; Tucker and Walker, 1992). In several epidemiological studies of commercial broiler farms a significant effect of feed on the prevalence of contact dermatitis has been found (McIlroy *et al.,* 1987, Bruce *et al.,* 1990; Ekstrand and Carpenter, 1998a; Ekstrand *et al.,* 1998c), which could be explained by a correlation between feed composition, faecal viscosity and litter moisture.

It has been shown that there is an association between drinker design and wet litter (Elson, 1989; Lynn and Elson, 1990; Tucker and Walker, 1992; Cholocinska *et al.*, 1997; Ekstrand *et al.,* 1997), mainly related to the variations in the amount of water spillage between different types of drinkers, but also to the level of actual water consumption. Several studies have shown that nipple drinkers, with or without drip cups, reduce water usage and water splashing compared to traditional bell type drinkers, and that this results in a reduction in litter moisture and an improvement in litter hygienic quality (Bray and Lynn, 1986; Meijerhof, 1989; Cholocinska *et al.,* 1997).

Stocking density has been reported to influence litter quality, with poor litter quality when stocking density is increased (McIlroy *et al.,* 1987; Blokhuis and Van Der Haar, 1990; Gordon, 1992; Tucker and Walker, 1992) leading to an increased incidence of foot-pad dermatitis (Cravener *et al.,* 1992; Gaardbo Thomsen, 1992; Martrenchar *et al.,* 1997a,b). Berg (1998) has suggested that this relationship may not be as evident when the increased stocking density is compensated by improvements in management factors such as ventilation capacity.

Climatic conditions influence litter quality , with high relative humidity both outdoors (Payne, 1967; McIlroy *et al.*, 1987) and inside the house (Payne, 1967; Weaver and Meijerhof, 1991) being associated with poor litter quality. McIlroy *et al.* (1987) stated that although the ventilation capacity might be good, adequate ventilation is often wrongly constrained by the desire to conserve heat which frequently leads to a humid atmosphere with associated wet litter conditions.

Conclusions

- Maintaining a good litter quality is essential for broiler welfare. Failure to do so may result in respiratory problems and contact dermatitis in the birds. Litter quality is partly related to the type of litter substrate used and partly to different management practices. Such management practices include careful choices of type of water equipment and litter depth and the use of proper ventilation equipment in combination with ventilation management adjusted for the stocking density applied. Poor feed composition may result in wet or sticky droppings, which can lead to wet litter or so called litter capping.

7.3 Temperature

The ambient temperature requirements of domestic chicks change with age, because in the first week or so their body temperature, metabolic rate, body mass to surface area ratio, insulation from feathering and thermoregulatory ability are all relatively low (Freeman, 1965; Jurkschat *et al.*, 1989). In a study with bantam chicks, rectal temperatures increased consistently from 38.5 °C on day 1 to 41 °C on day 10 and thereafter, regardless of whether chicks were reared in warm or intermittently cold conditions (Myhre, 1978). In the same study, the preferred ambient temperature of chicks given the opportunity to choose in a "thermal gradient box" fell from 38 °C on day 1 to 28 °C on day 8 and thereafter. In another study, with chicks of a layer strain, "zones of thermoneutrality" where resting oxygen consumption is minimal were 34-35 °C in the first week of life, 31-35 °C in the second, 30-33 °C in the third, and 26-31 °C in the fourth (Freeman, 1963). The adult level of thermoregulation, or "complete homeothermy", is considered to be reached when birds are able to maintain a constant body temperature under changing ambient temperatures. Estimates of when this occurs vary from 1 to 3 weeks of age (Misson, 1976; Jurkschat *et al.*, 1989)

Recommended (whole house) ambient temperatures for all broilers (including breeders) decline progressively from 29 °C in the first 3 days of life to 21 °C at 24 days and thereafter (Ross Breeders, 1996, 1998). These are lower than the temperatures preferred by bantam chicks and zones of thermoneutrality of layer chicks (see above), but may be optimal for broilers in terms of food intake, FCR and growth rate (cf. Deaton *et al.*, 1978). Presumably broiler chicks differ from bantam and layer chicks in having a higher body mass to surface area ratio and increased heat production due to greater food intake. At least one company uses a temperature regime that falls consistently from 31 °C in the first few days to 19 °C in the sixth week of life.

All homeothermic animals attempt to maintain body temperature by preserving a dynamic balance between metabolic heat production and heat loss to the environment. In the broiler, heat production is affected by body weight, food intake, food quality and activity level. It increases with age as body weight and food intake increase. Characteristics of the bird which affect heat loss include feather cover, size of comb and wattles, and posture. Heat is lost by convection (and hence air movement), conduction (e.g. to cooler litter), radiation (proportional to the temperature difference between the body surface and surrounding air) and evaporation (panting). Factors having a major influence on thermoregulation include building design, insulation, ventilation system, aspect, ambient temperature and relative humidity, and stocking density.

Heat is added to the air of a building from birds' metabolic heat production, from brooders, lights and motors, sometimes from the roof and walls (depending on insulation), and from fermentation of litter and accumulated droppings. Heat from brooders is essential early in life, when there is a risk of cold stress if equipment is deficient. Recommended house temperatures of 29-25 °C (Ross Breeders, 1996, 1998) in the first 2 weeks may be lower than chicks would prefer. Consequently, they may huddle together in clusters, thus increasing the risks of smothering and ascites. Subsequently, the dominant source of heat is the birds themselves, and as a slaughter weight of 2 kg is approached they each produce about 10-15 watts of heat (Mitchell and Kettlewell, 1998). If the stocking density then is too high for the size and design of the house and ventilation equipment, the temperature may rise dangerously as there will be more metabolic heat being added to the house air than was planned for. Radiant transfer from bird to bird is then greater, stagnant hot air is trapped between birds, and heat in the floor litter due to contact with birds and bacterial fermentation is less easily dissipated. In a comparison of 19, 30 and 40 kg/m^2 stocking densities at 5 weeks of age, Reiter and Bessei (2000) found respective temperatures of 23, 27 and 31 ^{o}C in the litter, 24, 27 and 30 ^{o}C at the litter surface, and 22, 22 and 29 ^{o}C between birds.

Conclusion

- The heat requirements of broilers change with age, and recommended ambient temperatures may be lower than birds would prefer early in life when stocking densities are low. The risk of cold stress is low once the thermoregulatory ability is fully developed in birds. The risk of heat stress increases with age and with stocking density as heat production increases and as space between birds (and hence their ability to lose heat) decreases.

7.4 Light

7.4.1 PHOTOPERIOD

Traditionally, broilers have been reared in near continuous light in order to maximise food intake and daily weight gain. After the first few days of life they are usually provided with a short dark period of 0.5–1 h each day to allow them to become accustomed to darkness in the event of power failure (Ross Breeders, 1996).

There is evidence that such long photoperiods (22-24 h light per day) can adversely affect the functional development of the eyes of chickens (Oishi and Murakami, 1985; Li *et al.*, 1995).

There is also evidence that broilers can benefit from a period of reduced growth rate early in life, through reductions in incidence of skeletal and metabolic disorders, mortality, downgrading, fat deposition, and FCR (Classen, 1992; Yu and Robinson, 1992; Zubair and Leeson, 1996). Daylengths of <16 h cause significant reductions in food intake and liveweight gain compared to constant light or a 23-h photoperiod. The use of short daylength to control body weight gain is particularly effective in the period from 4 to 14 days of age (a critical stage in development of skeletal, cardiovascular and immune systems). A move from 24 h to 12 h light at 4 days will reduce food intake by 30-40% for the first 3 days, but this reduction is <10% by day 12. Birds adapt by changing the pattern of feeding in the light period, especially by filling their crops in anticipation of the dark period. This ability improves their food consumption and FCR at later ages. Broilers also benefit from a clear pattern of day and night by having distinct periods of rest and more vigorous periods of activity; some developmental processes such as bone mineralisation are affected by diurnal rhythms. However, in a recent investigation of the association between leg weakness and daylength, it was found that a shorter photoperiod between 3 and 21 days reduced the incidence of tibial dyschondroplasia but did not improve walking ability (Sorensen *et al.*, 1999).

There are various recommended lighting programmes for modifying broiler growth, which usually start and end with 23 h light per day (Ross Breeders, 1996). “Increasing photoperiod programmes” combine daylengths as short as 8 h in the critical 4-14 day stage with steadily increasing daylengths at later ages, and are particularly effective for males grown to heavy weights (2.5-3.3 kg). “Reduced photoperiod programmes” combine a short daylength (e.g. 12 h) from 4 to 21 days with a return to 23 h in a single step, and are particularly effective in as-hatched or female only flocks. “Intermittent lighting programmes” provide several cycles of light and darkness (e.g. 5 h light and 1 h dark x 4, or 6 h light and 2 h dark x 3) each day from 4 to 35 days. They need not involve much reduction in total daylength, and are used in situations where leg disorders are a particular problem. The extra activity caused by the regular switching on and off of lights is thought to be beneficial in improving leg strength and reducing downgrading from contact dermatitis.

Although all such lighting programmes would appear to confer at least some benefits for broiler welfare, they are not yet used widely because the industry is not convinced of their efficacy. This is despite evidence indicating that overall FCRs need not be compromised (Yu and Robinson, 1992; Zubair and Leeson, 1996). One UK company has stopped using an intermittent programme of 9 h light and 3 h dark x 2, because birds were thought to be "flightier" with this, and now uses 23 h light from 0 to 4 days, 20 h light from 4 to 36 days, and 23 h light from 36 to 42 days ("to make birds less flighty at catch-up"). Another company, rearing birds according to the RSPCA's Freedom Food Standards (which require "a minimum period of 6 h continuous darkness in every 24 h cycle"), uses 23 h light from 0 to 3 days, 16 h light from 3 to 5 days, and 14 h light thereafter, producing birds weighing slightly less at slaughter (RSPCA 1995).

Preferences of broilers for light and darkness were investigated in experiments where birds were trained to operate light switches with pecking responses (Savory and Duncan, 1982). With a background of darkness, and 1 or 3 min of (15 lux) light per response, they had lights on for about 20% of time; when allowed to switch lights on and off, most birds were illuminated for >80% of time; with a background of light, and 3 min of dark per response, they were in darkness for <1% of time.

The recommended photoperiod for breeding birds falls progressively from 23 h at 1 and 2 days of age to 8 h at 10 days. It remains at 8 h until 19 weeks when it increases to 11 h, and thereafter increases steadily to 15 h at 27 weeks (Ross Breeders, 1998).

7.4.2 LIGHT INTENSITY

Exposure to light stimuli is known to induce behavioural arousal (movement) and desynchronisation of the electroencephalogram (physiological arousal) in rats (Sasaki *et al.*, 1996), and there is a fundamental positive relationship between ambient light intensity and general activity level seen in many species, including fowls (Boshouwers and Nicaise, 1987). It has important consequences for the production and welfare of broilers, because while their FCR can be improved by reducing energy expenditure with light intensities of 10 lux or less, the same intensities may also suppress food intake and cause increases in the incidence of leg disorders and contact dermatitis due to reduced activity. In a comparison of 6 and 180 lux treatments, significantly more broilers had impaired walking ability and bruised carcasses with the lower light intensity (Newberry *et al.*, 1988). However, in another comparison of 2 and 200 lux with male broilers, the tibial plateau angle (tibial "bowing") was significantly greater at 7 weeks of age with the higher intensity, presumably because of increased activity during a crucial stage of bone development (Gordon and Thorp, 1994). Very low light intensities (<5 lux) have been found to cause eye abnormalities in young turkeys (Siopes *et al.*, 1984) and chickens (Harrison and McGinnis 1967, Jenkins *et al*. 1979). Young birds were more fearful at 17-22 lux than at 55-80 lux (Hughes and Black, 1974), activity in hens is reduced at 50 lux or less (Martin, 1989) and turkeys have more leg problems at 19 lux than at higher light levels (Davis and Siopes, 1985). Such intensities are in any case undesirable because they make it difficult or impossible for all birds to be inspected clearly.

In commercial broiler production, it is common to use intensities of 20 lux minimum until 7 days of age, then gradual reduction from 20 to 10 lux between 7 and 21 days, and 10 lux thereafter (Ross Breeders, 1996). Alternatively, intensity can be kept at 15-20 lux throughout the growing period. With "modified lighting programmes" providing shorter days, dimmer switches can be used to simulate dawn and dusk. Dawn prevents crowding of birds at feeders and drinkers, and dusk provides them with a cue that darkness is imminent. Transitions between light and darkness should be completed over periods of at least 30 min. It is possible that broilers might benefit from exposure to natural daylight because of the known effect of UV light on vitamin D synthesis, and the implications that this has for bone metabolism, but this has not been studied systematically.

In an experiment where preferences of broilers and layers for chambers illuminated continuously at four different light intensities (6, 20, 60 and 200 lux) were tested at 2 and 6 weeks of age, both strains spent most time in the brightest environment at 2 weeks, but the dimmest at 6 weeks. This change was associated only with the two behaviours which took up most time, resting and perching, whereas the highest intensity was consistently preferred for all other behaviours; older birds thus preferred to be in dim light only when they were relatively inactive (Davis *et al.*, 1999). Breeding birds are illuminated at 80-100 lux for the first few days of life, then 15-20 lux until 19 weeks of age, when intensity increases to "60 lux minimum". Research has indicated benefits in egg numbers and male fertility in adult flocks by increasing light intensity to 100-150 lux (Ross Breeders, 1998). However, a problem with brighter lighting is that it increases the risk of outbreaks of injurious pecking amongst birds subjected to (mild) chronic food restriction (such pecking is exceptional in *ad libitum*-fed broiler progeny). Such problems do not apply to birds kept for meat production

Light intensity in the broiler house should be measures as the average light intensity in three planes at right angles to each other.

7.4.3 LIGHT SOURCE AND WAVELENGTH

Domestic fowls, like other birds, have well developed colour vision. Their spectral sensitivity is broader than that of humans and they can "see" into the ultraviolet range (Nuboer, 1993); this has been confirmed with broilers (Prescott and Wathes, 1999).

An implication of this is that the measurement of light intensity in poultry housing using the lux unit does not accurately describe the intensity perceived by the broiler, because the perceived intensity of artificial light will be greater for a fowl than for a human (Nuboer *et al.*, 1992a). Another implication is that, in poultry houses illuminated with different light sources, equating intensity using lux will inevitably produce houses lit at different intensities as perceived by fowls. Prescott and Wathes (1999) estimated that broilers see fluorescent lighting as 30% brighter than incandescent lighting at the same lux. Regulations or codes designed to standardise lighting across different types of lighting therefore need to take account of this.

The same phenomenon can presumably also explain why the physical activity of laying hens was found to be greater in fluorescent light than in incandescent light at the same (120) lux (Boshouwers and Nicaise, 1993), and why, in a choice situation, hens preferred fluorescent light over incandescent light at the same (12) lux (Widowski *et al.*, 1992). Boshouwers and Nicaise (1992) compared the behaviour of broilers in low- (100 Hz) and high-frequency (26000 Hz) fluorescent lighting at the same (90) lux, and found that birds were less active in the low-frequency light; however, all the birds had been reared in high-frequency fluorescent light prior to testing. The critical flicker fusion frequency (where continuous and discontinuous lighting can be distinguished) for fowls is about 105 Hz (Nuboer *et al.*, 1992b), so 100 Hz flicker from fluorescent lights might provoke discomfort in fowls similar to that in humans. Hens showed no preference, however, between low- (120 Hz) and high-frequency (30000 Hz) fluorescent lighting in a choice situation with the same (14) lux (Widowski and Duncan, 1996). No differences in broiler growth rate, FCR and mortality have been found between fluorescent and incandescent lighting (Zimmermann, 1988; Scheideler, 1990).

In a comparison of effects of red and blue (incandescent) lighting on broiler performance, with intensities that were judged to be equal for the birds, it was found that red light caused increased activity levels and reduced leg disorders, final body weight and FCR (Prayitno *et al.*, 1997).

Conclusions

- Except during the first days, problems may arise if broilers receive less than 2 h of darkness per day., "Modified lighting programmes" that provide shorter (12-16 h) photoperiods between about 4 and 14 days of age would appear to confer benefits for broiler welfare without necessarily compromising performance. Brighter lighting (e.g more than 100 lux) is important to stimulate activity and is essential for survival in the first week of life. There are various welfare problems at light intensities below 20 lux. Equivalent light intensities in lux units are 25% lower with fluorescent than with incandescent lighting.

7.5 Stocking density

Stocking density has become a major issue in the debate on broiler welfare. Very high densities may impair the birds welfare directly through physical restriction of the movement. Indirect effects through poor litter quality, high ammonia level and heat are also suggested to have a welfare impact. In most experiments on stocking density in broilers, the variation of density is achieved be varying number of birds at a given floor space. Hence density is confounded with group size. Also the ventilation rate at different stocking density is generally not adjusted to the number of birds in all treatment. This causes further complications.

Slaughter age respect to body weight at slaughter should also be considered. There are two factors which impair the dissipation of metabolic heat with these factors: Feathering and thus insulation of the broilers improve with age, and the body surface in relation to body weight is reduced. With this regard stocking density expressed as weight per m^2 floor space should be lower at higher slaughter age and slaughter weight. In practice, however, the opposite is often found, and recommendation for stocking density are higher for production systems with higher slaughter weight.

7.5.1 EFFECTS OF STOCKING DENSITY ON GROWTH RATE

There exist experiments with broiler densities varying from less than 10 to more than 80 kg/m² on litter and cage systems. The very high densities of over 80 kg/m² stem from caged broilers (Andrews, 1972). There a is general tendency of reduced growth rate with increasing stocking density. The critical value, however, varies between the experiments.

Scholtyssek (1971) increased the stocking density from 18.4 to 28.6 and 32.7 kg/m². The slaughter weight was significantly reduced at the highest density. But in later studies, there was no depression of growth rate when the stocking density was raised to about 30 and 32 kg/m² (Scholtyssek, 1973; Scholtyssek and Gschwindt-Ensinger, 1983). Stocking density in caged broilers is generally higher than on litter. Nevertheless growth rate under high densities in cages has been found to be similar to that of lower density in litter systems (Scholtyssek, 1973). In most experiments with broilers under litter conditions there was a tendency of growth depression from about 30 kg/m² onwards (Weaver *et al.*, 1973; Proudfoot *et al.*, 1979; Shanawany, 1988; Cravener *et al.*, 1992; Gordon, 1992; Grashorn, 1993). It is interesting to note that the growth depression occurred in early growth phases (Shanawany *et al.*, 1988, Cravener *et al.*, 1992), when physical density was not considered as a problem in the birds. The results may be explained by the procedures used in the experiments. The different densities have been tested under the same ventilation rate. Grashorn and Kutritz (1991) showed, that the negative effects of high density disappeared with increasing ventilation rate .

7.5.2 STOCKING DENSITY, FEED INTAKE AND FEED CONVERSION

There was a reduction of feed intake in response to increasing density even though the feeder space per bird was kept constant (Scholtyssek, 1974; Scholtyssek and Gschwindt-Ensinger, 1983), and in some cases the depression of feed intake was higher than the reduction of growth rate. This resulted in a better feed conversion when stocking density increased (Scholtyssek and Gschwindt-Ensinger, 1980; Shanawany, 1988; Grashorn and Kutritz, 1991; Cravener *et al.*, 1992). In other experiments, however, there was no influence (Waldroup *et al.*, 1992; Scholtyssek and Gschwindt-Ensinger, 1983) or even a worse feed conversion (Scholtyssek, 1974) when stocking density was increased. Bessei (1993) assumed that moderately increased stocking density represents a mild feed restriction which usually improves feed conversion. Since this effect occurred even under conditions of sufficient feeder space, access to the feed can be excluded as a causal factor. Recent records of temperatures inside the litter, in between the birds, and above the birds at different densities have shown that the temperature inside the litter and in between the birds were considerably higher than above the birds, and varied with stocking density. The temperature above the birds, where it is usually measured was constant in all compartments (Reiter and Bessei 2000). A mild feed restriction may be the cause for reduced feed intake with increasing stocking density and feed conversion may become worse as heat stress further increases and/or ammonia level rises (Koslowski, 1984; McFarlane and Curtis, 1986; McFarlane *et al.*, 1989a,b; Johnson *et al.*, 1991).

7.5.3 STOCKING DENSITY AND MORTALITY

Shanawany (1988) found increased mortality when stocking density was increased from 5 to 45 kg/m². Despite the increase of mortality and the decrease of growth rate in this experiment net profit per crop increased linearly with stocking density. The costs for chicks and the feed of the dead birds are made up by the lower costs per birds for buildings and equipment. In the other experiments with a high density (ranging from 14 to 54 kg/m^2) there was no significant effect of density on mortality (Scholtyssek, 1971; Bolton, 1972; Proudfoot *et al.*, 1979; Cravener *et al.*, 1992; Grashorn, 1993).

7.5.4 STOCKING DENSITY AND PATHOLOGIES

The interrelationships between stocking density and pathologies, such as chronic dermatitis, breast blisters and leg disorders have been reported in various experiments. Pattison (1992) stated that stocking density is the main husbandry factor which increases the level of mortality resulting from leg disorders. It was found in most studies that the incidence or frequency of the disorders increased with increasing stocking density (Cravener *et al.*, 1992; Gordon, 1992, Weaver *et al.*, 1973; Proudfoot *et al.*, 1979). Locomotor problems, which are very likely to be a consequence of leg disorders, were more frequent in birds at 15.9 than at 12.2 birds/m^2 and more frequent at 22.7 than at 15.9 birds/m^2 (Kestin *et al.*, 1994). Grashorn and Kutritz (1991) found no direct links between density and health disorders. It seems that - as in the case of growth rate - the density only indirectly influences the development of pathologies. High stocking density has generally been regarded as leading to a greater risk of wet litter and high ammonia concentration which have been reported as causes of breast blisters and dermatitis and hock burn was worse at 30-40 kg/m^2 than at 24 kg/m^2. (Wismann and Beane, 1965; Harms *et* al., 1977; Proudfoot *et* al., 1979; McIlroy *et al.*, 1987; Weaver and Meijerhof, 1991; Grashorn and Kutritz, 1991; Grashorn, 1993, Gordon and Tucker, 1993, von Wachenfelt 1993; Harris *et al.*,1978; Proudfoot and Hulan, 1985). However, although Algers and Svedberg (1989) found significant relationships between wet litter and ammonia in broiler houses on acute and chronic dermatitis, leg disorders and general constitution disorders, they found no direct relationships between these disorders and stocking density within the high stocking density range of 20-35 birds /m². Frankenhuis *et al.* (1991) described the scabby hip-syndrome as a result of the stepping over pen mates which is likely to occur under high densities. Claw clipping (Vertommen *et al.*, 1989; Frankenhuis *et al.*, 1989) and toe clipping (Harris *et al.,* 1989) reduced the incidence of scabby hips. This shows that scabby hips are the result of physical constraint or nervousness which lead the birds to step on the back of the pen mates. This syndrome, however, has only been reported in a few experiments using high densities. It is assumed that the high stocking density may elicit this syndrome in combination with other factors e.g. the presence of infectious agents.

In dry conditions, increased stocking density can lead to increased levels of airborne dust (Gustafsson and Martensson 1990) and hence more respiratory disease challenge (Madelin and Wathes 1989). However, at stocking densities of over 30 kg/m^2, increases in airborne dust caused by bird disturbance of litter reach a plateau.

7.5.5 STOCKING DENSITY AND PHYSIOLOGICAL STRESS PARAMETERS

There is little information on physiological changes in response to increasing density in broilers. Scholtyssek and Gschwindt-Ensinger (1980) found reduced hematocrit and creatine kinase values in broilers when the density was increased from 24-32 kg/m^2. In further experiments Scholtyssek and Gschwindt-Ensinger (1983) could not confirm the previous results for hematocrit and creatine kinase under densities from 25 to 39 kg/m^2. Blood sugar and cholesterol were not changed either in this experiment. Cravener *et al.* (1992) reported a low heterophil-leucocyte ratio under high stocking density. The opposite result is considered to be produced by stressful situations (Gross and Siegel, 1983; Mc Farlane and Curtis, 1987).

7.5.6 STOCKING DENSITY AND BEHAVIOUR

There are conflicting experimental results on the effect of stocking density on behaviour. Scherer (1989) and Bessei (1992) observed commercial broilers under densities of 10 and 20 birds per m^2 (19 and 35 kg/m^2 resp.) and 15, 20 and 25 birds per m^2 (30, 37.5 and 45kg/ m^2). There was no significant difference in locomotor activity, feeding, drinking, scratching or resting. Blokhuis and van der Haar (1990) observed the behaviour of broilers at different stocking densities: 2, 8, 14 and 20 birds per m^2 (4.3 to 42 kg/m^2), and Lewis and Hurnik (1990) worked on densities from 7.5 to 15 birds per m^2. In these experiments the locomotor activity and scratching declined with increasing density. This effect was confirmed by Reiter and Bessei (2000). In this experiment group sizes of 5, 20, 40 and 60 birds have been combined with densities of 5, 10 and 20 birds per m^2. There was a significant decrease of locomotion and scratching between 5 and 20 birds per m^2. The data of 10 birds per m^2 density were intermediate. Feeding, drinking, and sitting were not influenced by density. There was a significant effect of group size on both, feeding activity and scratching. Scratching increased continuously with increasing group size.

Üner *et al*. (1996) compared commercial systems for broiler chicken housing at 24 and 32, 28 and 33, 30 and 36 kg/m^2. The birds kept at the lower stocking density in each case showed more walking, running, preening and calm behaviour, spent less time concentrated in the areas around the feeders and drinkers and were more active, in the last week before slaughter than birds kept at the high densities. Increased activity near the feeders and drinkers but lower activity elsewhere at 30 kg/m^2 than at 25 kg/m^2 was also reported by Lewis and Hurnik (1990) and by Üner *et al*. (1996). It appears that at stocking densities above 25 kg/m^2 birds have to spend longer and move more close to feeders and drinkers in order to obtain enough food and water, but, especially in the latter stages of growth, their movements are also considerably restricted elsewhere and activity levels are lower. This great restriction of locomotion and other normal behaviour is a direct indication of poorer welfare and is likely to result in greater leg problems. Murphy and Preston (1988) reported that at 14 $birds/m^2$, many birds stopped lying when other birds stepped on them and restlessness was very high because only 4% of lying bouts were of more than 3 minute's duration and 60% were of less than 1 minute's duration. At this density, of about 28 kg/m^2, the stocking density was too high for normal resting to occur.

It is clear from the behaviour and leg disorder studies that the stocking density must be 25 kg/m^2 or lower for major welfare problems to be largely avoided and that above 30 kg/m^2, even with very good environmental control systems, there is a steep rise in the frequency of serious problems.

Conclusions

- There is a clear tendency for reduced growth rate at high stocking densities in broilers. The negative effects of stocking density on growth rate are reduced when adequate ventilation rates are provided. This indicates that problems of heat dissipation are the main causes of poor growth under high stocking rate. The effect of stocking density on feed conversion and mortality is not consistent among the experimental reports. It seems that poor feed conversion and high mortality occur only concurrently with other stressors such as heat stress.

- Pathologies (breast blisters, chronic dermatitis and leg disorders) are a result of high stocking and the presence of infectious agents and hockborn has been shown to be worse at 30-40 kg/m^2 than at 24 $kg/m^{2.}$ Studies have shown that walking ability is severely affected at 45 kg/m^2 and is worse at 32 kg/m^2 than at 25 kg/m^2. There is no clear effect of stocking density on physiological stress measures. Increasing stocking density has been found to reduce behavioural activities. Studies have shown that locomotor behaviour, preening and general activity are reduced and disturbance of resting is increased at the higher stocking density in comparisons between 25 and 30, 24 and 32, 28 and 33 and 30 and 36 kg/m^2. These finds are all indicative of poorer welfare at the higher stocking densities.

7.6 Stockmanship

In broilers an imprinting on humans is unlikely since the caretaker spends only relatively short time with the animals and the birds are in a socially rich environment. They are thus more likely to imprint on other chicks.

The major man-animal interactions, except flock inspections which do not cause a negative reaction, are of neutral nature, are aversive to broilers. Other environmental interactions such as food distribution are automated and not directly done by man. This lack of positive interactions leads the animal to perceive man as a fear inducing stimulus (Duncan, 1990) or as a predator (Suarez and Gallup, 1982).

Regular handling reduces fear of man but not of other stimuli (Jones and Faure, 1981a; Jones, 1996). It also reduces adrenocortical responses to capture and blood collection (Hemsworth *et al*, 1994), improves antibody production (Gross and Siegel, 1979) and growth rate (Gross and Siegel, 1979; Jones and Hughes, 1981). Handling, associated with enrichment and music, was shown to increase activity and body weight (Nicol, 1992) but to also increase tonic immobility (fear) after transport. There does not appear to be a sensitive period as contacts during the period 1-9 or 10-18 days of age have the same effect (Jones and Waddington, 1993) and the quality of the contact (rough vs gentle handling) is not essential (Jones, 1993). However, catching or feeding the animals by hand and stroking them were efficient to reduce fear of man whereas stroking alone was not (Nicol, 1992). It seem more efficient to increase contacts as early as possible so that the first contacts takes place before fear develops (Broom, 1969a).

In all the experiments cited, animals had daily individual physical contacts with man and this is obviously impossible to realise in farms with large flocks. It is however possible that a long presence of the stockman during the first days of life could be sufficient to reduce fear of man (Gross and Siegel, 1982). As the chicks seem to be unable to individually recognise persons, it is possible to accustom them to someone other than the usual stockman. They however seem to be sensitive to the general appearance of clothing so a uniform style of clothing for all the people entering the building seems to be a good way of minimising fear reactions (Barnett *et al*, 1993; Jones, 1994; Marcuse and Moore, 1950). However, it is important that this fear reduction should be only moderate because if bird are not fearful it is difficult for the stockman to move in the building without trampling on the birds (this is for example a high risk in quail who show nearly no fear of man) and it is also difficult to move the birds.

Broilers with a higher food conversion ratio showed reduced fear of man (Hemsworth and Coleman, 1998). This is the only result obtained in production units and the reason why some flocks were less fearful was not analysed.

Another solution to decrease fear of man is genetic selection as it has been demonstrated in quail, and is likely to be true for chicks, that selection for decreased fear or increased sociability reduces avoidance of man (Faure and Mills, 1998).

The relationship between man and animals is very important but the stockperson should also be well trained in inspection. This aspect has not been the subject of scientific studies but its is well known that standard of stockmanship can influence flock performance. The stockperson should surely have good capacities to observe what is wrong either through the observation of animals or of the building's furniture (ventilation, feeding system, waterers, litter...). The stockperson should also regularly check that security mechanisms such as alarms or emergency systems are properly working.

The observation of the animals is particularly important as problems are likely to be expressed through animal behaviour. The stockperson also has to detect sick or injured animals and take the decision to cull those that are likely to suffer or to have poor performances. However this decision is very personal and unless clear and well agreed guidelines are provided culling decisions are likely to remain very variable. A detailed inspection, particularly during the first days of the broiler's life can also contribute to familiarise the animals with the caretaker.

Conclusion

- The quality of contact between the stockperson and the animals is important in reducing the fear of man shown by broilers. Regular inspection by a competent stockperson is important in assuring good welfare of the birds.

7.7 Environmental Enrichment

We will exclude from this chapter alternative rearing systems, such as free range, providing an environment obviously enriched in so many aspects that it is impossible to make conclusions on what are the key factors.

The environment provided to poultry is usually rather bare and broilers are usually kept in large pens with uniform litter on the floor, usually white (but anyway uniformly coloured) walls, feeders, drinkers and sometimes heaters. This environment provides minimal stimulation to the animals.

Enrichment can have two purposes. The first one is to provide the animals with some aspects of the environment that are necessary for the performance of certain behaviour patterns (perches, litter, nest...). In broilers only perches were studied.

The second purpose is to provide the animals with objects, sounds or odours that are not directly linked with the performance of some behaviour (except perhaps exploration) but provide the animals with a more stimulating environment (Newberry, 1995).

7.7.1 PERCHES

With moderate (up to 17 birds/m^2) densities the provision of perches has very little, if any, effect on performance and are rarely used by the birds (Hughes and Elson, 1977). With higher densities the perches are used but, whereas some birds use them frequently, others never use them at all. For the perchers the use of the perches only starts when they are more than 6 weeks old. This experiment was conducted at a time when growth rate was far lower than today (1861 g when 56 days old) and with perches placed 30 cm above the floor. In a recent experiment with perches placed 20 and 33 cm above the floor and providing 5 cm of perches per bird, nearly no perching behaviour (less than 1% of the birds) was observed in a low density (11 birds/m^2) and only 10% of the birds perched at a density of 22 birds/m^2 (Martrenchar *et al.*, 1999).

Berk (1997) also observed that only a small proportion of birds perched (6.7%) and noted a large individual variation that could be related to leg weakness.). Only in the studies of Davies and Weeks (1995), where the perches' height was adjusted from 2.5

to 26 cm according to the size of the chickens, was a reasonably high rate of perching observed (average 22% of birds perched over the whole study)

In an experiment where metal pipes, cooled by circulating tap water, were used to test their potential anti heat stress effect (Reilly *et al*, 1992), heights of 0, 10 and 20 cm were compared. The broilers preferred the low (0 cm) perch (Gonyou, personal communication).

In all the experiments cited the height used were preventing the birds to go underneath the perches which should be higher to avoid this problem. It is however very likely that higher perches would be used even less.

7.7.2 OTHER OBJECTS

Three types of objects have been used to enrich the poultry environment:

- Objects designed to redirect activities. The objects provide either pecking material and are aimed at reducing feather pecking (Randall and Poggenpoel, 1993; Gvaryahu *et al*, 1994, Jones and Carmichael, 1998) or stimulating foraging behaviour (Sherwin, 1993, 1995). These objects are used by the animals and there is usually little habituation. Their consequences on other aspects of the animals' behaviour are however sometime inconsistent. In some experiments it reduces aggressiveness (Gvaryahu *et al.*, 1994) and mortality, but can also have no effect (Randall and Poggenpoel, 1993). All the studies of this type were performed with layers.

- Imprinting objects. Individually reared chicks show shorter fear reactions after a novel stimulus if provided with an imprinting object or a mirror (Broom, 1969b). Small (20) groups of chicks can be imprinted to a static imprinting object playing music and this induced a reduced fear of a novel object and shorter tonic immobility. It also improved growth rate (Gvaryahu *et al*, 1989). The same procedure can also be applied to large (10000) groups and it was shown that this can help chicks to move from a familiar to an unfamiliar environment and to spread them in the new environment (Gvaryahu *et al*, 1987).

- Toys. In mammals it has been shown that the provision of toys not only modified some aspects of the behaviour but also brain development (Jones, 1987). In birds the research has been mostly focused on behavioural consequences of environmental enrichment (Jones, 1996). The major effect observed has been a reduction of fear. This can be very useful as excessive fear reactions can have harmful effects such as panic (Mills and Faure, 1990) but also more moderate fear reactions are detrimental to bird welfare. The reduction of fear is observed in several experimental situations such as open-field, hole-in-the-wall tests, avoidance of man or a novel object or tonic immobility tests (Jones, 1996). Another way is to introduce in the animal environment some video image. Birds are attracted to such images even if they have no significance for the birds (screensaver programmes) and a slight increase in novelty increases the attractiveness of the image (Jones, 1996).

Despite the largely demonstrated beneficial effect of environmental enrichment in experimental conditions no large scale measure of these effects in production conditions has been reported so far.

7.7.3 MUSIC

Despite the fact, often reported by animal keepers, that music is a powerful tool for reducing fear reactions in broilers, there are no reports of large scale experiments on the effects of music and there is very little information under laboratory conditions.

It was demonstrated that music, but not human speech, profoundly modifies the levels of brain neuro-transmitters (NE: 400%; MHPG: 600%; dopamine: 200%; HVA: 200%) (Bernatsky *et al*, 1997). In hens music was also shown to decrease heterophil/lymphocyte ratio and grooming activities whereas feeding activities and head shaking were increased (Ladd *et al*, 1992). Again in laying hens Belanovskii and Omel'yanenko (1982) claimed that music improved the state of the animal, the effect being attributed to the masking of noises produced in the building. However, information was not given on the specific nature of the improvement and the reported laying rate (40 to 65%) put some doubt on the general relevance of the results.

7.7.4 ODOURS

Natural (Jones and Faure, 1982) or artificial (Jones and Gentle, 1983; Turro-Vincent, 1994) odours can be attractive for chicks. This has not been tested under practical conditions but from the experimental results available it is likely that the use of a familiar odour can decrease fear reactions of chicks placed in a novel environment (Jones and Gentle, 1985).

7.7.5 GENERAL CONSIDERATIONS

If environmental enrichment has to be applied in practical conditions, and the method is promising to reduce fear, it should be kept in mind that a level of novelty is surely stimulating for the animal but that too much novelty can be very frightening. One possible effect of enrichment is to have animals habituated to a varied environment (particularly true for objects and music) and thus showing less fear reactions when exposed to unpredictable stimuli. It is probably better to habituate the animals to a rich environment as early as possible to avoid initial fear reactions as these increases with age (Broom, 1969a). For example in an experiment where 1 week old broilers were exposed for the first time to music, their first reaction was to pile up as far as possible from the loudspeaker (Christensen and Knight, 1975). This type of reaction is not too detrimental for small experimental groups but can be catastrophic in large production units.

The tendency in poultry rearing is to have conditions as stable as possible (temperature, light, food...). This reduces the range of available stimulations for the animals and environmental enrichment could be a way to create a more stimulating environment. However a lot of experimental work has to be performed before environmental enrichment can be used in practical conditions.

Conclusion

- There is a possibility that enrichment of the environment can improve welfare of broilers, but this has not been studied. Perches are probably not a good candidate as broilers hardly perch at all. Objects and music have a good potential but more research is needed in practical conditions to determine what is their effect and what should be used.

7.8 Broiler catching

During the last fifteen years several reviews on broiler catching have been published (see for example Gerrits *et al.*, 1985; Kettlewell and Turner, 1985; Parry, 1989; Scott, 1993). The background is the ongoing development of automatic broiler catching machines, which has been considered necessary for several different reasons, of which animal welfare is one.

7.8.1 MANUAL CATCHING

In most European countries, manual catching of broilers is carried out by catching the birds by one or two legs and carrying them together, three or four birds in each hand, to be placed in plastic crates (Gerrits *et al.*,1985; Moran and Berry, 1988; Bayliss and Hinton 1990). In some cases, the catcher takes the bird around the body and holds each pair of birds upright together with both hands on the way to the crates (Gerrits *et al.,* 1985). This way of catching the birds is recommended in order to reduce the risk of injuring the birds and thus downgradings (Parry 1989). In order to avoid injuries and subsequent downgrading of the meat as well as welfare problems it is important that the birds are handled gently during catching, loading, transport and unloading (Berry *et al.,* 1990). Manual catching may result in low levels of injuries if all catchers are careful, conscientious and well supervised (Berry *et al.,* 1990; Kettlewell and Turner 1985). In practice, however, manual catching is often rather rough and may cause injury to the birds (Bayliss and Hinton 1990). Manual catching is also labour intensive, which makes it expensive. Apart from animal welfare considerations, the demand for good quality meat means that rejection rates must be kept at a low level (Jee 1986), which is not always the case with manually caught flocks. The poor working conditions for the manual catching teams, with strenuous, repetitive work in a dusty environment, often at night, are also an important factor (Bayliss and Hinton 1990; Berry *et al.,* 1990; Bingham 1986a).

7.8.2 MECHANICAL CATCHING

A considerable number of different technical innovations have been presented as prototypes or commercially available products, all aiming at facilitating the catching of birds before slaughter. There are herding systems which have been constructed to move the birds onto a belt conveyor in the rearing compartment (Reed 1974). Others have tried to lift the broilers from the floor by using a scoop mounted on a tractor, and there have been experiments on mat-pulling systems, where fabric mats have been put out and later rolled up, bringing the birds to a conveyor in one end of the house (Berry *et al.,* 1990; Gerrits *et al.,* 1985). Some companies have worked with vacuum systems, but these have led to injury problems (Scott 1993). None of these systems became commercially widespread, as they have been too expensive, clumsy or slow, and in some cases have not handled the birds acceptably from animal welfare points of view (Berry *et al.,* 1990; Kettlewell and Turner 1985). Another alternative is to rear the broilers in cages with a moving floor (Kettlewell and Turner 1985). This system has rather high investment costs and, although it minimises the need for manual handling, may be not be seen as acceptable by the consumers (Scott 1993).

Since the beginning of the 1980's, interest has been focused on systems with soft rubber paddles or fingers (Bingham 1986b; Parry 1989). A broiler company in Northern Ireland has introduced a so-called broiler harvester, with a design which resembles that of a combine-harvester, with a wide horizontal rotor with foam rubber paddles in the front (Anon., 1988). Another type of design, a sweeping system with three vertical rotors has been developed by researchers at AFRC Silsoe Research Institute in England (Jee 1985; Parry 1989; Berry *et al.*, 1990). The machine has soft rubber fingers which are mounted on three slowly rotating pick-up heads, and a conveyor belt takes the birds to a loading unit at the rear of the machine (Parry 1989). A telescope construction allows the machine to work near columns or extend into the corners of a building in order to harvest birds (Berry *et al.*, 1990; Moran and Berry 1992). This type of machine is today commercially available in several different versions (Moran and Berry 1992), and is used in several different European countries.

7.8.3 MANUAL CATCHING VERSUS AUTOMATIC CATCHING

Studies have shown that both manual and mechanical catching and handling are stressful to the birds, but that the effects are of short duration (Duncan *et al.*, 1986). The same authors compared the stressfulness of harvesting broilers using mechanical and manual methods and concluded that stress could be reduced by a carefully designed machine (Duncan *et al.*, 1986). The effect of the experience, knowledge and dedication of the crew is important, regardless of catching method. From an animal welfare point of view, it is also important to remember that machines may fail, and therefore contingency plans to obtain a replacement or muster a catching team must be in place (Jee 1985). Experiments on the light intensity during catching have shown that the birds are calmer and less affected by the catching process if they are handled in darkness (Duncan 1989). This was found to be the case for both manual and mechanical catching and loading.

A large part of the bruises found on broiler carcasses arise during the catching and loading of birds prior to slaughter (Gerrits *et al.*, 1985; Bingham 1986a,b; Bayliss and Hinton 1990; Scott 1993). Factors that influence the level of downgradings are the attitude and care of the personnel handling the birds, the age of the birds, the number of birds per crate and the length of time spent in the crates or modules (Bingham 1986a). Claims of reduced carcass rejection rates when different types of catching machines have been used are widely quoted in commercial poultry press (see for example Anon. 1983; Anon. 1986; Anon. 1988), but scientific studies on the effects of catching machines on bird health are scarce. In a recent observational study it is indicated that the results of such comparisons are highly dependent on the standard of manual catching in the flocks used as control groups (Ekstrand, 1998). The results from the later study, which focused on bird health and welfare in terms of transport mortality and carcass rejection rates, showed that the injury levels were higher in the mechanically caught flocks than in the manually caught flocks, although these differences were small and not consistently significant during the entire study period. The use of catching machines may impair the possibilities of finding and culling sick or underweight birds at catching. This may, in turn, lead to an increase in transport mortality, even if the damage is not caused by the machine itself (Ekstrand, 1998).

Gracey (1986) reported transport mortality figures between 0.29 per cent and 0.56 per cent for manually caught flocks and 0.24 per cent for mechanically caught flocks, whereas Ekstrand (1998) reported a mean of 0.32 per cent for flocks caught manually, and 0.39 per cent for the flocks caught mechanically, a difference which was not statistically significant. The catching system is unlikely to be a major factor in determining the mortality rate during transport. There are other factors, such as health status of the flock prior to transport, number of birds per load and length of waiting period at the slaughterhouse which are more likely to be associated with the mortality rates (Bayliss and Hinton 1990). The conditions during transport are obviously of high importance, but are not in the scope of this report.

The type of sweeping system with vertical rotors mentioned above has been evaluated from an animal welfare point of view by the Swedish National Board of Agriculture, and has been approved for commercial use, under certain conditions (related to details in the construction design and to the training of the personnel handling the machines).

Conclusion

- Traditionally broiler catching has been carried out manually, but during the last decades different types of automatic catching machines or systems have been developed. Rather few scientific studies have been carried out to compare the animal welfare aspects of manual and mechanical catching, but it can be concluded that when properly carried out, using optimal equipment and trained personnel, both methods can result in low levels of injury and low levels of stress to the birds. Conversely, both manual and mechanical catching can result in unacceptably high levels of bruises, fractures and other injuries, as well as high stress levels, if carried out in an improper way.

8 NUTRITION AND FEED MANAGEMENT (INCLUDING WATER)

8.1 Performance

The general objective of broiler nutrition is to maximise the economic production performance of broilers. Diets are formulated by least cost linear programming to provide specified levels of nutrients that are needed for optimum performance. The main production criteria are body weight, feed conversion, health and body composition.

Diets are usually compounded from cereals, such as wheat and maize, as the principal source of energy and protein rich ingredients such as oilseed meals, pulses and animal proteins. Fats or oils are added as additional sources of energy and diets are routinely supplemented with a range of additives, including minerals, vitamins, amino acids, growth promoters, enzymes and medications. The main components of diets are usually added in ground or flaked form but after the diets have been mixed, they are formed into pellets. Feeding diets as pellets has two advantages. Firstly, it improves feed intake and the efficiency of eating. Secondly, the pelleting process involves heating the feed, usually by treatment with steam, which has the added benefit of killing pathogenic organisms that may be present in the raw materials. Indeed, higher temperatures and length of exposure to these temperatures have been introduced in recent years during the different stages of feed compounding with the specific aim of eliminating this contamination. These treatments can degrade some of the dietary constituents, so higher levels of some nutrients, such as vitamins, may be added to diets beforehand in compensation and other dietary components such as enzymes may be added in liquid form after pellet production. Feed is given as small crumbs to newly hatched chicks but as larger pellets to older birds.

Birds are able to discriminate between food sources and when offered a choice between feeds can select a mixture of the major nutrients, such as energy and protein, that is broadly appropriate for their individual needs. True choice feeding, where the birds can select from separate food sources, is rarely used commercially, partly because of the cost of having to provide separate feeding systems. However, birds are able to exercise a degree of selection under feeding practices common in some countries (e.g. UK) that involve blending 12 to 15% of whole wheat in with standard pelleted broiler feeds. This practice has several advantages. It saves milling costs of the wheat and gives as good performance as could be achieved by feeding the pellets alone. The reason for the good performance under these conditions is not fully understood, but may be related to better overall digestion resulting from longer retention of feed in the gizzard and the presence of endogenous enzymes that would normally be destroyed during the milling of wheat. More sophisticated feeding systems are also available that can adjust the balance between whole wheat and a complete diet in the broiler house on a daily basis. These systems use measurements of body weight and feed intake as a basis for calculating the optimum nutrient balance needed to maintain the desired level of performance.

8.1.1 ENERGY AND PROTEIN

The energy, protein and amino acid contents of the diet are major factors determining the growth, feed efficiency and body composition of broilers. Diets of high energy content promote fast growth, so metabolisable energy (ME) contents are generally not less than 12.5 MJ/kg. As birds grow, the proportion of the feed needed for body maintenance increases. Thus starter diets usually have relatively high crude protein (CP) content (22-23% CP) whereas finisher diets may contain only 16-18% CP, depending upon the age to which the birds are grown. However, there are considerable variations in the nutrient compositions of commercial diets fed at different stages, for a number of very different reasons.

The amount of protein needed to provide the required amino acid content and balance will depend upon the amino acid composition of the feed ingredients and the availability and cost of synthetic amino acids. Protein is a relatively expensive component of a diet and it seems that the requirement for the first limiting amino acid increases nearly in direct proportion to the CP content of the diet (Morris *et al.*, 1999). It is therefore a desirable practice to formulate diets to meet the individual amino acid requirements at the lowest economical CP content. Failure to meet the requirement for an amino acid can result in depressed growth but without the appearance of any specific lesions.

Broilers have an appetite for both protein and energy and will regulate food intake to meet their needs for both of these nutrients. Thus a bird will overconsume a diet marginally deficient in protein or an amino acid in order to optimise its intake of the limiting nutrient. Overconsumption of energy will be consequence of this adaptation, with the excess energy being deposited as fat. Conversely, a bird will consume less of a diet containing a high protein content and will have an improved feed conversion and be leaner. Manipulation of the dietary ME/CP, particularly in finisher diets, is used as a means of controlling the body fatness of market broilers (Jackson *et al.*, 1982). The growth and body composition of broilers during different periods can thus be regulated by altering the dietary contents of protein (and amino acids) and energy. This practice is not considered to have any detrimental welfare effects, even though a broiler may not reach its maximum potential weight for a given age. It may even be beneficial for a broiler not to achieve its maximum growth potential, given the association between fast growth and a number of metabolic disorders.

8.1.2 FAT AND FATTY ACIDS

Broilers have a dietary requirement for essential fatty acids (EFA). The main EFA is linoleic acid which acts as a precursor for other members of the n-6 series such as arachidonic acid and derived prostaglandins. Birds also appear to have a much smaller requirement for fatty acids of the n-3 (linolenic acid) series. Other body fatty acids (n-9 series) can be synthesised de novo from carbohydrate precursors. Specific lesions, particularly in the skin, can result from EFA deficiency if the diet content of linoleic acid falls below the requirement of about 10g/kg. However, this seldom occurs in practice since diet ingredients contain EFAs and supplemental fats and oils are widely used to achieve the high dietary ME values associated with high performance.

8.1.3 CALCIUM AND PHOSPHORUS

These nutrients are essential for good bone formation and bone quality is more sensitive than growth rate as a criterion of the requirements for these nutrients. The balance between these nutrients is also important and the normal contents of starter diets are about 10 g calcium and 4.5 g available phosphorus / kg in the approximate ratio of 2:1. Deficiencies or imbalances of these nutrients can have severe effects on the bone quality and welfare of broilers. The main consequence is rickets, either of the calcium deficiency or phosphorus deficiency type, which can occur when the diet content of either nutrient is too low, or the diet content of one is too high and induces a deficiency of the other. Tibial dyschondroplasia (TD) is another consequence of an imbalance when the calcium:phosphorus ratio falls below the optimum (Edwards and Veltmann, 1983).

TD can still occur even under optimum calcium and phosphorus feeding but rickets should be preventable by correct diet formulation. In practice, rickets is often encountered, for two main reasons. Firstly, given the tightness of dietary specifications for calcium and phosphorus, and the importance of avoiding excessive use of phosphorus to minimise pollution, diet contents sometimes fail to meet specifications. Secondly, even when diet contents appear to be adequate, cases of rickets often accompanied by uneven growth within a flock are sometimes seen. These cases are called ‘field rickets’ and it is suspected that the aetiology may involve malabsorption or interference with vitamin D metabolism caused by infectious agents. Rickets and TD can cause distortions of bone growth that may not be apparent at the time of the deficiency but may show up later in the growing period and result in clinical leg bone abnormality and lameness, even though the bird by then is receiving a normal diet. The cartilage abnormalities can also act as foci for bacterial infections resulting in the more serious welfare problems of osteomyelitis and femoral head necrosis.

8.1.4 OTHER MINERALS AND VITAMINS

Diets are routinely supplemented with a large number of minerals and vitamins within ranges designed to avoid deficiencies or toxicities. Deficiencies of these nutrients generally result in impaired performance and specific lesions that can be considered to be detrimental to the welfare of the bird. Toxicities are less common, but also impair welfare.

Sodium is a major supplemental mineral, usually in the form of sodium chloride (salt). Deficiency can result in stunted growth and skin and feather abnormalities. Dietary salt concentrations above the optimum can predispose broilers to ascites or the development of testicular cysts that can impair male reproductive function. The dietary balance between the different anions and cations (principally Na^+, K^+ and Cl^-) is thought to influence broiler performance and an optimum value for the balance has been proposed (Mongin and Sauveur, 1977).

Trace mineral supplements usually provide sources of iron, manganese, zinc, copper, selenium and iodine. The amounts of these supplements depend upon the nature and absorbability of the particular compound. Inorganic sources have been commonly used in the past, but organic chelates or complexes are being introduced to provide more absorbable sources for several minerals.

Practical diets have a natural content of the vitamins needed by broilers but not in amounts adequate for normal health and performance. Supplements of all vitamins are therefore routinely added to broiler diets. The amounts required by broilers have been established experimentally and are reviewed regularly (e.g. NRC, 1994). However, these requirement values are the minimum needed under good experimental conditions and the total amounts provided in commercial diets are generally considerably higher than the requirements. These higher amounts are needed to enable birds to cope with the more stressful conditions experienced under practical conditions, to maximise the capacity of the immune system and to take account of any destruction that might occur during diet preparation and storage.

Deficiencies of individual vitamins give characteristic lesions and can also have some general effects. For instance, deficiencies of a number of B-vitamins result in leg abnormalities associated with stunted longitudinal bone growth. However, under modern conditions of good nutritional practice, simple deficiencies of B-vitamins rarely occur.

8.1.5 FEED ADDITIVES

Diets are supplemented with a number of additives aimed at improving performance or health of birds or the nutritive value of the diet. The threat of coccidiosis is ever present in broiler production and is countered by the routine addition of anticoccidial drugs to diets. Different combinations of compounds are used during the production periods in shuttle programmes designed to prevent the build up of resistance to individual drugs within the various species of Eimeria. Anticoccidials are essential constituents of broiler diets. Sources of coccidial infection are widespread and without control the disease causes extensive damage to the intestinal tract with resultant impairment in performance, morbidity and death.

Some anticoccidials also have antibacterial activity, but more active antibacterial compounds have been routinely added to diets. The main purpose of these antibiotics is to improve digestive efficiency and performance by modifying the population of gut microflora. They are added to diets in sub-therapeutic amounts, but have the effect of reducing the populations of pathogenic bacteria. This has a beneficial effect on the health of flocks maintained under high stocking densities. The recently adopted ban on the continued use of a number of antibacterial compounds for the purpose of performance enhancement could lead to health and welfare problems in intensively housed broiler production unless other means are adopted for controlling pathogens. Broilers have been grown successfully for a number of years in Sweden without the use of antibacterials and production of broilers without use of antibacterials is rapidly increasing in other countries (e.g. UK). Under these conditions, health of broilers has been maintained by good sanitary and environmental controls and reductions in stocking density. The use of antibacterials has also not been permitted in the rearing of some specialised types of broiler such as "Label rouge" in France.

An alternative procedure for modifying gut microflora involves feeding probiotics, cultures of Lactobacilli and other bacteria that have benign intestinal effects. Probiotics can result in performance improvements, though less reliably than antibacterials. Other types of feed additives include organic acids and oligosaccharides. These can help to minimise pathogenic micro-organisms in the feed or their populations in the intestinal tract. Oligosaccharides may also enhance immunological responses. These alternative ways of maintaining bird health are likely to become more important in the absence of specific antibacterials.

Enzymes are another class of feed additive widely used in Europe. A range of enzymes cleaving polysaccharide and protein linkages of food in the digestive system is used to improve the nutritive values of feeds. The breakdown of non-starch polysaccharides that are not normally digested decreases the viscosity of intestinal contents and improves the absorption of nutrients. The main purpose of these enzymes is to improve the performance and feed efficiency of broilers but there are also welfare advantages. Excreta are less sticky, resulting in better litter quality and lower incidences of hock burn or other skin lesions. Phytase is another widely used enzyme that improves the availability of phytate-bound phosphorus. Apart from this effect, phytase does not have any specific impact on the welfare of broilers.

8.2 Nutrition and stress

Modifications to diet compositions can be made to help birds cope with stress. For birds reared under climatic conditions giving rise to heat stress, decreasing the CP content of the diet, using synthetic amino acids to maintain amino acid intake, and increasing the proportion of ME provided as fat will help to decrease the heat increment of the feed and metabolic heat production by the bird. Adjustments can also be made to supplements. Providing a proportion of the sodium supplement as the bicarbonate can help to maintain optimum blood electrolyte balance. Vitamin C is not an essential nutrient for poultry under normal conditions, but dietary supplementation with this nutrient can help to alleviate some of the metabolic problems of heat stress (Pardue *et al.*, 1985) and allow the birds to grow better. Increasing the dietary content of other vitamins is also helpful. For other types of stress, such as disease challenges, provision of higher amounts of vitamins, especially vitamins A or E, can be effective in enhancing the activity of the immunological system (Tengerdy and Brown, 1977).

8.2.1 METABOLIC DISORDERS

Nutrition can influence the occurrence or severity of several metabolic disorders. Even when the disorder does not have a direct nutritional cause, manipulation of feed composition or supply can help to combat the problem. This is particularly true for conditions such as valgus /varus leg disorders that are linked to fast growth. The occurrence of these problems can be decreased by slowing growth in a number of ways. Providing diets in mash form will result in lower food intake and growth. Slower growth can also be brought about by qualitative or quantitative food restriction as discussed in 8.4.

The incidences of cardiac or cardiopulmonary disorders in poultry can also be reduced by slowing growth. Thus feeding mash rather than pelleted diets or feed restriction have been reported to decrease the incidences of SDS (Proudfoot and Hulan, 1982) and ascites (Shlosberg *et al.*, 1991). Modifications of dietary energy and protein contents that slow growth are also effective, though Mollison *et al.* (1984) have reported a beneficial effect of a high protein finisher diet (24% CP) in decreasing ascites mortality independent of an effect on growth. Effects of dietary calcium and phosphorus have also been reported. Scheideler *et al.* (1995) concluded that dietary calcium or calcium:phosphorus above NRC (1994) recommendations resulted in increased mortality from SDS. Cardiac damage, such as that caused by mycoycotoxins, may predispose birds to SDS (Reams *et al.*, 1997) and perhaps also ascites.

Nutritional manipulations that cause water retention or hypertension can increase the susceptibility of broilers to ascites. Thus excesses of sodium salts such as sodium chloride or sodium bicarbonate or other ionic substances in feed or drinking water can give rise to ascites (Shlosberg *et al.*, 1998a). Other minerals, including cobalt, nickel and manganese, can cause hypertension resulting from increased blood haemoglobin concentrations when fed in excess (Martinez and Diaz, 1996) but excess of these nutrients are rare under practical conditions. Phosphorus deficiency has been observed to increase mortality from ascites (Julian *et al.*, 1986). This has been explained on the basis that poor rib strength resulting from rickets impairs normal breathing and thus contributes to hypoxia. Nutrition is not the fundamental cause of ascites and optimising diet composition will not prevent ascites. In practice the most useful nutritional measures are to ensure that diets contain a good nutrient balance and in particular do not contain excesses of sodium salts.

Some disorders are linked more directly to nutrition. Fatty liver and kidney syndrome caused considerable broiler mortality in the 1960s and 1970s but is now prevented by dietary supplementation with biotin (Whitehead *et al.*, 1976). The most prevalent current metabolic disorder with a strong nutritional involvement is perhaps TD. Several nutritional factors have been associated with TD. A decreased calcium:phosphorus ratio in the diet will increase the incidence of TD (Edwards and Veltmann, 1983), but TD is not prevented by an optimum ratio of these nutrients. The dietary balance between the different anions and cations, principally Na+, K+ and Cl-, can also be a factor in the development of TD, with a metabolic acidosis resulting from a high Cl- content being associated with an increase in incidence of TD and alkalosis with a decrease (Hulan *et al.*, 1986;1987). However, manipulation of ionic balance has not been shown to be an effective strategy for preventing TD.

Feed contamination with a mycotoxin, fusarochromanone, can result in TD (Walser *et al.*, 1982) and TD can also be induced experimentally by feeding the drugs thiuram or disulphiram (Edwards, 1987) or increasing the dietary content of cysteine (Bai *et al.*, 1994). The incidences of TD caused by these factors can be decreased by dietary supplementation with different trace minerals (copper, molybdenum, zinc) but there is no indication that spontaneous TD is linked to a deficiency of these nutrients.

Dietary supplementation with vitamin D metabolites is the most effective nutritional means of preventing TD. Although supplementation with 1,25-dihydroxyvitamin D has been shown to prevent TD completely (Edwards, 1990, Rennie *et al.*, 1993; 1995), this metabolite is not currently available as an animal feed additive. Another metabolite, 25-hydroxyvitamin D, is available commercially and can also decrease TD incidence or severity (Rennie and Whitehead, 1996). This metabolite is not so potent as 1,25-dihydroxyvitamin D and its effect is more variable but increased use of this product could contribute to improved leg health in broilers (see also section 6.2.2.2.).

8.2.2 NUTRITIONAL MANAGEMENT AND FOOD RESTRICTION

Food restriction is used routinely in the rearing of broiler breeder stock to limit body weight gain and optimise reproductive performance. This topic is discussed more fully in 9.1. Qualitative or quantitative food restriction can also be used during broiler growing as a means of improving production efficiency or health.

8.2.3 MANIPULATION OF THE GROWTH CURVE

Broilers are generally fed so as to maximise body weight at all ages. However, manipulation of the growth curve by nutritional management can have advantages. Slowing early growth can improve leg bone quality during the important first 3 weeks when bones appear to be most susceptible to the initial development of lesions (Lilburn *et al.*, 1989). This slowing of growth can be achieved by feeding starter diets of lower nutrient density (e.g. 11.5 MJ ME, 190 g CP/kg). Feeding diets of higher nutrient density during the later period of growth will allow birds to catch up lost body weight, though complete compensation is more easily achieved in birds grown to older ages. However, birds grown in this way usually show lower incidences of leg abnormalities and mortality from cardiovascular problems and improved food conversion over the production period (Raine, 1986).

8.2.4 FOOD RESTRICTION

Alterations in the growth profile of broilers can be achieved by food restriction. Various types of restriction have been studied, from severe over a short period to mild over a longer period. Severe restriction early in life has been reported to result in leaner birds with better food efficiency and health, particularly improved leg health and lower mortality from ascites and SDS. The method involves feeding amounts of food sufficient only to maintain body weight for periods of 5 to 6 days commencing at 4 to 6 days of age (Plavnik and Hurwitz, 1991; Fontana *et al.*, 1992). The birds can catch up lost body weight if kept to older ages (up to 8 weeks) but may not compensate fully if killed at 6 weeks (Su *et al.*, 1999) when the lost body weight can represent the equivalent of 2 extra days of growth. Prolonging the period of food restriction (McGovern, 1999) depresses final body weight to a greater extent. The health benefit of improved walking ability has been found to be related to the degree of body weight reduction achieved by the restriction. Thus food restriction programmes allowing more growth during the restriction period (up to 75% of *ad libitum* growth) are less effective in improving walking ability at 6 weeks (Su *et al.*, 1999).

An alternative food restriction regime involves mild restriction, by about 5%, over a greater part of the production period. This can result in little or no loss in body weight but improved food efficiency. The explanation for this is that the birds become more efficient at recovering food that has been spilled in the litter. The greater activity of the birds may also result in better leg quality.

8.2.5 MEAL FEEDING

Fasting has been reported to decrease the incidence of TD, without causing growth depression, provided the fasts are of about 8h duration (Edwards & Sorensen, 1987). A subsequent comparison of regimes involving providing meals 2, 3 or 4 times daily has confirmed that meal feeding results in improved walking ability. Body weight at 35 days was observed in this case to decline with the frequency of meals, but the improvement in walking ability as assessed by gait scoring was greater than could be accounted for by the reduction in body weight (Su *et al.*, 1999). It is probable that changes in activity or hormonal patterns of birds given meals have a beneficial effect on leg development and quality. The widespread adoption of meal feeding, integrated with the changing of lighting procedures to give longer dark periods, is thought to be a major factor in the improved leg health seen in UK broilers in recent years.

Conclusion

- Good nutrition is important for rearing healthy broilers. Overt nutrient deficiency is rare but more information on optimal dietary specifications for birds under stressful conditions might improve bird health and welfare. Nutritional management can have an impact on metabolic disorders. Decreasing the early growth of broilers by qualitative or quantitative food restriction or by providing feed in meals rather than *ad libitum* can lower the incidences of leg or cardiopulmonary disorders. The use of vitamin D metabolites as dietary additives may have a role in promoting better leg health.

8.3 Water

The water quality and method of supply can affect welfare. For instance, saline water from artesian sources can add to the salt load in birds and increase the occurrence of ascites. Water supply systems that allow the spillage of water onto the litter can result in poor litter quality, with the attendant risk of breast blisters or hock burn. The use of nipple drinkers leads to welfare problems because some young birds do not learn how to use them. The nipple cup system allows easy access to water and minimises spillage. Excessive drinking may occur in food restricted breeding birds and water restriction is commonly used for these birds (see also section 9.2.).

8.3.1 DRINKERS

At moderate ambient temperatures, there is a close positive correlation between water consumption and *ad libitum* food intake in poultry, on both hourly and daily bases (Savory, 1978). A water supply which is inadequate in either volume or number of drinking points will thus reduce both food intake and growth rate. This is important for production, but does not necessarily matter from a bird welfare point of view, as long as ambient temperature is within the thermoneutral zone. With breeding birds, the water supply is sometimes restricted deliberately to prevent overdrinking which is a common response to chronic food restriction (see section 8.2).

Over the growing period, the average water to food intake ratio of broilers is 1.8:1 with bell drinkers and 1.6:1 with nipple drinkers, this difference being accounted for mainly by evaporation and spillage (A. Tinch, Ross Breeders, personal communication). Although some broiler producers still use bell or cup drinkers, many are now using nipples, often with cups or trays underneath to catch drips, to reduce problems associated with poor water hygiene (disease risk), evaporation (increased relative humidity) and spillage (wet floor litter). One company's recommended minimum drinker requirement is one nipple per 12 birds (Ross Breeders, 1996). Increases in (apparent) water consumption, water to food intake ratio and litter moisture content, with bell drinkers, have been confirmed in systematic comparisons with different types of drinking system (Bray and Lynn, 1986; Lynn, 1989; Van Middelkoop and Van Harn, 1992). In general broilers spend about twice as much time drinking from nipples as from bell drinkers (O'Rawe *et al.*, 1998a,b; McLean *et al.*, submitted; Savory and Maros, 1993), individuals vary in both the strategy and efficiency with which they obtain water from nipples (J. Savory, unpublished observations), and it is possible that some birds' water intake (and hence food intake) is constrained by inefficient use of nipples.

As drinking in domestic fowls depends on gravitational flow of water down the oesophagus, drinkers are usually positioned at a height where birds have to raise their heads and necks to reach them. Nipples are positioned higher than bell drinkers, and lines of drinkers must be raised frequently and precisely during the growing period. Water intake of the smallest birds may become increasingly constrained as it becomes harder for them to reach drinker nipples.

The water requirement of broilers increases by about 6.5% per degree centigrade over 21 ^{o}C, and in tropical areas prolonged high temperatures will double daily water consumption (Ross Breeders, 1996). In a trial where breeding birds were given a choice between cool (8-12 ^{o}C) and warm (25-30 ^{o}C) drinking water, cool water was preferred consistently regardless of ambient temperature (Degen and Kam, 1998).

Conclusion

- Nipple drinkers are now used more widely than bell or cup drinkers in the broiler industry, to improve water hygiene and reduce evaporation and spillage. As drinking takes twice as long with nipples as with bell drinkers, however, some individuals' water intake (and hence food intake) may be constrained through inefficient use of nipples, and these and other slower growing birds may have increasing difficulty in obtaining water as nipple lines are raised progressively during the growing period.

9 BREEDING BIRDS

9.1 Food Restriction

As a consequence of the continuing genetic selection for faster growth and lower FCR in broiler progeny, it became necessary to impose progressively more severe food restriction on parent stock (breeders) during rearing in order to limit their body weight at sexual maturity (about 24 weeks of age). Currently recommended weights for Ross 308 birds at 24 weeks are 2.8 kg for females and 3.7 kg for males (Ross Breeders, 1998). If breeding birds are fed *ad libitum* (like the progeny), their weights then are much higher (females >6 kg), fat deposition is excessive, many birds are lame, and mortality associated with skeletal disease and heart disease is unacceptably high (Katanbaf *et al*., 1989; Savory *et al*., 1993; Hocking, 1999). High body weight is also associated with impaired immune function (Han and Smyth, 1972; O'Sullivan *et al.*, 1991; Hocking *et al.*, 1996a), increased incidence of multiple ovulations causing reduced production of hatching eggs (Nestor *et al.*, 1980; Hocking *et al.*, 1987; Hocking *et al*., 1989), poor shell quality (Robinson *et al.*, 1993), and reduced fertility in males (Hocking and Duff, 1989). Hence, the chronic food restriction applied routinely to breeding birds decreases fat deposition, heart disease, skeletal disease, lameness, mortality and food costs, and it increases fertility in both females and males.

All breeding birds are fed *ad libitum* to 1 week of age, and thereafter according to programmes of quantitative restriction recommended by the breeding companies. In the EU, rations are usually provided once a day and are eaten in <30 min; elsewhere they may be provided every alternate day ("skip a day") because this is thought to provide greater uniformity of body weight. Male and female birds are reared separately. Females fed according to one such programme (Ross 1) to 21 weeks of age gained about a third as much weight and ate about a third as much food as did *ad libitum*-fed control birds (Savory *et al*., 1993). This level of food restriction (two thirds relative to *ad libitum*) is twice as severe as that recommended for pregnant sows (Lawrence *et al.*, 1988). It is at its most severe from 7 to 15 weeks of age, when females' daily intake is only about a quarter of that of ad libitum-fed controls at the same age (Savory *et al*., 1993).

Using an operant conditioning procedure to measure feeding motivational state, where birds worked for access to food during short test sessions at different times of day and ages, it was found that females reared according to the Ross 1 restricted feeding programme were highly motivated to eat at all times. Their feeding motivation was just as great one hour after their daily meal as it was one hour beforehand, and was nearly 4 times greater than that of ad libitum-fed control birds subjected to 72 h of food withdrawal (Savory *et al.*, 1993).

Behaviour of breeding birds differs markedly from that of (ad libitum-fed) broiler progeny. The former are much more active than the latter, and they show increased pacing before expected feeding time and increased drinking and pecking at non-food objects afterwards (Kostal *et al.*, 1992; Savory *et al.*, 1992). Expression of these activities is often stereotyped in form, and is characteristic of frustration of feeding motivation (Duncan and Wood-Gush, 1972). It is correlated positively with the level of food restriction imposed (Savory and Maros, 1993).

There is also evidence that blood indices of stress (heterophil/lymphocyte ratio, basophil and monocyte frequencies, plasma corticosterone concentration) are higher in restricted-fed breeding birds than in unrestricted birds (Katanbaf *et al.*, 1988; Maxwell *et al.*, 1990a, 1992b; Hocking *et al.*, 1993), and are correlated positively with the level of restriction imposed (Hocking *et al.*, 1996a).

Taken together, these facts indicate that current commercial food restriction of breeding birds causes poor welfare. The breeding bird sector is thus presented with a welfare dilemma, because on the one hand stock may be suffering through chronic hunger, while on the other hand less severe restriction leads to defects in health and reproduction. In an experiment in which qualitative food restriction treatments (diet dilution with sugar-beet pulp, oat hulls or sawdust; appetite suppression with calcium propionate), with ad libitum access to food, were compared with quantitative restriction treatments (Savory *et al.*, 1996), several conclusions were drawn. Different methods of qualitative restriction can be used to control broiler breeder growth rate within desired limits. Problems with these include reduced uniformity in weight gain, increased excreta production and/or increased cost. Although they may suppress abnormal oral behaviours, they do not alter the increased general activity correlated with suppression of growth rate, which may more accurately reflect associated hunger. Suppression of abnormal oral behaviours may only rarely correspond with reduction in blood indices of stress, and so cannot be taken to indicate improved welfare. Some methods can add to physiological stress. There was insufficient evidence of improved welfare, based on behavioural and physiological criteria, to justify advocating the suitability of any of these methods for commercial use. In another experiment in which feeding motivational state was measured with different qualitative and quantitative restriction treatments (Savory and Lariviere, 1999), there was evidence that feeding motivation may be partially suppressed (in the short-term) with qualitative restriction due to a "gut-fill" effect.

It seems possible that current recommended restricted feeding programmes may represent minimum amounts of food required to achieve maximum production performance, and that the same levels of production might be achieved with less severe restriction. Indeed in a recent experiment where (Hybro) broiler breeder females were fed either ad libitum (A) or on recommended restriction (R) during three stages of development (weeks 2-6, 7-15, 16-25), according to eight combinations/treatments (RRR, RRA, RAR, RAA, ARR, ARA, AAR, AAA), high numbers of settable eggs resulted from any treatment with food restriction from 7-15 weeks of age. In fact the highest number of settable eggs was with the ARA treatment, where birds were fed ad libitum before and after 7-15 weeks (Bruggeman *et al.*, 1999). These results should probably be treated with caution, because the body weight gain information seems anomalous (body weight may be a major determinant of reproductive output (see above)), and because no information is given on mortality level or health status. Nevertheless, they suggest that high reproductive performance can be achieved with only temporary food restriction, and more research is required to fully understand interactions between food restriction, body weight, health and fertility.

Food restriction is relaxed when breeding birds reach sexual maturity, but continues in mild form throughout adulthood. It is desirable in adult flocks to separate the sexes during feeding, so that each can receive its prescribed ration (Ross Breeders, 1998). Various forms of special feeding equipment have been designed to achieve this. One, with a high trough for males that females cannot reach and a lower one with a grid that allows access to the narrower heads of females only, can lead to problems with facial abrasion, swelling and infection in females with the widest heads (Duff *et al.*, 1989; Hocking, 1990).

9.2 Behavioural Problems

Overdrinking by breeding birds is a common response to chronic food restriction (Savory *et al.*, 1992; Savory and Maros, 1993), and in commercial conditions the water supply is often cut off a few hours after feeding to prevent wetting of floor litter and associated problems. This does not appear to compromise the birds' welfare when ambient temperature is within the thermoneutral zone (Hocking *et al.*, 1993), presumably because the water is removed after food-related thirst has been satisfied.

In commercial broiler breeder flocks it is common practice for food rations to be scattered evenly on the floor by machine during rearing, to reduce competition and increase time spent feeding (slightly), but to be provided by chain delivery systems in adulthood. Rations are usually provided once a day. Feeding time for adults is typically soon after lights on early in the morning (as with juveniles), but this is also peak oviposition time, so motivation to feed then may often conflict with motivation to lay an egg. This may be a cause of the relatively high incidence of eggs laid on the floor in broiler breeder flocks. Currently there is an increasing tendency for adult flocks to be fed nearer to or at midday, because this has been found to reduce the problem of floor-laid eggs (Grampian Country Food Group and Sun Valley, personal communication).

Another common problem in broiler breeder flocks is reduced fertility as birds get older (Urrutia, 1997), which is thought to be due to declines in male libido (Duncan *et al.*, 1990), number of sperm per ejaculate (Hocking, 1989) and sperm storage capacity in females (Brillard *et al.*, 1989). Many companies now routinely add young males to flocks at least once, and remove older ones that are judged to have low libido (from the pale colour of their cloacas), in order to maintain adequate mating frequencies (Appleby *et al.*, 1992).

As with immature breeding birds, general activity levels in adult flocks are higher than in broiler progeny. Increased activity in adults is reflected by increased incidence of pecking damage due to feather pecking, cannibalism and aggression (which are seldom seen in progeny). Agonistic behaviour may be particularly apparent in periods preceding regular feeding times, when arousal states (in hungry birds) are likely to be high. Lacerations on females' backs and tail regions are also common, due to scratching by males' claws and spurs during mating. These problems have not been studied systematically, but in a survey of three adult broiler breeder flocks, "vent cannibalism" and "cellulitis" (due to pecking damage or laceration) accounted for 24% of all female mortality (Jones H.G.R. *et al.*, 1978).

9.3 Mutilations

Beak trimming of broiler breeder chicks is common with males, but not females, in order to reduce the risk of damage due to aggressive pecking when birds are older. The removal of all or part of male broiler breeder chicks' combs (dubbing), at day-old, used to be common but now is less so. It was done to avoid damage to the comb, and associated risk of infection, due to either pecking by other birds or accidents with house fittings. Removal of the spur bud on the back of each of a male chick's legs (despurring) is often done routinely, at day-old, in order to reduce the risk of subsequent injury to females during mating. Removal of either one (dew) or two (dew and pivot) claws from each foot of male chicks (declawing) is also often done routinely at day-old, again to prevent injury to females during mating. Removal of a specific toe at the first knuckle is occasionally practised on a limited number of pedigree birds, solely for identification purposes.

9.4 Leg weakness

In studies of leg weakness in adult male breeding birds, it was found that musculo-skeletal lesions (dyschondroplasia, destructive cartilage loss, ruptured ligaments and tendons) were common. It was concluded that they are an important cause of declining fertility in older males, and that they are associated with inadequate control of body weight gain (Duff and Hocking, 1986; Hocking and Duff, 1989).

9.5 Egg peritonitis

In a survey of mortality in three adult breeding flocks in 1976-77, "reproductive disorders" accounted for 25% of all female deaths, the commonest, acute egg peritonitis, accounting for 12.5% (Jones H.G.R. *et al.*, 1978). This disorder may perhaps be associated with increased incidence of multiple ovulations resulting from insufficient control of female body weight, but it is said not to be a serious problem now (B. Thorp, Ross breeders, personal communication).

Conclusions

- The most important welfare issue in breeding production is the chronic quantitative food restriction to which birds are routinely subjected, severely so during rearing and more mildly in adulthood. Substantial evidence indicates that growing birds are very hungry, and that this has major effects on their behaviour and physiology. Qualitative food restriction (diet dilution, appetite suppression) can be used to limit growth, but does not suppress long-term feeding motivational state or provide evidence of improved welfare. Recent research indicates that high reproductive output can be achieved by alternative methods. More research is required to fully understand interactions between food restriction, body weight, health and fertility, to determine when and how much food restriction is required. Other welfare concerns are the mutilations commonly inflicted on male breeding chicks and, to some extent, declining fertility in ageing flocks.

10 SOCIOECONOMIC ASPECTS

10.1 The EU Market for Chicken Meat

10.1.1 CONSUMPTION OF CHICKEN PRODUCTS IN E.U.

The E.U. chicken production was approximately 6 million tonnes (carcass-weight) in 1998. The main producer and consumer Member States are listed below.

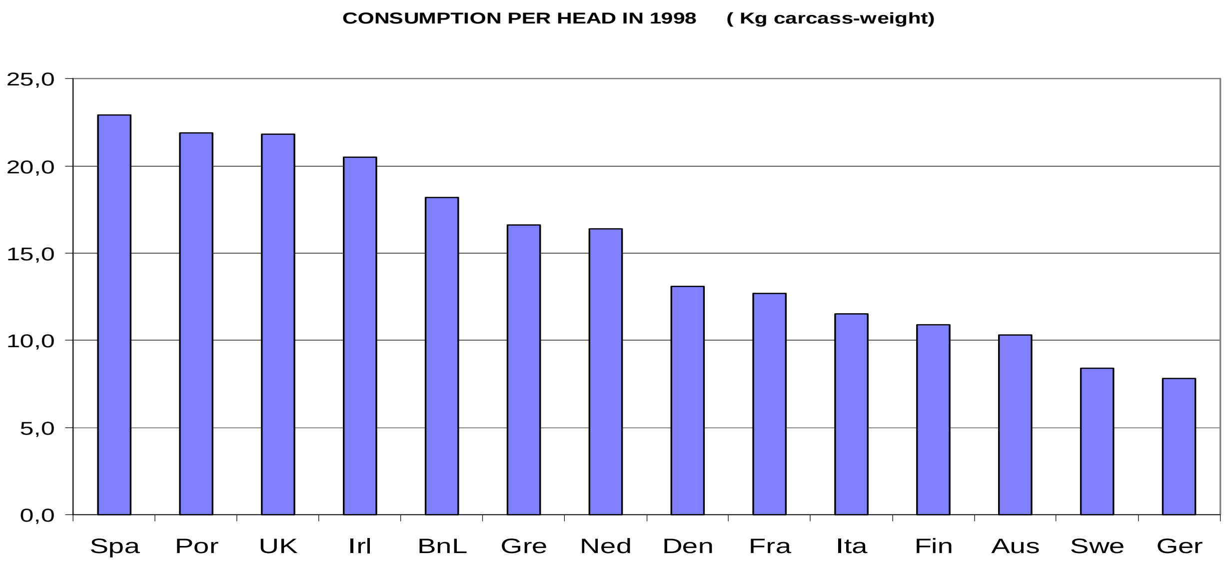
Table 5. Main broiler producer and consumer States in the EU

Main producers	% EU production	Main consumers	% EU consumption
France	20.2	United Kingdom	23.6
UK	18.6	Spain	16.6
Spain	14.6	France	13.7
Italy	11.0	Italy	12.1
Netherlands	9.9	Germany	11.8
Others	25.7	Others	22.2

Source: EC DG AGRICULTURE

Average chicken meat consumption per head in E.U. was 14.47 kg carcass-weight in 1998. However, there are important national differences since consumption per head ranges from 7.8 kg (Germany) to 22.9 kg (Spain).

Figure 6: Chicken meat consumption in Europe



Source: Poultry World Sept 99

The European meat market has almost reached saturation point with the total apparent meat consumption per head (i.e. the amount of slaughtered meat + meat imports – meat exports) only growing by 0.5% since 1991. However, the consumption of chicken meat and meat products, is still growing rapidly. The annual growth rate of chicken consumption per head has been 2.1% over the last ten years. When demographic growth is taken into account, this means that E.U. chicken market is growing by 2.6% yearly.

Table 6. EU Chicken trade balance and consumption

	Production	Exports	Imports	Consumption	consumption per capita
	1000 tec	1000	1000	1000 tec	kg
1986	3882	305	29	3606	11.16
1987	4153	334	25	3844	11.89
1988	4302	341	45	4007	12.34
1989	4317	387	57	3987	12.23
1990	4471	365	75	4181	12.76
*	*	*	*	*	*
1991(1)	4931	409	69	4591	12.54
1992	5052	444	76	4685	12.78
1993	5000	556	83	4526	12.25
1994	5307	546	97	4859	13.1
1995	5592	676	121	5038	13.54
1996	5823	672	141	5291	14.18
1997	5917	730	194	5381	14.38
1998	6019	807	214	5428	14.47
1999	6128	764	222	5583	14.85

(1) East Germany, Austria,Finland and Sweden are included since 1991

Source :EC DG Agriculture   Tec = carcass equivalent tonnes

The total apparent chicken consumption in the E.U was 5.4 millions tonnes (carcass-weight) in 1998. Chicken represents now more than 17% of the total meat and meat products which are consumed in the EU which is an increase from 14.3% ten years earlier.

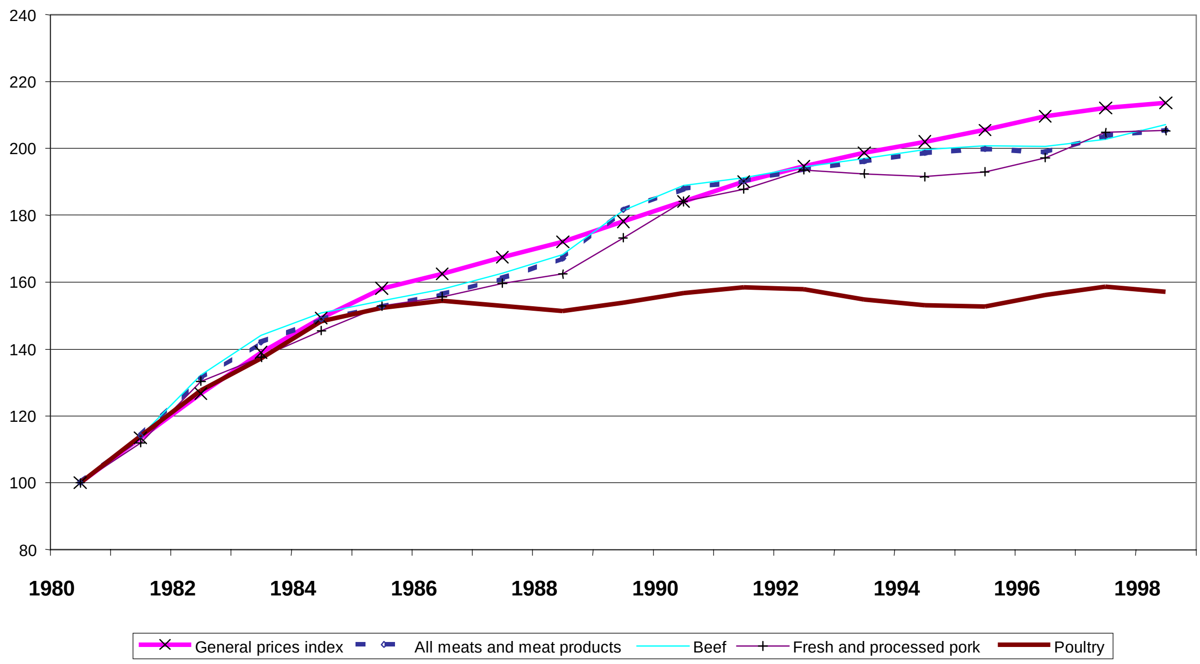
Though other types of poultry are on the market such as turkey and duck, chicken consumption still represents 68% of the EU poultry consumption. This share has been quite constant for 15 years.

Attractive relative prices and positive consumer attitudes have determined the faster growth of poultry (and in particular chicken) compared to other meats.

10.1.2 PRICES OF CHICKEN MEAT RELATIVE TO OTHER MEATS

The evolution in consumer prices has favoured the consumption of chicken. As an example consumer price indexes in France are shown in Table 6, almost the same trends have been observed in the other EU Member States. The Chicken is an inexpensive meat which has become cheaper compared to the other meats resulting in an increased market share at the expense of other meats, particularly beef.

Figure 7: Consumer price indices for meat 1980-1998. (1980=100)



(source: INSEE Bulletin Mensuel de Statistiques Indices des prix à la consommation)

The relative reductions in the consumer prices have obviously been linked to the prices received by the farmers which in turn are related to the farm production costs. Since 1980, white meats (pork and poultry) have been favoured not just by higher productivity gains but, above all, by developments in the Common Agriculture Policy (CAP). Reductions in grain prices under this policy have resulted in reduced white meat production costs. Conversely the intervention prices for beef was increased, leading to higher prices for this meat. The 1992 CAP reform tried to achieve a more balanced policy but did not fully succeed in this objective.

10.1.3 Evolution of production costs

According to the annual production costs data of ITAVI, from 1980 to 1998 the production cost of 100kg of basic ("standard") chicken in France has dropped every year by an average of 4.27 (1998 prices). The cost cut comes from reductions in :

1) compound feed price - 2,79 € (65%)

2) chick price : - 0,47 € (11%)

3) other factors : - 1,01 € (24%)

while the productivity gains on feed, genetics, fixed capital and labour have generated a yearly cost reduction of 1.26 €. See Table 7 below.

Table 7. Changes in the costs of the French basic chicken. (Euro /100 kg, 1998 prices)

	1980	1998	Change
Feeding cost	97,70	42,07	-56,9
Feed price (100kg)	48,85	22,26	-54,4
Chick cost	22,33	11,76	-47,3
Chick price (100 u.)	39,08	22,11	-43,4
Other costs	29,13	18,43	-36,7
Total	149.16	72.26	-51.6

Source: ITAVI

In the future, the competitive environment might change with the advent of Agenda 2000 and the Berlin arrangement. According to proposals, the beef market price would be cut by 30%, while, as a consequence of the 15% cut of the market grain prices, chicken production costs are expected to be reduced by only 3.5%(Porin and Mainsant, 1999).

10.1.4 FOREIGN TRADE

The European Union is a net exporter of chicken meat and products and was 110% self-sufficient in 1998.

France, the Netherlands, the United Kingdom and Denmark are the main exporters.

Table 8. EU Chicken trade with Third Countries

TABLE EU CHICKEN TRADE WITH THIRD COUNTRIES								
	EXPORTS				IMPORTS			
	1000 tec			(million €)	1000 tec			
	Whole	Cuts	Total		Whole	Cuts	Total	(million €)
1990	293,7	71,1	364,8	371,6	23,6	51,3	74,9	193,3
1991	318,8	89,6	408,4	417,7	16,5	52,2	68,7	190,2
1992	346,1	98,3	444,4	428,1	16,1	62,0	78,1	225,4
1993	415,4	140,2	555,6	543,1	13,7	69,5	83,2	245,1
1994	372,1	173,5	545,6	551,2	9,6	87,8	97,4	296,1
1995	406,1	269,0	675,2	633,9	7,6	89,5	97,1	276,1
1996	390,8	282,5	673,3	683,7	7,6	118,1	125,7	323,7
1997	356,9	336,1	693,0	743,3	9,0	138,7	147,7	414,9
1998	399,6	368,1	767,7	732,8	6,2	146,0	152,2	390,1

SOURCE EC DG AGRICULTURE

Exports reached more than 750 000 tonnes (carcass-weight) whereas imports were 152,000 tonnes.

Over the ten last years EU trade with third countries (exports and imports) (see Table 8) has been growing three time faster than home production and consumption.

It is necessary to make a distinction between two types of exports:

(1) Exports which depend heavily on the price competitiveness of E.U. chicken production (and export subsidies). Almost all the whole chicken exports and about a quarter of the exports of chicken cuts are of this type. Even though this trade has stagnated since 1993, it still represented more than 400 000 tonnes carcass-weight in 1998. An increase of the production cost in E.U. could greatly affect this business.

(2) By-products which cannot be sold on home market and are disposed of on foreign markets. These exports are growing fast; their destinations are often countries with lower purchasing power such as Russia (before August 1998), Africa or Eastern Asia.

Imports are growing faster than exports. However they supply less than 4% of the EU consumption. The main feature is the recent development of trade in low price chicken breasts from Brazil and Thailand. These imports are mainly used as raw materials by the processors of convenience foods.

Third Countries are not committed to follow EU welfare rules.

10.1.5 EMPLOYMENT

There are no specific data about the employment in the chicken production and sales chain since many firms which are involved in the chicken business are dealing with the other kinds of poultry too. However employment ratios for the chicken industry (employees per tonnes of production) are likely to be not very different from poultry ones.

In France According to “L'emploi dans la filière volailles de chair en France en 1997”, the employment in the French broiler industry is estimated as follows:

Table 9. Employment in the French poultry meat industry

Industry Sector	Employment (full time worker equivalents)
Compound feed industry	4500
Breeder flocks	950
Hatcheries	3000
Other farm suppliers (building, equipment, services)	2000
Commercial flocks (15000 specialised farms)	12000
Catching	2000
Slaughtering and processing	30000
Total	**54450**

(Source: “L'emploi dans la filière volailles de chair en France en 1997”)

The estimate gives a ratio 23.2 employees per 1000 tonnes (carcass-weight) produced.

If we assume that French ratio can be extrapolated at EU level, employment in EU chicken chain is estimated to be about 140.000 full time worker equivalents.

According to French data, farm employment would be less than 25% of the total industry employment, with processing industries employing more than 50%.

Employment in the broiler industry is likely to grow: The growth in the market of 2,8% per annum and the development of convenience products with higher added value compensate for the large increase in labour productivity which is being achieved.

10.1.6 CHANGES IN THE EU CHICKEN PRODUCTS MARKET

In recent years, there have been two major developments in the market for chicken products, both of which may affect animal welfare issues. These have involved a preferential use of fresh products rather than frozen and the development of more convenience foods.

1)Fresh rather than frozen products

The development of fresh products, in particular fresh cuts which are much more perishable products, has led to shorter delays between slaughtering and consumption for this type of product. This change is creating a barrier to the imports from third countries. Note however, that imports of frozen products for the preparation of certain convenience foods is increasing.

2)More convenience products

The development of chicken convenience products (e.g ready to cook foods, easy preparation at home) has not reached the same level in the different E U countries and there are considerable production differences (slaughterweight, age etc). However the trends in all Member States are the same: consumption of whole chickens is stable and even declining, while convenience products are growing fast, with annual growth rates of at least 5% and more than 10% in some countries.

- Chicken convenience products are likely to reach 25% of the total EU chicken market in the near future. In the longer run, their share could be even higher since:
- chicken meat is a cheap raw material which could become cheaper with the improvement of the deboning techniques;
- with a 30% market share, chicken processed products still have a small share compared with pork situation;
- new products developments are expected which will create more diversity.

The development of convenience products may have three consequences:

- More processed products are more distant from the animal in the mind of the consumer. While many consumers give attention to the way animal have been reared when they are buying whole chickens (and more generally fresh meats), very few consumers care when they are buying processed meat products. Moreover, most of the convenience products are promoted in a manner which reduces the link between them and the live broilers in the mind of the consumer..

- Convenience products (even if final products are chilled) could be processed from frozen raw materials. Since processors are not bound to mention the origin of the raw materials, they could import cheaper frozen raw materials from countries which would not apply chicken welfare regulations.

- In future consumer demand and different productions methods (e.g. deboning mechanisms) are likely to lead to the production of broilers with a heavier slaughterweight. Such chickens have obviously more welfare problems than lighter chickens

In France, the use of frozen chicken meats imports as raw material is already a fact: According to Magdelaine and Philippot (1999), most of the chicken breasts used by the delicatessen processors to produce chicken ham are imported.

10.1.7 CONSUMERS ATTITUDES AND MARKETING

The broiler industry has made the most of three important consumer factors: health concerns, need for more convenience foods and desire for more diversity.

10.1.7.1 Health concerns

There are two major issues, healthier diet and food safety.

<u>The perception of chicken meat as healthier diet</u>

While much professional and media attention has been paid to the ‘risks’ of beef production, the chicken industry have highlighted the leanness of chicken meat and the dietary quality advantages of the low chicken fat levels.

<u>The requirement of food safety</u>

Consumer demand in the area of food safety appears to be for a product, without "chemicals" and without pathogens. In the future microbiological contamination may become a major issue for the chicken industry. Until recently, in most EU countries, chicken was generally considered as a microbiologically safe food, since long oven cooking times guaranteed safety of the cooked whole chicken. The shorter cooking times of the chicken cuts do not ensure the same safety. Therefore, though industry has strongly improved the microbiological quality of its products, the safety image of chicken could be affected.

10.1.7.2 More convenience and more diversity

The chicken industry has developed a wide range of chicken products. Twenty years ago, whole chicken (mainly frozen) was virtually the only chicken product; nowadays, besides whole chicken, there are different cuts and many types of convenience foods available. This evolution has a clear connection with socio-demographic changes (such as the increase of the womens' employment or the reduction of the households size). As household size has decreased the market has developed smaller consumer portions in response. Table 10 shows the structure of chicken supply in several countries.

Table 10. Household consumption (%) of types of chicken product

		Whole	Cuts	Convenience products	Total
France (1)	Total	52	33	15	100
Germany (2)	Chilled	15.9	34.1	13.6	63.6
	Frozen	13.6	11.4	11.4	36.4
	Total	29.5	45.5	25	100
U.K.(2)	Chilled	30.1	37.4	14.5	82
	Frozen	3.4	4.8	9.7	18
	Total	33.6	42.2	24.2	100
Italy (3)	Total	19	66	15	100

(1) 1997 Source ITAVI-AND 1998 (2) 1999 Centre Français du Commerce Extérieur (CFCE) (3) Pasquarelli, UNA, 1998; Vermillo, 1999.

10.2 Market Sensitivity

Market sensitivity to a change in production costs must be evaluate through two criteria:

the consumer price changes

the demand changes

Two basic figures are needed to estimate these effects, the marketing margins and the price elasticity for the product.

Marketing margins (or their symmetric data, the farmers' share of retail price) make the connection between farm prices and consumer prices: If we assume that a production cost increase is totally passed on to the consumer price (or that operators are not changing their own margins), there is a direct relationship between the relative change of the consumer price C and the relative change of the production cost P such as

$\Delta C/C = (1- M)\ \Delta P/P$, where M is the marketing margin in percent of the consumer price

and, of course, 1- M represents the farmers' share on retail price.

Price elasticities which make connection between consumer price and demand volume.

The EU domestic demand must be broken down into three different markets which are likely to react differently toward a farm price change:

1. Household demand of chicken butcher meat (uncooked whole chickens and cuts) which still represents 60-70% of the total EU chicken consumption;

2. Catering and restaurants market demand of butcher meat(10-15%);

3. Raw material demand from convenience food processors (15-25%).

10.2.1 HOUSEHOLD CONSUMPTION

Fresh products compose most of this market; therefore it can be assumed that there would not be many opportunities to substitute home products for imports (moreover these opportunities will be more reduced with the EU membership of the Central and Eastern Europe countries), and, as a result, an increase of production cost would have small impact on the volumes of the imports of chicken butcher meats. However possible negative impacts on the EU market of marginal increases of the imports must not be neglected.

10.2.1.1 Marketing margins

There are very few studies on poultry marketing margins in Europe; that can be explained by the fact that, in Europe, most of chicken are produced under contracts, and, as a result, spot markets for farm products do not exist (or are thin markets); therefore it is difficult to get chicken farm prices series.

Only data from two Member States, the UK and France, was obtained and these presented very different pictures.

In the United Kingdom, according to the N.F.U. Economics Department which has compared farm gate and retail prices over three years, the farmers' share of the retail price for chicken has been 27%, 24% and 23% respectively during the first semesters of 1997, 1998 and 1999.

In France, according to Porin et Mainsant (1998), in 1997, the average marketing margins for poultry products sold for households consumption were 55% of the consumer price – and farmers' share of the retail price was 45%. The difference between British and French estimates seems to be very large and cannot be explained just by the differences in product mix or margins strategies of the operators. It may come from differences in price definitions and methodologies.

10.2.1.2 Price elasticity

There are few references on chicken price elasticity; most estimates refer to poultry. However, since chicken makes up more than two thirds of the poultry demand, we can assume that chicken price elasticities are not very different to those of poultry. Table 11 shows important differences between the EU countries; price elasticities range from almost 0 (Germany) to –1.14 (United Kingdom)

Table 11. Own-price elasticities for chicken and poultry meat in different European countries (Marshallian price elasticities)

Country	Authors	Data period	Price Elasticity
Belgium	Verbeke (1999)	1995-1997	-0.47 (p)
France	Fulponi (1994)	1959-1985 1985	-0.86 (p) -0.88 (p)
Germany	(Stephen van Cramon-Tautabel, personal communication)		> -0.20
Italy	Dono and Thompson (1994)	1988	-0.48 (c)
Spain	Laajimi and Albisu (1997)	1989-1992	-0.70 (c)
United-Kingdom	Burton and Young (1992)	1961-1987	-1.14 (p)

(p) : poultry, (c) : chicken.

The authors generally used the same method, with an Almost Ideal Demand System.

With these data from six countries which represent more than 80% of the EU demand, it is possible to estimate an aggregate elasticity for EU; this price elasticity would range between – 0.6 and – 0.7 .

The comparison with the elasticities of the other meats which have been estimated in four countries shows that the important differences between E.U. countries which are shown for chicken demand applies also to demand for other meats. In general, beef demand is usually more elastic than that for white meats.

Though chicken and pork are both white meats , consumer behaviour towards these two meats are very often different. Price elasticity for chicken is higher than that for pork in France, while it is lower in Italy and Spain and almost the same in United Kingdom (see Table 12).

Table 12. Some data price elasticities (price uncompensated elasticities)

Country	Period	Beef	Pork	Chicken

		B/B	B/P	B/C	P/B	P/P	P/C	C/B	C/P	C/C
France	**1989**	-0,76	-0,03	-0,03	-0,32	-0,48	-0,08	-0,23	-0,23	-0,83
Italy	**1988**	-1,21	+0,11	+0,03	+0,03	-0,94	-0,49	+0,10	-0,82	-0,40
Spain	**89-92**	-0,98	+0,27	+0,13	+0,14	-1,09	+0,19	+0,03	+0,17	-0,72
U.K.	**61-87**	-1,76	+0,14	+0,30	+0,14	-1,07	-0,16	+0,81	-0,34	-1,14

Note : B/B, P/P and C/C are own-price elasticities for beef, pork and chicken; the others are cross price elasticities. (Source: see Authors in Table 11)

10.2.2 CATERING AND RESTAURANT DEMAND

There are no scientific references on this topic. However, it is possible to conclude that marketing margins are larger in catering and that therefore final prices would be relatively less affected by an increase in the chicken production cost.

Demand for catering cuts does depend not only on the attitudes of the final consumers but mainly on purchasing decisions by caterers and restauranteors. There are no figures about such purchasing decisions which might help to estimate market changes.

10.2.3 CONVENIENCE PRODUCTS

10.2.3.1 Price elasticity

Researchers have focused on revenue elasticities of convenience products but they have not paid attention to price elasticities; data are needed to estimate demand changes.

10.2.3.2 Marketing margins

There is no specific data available about marketing margins on chicken (or poultry) convenience products. Nevertheless a comparison with the situation relating to pork may help to arrive at an estimate for chicken. In France, the average marketing margin on pork convenience products (delicatessen) was 82%, whereas the average marketing margin on fresh pork was 58%. This example suggests that the farm product value in a convenience product might be two times less than that for butchers' meat.

10.2.3.3 Decisions to import raw materials

An increase of the home production costs might induce substitutions of imports for home raw materials. Theoretical models exist which could be appropriate tools to obtain a better appreciation of this issue.

10.3 Market Sensitivity to Broiler Welfare Issues

The is no European reference on the willingness of consumers to pay more for chickens raised with a system giving an improved welfare, though there are references (French and British) for pig and laying hens.

Consumers sensitivity to chicken welfare is less apparent at least for three reasons:

- There is no clear symbol for the mistreatment of chickens, unlike in the case of laying hens where cages are a strong symbol for poor welfare..
- Scientists are able to suggest only relative changes (for example slower growth rate, lower stocking density or better air quality) which are less easily understood by consumers than "binary changes" (with/without).
- There is a general lack of information and an apparent limited knowledge about broiler rearing systems (e.g. many consumers believe that broilers are reared in cages) .

There appears to be a gap in understanding between what chicken welfare means to consumers and what it is for scientists. However, in some member states, it seems that an increasing number of consumers are expressing concern about the welfare of chickens since this is being reflected in the use of production standards by some food retailers.

10.4 Economic consequences of different means of improving chicken welfare

Two simulations have been carried out to estimate the order of magnitude of the additional costs and benefits involved in the implementation of various measures to improve the welfare of the birds.

These evaluations are necessarily incomplete. It has been possible to take into account the costs related to the implementation of possible new rules but indirect effects, especially benefits, which could result from the improvement in animal welfare have, in general, not been evaluated.

Even though one can envisage these indirect effects, the absence of commercial scale trials means that it is impossible to accurately estimate their financial implications.

Simulations are based on the French situation since France has on many criteria (i.e. types of housing, stocking density) a median position between Northern Europe countries and Southern ones. When it proved possible, comparisons were also made with Sweden and Spain as models of Northern Europe production and Southern Eupopean production systems respectively.

The results of the simulations are given below. The basic assumptions and computations of these simulations are given in Annex 1 of this report.

10.4.1 REDUCTION IN STOCKING DENSITY

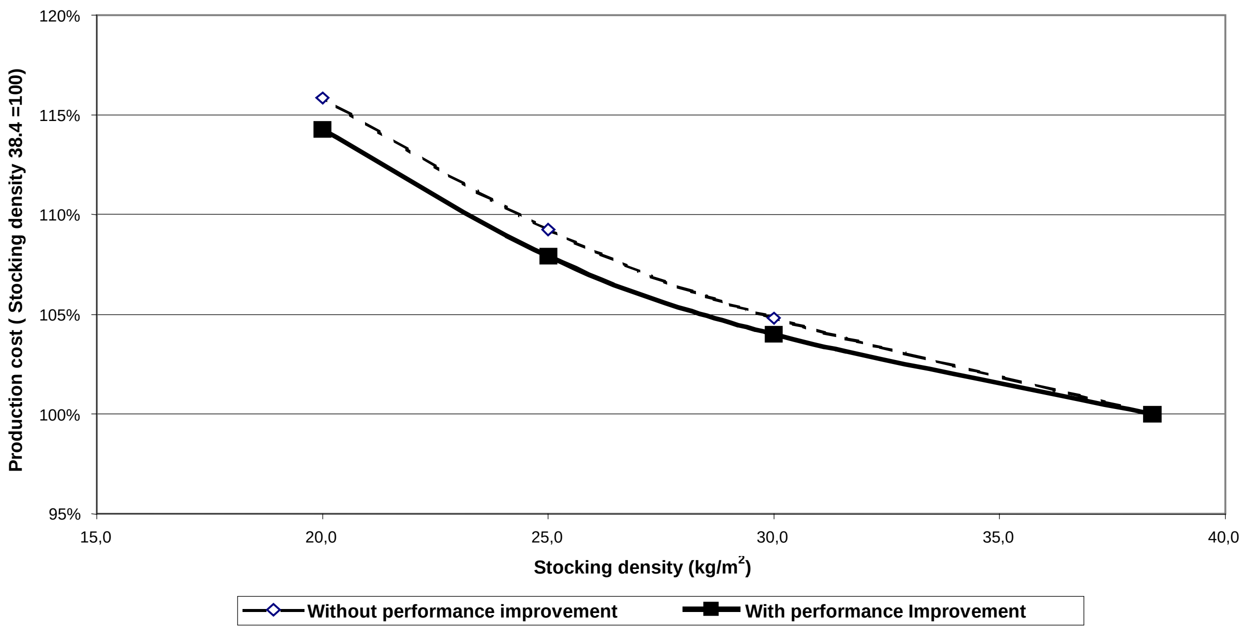
Three stocking densities have been simulated (20, 25 and 30 kg/m^2) and compared with the current density of chicken which is 38.4 kg/m^2. The direct effect of a reduction of the stocking density would be an increase of production cost which is estimated as 5.3%, 10.2% and 17.5% when stocking density is reduced to 30, 25 and 20 kg/m^2 respectively.

The gap in the these production cost compared to the production costs of basic chicken would be reduced only if the stock performances were highly improved. For example, if we assume that reduced stocking density improves chicken welfare so that mortality decreases as follows;

Stocking density kg/m^2	**38,4**	**30**	**25**	**20**
Mortality rate (%):	**5.9**	**4.13 (-30%)**	**2.95 (-50%)**	**2.36 (-60%)**

and FCR is mechanically reduced by 0.4% when mortality is reduced by 1%, then these effects, though important, would compensate for less than 20% of the cost increase.

Figure 8: Model of the effect of stocking density on production



If stocking density would be reduced to 25 kg/m^2, the gap of production cost with the current basic chicken might be reduced by half if mortality would be reduced by half and FCR by 7.7%. Such performances improvements are higher than what scientific literature leads us to expect.

Therefore, it is likely that a reduction of the stocking density to 25 kg/m^2 would lead, in the French situation, to an increase of production cost which would range between 7% and 10%.

The effects of a reduction of stocking density would be almost the same in Sweden (cost increase would be respectively 3.7%, 7.5% and 14.2% at 30, 25 and 20 kg/m^2.

Spanish production costs would not be affected (if there is no regional modulation) since stocking density there is usually lower than 20 kg/m^2.

The costs of restricting ammonia or other emissions have not been included in the calculations because of lack of evidence. Reduced stocking density would result in lower output of nitrogenous waste but increased activity could result in increased gas release.

10.4.2 REDUCTION IN GROWTH RATE

This simulation is based on French technical data. In France, strains with a lower growth rate have been used to produce "Label rouge"" chicken for more than 20 years. It is possible to use a cross of a female "Label rouge" and a male standard to produce a more basic chicken, which could result in the improvement of several welfare criteria: Weekly mortality rate could drop from 1% to 0.35%; breeders welfare would also be improved, since female breeders would not require feed restriction.

As a result, slaughter age would be increased (50.5 days compared with 40.7 for basic chicken) and food conversion ratio would go up from 1.89 to 2.10. These steps would increase the cost of production but this would be partly offset by a lower feed price (because feed nutritional density is lower) and a lower chick price (because breeder fertility and egg hatchability are greatly improved). In the French context, with the large scale development of this type of production, chick price is expected to be 10% to 15% lower than the chick price from dwarf strains and 25% lower than the chick price of other strains.

In the French situation, the production cost of this type of lower growth rate chicken would be about 5% higher than the basic chicken and simulation using Spanish and Swedish data produce almost the same estimate.

These technical as well economical results must be confirmed, on the one hand, for France, on the other hand, for the other types of chickens. It is likely that the production gap between a lower growth rate chicken and the current basic chicken, which has been estimated for a chicken with a 1.9 kg slaughter weight might be different for heavier or lighter chickens.

Conclusions

- Chicken meat has increased its proportion of the total meat market because of beneficial price development and a positive health image among consumers. It is relatively inelastic in price-sensitivity compared with beef, and about the same as pork.

The production of chicken meat has not been in the focus of any extensive public welfare debate, and so there has been little pressure from consumers on the broiler producers to improve the welfare of the animals. However, in some member states, it seems that an increasing number of consumers are expressing concern about the welfare of chickens sincethis is being reflected in the welfare standards during production by some food retailers

• Simulation models indicate that reducing maximal stocking density from 38 to 30 kg/m^2 and increasing growing time (i.e. reducing growth rate) by 10 days would each cause a similar increase in total production cost of about 5%. Reducing stocking density from 38 to 25 and 20 kg/m^2 would cause increases in total production cost of about 10% and 15%, respectively.

- Such cost increases may be expected to increase final consumer prices by about 2.5% to 7.5%, or less in processed products. In modelling the cost changes, possible increases or decreases in costs of restricting ammonia or other emissions could not be included.

• The effects of increases in production costs on EU foreign trade in chicken products need to be evaluated. EU exports about 400000 tonnes carcass-weight of chicken products and imports raw material for production of convenience food.

11 FUTURE RESEARCH

1. Efforts should be made to develop a better fundamental understanding of the causes of skeletal and developmental leg abnormalities, with a view to establishing markers for more effective genetic selection against these disorders.

2. Research should be continued to identify optimum nutritional and environmental conditions for minimising leg problems.

3. An objective system should be developed for the assessment of leg quality and walking ability in commercial flocks.

4. Myopathies and biochemical indices of muscle damage have been identified in modern broilers. A better understanding is needed of whether or how changes in muscle physiology resulting from modern breeding practices have an impact on broiler welfare.

5. Research should be continued to identify nutritional methods for controlling pathogens and optimising immunological competence and health in broilers in the absence of growth promoting antibacterials.

6. More information is needed on nutritional means of alleviating the various effects of stress.

7. Research is needed to identify genetic and management strategies for minimising the need of breeding birds for feed restriction.

8. Research should be conducted to closer elucidate the behavioural needs of broilers. In particular, it is not known to what extent the reduced activity in broilers is caused by a simple physical incapacity to carry out physical activity, or to what extent it is caused by reduced motivation for active behaviour. The genetic correlations between growth and behavioural responses also needs closer study.

9. More information is needed about efficient methods for the humane culling of broiler, both at individual and at flock level, in case of injury or disease.

10. Commercial scale trials should be carried out in order to better estimate the economic effects of various measures designed to improve animal welfare. Even though it has been possible to evaluate the direct costs of various animal welfare regimes, the indirect effects, especially economic benefits, (reduction of certain aspects of the cost of production or improvements in the quality of the product) which could result from the improvements in welfare for the chicken remain to be quantified.

11. Research should be carried out on the relationship between light intensities and broiler welfare.

12. More research is needed on different methods of environmental enrichment for broilers, for example the use of perches, etc.

12 CONCLUSIONS

1. For an adequate assessment of welfare a wide range of indicators must be used, although single indicators can show that welfare is poor. Animal welfare can be assessed in a scientific way and indicators of welfare include those of physiological states, behaviour and health. Estimates of welfare using mortality and morbidity figures have to be based on comparisons between productions systems since reference values on acceptable levels are rarely available.

2. Most of the welfare issues that relate specifically to commercial broiler production are a direct consequence of genetic selection for faster and more efficient production of chicken meat, and associated changes in biology and behaviour. There are also differences in biology and behaviour between male and female broilers, and between broilers and breeding birds, that have implications for welfare.

3. Broiler chickens are mostly selected for growth rate and food conversion ratio. Other traits such as low frequency of leg disorders or resistance to pathogens are likely to be also included in the selection index by most breeders but the importance given to such traits is often low and up to now has not improved welfare.

4. A wide range of metabolic and behavioural traits in broilers have been changed by selection practices. Major concerns for animal welfare are the metabolic disorders resulting in leg problems, ascites and sudden death syndrome and other health problems.

5. Mortality rate is a rather complex measurement . In most cases, it comprises birds that have been culled as well as those dying naturally. Pre-hatching factors related to egg size and shell quality influence early mortality and can be reduced by appropriate screening of hatching eggs. Mortality in older birds is often related to metabolic disorders caused by rapid growth.

6. Leg disorders are a major cause of poor welfare in broilers. Gait scoring surveys have shown that large numbers of broilers have impaired walking abilities and there is evidence that birds with score 3 or higher experience pain or discomfort. However, the subjective nature of the scoring system leads to difficulties in making direct comparisons between different studies and there is a strong need to develop objective measurement systems and to carry out systematic epidemiological studies. Femoral head necrosis is an acute cause of poor welfare. Developmental disorders resulting from dyschondroplasia or other bone growth abnormalities represent less severe but more widespread problems. Continued effort is needed to improve genetic, nutritional and management methods in order to minimise these problems.

7. Myopathies and biochemical indices of muscle damage have been identified in modern broilers. A better understanding is needed of whether or how changes in

muscle physiology resulting from modern breeding practices have an impact on bird welfare.

8. Contact dermatitis is a relatively widespread problem in the European broiler production. The problem cannot easily be handled by breeding efforts or by changes in age or weight at slaughter within commercial ranges. Management practices seem to be the most important factor in preventing the occurrence of wet litter which, together with feed composition, is believed to be the main underlying factor of the disease.

9. Ascites has a serious negative effect on broiler welfare. The problem has increased in recent years. There are direct correlations between high growth rate, hypoxia and ascites. The hematocrit and troponin-T levels, are valuable tools to predict and diagnose ascites under experimental conditions, and might be used together with selection under reduced pressure in breeding for increased resistance. Air quality, light conditions, temperature, and nutrition are important managemental factors that may affect risk of ascites.

10. Sudden-Death-Syndrome (SDS) is an acute heart failure condition that affects mainly fast growing male birds, otherwise in generally good condition. Even though the apparent time from onset of the syndrome until death occurs is only a matter of minutes, it may still have an important impact on bird welfare. Genetics, nutrition and environmental conditions can influence the incidence of ascites and SDS. Fast growth rates increase the risk of ascites and SDS by increased oxygen demand of the broilers, which intensifies the activity of the cardio-pulmonary system. Since growth rate and oxygen demand coincides with other physiological challenges in the young chick (e.g. change in the thermoregulation), this may lead to failure of cardiac function.

11. Infectious bronchitis, Avian Pneumovirus infection and chronic respiratory disease are currently the main infectious respiratory diseases affecting the welfare of broilers, because of their effects on trachea, bronchi, lungs, mucous membranes and whole body functions. The incidence of these diseases varies substantially between different EU member states. The respiratory pathology can be a good indicator of the state of the environment and the success of preventive treatments given to broiler chickens. Respiratory diseases may contribute to the appearance of ascites.

12. A range of behavioural and physiological changes has been used to identify and quantify stress. These changes may differ qualitatively or quantitatively depending on the stressor so a number of indices need to be used in order to assess the extent of the stress or welfare.

13. The risk of thermal discomfort increases with age, and may be greater in females than in males. A useful index of thermal load is the “apparent equivalent temperature”, derived from absolute temperature, water vapour pressure, and a psychrometric constant.

14. The greatest threat to broiler welfare due to behavioural restriction would appear to be likely constraints on locomotor and litter directed activities caused by

crowding, and consequences for leg weakness, poor litter quality and contact dermatitis

15. Air quality in a broiler house is determined by a complex interaction between many factors such as the ventilation, stocking rate, litter quality, health status of the birds, etc.

16. Air humidity is largely dependent on factors within the broiler house, and can increase because of malfunction of technical equipment, poor ventilation or disease. When levels increase to 80% or more, serious welfare problems may occur, and animals may die from hyperthermia or hypoxia if such humidity levels are combined with high temperatures.

17. Levels of CO_2 of 1% do not, by itself, cause any harm for animals. However, an increase in CO_2 levels is usually accompanied by increased levels of other detrimental air pollutants such as ammonia, dust and micro-organisms. Therefore CO_2 is used as an air quality indicator by which the ventilation can be calculated.

18. Concentrations of ammonia having detrimental effects on broiler welfare are regularly observed in practice. The effects result from a combination of concentration and exposure time, and at exposures for three days, detrimental effects can be found at concentrations of 30 ppm.

19. N_2O and CH_4 do not occur in concentrations in animal housing which may influence health or welfare of animals. Other gases, such as CO, H_2S, and $HN(CH_3)_2$, are potential risk factors, but there are little data available on the commonly occuring concentrations or on risk levels.

20. Dust are a potentially harmful air contaminant mainly in combination with ammonia and other gases and may directly affect the respiratory tracts of the broilers, as well as act in the transmission of bacterial and viral infections. Dust levels can be kept to a minimum by appropriate ventilation and by maintaining recommended humidity levels.

21. Maintaining a good litter quality is essential for broiler welfare. Failure to do so may result in respiratory problems and contact dermatitis in the birds. Litter quality is partly related to the type of litter substrate used and partly to different management practices. Such management practices include careful choices of type of water equipment and litter depth and the use of proper ventilation equipment in combination with ventilation management adjusted for the stocking density applied. Poor feed composition may result in wet or sticky droppings, which can lead to wet litter or so called litter capping.

22. The heat requirements of broilers change with age, and recommended ambient temperatures may be lower than birds would prefer early in life when stocking densities are low. The risk of cold stress is low once thermoregulatory ability is fully developed in birds. The risk of heat stress increases with age as heat production increases and as space between birds (and hence their ability to lose heat) decreases.

23. Except during the first days, problems may arise if broilers receive less than 2 h of darkness per day. "Modified lighting programmes" that provide shorter (12-16 h) photoperiods between about 4 and 14 days of age would appear to confer benefits for broiler welfare without necessarily compromising performance. Brighter lighting (e.g. more than 100 lux) is important to stimulate activity and is essential for survival in the first week of life. There are various welfare problems at light intensities below 20 lux. Equivalent light intensities in lux units are 25% lower with fluorescent than with incandescent lighting.

24. There is a clear tendency for reduced growth rate at high stocking densities in broilers. The negative effects of stocking density on growth rate are reduced when adequate ventilation rates are provided. This indicates that problems of heat dissipation are the main causes of poor growth under high stocking rate. The effect of stocking density on feed conversion and mortality is not consistent among the experimental reports. It seems that poor feed conversion and high mortality occur only concurrently with other stressors such as heat stress.

25. Pathologies (breast blisters, chronic dermatitis and leg disorders) are a result of high stocking and the presence of infectious agents and hockborn has been shown to be worse at 30-40 kg/m^2 than at 24 kg/m^2 Studies have shown that walking ability is severely affected at 45 kg/m^2 and is worse at 32 kg/m^2 than at 25 kg/m^2. There is no clear effect of stocking density on physiological stress measures. Increasing stocking density has been found to reduce behavioural activities. Studies have shown that locomotor behaviour, preening and general activity are reduced and disturbance of resting is increased at the higher stocking density in comparisons between 25 and 30, 24 and 32, 28 and 33 and 30 and 36 kg/m^2. These finds are all indicative of poorer welfare at the higher stocking densities.

26. The quality of contact between the stockperson and the animals is important in reducing the fear of man shown by broilers. Regular inspection by a competent stockperson is important in assuring good welfare of the birds.

27. There is a possibility that enrichment of the environment can improve welfare of broilers, but this has not been studied. Perches are probably not a good candidate as broilers hardly perch at all. Objects and music have a good potential but more research is needed in practical conditions to determine what is their effect and what should be used.

28. Traditionally broiler catching has been carried out manually, but during the last decades different types of automatic catching machines or systems have been developed. Rather few scientific studies have been carried out to compare the animal welfare aspects of manual and mechanical catching, but it can be concluded that when properly carried out, using optimal equipment and trained personnel, both methods can result in low levels of injury and low levels of stress to the birds. Conversely, both manual and mechanical catching can result in unacceptably high levels of bruises, fractures and other injuries, as well as high stress levels, if carried out in an improper way.

29. Good nutrition is important for rearing healthy broilers. Overt nutrient deficiency is rare but more information on optimal dietary specifications for birds under stressful

conditions might improve bird health and welfare. Nutritional management can have an impact on metabolic disorders. Decreasing the early growth of broilers by qualitative or quantitative food restriction can lower the incidences of leg or cardiopulmonary disorders. Vitamin D metabolites as dietary additives may have a role in promoting better leg health.

30. Nipple drinkers are now used more widely than bell or cup drinkers in the broiler industry, to improve water hygiene and reduce evaporation and spillage. As drinking takes twice as long with nipples as with bell drinkers, however, some individuals' water intake (and hence food intake) may be constrained through inefficient use of nipples, and these and other slower growing birds may have increasing difficulty in obtaining water as nipple lines are raised progressively during the growing period.

31. The most important welfare issue in breeding bird production is the chronic quantitative food restriction to which birds are routinely subjected, severely so during rearing and more mildly in adulthood. Substantial evidence indicates that growing birds are very hungry, and that this has major effects on their behaviour and physiology. Qualitative food restriction (diet dilution, appetite suppression) can be used to limit growth, but does not suppress long-term feeding motivational state or provide evidence of improved welfare. Recent research indicates that high reproductive output can be achieved by alternative methods. More research is required to fully understand interactions between food restriction, body weight, health and fertility, to determine when and how much food restriction is required. Other welfare concerns are the mutilations commonly inflicted on male breeding chicks and, to some extent, declining fertility in ageing flocks.

32. Chicken meat has increased its proportion of the total meat market because of beneficial price development and a positive health image among consumers. It is relatively inelastic in price-sensitivity compared with beef, and about the same as pork. The production of chicken meat has not been in the focus of any extensive public welfare debate, and so there has been little pressure from consumers on the broiler producers to improve the welfare of the animals. However, in some member states, it seems that an increasing number of consumers are expressing concern about the welfare of chickens sincethis is being reflected in the welfare standards during production by some food retailers

33. Simulation models indicate that reducing maximal stocking density from 38 to 30 kg/m^2 and increasing growing time (i.e. reducing growth rate) by 10 days would each cause a similar increase in total production cost of about 5%. Reducing stocking density from 38 to 25 and 20 kg/m^2 would cause increases in total production cost of about 10% and 15%, respectively.

34. Such cost increases may be expected to increase final consumer prices by about 2.5-7.5%, or less in processed products. In modelling the cost changes, possible increases or decreases in costs of restricting ammonia or other emissions could not be included.

35. The effects of increases in production costs on EU foreign trade in chicken products need to be evaluated. EU exports about 400000 tonnes carcass-weight of chicken products and imports raw material for production of convenience food.

13 RECOMMENDATIONS

It is clear that the major welfare problems in broilers are those which can be regarded as side effects of the intense selection mainly for growth and feed conversion. These include leg disorders, ascites, sudden death syndrome in growing birds and welfare problems in breeding birds such as severe food restriction. It is apparent that the fast growth rate of current broiler strains is not accompanied by a satisfactory level of welfare including health. The most important recommendation is therefore that every effort should be taken to remove such side effects from breeding. Breeders should give a considerably higher priority to health variables in the breeding index, if necessary at the expense of the selection pressure for growth and feed conversion. Breeding which causes very poor welfare should not be permitted and breeders should be responsible for demonstrating that the standards of welfare in the chickens produced by them are acceptable.

The effects of stocking density on broiler welfare vary according to the slaughter-age, the slaughter-weight, the ventilation rate or quality of ventilation equipment and the climatic conditions. It therefore appears that the problems of high stocking rates are less in buildings where good indoor climatic conditions can be sustained, and any recommendations on stocking rate should take that into account. When stocking rates exceed approximately 30 kg/m^2, it appears that welfare problems are likely to emerge regardless of indoor climate control capacity. When ventilation and management is poor, welfare problems may arise at much lower stocking densities. The Committee therefore recommends that maximum stocking rates should be specified for a particular building and climatic control capacity. Only when a producer is able to maintain an air and litter quality as specified in this report should an increase in the stocking rate towards the maximum specified above be allowed. Efforts to enrich the environment and stimulate the expression of a wider range of natural behaviour should be encouraged.

In addition, we give the following recommendations:

- Welfare in broilers is to a large extent influenced by the quality of the stockmanship. Therefore, stockmen should be well trained for their tasks. The training should comprise biology of broilers as well as technical knowledge of the equipment and how to achieve optimal function of a system.

- Broilers should be inspected every day. Animals with signs of poor health who are likely to suffer should be culled immediately and in a humane manner. Particular attention should be given to signs of poor leg condition, and animals with considerable difficulties in walking should be culled. Other signs that birds require immediate culling are severe ascites, malformations, severe wounds and seizures.

- It is essential that adequate monitoring schemes are set up and made publicly available. Monitoring schemes should be set up for continuous evaluation of leg health across broiler stocks, using the best available methods for objective assessment. Every building should have monitoring of ventilation functionality, air- and litter quality, and of animal health and mortality. Culling rates should always be included in any monitoring of mortality levels.

- Bone characteristics of broiler lines should be assessed to ensure that current selection procedures decrease the incidence of bone abnormalities. In addition, improving selection to minimise leg and muscular problems of broilers by genetic means, increased efforts should be made to address this problem by improving the nutritional and management methods.

- The litter surface should be kept dry. A good litter quality also reduces the risk of contact dermatitis and problems with gas contaminants and can be achieved by using a litter material with high water-holding capacity. A water system which minimises water spillage should be used, such as water nipples with drip cups positioned at an appropriate height for all birds. Nipple drinkers alone should not be used. The ventilation capacity should be sufficient to avoid overheating and to remove excess moisture. The feed composition should be well balanced to avoid problems with wet or sticky droppings.

- Every effort should be made to keep the “apparent equivalent temperature” (AET, a measure which combines temperature and humidity; see chapter 6.8) under 40ºC with five- to six-week old birds (younger birds will tolerate higher AET), by prevention of overstocking and moist litter, appropriate environmental monitoring and adjustment of ventilation rate. When birds show obvious panting ventilation levels and distribution should be adjusted and, if necessary, destocking should be carried out.

- Air quality, which is a complex of many aspects of air content, such as dust level and concentrations of CO_2, CO, and NH_3, should be controlled and kept within limits where the welfare of the broilers is not negatively affected. In particular, the concentration of NH_3 should not exceed 20 ppm.

- Growing broilers should always receive at least 2 hours of darkness per 24 hours. Recommended average minimum light intensities (measured in three planes at right angles to each other) with incandescent lighting should be 100 lux for the first week and 20 lux thereafter. If fluorescent lighting is used, the light intensity can be 25% lower.

- In order to keep the levels of stress and injury as low as possible during the catching process, staff carrying out the catching, regardless of whether it is done manually or mechanically, should be properly trained for the task. Sick or injured birds should be identified and removed or culled before the catching of the rest of the flock is commenced. All birds should be handled carefully. The equipment used, whether for manual or mechanical catching, should be designed and maintained in a way that reduces the risk of stress or injury to the birds.

- The welfare of breeding birds must be improved. The severe feed restriction needed to optimise productivity results in unacceptable welfare problems. However, industry is faced with a dilemma because allowing birds to reach a high body weight through free access to feed results in other serious welfare problems. New approaches are required to the breeding and management of broiler parent stock so that both the period and severity of feed restriction can be reduced considerably without adverse welfare consequences. Animals should be kept in such a manner that mutilations are not necessary.

- Further research is needed to resolve many of the issues identified in this report. These issues are listed in chapter 11.

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16 ANNEX

Production costs model for an improved welfare broiler chicken

This model is based on 1998 data. It is known that, since 1998 technical performances and input prices (and above all, feed prices) have changed. However, these changes have had very little effect on simulation results since the purpose of this exercise is to estimate an order of magnitude of the additional costs involved in the implementation of various welfare measures.

BASIC ASSUMPTIONS

Land

The alternative systems may require extra poultry houses and, as a result, extra land. However the costs for additional land have not been calculated. In some areas, land availability and building permission could be expected to be a problem.

Capital investment/m²

In order to compare the different systems, it was assumed that investment costs and financial conditions are those of 1998**.**

There are important differences in investment costs between Northern Europe and Southern Europe. However these differences are partly offset by differences on depreciation rates.

Housing investment costs have been taken as: €76.22 for France, €86 for Spain, €150 for Sweden

The annual costs of housing (depreciation, maintenance, interest) has been taken as: 11.5% (Depreciation 12 years, Interest rate 5.7%) for France and Spain and 8.5% for Sweden, where the depreciation period is 20 years.

In order to get better simulation of lower stocking densities, the following assumption was added:

In the short term, no change could be expected on housing investment costs. In the longer term, changes can be expected in the house design which may reduce both house investment costs and heating costs.

Investment costs for equipment have been taken as: 38.87 € for France, 44 € for Spain, and 75 € for Sweden

Annual costs (depreciation, maintenance, interests) of equipment has been taken as: 17.5% (Depreciation 7 years, Interest rate 5.7%) for France and Spain and 13.5% for Sweden (depreciation period 10 years).

In order to get a better simulation of lower stocking densities, the following assumption was added:

Equipment investment costs. They are based on equipment costs required by the basic chicken production system. It was assumed that fixed costs/m^2 make up 60% of the costs while 40% are proportional to stocking density used.

Other costs /m^2

These costs are based on French estimates, they include:

Insurance: is assumed to be proportional to the value of the total capital employed in a production cycle.

Water: is assumed to be proportional to the stocking density

Electricity: 50% fixed costs and 50% proportional to the stocking density

Heating: fixed

Prophylaxis: proportional to the stocking density

Disinfection: proportional to the number of batches per year

Catching: proportional to the stocking density (number of birds/m^2 at slaughter age). In Spain catching cost is assumed to be 30% less than in France and in Sweden.

Litter and manure removal: proportional to the number of batches/year

Miscellaneous: fixed

Labour costs

It is assumed that one full time worker can manage 3000 m^2 in the basic production system.

It is assumed that labour requirements/m^2 has three components:
- one is fixed ,
- one is proportional to number of batches/year,
- one is proportional to the stocking density,

These represent 20%, 60% and 20% respectively of the labour requirements/m^2 of the basic production.
The annual cost per worker has been taken as 32000€ (209 906 FRF) for France and Sweden and 30% less for Spain.

Feed Costs

Feed prices for basic production are national estimates. The feed price for a reduced growth rate chicken model is 2.5-3% lower than for the basic chicken production system. The difference comes from a lower energy density (while protein/energy ratio is unchanged).

Chick costs

Chick prices for the basic system are national estimates. Chicks prices for lower growth rate strains are based on French data (personal communications) and take account of increased fertility in these strains.

	Spain as a southern European Model			Sweden as a northern European Model								
	Basic Production	Reducing Growth Rate		Basic Production	Reducing Growth Rate		Reducing stocking density with performance improvement					
Performances							**30 kg**		**25 kg**		**20 kg**	
Stocking density	15	15		23.3	22.9		19.2		15.9		12.7	
Kg/m^2	33.1	34.2		35.9	30		25.0		20.0			
Slaughter age (d)	50	61		33.5	42.4		33.5		33.5		33.5	
No. Batches/year	5.6	4.8		7.37	6.25		7.37		7.37		7.37	
Slaughter weight	2.35	2.35		1.6	1.6		1.6		1.6		1.6	
Mortality (%)	6.00	3.10		3.50	2.1		2.45		1.75		1.40	
Production/m^2/	186	164		264.7	224.4		221.2		184		147	
Food conversion	2.1	2.35		1.73	1.92		1.723		1.718		1.715	
Production	**€/kg**	**€/kg**	**% (1)**	**€/kg**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**
Feed	0.452	0.493	9.1	0.363	0.393	8.2	0.362	-0.4	0.361	-0.7	0.360	-0.8
Chicks	0.095	0.074	-22.4	0.207	0.172	-16.8	0.205	-1.1	0.204	-1.8	0.203	-2.1
Feed+Chicks	0.547	0.586	3.6	0.571	0.565	-0.9	0.567	-0.7	0.564	-1.1	0.563	-1.3
Fixed capital	0.095	0.107	13.2	0.091	0.107	18.0	0.108	19.7	0.123	35.6	0.150	65.2
Other costs	0.097	0.104	7.7	0.075	0.091	22.2	0.083	11.2	0.093	24.6	0.108	45.1
Labour	0.040	0.041	0.8	0.040	0.042	3.6	0.047	15.7	0.054	34.9	0.066	63.6
Total cost/kg	**0.7785**	**0.8187**	**5.2**	**0.7763**	**0.8056**	**3.8**	**0.8051**	**3.7**	**0.8348**	**7.5**	**0.8872**	**14.3**
Cost/kg Structure in percent for												
Feed %	58.0	60.2		46.8	48.8		44.9		43.2		40.6	
Chickens %	12.2	9.0		26.7	21.4		25.5		24.4		22.9	
Feed+Chick %	70.2	69.2		73.5	70.2		70.4		67.6		63.5	
Fixed capital %	12.2	13.1		11.7	13.3		13.5		14.7		19.9	
Other costs %	12.5	12.8		9.6	11.3		10.3		11.2		12.2	
Labour %	5.2	5.0		5.2	5.2		5.8		6.5		7.4	

(1) percentage of change compared with current production

FRANCE														
	Basic Production	**Reducing Growth Rate**		**Reducing stocking density without improvement in performance**						**Reducing stocking density with improvement in performance**				
Performance				**30 kg**		**25 kg**		**20 kg**		**30 kg**		**25 kg**		**20 kg**
Stocking density birds/m^2	21.7	20.8		17.0		14.1		11.3		16.6		13.7		10.9
Kg/m^2	38.4	38.1		30.0		25.0		20.0		30.0		25.0		20.0
Slaughter age (d)	40.7	50.5		40.7		40.7		40.7		40.7		4.07		40.7
No. Batches/year	6.43	5.48		6.43		6.43		6.43		6.43		6.43		6.43
Slaughter weight (kg)	1.88	1.88		1.88		1.88		1.88		1.88		1.88		1.88
Mortality (%)	5.9	2.5		5.9		5.9		5.9		4.13		2.95		2.36
Production/m^2/year	247	208.9		192.9		161		129		192.9		161		129
Food conversion rate	1.890	2.1		1.89		1.89		1.89		1.887		1.868		1.863
Production Costs	**€/kg**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**	**€/kg**	**% (1)**
Feed	0.421	0.455	8.1	0.421	0	0.421	0	0.421	0	0.418	-0.7	0.416	-1.2	0.415	-1.4
Chicks	0.124	0.104	-16.6	0.124	0	0.124	0	0.124	0	0.122	-1.8	0.121	-3.0	0.12	-3.6
Feed+Chicks	0.545	0.558	2.4	0.545	0	0.545	0	0.545	0	0.540	-1.0	0.54	-1.6	0.535	-1.9
Fixed capital	0.063	0.075	18.1	0.078	23.1	0.091	44.2	0.111	75.9	0.077	22.8	0.077	43.7	0.111	75.2
Other costs	0.077	0.089	15.4	0.089	15.8	0.1	30.2	0.117	51.8	0.089	15.3	0.089	29.4	0.116	50.9
Labour	0.043	0.045	4.0	0.053	22.4	0.062	42.9	0.075	73.6	0.053	22.4	0.053	42.9	0.075	73.6
Total cost/kg	**0.7283**	**.7665**	**5.2**	**.7647**	**5.0**	**.7979**	**9.6**	**.8478**	**16.4**	**.7588**	**4.2**	**.7883**	**8.2**	**.8363**	**14.8**
Cost/kg Structure in percent for														
Feed %	58	59		55		53		50		55		53		50
Chicks %	17	14		16		16		15		16		15		14
Feed + Chick %	75	73		71		68		64		71		68		64
Fixed capital %	9	10		10		11		13		10		11		13
Other costs %	11	12		12		13		14		12		13		14
Labour %	6	6		7		8		9		7		8		9
(1) percentage change compared to current production														

Reports of the Scientific Committee on Animal Health and Animal Welfare of the European Union are available at the Committee Website;

http://europa.eu.int/comm/dg24/health/sc/scah/index_en.html

Recent reports include;

No.	Title	Date Adopted
16	Possible links between Crohn's disease and paratuberculosis	21 March 2000
15	The welfare of Chickens kept for Meat Production (broilers).	21 March 2000
14	Bacterial Kidney Disease	8 December 1999
13	Standards for the Microclimate inside animal Transport Road Vehicles	8 December 1999
12	Estimations of the Infective Period for Bluetongue in cattle	8 December 1999
11	Diagnostic Tests for Crimean Congo Haemorrhagic Fever in ratites	11 October 1999
10	Modification of Technical Annexes of Council Directive 64/432/EEC to take account of Scientific Developments regarding Tuberculosis, Brucellosis and Enzootic Bovine Leucosis	11 October 1999
9	Classical Swine Fever in Wild Boar	10 August 1999
8	Animal Welfare Aspects of the Use of Bovine Somatotrophin	10 March 1999
7	Strategy for the emergency vaccination against Foot and Mouth Disease	10 March 1999
6	Welfare Aspects of the production of Foie Gras in Ducks and geese.	16 December 1998