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The effects of colour and intensity of light on the behaviour and performance of broilers

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THE EFFECTS OF COLOUR AND INTENSITY OF LIGHT ON THE BEHAVIOUR AND PERFORMANCE OF BROILERS

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SEMOGA KEHIDUPAN KAMI SEKELUARGA
BERJALAN DENGAN PENUH
KEBAHAGIAAN DAN KEDAMAIAN

Karya ini kupersembahkan untuk :
Budi, mas Anang dan mas Adhi,
Bapak dan Ibu

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SUMMARY

The objective of this research programme was first to examine the effects of light colour on the behaviour and performance of broilers and to see whether this could be utilised to alleviate leg disorders. Secondly, the research programme investigated the birds' preference for different colours and the interactions between colour and intensity in the birds' perception.

Under 30 lux intensity of light, the birds were found to be more active in red and less active in blue and green light. Birds in white light were in between red and blue or green. The greater activity occurred under red light, while birds in the blue or green light seemed more inclined to sit passively and doze. Broilers reared under different colours of lighting exhibited similar growth but developed more skin compared to broilers reared under white light. The heaviest gut contents were found in birds under blue light and the lightest were under red light. Both male and female broilers showed the greatest longterm preference for blue light, followed by green light, although their initial preference after the neutral colour was for red light. Birds reared in a coloured light showed an initial preference to remain in that light but after one week had elapsed, they preferred a change to a different colour, usually blue.

The chickens failed to differentiate the brightness of blue and red lights at a (photon) ratio of 3.1 - 3.6 : 1.0. Birds were reared under red and blue lights in equated brightness at three intensities, low ($12x10^{20}$ photons and $36x10^{20}$ photons for red and blue lights respectively), medium ($18x10^{20}$ and $60x10^{20}$ photons for red and blue) and high ($30x10^{20}$ and $108x10^{20}$). The results showed that the time spent feeding and sleeping and the quantity of pecking, wing stretching and aggression were increased in red light, whilst birds in blue light increased their time spent standing, sitting and dozing. As the light intensity increased, feeding, walking, wing stretching and aggression tended to increase, particularly for birds reared in red light. No interactions between colour of light and intensity were found for the time spent feeding and sitting but they were for other behavioural parameters. Again, the treatments did not affect growth rate, feed consumption and conversion ratio.

During the rearing period three colour light patterns, [dim blue light from day 1 to 49 as a control(TO); red light from day 1-16 followed by dim blue from day 17-49(T1) and dim blue from day 1-16 followed by red at day 17-32 and blue from day 32-49(T2)] were applied to examine the effects on the behavioural and physiological responses of broilers. The red and blue light were of intensity $860x10^{20}$ and $1.5x10^{20}$ photons respectively, and were produced from white light covered by filters. Standing time during the life of the birds was not affected by treatment, but using bright red light increased the time spent walking, stretching and feeding, particularly when applied in the first 16 days. The heaviest final body weight and highest feed efficiency were obtained in T1 although, there was a tendency for an increase in feed consumption in T0. In addition, the treatment did have an effect on bone strength, causing a reduction in the bone strength of birds in T2. The sex of the birds did not affect their behaviour or response to light. Similarly, tibia strength was not affected by sex and neither were

differences between left and right leg. The use of continuous blue light gave rise to the highest incidence of lameness problems.

It is concluded that, first, the birds are more active in red and less active in blue and green light. Second, giving bright red light in early life increased the time spent walking, stretching, and feeding, which allowed young chicks to exercise sufficiently. As a result, it tended to increase bone strength and alleviated lameness problems. However it reduced bone strength when applied later in life. Broilers reared under different colours of lighting had more skin compared to broilers reared under white light. The heaviest gut contents were found in birds under blue light and the lightest were obtained under red light. Third, both male and female broilers show the greatest longterm preference for blue light, followed by green light, although their initial preference, after a neutral colour, is for red light. Birds reared in a coloured light show an initial preference to remain in that light but after one week prefer a change to a different colour. Fourth, in the equated brightness of red to blue at a ratio of circa 1.0 : 3.3, there were distinct effects of colour of lighting on broiler behaviour with increased activity in red light. Increased intensity also stimulated behavioural activity, particularly in red light.

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Chapter I

INTRODUCTION

Today, poultry keepers are giving increasing attention to bird behaviour and environmental control, including lighting, space requirement, air temperature, humidity, air velocity, wet bedding, ammonia build up, odours and manure disposal.

Light is an essential factor controlling the general activity and performance of poultry (Tienhoven and Ostrander, 1973; Cavalchini *et al.*, 1983; Legare *et al.*, 1986 and Noll, 1989). In any experiment on the effects of light on poultry, four characteristics of the light environment must be specified : the photoperiod, the cycle length (including intermittent light), the spectral composition and the light illuminance.

Light affects both the growth of birds and egg production. Light is not only perceived by the eye, but also penetrates the skull and appears to exert a direct effect on the encephalon of the pituitary to increase gonadotrophin secretion. Under natural sunlight, hormonal secretions are activated once the total length of the day light reaches 11 to 12 hours, as in the spring months. During the winter, the length of the day light is not normally long enough to produce maximum egg production; hence poultry keepers must use artificial lighting. Additional light can stimulate lengthening days or compensate for a decreasing amount of natural light and as a result a constant egg production throughout the year can be achieved.

" The published evidence about the minimum photoperiod for maximum egg production, when daylength is held constant from 0 to 72 weeks of age, suggests that 10L : 14D is sufficient but 8L : 16D is not (Morris,1979)". There are some intermittent light programmes such as 4(3L : 3D), 2(2L : 10D), which allow the hen's oviposition rhythm to break away from 24h entrainment (Lewis, 1987; Tucker and Charles, 1993). However, Gordon (1994) stated that the implication of a 23h daylength on broiler well-

being must be considered. Sleeping behaviour and physiological stress have both been shown to be affected by light programmes.

Light greatly influences sexual maturity, egg production in females and semen production in males. Light also acts as a signal to govern the time of day at which eggs are laid. It is noteworthy, too, that birds are more stimulated by light near the red end of the spectrum than by light in the green, blue or violet regions (Ensminger, 1980; Foster and Follet, 1985).

Experiments conducted in 1964 and 1966 showed a curvilinear relationship between light intensity and rate of lay, with an optimal dose of about 5 lux measured at the cage front (Morris, 1981). More recent studies (Hill *et al.*, 1988; Tucker and Charles, 1993) have shown no significant differences in yield with light intensities ranging from 34 down to 1.75 lux. Thus, it seems that the laying strains of the 1980's were less sensitive to light intensity than those of the 1960's. At the commercial level, in artificially controlled buildings it is recommended that levels of light intensity of circa 20 lux are required in the initial brooding period to ensure that broiler chicks find the feeding and drinking points. Light intensity is often then gradually reduced so that by 21 days it is in the range of 1 to 3 lux.

Simmons *et al.* (1982) suggested that the evidence of leg abnormalities increases as the birds exercise less. Riddell and Springer (1985) observed a trend of a lower incidence of leg disorders in flocks brooded under bright light. If activity is higher under brighter light, then it would be expected that light intensity or light colour would be inversely correlated to the evidence of leg disorders. Otherwise, it is not clear whether intensity and colour of light affect leg disorders.

From the research available so far, those working on lighting for poultry have mostly concentrated on laying hens, turkeys, broilers, and quails, covering aspects of weight gain, egg production, oviposition, reproduction, feeding, feed efficiency and other hormonal effects (Cavalchini *et al.*, 1983; Dobrescu, 1986; Bhatti and Mian, 1987; Sharp and Dunn, 1987; Ibaraki *et al.*, 1988; Brake and Baughman, 1989). Very few studies have been reported on the behavioural and leg abnormality aspects; particularly in relation to the colour and intensity of lighting. Almost all the research using different coloured lights did not equate the lights for brightness, so it is unclear which cue (colour or brightness) the birds are responding to.

1.1 **Objectives**

The objective of this research programme was, first, to examine the effect of light colours on the behaviour and performance of broilers, and to see whether this could be utilised to alleviate leg disorders. Secondly, the research programme investigates the birds' preference for different colours and the interaction between colour and intensity in birds' perception.

Chapter II

REVIEW OF LITERATURE

2.1 ANATOMY AND PHYSIOLOGY OF THE CHICKEN'S EYE

Bradley (1960) stated that the eyeball of the fowl consists of segments of two spheres of different curvature, connected by a conical intermediate portion. The posterior segment corresponds to the greater part of the sclera, the anterior segment is formed by the cornea, and the conical connection consists of that part of the sclera in which the body scleral ring is developed (Figure 2.1).

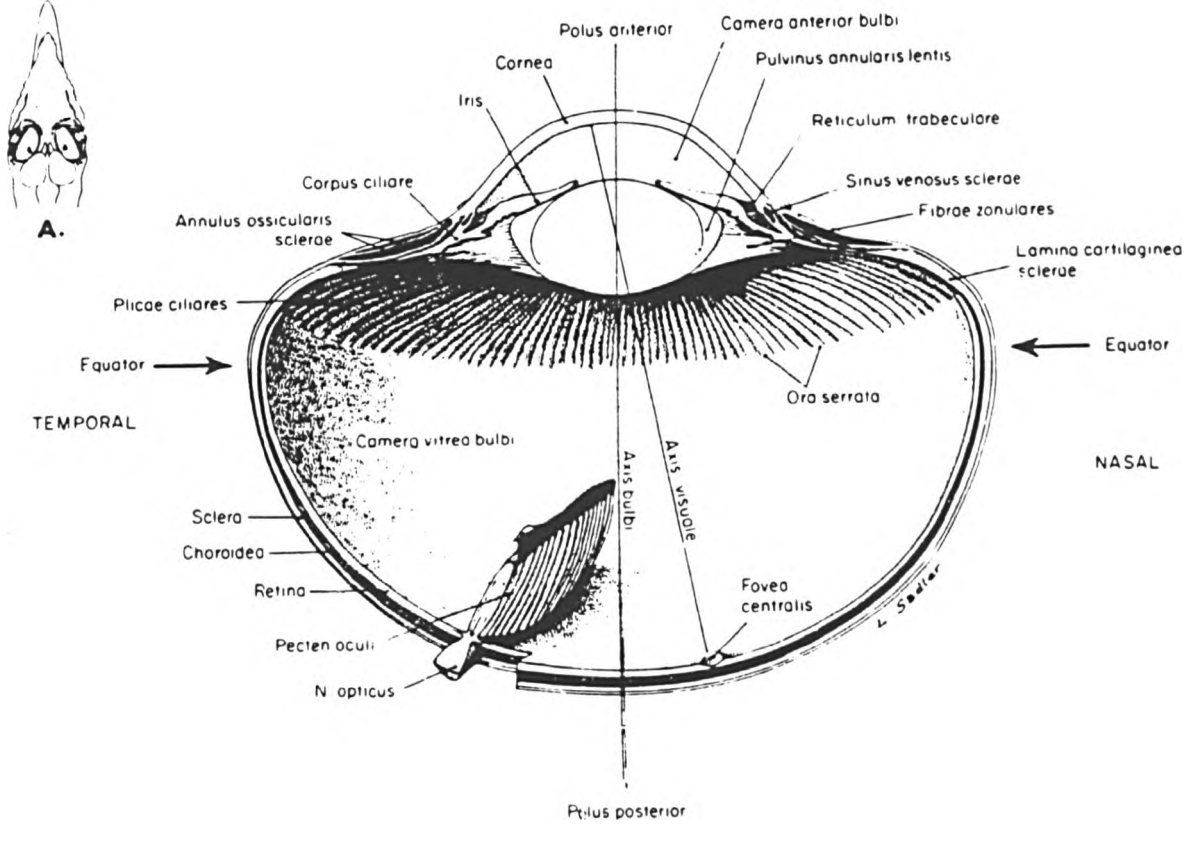


Figure 2.1 Drawing of transverse horizontal section of the chicken's eye. Insert A indicates position of eyes within the head (From Evans, 1979).

In comparison with other senses, vision is important in most vertebrates. Halpern (1962) and Gentle (1975) mentioned that acid and bitter flavours are rejected by the domestic fowl, as they are by the rat, but whereas rats prefer weak and moderate salt solutions to pure water, fowl do not. Both reject strongly saline solutions. Sweet flavours too, whether of natural or artificial origin, are generally not especially attractive to fowls, whereas they are selected strongly by rats. It may be that fowls use visual and tactile senses for food selection much more than do mammals, the primary function of taste being to reject items which may be noxious. Bremond (1963) stated that the audible frequency range to which birds are sensitive is about 15 to 10,000 Hz and, like vision, this sense is generally very important for birds. However, the range of most sensitive hearing lies between 3000 and 5000 Hz (Temple *et al.*, 1984). A well-developed sense of smell exists in birds. It is known for example that, for migrating pigeons, odour carried on the wind can be an important navigational cue, while domestic fowls can be trained to respond selectively to particular scents, such as oil of citron (Jones and Gentle, 1985). For most bird species, olfaction is not as important as it is for mammals. On the other hand, in accordance with cutaneous sensitivity (Appleby *et al.*, 1992) the skin of the bird is well supplied with sensory receptors, especially those areas of the body not covered by feathers, such as the beak. In the beak there is also a concentration of touch receptors grouped to form special beak tip organs, which allow the bird to make very fine tactile discriminations. Damage to the beak, of the kind imposed by beak trimming, will greatly impair birds' sensory abilities. There are three different types of touch receptors present : two which respond to a moving stimulus (Herbst and Grandry corpuscles) and one which responds to static pressure (slowly-adapting mechanoreceptors). Environmental temperature is monitored by cold receptors which respond to cooling of the skin, and warm receptors which respond to heat. Noxious (unpleasant or painful) stimulation is detected by another

group of receptors, the nociceptors, of which there are at least three types present in domestic fowl and which respond to either severe pressure or major changes in temperature.

2.1.1 Vision

The importance of the visual sense in the fowl is indicated by the remarkable size of the eyes in comparison with the size of the head and brain. Thus, the weight ratio of the two eyes to the brain is almost 1 to 1 (Bell and Feeman, 1971), while in man the corresponding ratio is about 1 to 25. Furthermore, it has been shown by Appleby *et al.* (1992), that the laterally placed eyes of herbivorous and omnivorous species like poultry extend over a visual field of more than 300^0, but they cover a much smaller binocular zone than predatory carnivorous species with frontally directed eyes (Figure 2.2).

The light or photic receptors of the fowl's eye are classified into three basic types : rods, single cones and double cones (Bell and Freeman, 1971). Rods are concerned with dim light-vision and are very sensitive to light, functioning primarily at low levels of illumination (Sturkie, 1986). In birds the rods are characterised by a relatively large cylindrical outer segment, this being the visual pigment containing disc. Cones are used for bright light vision and function in both colour discrimination and high visual acuity. Morris and Shorey (1967) stated that two types of single cone; type 1 and 2, are distinguishable. The double cones consist of two receptors in close contact, the principal and accessory cones.

Cornsweet (1970) found that the cones of the eyes in human and fowl are trichromatic, although the anatomy of their eyes differs. However, the visual pigments in the rods are unable to distinguish between the actual amounts of light of different wavelengths, and at low levels of environmental light, vision is monochromatic.

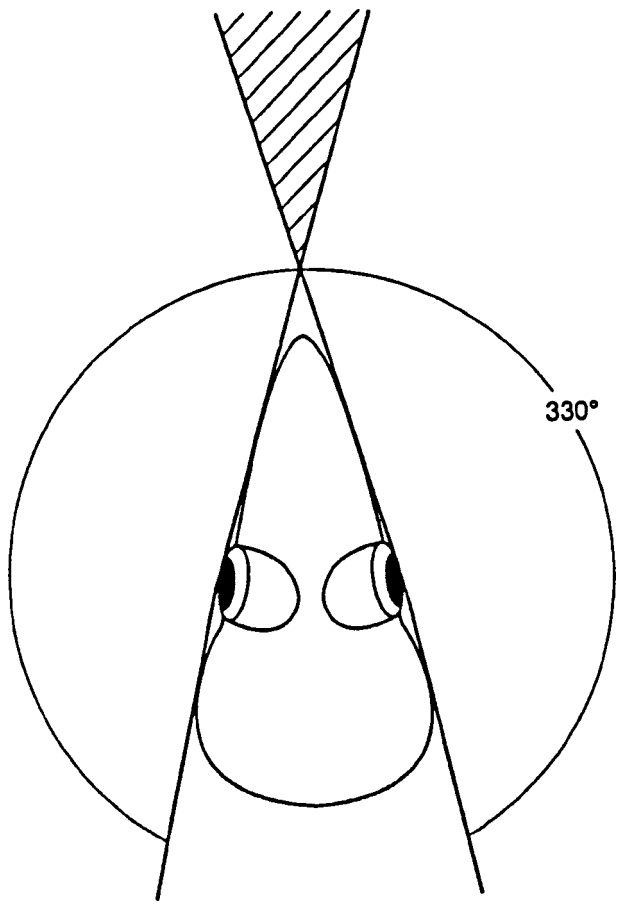


Figure 2.2 Fowl's head from above showing how each eye has a very extensive field of view forward, sideways and backwards, but that the area of binocular overlap (shown hatched) is relatively small.

In birds the cones are distinguished by oil droplets, normally brightly coloured. Avian single cones contain a large circular oil droplet of variable coloration. In the chicken it is reported as being red or yellow-green (Galego *et al.*, 1975) and predominantly red (Meyer and Cooper 1966). Double cones, present in all vertebrates, consist of two associated cones of different size, shape and structure, one being a tall thin chief cone and the other a broad short accessory cone. The significance of double cones is not clear; however, in the chicken they are twice as numerous as single cones throughout the retina. In the chicken the chief cones possess a large circular yellow oil droplet, and the accessory cone is reported to have a small oval, yellowish green droplet. Kare (1965), reported that chicken eyes have coloured oil droplets from red to yellow but they do not have any blue or violet droplets. This is the reason why some researchers stated that the chicken is congenitally night blind.

The strongest sensitivity of the chick eye to a light stimulant is in the green light spectrum with a wavelength of 560 nm, but for the adult chicken it is yellow, with a wavelength of 580 nm (Kare,1965). The different sensitivity may be due to changing production of different coloured oil droplets as they grow older.

These coloured oil droplet mosaics have aroused considerable interest regarding the possible role they play in the visual processes of birds. They have been implicated as protective screening devices against ultraviolet light (Goldsmith, 1980) and as colour discriminatory devices, or more simply as bypass filters for absorbing visible light rays. In combination with different visual pigments, they have recently been shown to increase colour contrast by cutting off the short wave spectrum of the pigment sensitivity curve and displacing the sensitivity maximum to a longer wavelength (Barlow, 1982; Govardovskii, 1983), the net result being an improvement in colour discrimination. Behavioural studies utilising Japanese quail with experimentally

produced carotenoid - free (colourless) oil droplets (Meyer *et al.*, 1971) have reported normal colour discrimination. This result indicated that oil droplet pigments are not essential for colour vision (Meyer, 1977). Since animals are unable to synthesise these pigments, such carotenoid-free retinas are easily produced and maintained in newly hatched quail by the exclusion of carotenoid pigments from the diet of their parents (Meyer *et al.*, 1971).

The role of oil drops in colour vision is still controversial. It seems reasonable, however, that the oil droplets must have some effect on the appearance of colours even if this effect is not their primary function. There are at least two opposed theories on the role of the oil droplets in colour vision (Bell and Freeman, 1971). First, there is the multiple (visual) pigment theory. Colour vision is basically dependent on the presence of three or so different visual pigments in the cone outer segments, as in man. Hence the oil droplets merely modify a colour vision system which would still function in their absence. Second, there is the single pigment hypothesis. Only one visual pigment is assumed present in the cone outer segments (i.e. iodopsin in fowl), and in the absence of oil droplets no colour vision would be possible (the achromatic night vision of man is based on the one rod visual pigment-rhodopsin).

As seen by the human eye, light is part of the radiant energy spectrum that is represented by wavelengths between 400 and 700 nm. The limits of the chicken's eye are quite similar to those of the human eye (North, 1978). A rough guide to the wavelength of spectral colours (Keele and Neil, 1971) is as follows : 400 nm and slightly below is violet, 450 nm is blue, 500 nm is blue-green, 550 nm is greenish yellow, 600 nm is orange, and 650 nm up to 750 nm is red.

Colour discriminatory abilities have also been demonstrated in other diurnal birds such as pigeons (Watson, 1915), emus (Neumann 1962) and hummingbirds (Poley, 1968). The spectral sensitivities of chickens are generally described as trichromatic (Cornsweet, 1970). The chicken's retina is composed of six types of oil droplets and three visual pigments. These combine to give the chickens a broad maximum sensitivity band peaking at 569 nm, and two other narrower bands peaking at 606 nm and 533 nm. These sensitivity peaks coincide with the maximum transmission of chlorophyll (550 nm) and critical regions in the spectral distribution of light in the bird's natural environment due to forest vegetation at 510-540 nm and 590-650 nm (Bowmaker and Knowles, 1977). For this reason, the chicken is capable of a high degree of discrimination at critical wavelengths within its natural environment.

The visual pigments are present in the outer segments of rods and cones and absorption of light by these pigments constitutes the first stage in the generation of an electrical signal in the retina in response to light. Those of the fowl have received much attention, as it is one of the few animals from which two pigments, rhodopsin and iodopsin, have been extracted. Rhodopsin (visual purple), the rod pigment, has been extracted from the rods of many other vertebrates (Dartnall, 1957 and 1962). Iodopsin was first extracted by Wald *et al.* (1937) and assumed to be present in some or all of the cone outer segments.

The properties of rhodopsin and iodopsin have been comprehensively compared by Wald *et al.* (1955). Both pigments consist of a protein called an opsin (scotopsin in rhodopsin, photopsin in iodopsin) in combination with the carotenoid substance retinal$_1$ (the aldehyde of vitamin A$_1$). The action of light is to dissociate the two halves, i.e. :

Rhodopsin + light ----------> Opsin + A11-trans. retinal

As rhodopsin is bright purple and the products are only weakly coloured, this action is called bleaching. The visual pigments regenerate spontaneously in the presence of another isomer of retinal :

Opsin + 11-cis retinal ----------> rhodopsin

2.2 THE EFFECT OF LIGHT ON THE GROWTH OF POULTRY

2.2.1 Photoperiod effect

The length of the natural light varies not only by season, but also according to the location on the globe. At the equator the Sun is 'overhead' most of the time and the daily hours of light and dark are constant, but as one approaches the poles of the Earth the position of the Sun changes. This influences the length of the natural daylight hours and therefore artificial light must be provided to attain maximum egg production (North and Bell, 1990).

The usual pattern throughout most of the broiler industry is to have 23 h L and 1 h D per day. Some variations such as 18L:6D and 6L :18D have been tried and showed satisfactory results, but it is necessary to accustom the birds to the darkness prior to its application at an early age (Morris, 1988). If the light is suddenly withdrawn , the birds tend to crowd into corners and suffocate.

A previous study by Cherry and Barwick (1962) demonstrated that light was not necessary for feeding to occur. Broilers maintained in darkness from 1 to 10 weeks of age had similar body weights at 10 weeks to birds grown under a 23 hour daylength.

Morris (1968) reviewed work examining the effect of photoperiod on broiler performance and found growth to be maximised with a near-continuous daylength. Body weights were five to ten percent heavier with 23 hours light than when grown under an eight or 12 hour photoperiod. Although a lower feed usage may account for the difference in body weight with shorter daylengths, the ratio of light to dark periods within 24 hours may also affect feeding behaviour. Broilers housed under continuous light consumed similar quantities of feed at regular intervals throughout the 24 hour period (Savory, 1976). When daylength was 12 or 14 hours broilers did not eat during the 12 or 10 hour dark period (Morris, 1968; Savory, 1976). However, when daylength was only 6 hours, a considerable proportion of the total daily feed intake was eaten in darkness (Morris, 1968).

Classen (1990) reported that a light regime of 23L:1D led to better growth only up to 21 days compared to 8L:18D. A gradual increase in photoperiod weekly from 6L:18D to 23L:1D showed no significant difference compared to a continuous 23L:1D. However, there was 47% less leg disease as well as 63% less sudden death incidence with continuous 23L:1D.

This has been confirmed experimentally by Veldkamp (1992) who compared 23L:1D with 14L:10D. The 14L:10D treatment had a positive effect on the activity of turkeys. Breast blisters were reduced by 27% and breast buttons by 26% compared to 23L:1D treatment. Inferior feed conversion was also found which could be the result of increased activity. In the commercial situation this is likely to be counter-balanced by reduced losses from leg problems at the older ages. Most UK turkeys are grown on a day and night cycle, commonly 14L:10D.

Both Adekunmisi and Robbins (1987) and Classen (1988 and 1990) reported that photoperiod manipulation and feed restriction affect the electrolyte balance and performance of broilers. They further stated that there are interactions between photostimulation and plasma LH as well as ovary and oviduct weight. A previous study by Chiasson and Carr (1985) found that neuro-endocrine pathways were only involved in photoperiod information transmission after 3 weeks of age and that the pituitaries of broilers were sensitive to testosterone in a light pattern of 6 L : 18 D and their sensitivity disappeared in a 10L:14D light pattern. Siegel (1984) found that liver glycogen and fat contents indicated that the energy stored may be restricted in dark grown chicks up to 35 days old while plasma glucose, triglycerides and free fatty acid were not consistently affected by the light treatments. It can be concluded that both the physiology and performance of broilers are affected by photoperiod.

2.2.2 Intermittent light

Nowadays, there is an increasing interest in growing broilers in intermittent lighting patterns, as it appears that there is some improvement in growth rate, and more particularly in feed conversion ratio. The broiler is capable of improving digestion with suitable rest periods, decreasing activity and reducing 'boredom eating'. There will also be reduction in electricity usage which will result in at least a marginal saving.

Intermittent cycles of 15 min L for 1 h D or 15 min L for 2 h D gave enough time for broilers to feed with a good growth rate (Williams *et al.*, 1969). Two intermittent treatments of 1L:3D cycle and 0.25L:1.75D cycle showed no differences in live weight gain and carcass weight but, feed intake and abdominal fat were greater in 1L:3D than 0.25L:1.75D (Cave, 1981).

The effects of varying photoperiod for turkeys with a light sequence of 12L:12D as a control have been investigated by several researchers (Dobrescu, 1986; Lake, 1989 and Noll, 1989). Intermittent light has been shown to have some advantages. Levenick and Leighton (1988) reported that the growth rate was significantly better in 2L:2D intermittent cycles than a 12L:12D photoperiod. On the other hand, Wilson *et al.* (1979) stated that 7-day-old turkeys reared under intermittent light at 1L:2D cycles up to 49 days old had heavier body weights and fewer leg abnormalities, whilst the application of a 1L:2D light regime at high humidity (70%) did not show any better growth than the control of 12L:12D. In broilers, Weaver and Siegel (1968) have shown that intermittent light at 1L:2D cycles produced significantly heavier birds than continuous light.

Intermittent lighting does not always increase the growth rate of reared chickens, compared to continuous light, but it can save a little food and improve the feed conversion ratio (Buckland, 1975). The difference between intermittent and continuous light in feed consumption, light cost and production is usually about 2% in broiler at 7 weeks of age. Trials also show a reduction in the proportion of leg weaknesses and in the downgrading of carcasses due to other faults. There is only limited evidence available from comparing different patterns of intermittent lighting for broilers, but Buckland recommends continuous light for the first seven days and then adopting a repeating pattern of 1L:3D for the remainder of the growing period. Sainsbury (1980) proposed a suitable intermittent lighting pattern for broilers as follows, 0-3 weeks : continuous lighting (with 23 L : 1 D); from week 3 to 5 the use of 3 L : 1 D cycles; then the use of 2 L : 2 D cycles from week 5 to 7; and finally using 1 L : 3 D cycle from week 7 onwards.

Nixey (1994) reported that intermittent light programmes for turkeys are widely used in France. The most common programme uses cycles of 2.5L:3.5D for the first 6 weeks, then moves on to 15 minute stages each week, reaching 3.5L:2.5D at ten weeks of age. This is maintained until the females are killed at 13 weeks and the males at 16 weeks. The French get extremely good early weights. There is a view that leg problems in older ages of male birds are increased if intermittent light is used for the whole growing period. To prevent this, a 24 hour cycle which includes an eight-hour continuous dark period is introduced at 8 weeks.

2.2.3 Light intensity

There are several practices used by growers of broilers to optimise intensity (North, 1978). First, in the 23L:1D in an open-sided house, the light intensity at floor level should be 0.50 foot-candle (5.38 lux). One 150-watt bulb for each 1,000 sq. ft (93 sq. m) of floor space will provide this light intensity. Second, in light-proof houses, it should be 3.5 foot-candles (37.66 lux) of continuous light at floor level for the first five days. On the sixth day, the intensity should be reduced to 0.35 foot-candle (3.76 lux), which could be supplied by one 125-watt bulb for each 1,000 sq. ft (93 sq. m). In a continuous dim light system in a light-proof house, after five days, 23 h of light and one hour of darkness should be provided; but in an intermittent dim light system. During normal or cool temperatures, one hour of 0.35 foot-candle light intensity (feeding time) followed by 3 hours of darkness (resting time) should be provided.

The performance of male broilers was unaffected by light illuminescence of 0.7, 3.0, 15.0 and 46.5 lux , while the females performance was progressively decreased at light intensities above 3 lux (Wathes *et al.*, 1982). Thus, broad spectrum white light above 3 lux does not have any commercial application (Wathes *et al.*, 1982). Cherry *et al.* (1962) found that light intensity above one and below 0.1 foot-candle (10.8 and 1.08 lux respectively) decreased the growth and performance of broilers. North (1978) recommended that the intensity of illumination at bird level should be about 0.35 to 0.50 foot-candle (3.77 to 5.38 lux). Illumination above the optimum intensity induces cannibalism, activity and piling, so that the open house (not light-proof) is a decided disadvantage, unless some method can be used to restrict some of the natural daylight.

It is common practice to light broilers for 23.5 h per day for the whole of the housing period. Localised lighting of about 100 lux is used for the first few days to attract the chicks to the heated brooding. Thereafter lighting intensity should be less than 5 lux for economic production. Higher levels will lead to lower growth rates (Farm Electric Handbook, 1990). In more detail, Anonymous (1990) recommended that high levels of light intensity (20 lux) are required in the initial brooding period to ensure that the broiler chicks find the feeding and drinking points. Light intensity should then be gradually reduced so that by 21 days it is in the range of 1 to 3 lux. The majority of broiler growers use a continuous light programme. These basically consist of a long continuous period of light, followed by a short dark period (0.5 to 1.0 h).

2.2.4 Colour of lighting

Since it has been established that intensity should be considered as a factor in the effects of coloured light, some research has been carried out using a combination of these two factor. However, some of the researchers did not mention the intensity on their experiment.

Smith and Phillips (1959) suspended fixtures containing red, orange, green and yellow neon tubes over feeders in one pen and showed greater feed consumption under green light. However, no differences in feed consumption occurred when the colours were placed in separate pens.

Cherry and Barwick (1962) carried out a series of tests on male and female chickens, using white light and red light, which are often used at low intensities in poultry houses to reduce activity and cannibalism. In the first experiment red and white at different intensities, using 10 and 0.1 foot candles (107.60 and 1.08 lux respectively), were compared, but no significant difference was found in food consumption or body weight between either the colours or the intensities at any stage until the birds were 10 weeks of age. After this the feed conversion ratio was significantly lower in the presence of 0.1 foot candles. In a second experiment four intensities of red light were compared, 0.01, 0.1, 1.0 and 10 foot candles (0.11, 1.08, 10.76 and 107.60 lux respectively) and it was found that body weights measured at 8 and 10 weeks of age increased with decreasing light intensity. Until five weeks the relationship between light intensity and feed consumption was a positive linear one, but after six weeks birds under lower intensities had a higher feed intake. By ten weeks, there were no significant differences in total feed intake. It can be concluded from these results that red light has no significant effect compared to white light, but no comparison was made to other coloured lights.

Other experiments carried out by Kare (1965) and North (1978) found that green, blue and white light significantly increased the growth rate of broilers, but not red light. Levenick and Leighton (1988) found that the growth rate of turkeys was better in white and red than in blue light. They used monochromatic filters for red and blue lights. Transmission specifications reported by Poff and Norris (1967) were used to calculate the lamp size required to yield 86.1 lux of light intensity 1.86m from the source, i.e., at the head height of the bird. Furthermore, they also found that the feather condition was poorest in a white diurnal photoperiod (12L:12D).

Foss *et al.* (1972) suspected that some characteristics of white light and certain narrow wavelengths activated a physiological depressor of growth and growth response, which may be the absence of green light. That is the reason why broilers reared under green light grew better. This assumption was in good agreement with Cave (1990), who found that a green fluorescent light was able to increase pullet production (broiler), fertility and at the same time reduce mortality compared to birds reared under white light. Furthermore, Wabect and Skoglund (1974) reported that blue or green light produced the best growth rates, while white or yellow was intermediate and a red fluorescent light depressed broiler growth rate. Turkeys, on the other hand showed a different growth response to light (Levenick and Leighton, 1988). Levenick and Leighton found that blue light gave a better growth rate compared to red and white, but there were no significant differences in feed efficiency. The replacement of white light by red was also able to prevent feather pecking and cannibalism of pullets without affecting feed conversion (Wells, 1971).

The growth of broilers was inhibited at certain wavelengths (Foss *et al.*, 1972; Osol *et al.*, 1980). The physiological development of birds reared at various wavelengths at peak transmissions of 450, 545, 650 and 750 nm indicated that although combs and testes were heavier and gonadotrophic hormone levels were higher under red (650 nm) and white light, weight gain was greatest at 545 nm (green) while food consumption was not affected by light colour (Foss *et al.*, 1972). The radiant energy to which the chicks were exposed in this experiment was equalised to be 80 microwatts/cm^2, when measured at a height of 7cm above the wire floor. But this finding has recently received criticism because it would appear normal to assume that testosterone would act as a growth stimulant (Wathes *et al.*, 1982).

Wathes *et al.* (1982) investigated the responses of male and female broiler chicks to blue (425nm peak), green (525nm peak), red (610nm peak) and white (560nm median) light. There was no significant effect on either growth rate or feed intake to 8 weeks of age for either sex. Although the authors kept the illuminance of the four different light sources as near equal as was practically possible, it could not be assumed that there were no intensity effects, as the findings of Benoit (1964) and Hartwig and van Veen (1979) had already shown that in terms of differences in cranial penetration, light of different wavelengths caused large variations in intensity at the hypothalamic extra retinal photoreceptor.

Scheideler (1990) concluded that broiler chicks in commercial houses have a lighting requirement for optimum growth and respond differently to varying wavelengths of emitted light. Wabeck and Skoglund (1974) reported increased weight gain in broilers raised under blue or green fluorescent lamps compared to red or white incandescent bulbs, without any effect on feed conversion and mortality. The unit of energy was in microwatts per square centimetre and this was used to standardise the

four colour treatments at 200 $\mu W/cm^2$ (the intensity at bird height). This result was in harmony with the recent research conducted by Cave (1990) who also indicated that green fluorescent light was able to increase the growth rate of chickens.

Gill and Leighton (1984) showed that blue filtered light improved weight gain during the early growth period compared with birds reared under either white or red filtered light, whereas white or red filtered light improved weight gain during the later growth period.

Some possible reason for these conflicting results may relate to differencess in light sensitivity at different ages, the intensities of the wavelengths and possible spectral overlap in non-filtered coloured light.

2.3 THE EFFECT OF LIGHT ON EGG PRODUCTION BY POULTRY

2.3.1 Photoperiod

There are a number of techniques used in order to get the most favourable response and most of them are rather similar, but each breeder tends to suggest something different for his own stock, based on his own practical experience.

Two programmes are given below for a well known commercial hybrid (Sainsbury, 1980). In layers, it is noteworthy that the maximum amount of light in one day is usually given as 18 h. However, many firms prefer to go to no further than 16 h of light in a day, keeping in reserve the last two hours so they can give an extra boost if egg production for some reason shows signs of declining.

A suggested lighting programme for commercial hybrid layers is as follows: 0-1 week , 18 L : 6 D; 2-18 weeks, 6 L : 18 D; 19-22 weeks, increase light by 45 min per week to give a good stimulus in the first period of laying; 23-49 weeks, increase light by 20 min per week; 49 weeks onwards, the lighting is kept steady at 18 L per day. Those retailing eggs and seeking especially large eggs can use the following programme : 0-1 week, 23 L : 1 D; from week 2 to 18 decrease by 45 min per week; increase by 45 min per week in weeks 19-22 ; a further increase of 20 min per week is applied in weeks 23-48; finally the lighting is maintained at 18 L from week 49 onwards.

Further recommendation are made by Austic and Nesheim (1990) for laying hens. Any period of daylight greater than 11 to 12 hours will stimulate egg production, and maximum egg production will be achieved at 14 h of daylight. Most programmes call for 1 to 2 h more than this to provide a safety factor. On the other hand, there is some indication that a daylight period of 17 h or more will depress egg production in laying hen strains. During the laying cycle, the length of the light day may be increased, but it should never be reduced. In a house with windows or openings, it is very important to supply artificial light during the period of short daylight and it must always be as great as the length of the longest day of the year. This is the best way for the pullets to be kept in egg production, since natural daylight is very variable (Austic and Nesheim, 1990).

Brake (1990) demonstrated that a 2h increase of the photoperiod from 8 L to 10 L stimulated maturity and increased the fertility of broilers without adversely affecting male reproductive performance. A previous study by Brake and Baughman (1989) using artificial light of 10L compared to 8L also showed a similar trend to that found by Brake (1990), of better egg production but reduction in the laying rate and egg weight.

Morris (1994) stated that "seasonally breeding birds respond positively to increments in photoperiod and negatively to reductions in photoperiod. The concept of a threshold photoperiod (which is important in plants) does not seem to be helpful with animals. A middling day (e.g. 12L:12D) commonly evokes 'long day' responses when used after a run of short days (e.g. 8L:16D) but causes 'short day' responses in birds which have previously been exposed to long days (e.g. 16L:8D). Most experiments which have sought to define a threshold can be seen as experiments measuring the effect of transferring animals from one photoperiod to another. The published evidence about minimum photoperiod for maximum egg production, when daylength is held constant from 0 to 72 weeks of age, suggest that 10L:14D is sufficient but 8L:16D is not" (Morris, 1979). Furthermore, Morris mentioned that "a recent experiment at Bristol University showed that Shaver 288 pullets held on 8L: 16D throughout their lives laid just as well (298 eggs per hen to 72 weeks of age) as birds started on 8L:16D but transferred to longer photoperiods before coming into lay. On the other hand, an experiment at Reading with Shaver Brown and ISA Brown pullets found that birds held on 8L:16D from 0 to 72 weeks laid 3.7% fewer eggs than pullets reared on 8L:16D but transferred to 11L:13D at 21 weeks. The minimum (constant) photoperiod needed to elicit maximum yield is, thus, not more than 10 hours, but seems to be less than this for Shaver 288 pullets."

Unlike broilers which only require 45 days per production cycle, laying hens need a longer rearing period. This entails more costs and risks, and as a result more work has been published in this field.

Douglas *et al.* (1986) stated that an increase in the length of photoperiod given in the early morning from 02.00 to 19.00 compared with control light from 05.00 to 19.00 increased egg weight and egg production by 4% during the first four weeks. An

increase of photoperiod from 8 L to 14 L stimulated pullet growth while 8 L of photoperiod reduced body weight, liver, ovary and oviduct weight (Demitrov *et al.*, 1985; Berry and Brake, 1985; Leeson and Summers, 1985). Thyagarajan *et al.* (1988) found that among 12 L, 17 L and 22 L per day photoperiods, 22L:2D was the best in respect of both body weight gain and feed conversion ratio. Leeson and Summers (1985) found that laying hens reared under 14L:10D consumed more food and had greater body weight than hens reared in 8L:16D.

Okumura *et al.* (1988) and Andrews *et al.* (1987) both found that the natural photoperiod appears to be more important than ambient temperature but that it does, however, significantly affect hen mortality. On the other hand, it also significantly affects mean egg yield and egg shell weight (Odom *et al.*, 1985). In contrast, Brake (1989) found that no significant effect on production was observed between hens reared at 8 h natural day light and 8 h artificial light. Previous research by Leeson and Summers (1988) had shown that laying hens exposed to 14L:10D laid 9% more eggs than 14L:14D but with reduced egg shell quality and egg weight. Both the above light exposures still gave rise to larger in egg sizes and egg shell thicknesses, than 8L:16D. Makled and Charles (1987) found that an increase of the photoperiod to 24 L improved egg shell quality but this was more pronounced when birds were fed with 0.5% NaHCO3 and limestone as a Ca source. Koelkebeck and Biellier (1986), and Ibaraki *et al.* (1988) showed that egg yolk and albumen weights were significantly higher in a light dark cycle of 19L:9D than in 15L:13D or 15L:9D, but shell thickness and egg weight as well as breaking strength were better for birds in 15L:13D than in 15L:9D. Koelkebeck and Biellier further found that the effect of photoperiod on egg size and egg thicknes differed according to species.

Photoperiod also has an effect on oviposition in chickens (Millam *et al.*, 1986; Bhatti and Mian, 1987 and Bhatti et al. 1988). Lewis (1987) showed that as the duration of photoperiod lengthened, so the interval shortened between antecedent dusk and oviposition. He further demonstrated that for every extra hour added to the photoperiod, the interval between dusk and oviposition was reduced by 37.5 min.

The importance of light *per se* in triggering the processes leading to oviposition was demonstrated by Lewis and Perry (1990). The birds reared under a 12L:12D light programme were gradually subjected to replacement of the first 8 h of the 12 L with 8 h noise (recorded chicken or radio noises) i.e. : 4L and 12D. Mean oviposition time showed that the two noise groups regarded the regime as 4L : 20D, indicating that noise could not substitute for light as the initiatiator of ovulation and oviposition processes.

The migratory birds, turkey, goose and guinea fowl, show no gonadal development if they are kept permanently on short days. If such birds are maintained in constant long days the gonads eventually regress (a phenomenon which has been called 'refractoriness to light') and remain quiescent until a period of short days is provided to 'prepare' the animal for the next breeding cycle (Morris, 1988). In contrast, chicken and probably the domestic duck, which are both non-migratory, do not respond in this way. These species will reach sexual maturity whether reared on constant short days or on constant long days. They will then have a breeding cycle (not necessarily of normal length), pass through the characteristic non breeding phase and begin a new cycle in due course. Furthermore, Morris stated that for the modern domestic fowl, the time of onset of the moult and start of the second period of egg laying show wide individual variation, with the result that a flock held for two or more years under constant lighting conditions reaches a low, constant average rate of lay because the number of birds returning to production is in equilibrium with the number going out of lay.

Ahemeral cycles are those in which the light and dark periods do not add up to 24 h (ahemeral, 'not a day'). For example, a cycle of 14L:14D gives a 28 h cycle and six such cycles fit neatly into a week. Ahemeral light-dark cycles with periods between 20 h and 30 h have the effect of entraining the biological rhythms of the hen (Bhatti and Morris, 1978) and, in particular, the rhythm that determines the permitted hours for the surge in the circulating level of luteinizing hormone (LH) which causes ovulation. Furthermore, Bhatti and Morris stated that ovulating LH releases are limited to a maximum of one per cycle and so the use of a cycle longer than 24 h will reduce rate of lay (compared with 24 h controls) for the most prolific birds in the flock. The change in cycle length does not alter the rate of yolk accumulation in the ovary (except perhaps with a cycle as long as 30 h) and so there is an increase in yolk size, which leads to an increase in egg size inversely proportional to the reduction in rate of lay. Also, because of the increased time which each egg spends in the shell gland, there is an increase in the thickness (and strength) of shells laid under cycles longer than 24 h (Yannakopoulos and Morris, 1979).

Some poultry firms have used ahemeral cycles as a means of increasing early egg weight or of improving shell thickness late in the laying year. The benefits are small and depend upon the market prices for eggs of different sizes when the flock is young, or the extent of the cracked-egg problem in an older flock. It is possible to switch backwards and forwards between 24 hours and ahemeral cycles provided that certain special rules are observed (Morris, 1978), and so a producer who chooses to increase early egg size at the expense of rate of lay is not obliged to accept increased mean egg weight for the remainder of the year. This is in marked contrast to other techniques for increasing early egg size, such as delaying sexual maturity with a step-down pattern of lighting (Morris, 1968), when egg size is permanently and irrevocably increased

throughout the laying year. The inconvenience of having lights in the poultry house going on and off at odd times can be avoided by using alternating bright and dim light.

It does not seem likely that ahemeral cycles will find universal application in the poultry industry but, as a special tool for special circumstances, they have a part to play and they illustrate the elaborate nature of the control now exercised over productive responses in poultry by the artificial manipulation of the environment.

Morris (1980) found that increasing (Step Up) photoperiods advance sexual development in the pullet and tend to stimulate rate of lay after maturity. Decreasing (Step Down) photoperiods have the opposite effect. By contrasting a Step Up and Step Down rearing programme it is possible to obtain a difference of 6 weeks or more in age at 50% lay and there are important consequential effects on yield. Flock brought into lay early will give smaller eggs, not only when they start laying, but at all subsequent ages; but they start laying sooner and, for this reason. lay more eggs to a fixed finishing age than do later maturing flocks. Total egg output (kg egg per hen to a fixed finishing age) is usually a curvilinear function of age at 50% lay (as affected by light programme) with a maximum value for flocks which have been brought into lay near the middle of their potential range.

The sensitivity of the young pullet to an increase in photoperiod varies with age and is at a maximum between 9 and 12 weeks (Lewis *et al.*,1992). Increasing the photoperiod at or soon after 18 weeks has little effect on age at 50% lay, since that has already been determined, and will exert only a small influence on peak rate of lay. In modern layers, differences in overall performance between a flock which isgiven a rapid Step Up and one given a slow Step Up are not likely to be detectable.

" The maximum photoperiod which should be set for a Step Up programme is uncertain. Claims that the use of unnecessarily long days (or long days for an unnecessarily long time) will induce photorefractoriness do not seem justified for the modern layer (Morris, Sharp and Butler, in preparation). These authors report an experiment in which pullets given rapid increases from 8L:16D to 15L:9D laid the same number of eggs as other birds given the same increment more slowly A third group held on 11L:13D from 21 to 72 weeks of age laid 1.7% less. The expected difference in yield resulting from a ceiling of 14L:10D rather than 16L:8D might be 0.8%, which is too small an effect to be detected in any practicable trial."

2.3.2 Intermittent light

Sauveur and Mongin (1983) in their intermittent trial of 3L:3D, 6L:6D and 1.5L:4.5D cycles and continuous light found that egg production slightly decreased in short light cycles but that there was a better performance in egg weight and egg shell quality. Oviposition was more frequent during the first half of the solar day when the ratio was 1.5L:4.5D. There are other intermittent lighting programmes, such as 4(3L:3D), which allow the hen's oviposition rhythm to break away from 24 h entrainment. This usually results in fewer but larger eggs with thicker shells (Morris, 1988).

The effect of continuous, flashing light and their combination on eggs laid was reported by Mian and Morris (1988). They stated that a one minute pulse of light at hourly intervals at 10 lux (8i:8L:8D) advanced the mean time of lay by 2-3 h but had no effect on egg production compared to control (8L:16D). Midgley *et al.* (1988) showed that feed intake was reduced for birds reared under intermittent 15 min L : 45 min D and 15 min L : 30 min D cycles compared to 15 L : 8 D (control), although there were no significant differences in the rate of laying and egg weight.

Lewis and Perry (1989) stated that hens held for a year under 2L:4D:8L:10D had significantly less carcass fat than hens under 17L:7D. It was suggested that this was probably due to a reduction in body weight, rather than a lower rate of fat deposition, as the regression of fat against body weight was similar for both bird groups. Recent studies by Lewis and Perry (1990b) demonstrated that intermittent lighting regimes promote healthier poultry flocks by producing birds with a lower body fat content, and that this may in turn reduce the incidence of ruptured fatty livers and peritonitis. Furthermore, appropriate application of intermittent lighting is able to reduce electricity costs and feed consumption by about 41% and 9% respectively with no effects on body weight gain, egg production and egg size.

Hens submitted to asymmetrical regimes, including biomittent, interpret the longer (or longest) dark period in the cycle as night, and the remainder of the 24 h as day (Mongin *et al.*, 1978; Lewis and Perry, 1990a). The similar egg numbers and egg weights, with comparable oviposition time and distribution, and their entrainment to the same dawn and dusk as fully illuminated controls, indicate that the endocrine periodicity of intermittently lit hens, at least of hormones involved in the regulation of the ovulatory cycle, is unaffected by any scotoperiod which may interrupt their day.

Binkley *et al.* (1975) reported that the melatonin production of the hens' pineal gland is greatest at night and least during the day, whilst Lewis *et al.* (1989) reported that the melatonin concentration in plasma sampled from hens during the 4 h scotoperiod of an 8L:4D:2L:10D regime was similar to that in plasma from simultaneously tested 14L:10D controls. It seems that melatonin production is unaffected by the intermittent light regime.

The use of long cycles (e.g. 14L:13D) to reduce rate of lay and increase egg size early in lay probably has little application in the UK poultry industry. More surprising, is the failure to exploit long cycles at the end of the laying year, where the increase in egg weight is small, the improvement in shell thickness is substantial and there may, in some cases, be a small increase in rate of lay (Shanawany *et al.*, 1993).

2.3.3 Light intensity

The effects of photoperiod and light intensity on male and female fertility and broodiness in turkeys has been reviewed by Noll (1989). Haye and Simon (1978) found that a step up lighting program to high intensity (20 lux) significantly lowered leg weakness problems. This might be due to an increase in exercise and shortening of long bones.

High light intensities are essential during the first week of the rearing period to facilitate the search for food and water, but afterwards intensity must be low compared to natural light to prevent cannibalism (Cavalchini *et al.*, 1984). Midgley (1966) and Cavalchini *et al.* (1984) described the problems which may arise if there are marked changes in light intensity when point of lay pullets are moved from the rearing to the laying house. A reduction in intensity may hinder birds in finding food and water, especially those in cages fitted with nipple drinking systems. An increase in intensity could result in a flock becoming excessively nervous. Wilson *et al.* (1979) stated that low intensity, in the order of 1-2 lux, was effective for controlling feather pecking and cannibalism during the rearing period.

Japanese quail laid 89 - 90% eggs under 69 - 104 lux at 14L:10D compared to 82 - 88% under 69 - 104 lux at 24L:0D. In the 14L:10D light cycle at intensities of 2055 - 2152 lux, the laying rate increased by 4% but decreased by 24% at 2 - 3 lux. However, neither the greater nor lower intensities had any effect when a 24L:0D light cycle was applied.

Unlike the broiler, hens produce more eggs under high intensity light (400 lux) than low intensity (10 lux) (Merat *et al.*, 1989). Two experiments dealing with the effect of light intensity on laying birds have been reported by Morris and Owen (1966) and Morris (1966). The pullets transferred from normal (50 lux) lighting to various test levels of intensity showed a drop in production when the test level was below 10 lux. Furthermore, a long-term trial in which pullets were reared under three different light intensities and then exposed to various light intensities throughout the laying year showed a typical dose-response relationship (Figure 2.3). From this it may be concluded that an intensity of 10 lux at food level is probably the minimum which will support the maximum rate of egg production, although information on the effects of intensities between 5 and 50 lux on egg production has not been available.

The effect of light intensity in a range between 0.2 to 5.0 lux on growing pullets is small. Morris (1966b) reported that sexual maturity is delayed slightly at very low intensities but there is no significant effect on subsequent yield when birds are given an adequate intensity in the laying house. At present, there is no evidence to suggest that the intensity required by laying birds is in any way affected by previous exposure to lighting or by the intensity of natural light, where birds are given mixtures of natural and artificial lighting.

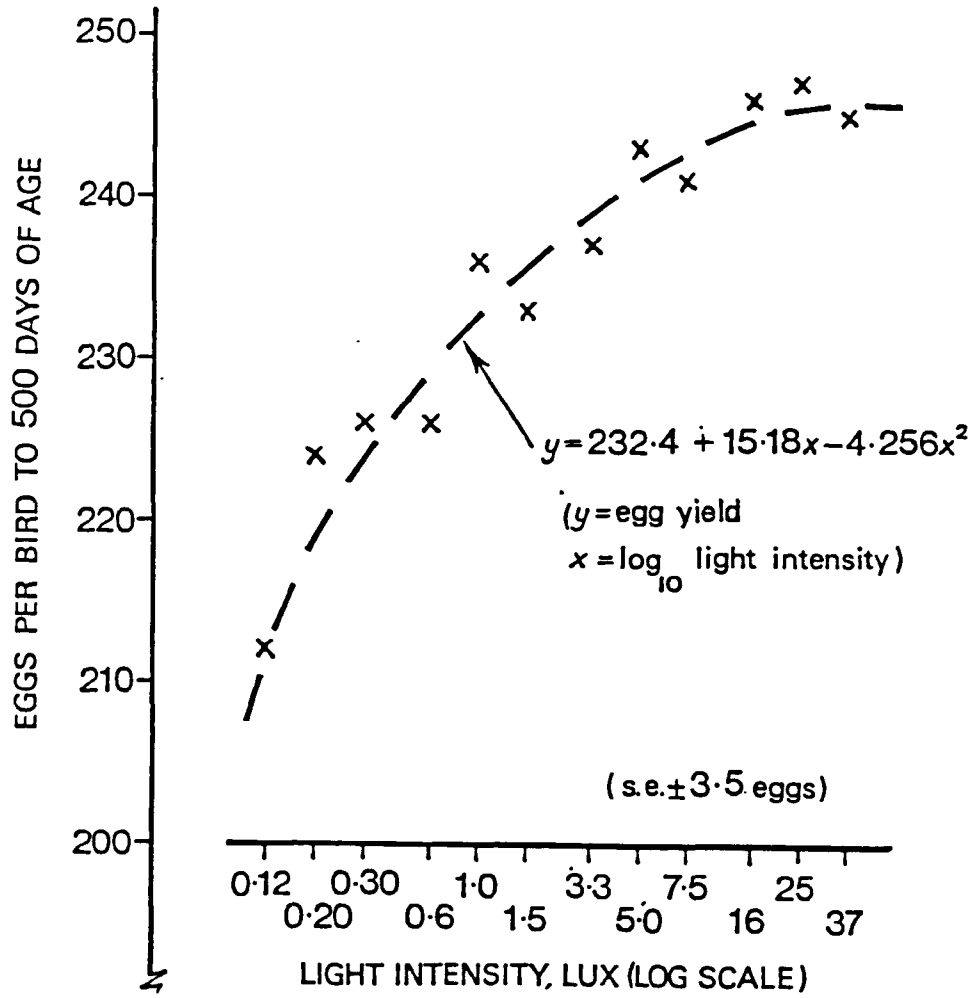


Figure 2.3 The effect of light intensity in a cage laying house on annual egg yield. The intensities indicated on the abscissa were measured at the food trough outside the cage (Morris, 1968).

Experiments conducted at Reading, UK in 1964 and 1966 showed a curvilinear relationship between light intensity and rate of lay, with an optimal dose of about 5 lux measured at the cage front (Morris, 1981). More recent studies (Hill *et al.*, 1988; Tucker and Charles, 1993) have shown no significant difference in yield with light intensities ranging from 34 down to 1.75 lux. Thus, it seems that the laying strains of the 1980's were less sensitive to light intensity than those in the 1960's.

2.3.4 Colour of lighting

As seen by the human eye, light is only that part of the radiant energy spectrum which is represented by wavelengths between 400 and 700 nm. The limits of the chicken eye are quite similar to those of the human eye. All chickens have colour vision. There is some indication that they are able to see better when illumination is by rays at the long end of the spectrum such as red, orange, yellow and blue. The quantity of light necessary for chickens to see and eat are unusually low. After some training, birds will find their way to feeders and eat even when the light intensity is less than 0.25 foot-candle (2.69 lux). However, it requires two to four times this amount of light to stimulate the pituitary and increase egg production (North, 1978).

Despite some confusion between wavelength effects and light intensity effects the avian species are known to be particularly sensitive to bands of light nearest red and orange (Morris, 1968; Cavalchini *et al.*, 1984).

The colour of the light rays has an effect on the productivity of chickens. A part of this difference is thought to be due to the fact that the oil droplets in the retina of the eye filter out some of the shorter rays such as green, blue and violet. In spite of the improvement in some colour categories, white light is used almost exclusively, as it represents the best average (Cavalchini *et al.*, 1983).

Van Tienhoven and Planck (1973) suggest that only wavelengths of light which are able to penetrate to the site of the hypothalamic extraretinal photoreceptor will be effective at initiating the photosexual response.

Benoit (1964) demonstrated the influence of intensity in colour/wavelength experiments with mallard drakes. He found that with an intensity of 0.015 lux only red light was effective in initiating a photosexual response. When the intensity was raised to 0.44 lux red and orange were effective, and at very high intensities blue, green and yellow also became photosexually inductive.

Benoit (1964) and Hartwig and van Veen (1979) demonstrated that photons of longer wavelength (700-750nm) were able to penetrate to the avian hypothalamus more effectively than those of shorter wavelength (400-450nm). However, Foster and Follet (1985) found castrated Japanese quail were sexually more photosensitive to green (500nm) than to red (650nm) light when the light was directed onto the hypothalamus. The twentyfold increase in sensitivity under green light was, however, cancelled out by red light's thirtyfold easier penetration of the skull when the birds were illuminated overhead by light of the same flux density.

The relationships between the colour of light rays and certain production factors are given in table 2.1. In many cases the relationships are weak. Dakan (1936) found that more satisfactory egg production was obtained when pullets were exposed to red than yellow light, but egg production decreased when the hens were exposed to blue light for two months. Furthermore, Carson *et al.* (1956) found that hens kept under red, green or cool white light laid significantly more eggs than hens which were exposed to normal daylight during an 11 week period. In contrast, McGinnis *et al.* (1966) showed that pullets kept in filtered artificial light from a day old reduced their egg production when a narrow band of light from either the red, green or blue was administered. Egg production, according to Platt (1952 ; 1953) can be improved when daylight is supplemented with dim red light during the night. However, this does not work in the tropics since the chicken house has open sides or windows, and the birds cannot readily adjust

to such an especially dim light after the bright, intense light of the daytime (North, 1978).

Table 2.1 The relationship between the colour of light rays and certain production factors (North, 1978)

Item	Colour of Light Rays				
	Red	Orange	Yellow	Green	Blue
Improves growth				x	x
Depresses feed efficiency			x	x	
Lowers age of sexual maturity				x	x
Increases age of sexual maturity	x	x	x		
Enlarges the eye					x
Reduces nervousness	x				
Lowers cannibalism	x				x
Increases egg production	x	x			
Lowers egg production			x		
Increases egg size			x		
Improves male fertility				x	x
Lowers male fertility	x				

Woodard, Moore *et al.* (1969) reviewed the literature on wavelength and quoted the work of Lauber and McGinnis (1965), Harrison, *et al.* (1966) and McGinnis (1967), which demonstrated that short wavelength light from the blue and green zone hastened sexual maturity in the domestic fowl. Woodard subjected Japanese quail to a 16L:8D photoperiod of either red, green, blue or incandescent light (white) from day-old to 5

weeks of age. From 5-16 weeks of age half the birds received incandescent light. In a second trial only blue or red light was given, but the intensity of each was 3.5 lux, as opposed to 40.0 and 12.0 lux respectively in the first trial. The results of body weights to 5 weeks of age were lower under blue and green light than under red or incandescent. There was no significant difference between the testis weight of those birds exposed to red or incandescent light, but their weights were twice those of green males, three times those of high intensity blue males and ten times those of low intensity blue males. Females reared under red lights reached sexual maturity 2 weeks earlier than those given blue or green light, irrespective of intensity or the transfer to incandescent light at 5 weeks of age. The birds which received low intensity blue light to 16 weeks of age took 96 days to reach 50% egg production, against 52 days for birds on high intensity blue and 45 days for birds on red of either intensity. Hatchability, average egg weight and feed conversion efficiency was unaffected by wavelength at any intensity.

Schumaier *et al.* (1968) compared debeaked and normal chicks reared under green, red or white fluorescent light from day old up to 20 weeks. They found that red light prevented feather picking and cannibalism during the rearing period whilst egg production was unaffected. When the pullets switched from white to red light at 20 weeks, egg production was significantly lower than under white light. They assumed that the lack of reproductive response to the different coloured light treatments may be due to the broad overlapping spectra between green and red fluorescence. In this case the highest intensity is green, white has medium intensity and the lowest is red with the wavelength 520 (peak), 560 (median) and 640 (peak) respectively. This does not necessarily mean that egg production is equally stimulated by light from various portions of the spectrum because the fluorescent tubes transmit light over a considerable portion of the spectrum.

There seems at present little reason to prefer red lighting to white in poultry houses, since putting red paint on a lamp only eliminates the blue and green components and does nothing to increase the red component of the lamp's output. Red fluorescent tubes are somewhat more efficient in their output of red light per watt of electricity but Ostrander *et al.* (1960) reported a 15% lower yield in pens lit with 40-watt (white) fluorescent lamps compared with 60-watt (red), although both differences are not statistically significant. This is an area in which a good deal more information is required.

2.4 THE EFFECT OF LIGHT ON POULTRY BEHAVIOUR

Historically, behaviour has played a subtle but primary role in chicken meat and egg production. Although the implications of behaviour for husbandry practices have become more visible in recent years, research has lagged behind the technological changes which have occurred in poultry production. Additional information is needed regarding the relationships between behaviour and husbandry, as well as the interface of these with other disciplines in determining production practices. Thus, behavioural research published relating to poultry is less voluminous than production research, especially with regard to the effect of lighting.

2.4.1 Photoperiod

Yeates (1963) and Blockhuis and van der Haar (1985) stated that there is a close relationship between locomotory activity in the domestic hen and the light:dark cycle to which it is subjected. Thus, activity is associated with light periods and inactivity with darkness.

Yeates (1963) observed semi-intensively housed pullets under natural daylight conditions to determine whether there was a critical light intensity at which bird decided it was either 'day' or 'night'. The results indicated that birds perched voluntarily approximately 30 min. before 'civil twilight' (intensity 13-14 lux) and they jumped down from the perches about 30 min. before morning 'civil twilight' (intensity 0.03 lux). He suggested that the birds' activity and inactivity were controlled by a circadian oscillator, because they did not jump down from their perches under bright moonlight conditions when the prevailing light intensity was higher than that 30 min. before dawn. The beginning and end of activity 30 min. before morning and evening 'civil twilight', irrespective of the time of year, suggests that birds can anticipate light changes. The rapidity with which birds can adjust was noted by Perry (unpublished data), who recorded the anticipation of dawn in 5-to 6 week-old pullets housed in a light-proofed building. When the artificial dawn was advanced by 2 h, the young birds were able to anticipate the new 'dawn' by the third day after the change. Savory (1980) showed that such birds often indulge in intense feeding activity before lights-out. The demand for nutrients to satisfy ovulation and shell calcification needs may cause these birds to increase their feeding before 'night' and fill their crops so that digestion and absorption of nutrients can take place during the hours of darkness. This increase in feeding activity is presumably triggered by the birds' anticipation of night (darkness).

When birds are maintained on lighting programmes experienced in tropical and temperate regions, they do not usually feed in the dark. However, when subjected to very short photoperiods, birds will eat in the dark (Lewis and Perry, 1986). Under a commercial programme (14L:10D up to 17L:7D) birds will commence feeding at dawn and cease at dusk. The demands of oviposition reduce feeding activity during the early part of the photoperiod, which results in an uneven distribution of activity during the bird's day (Purkiss *et al.*, 1974). A similar temporal distribution of water intake was noted by Hill *et al.* (1979).

2.4.2 Intermittent light

Coenen *et al.* (1988) demonstrated that hens are more active during the day than the night and much less active under biomittent conditions of 15 min L : 45 min D for 14 L than under a natural light regime of 14L:10D. Behavioural observation revealed that 15 min. light periods tended to decrease sleep and increase restlessness and wakefulness.

Blockhuis (1983) suggested that intermittent lighting regimes may interrupt a hen's normal activity rhythm, and that the effects of such interference on the synchronisation of sleep with other physiological and behavioural cycles are unknown, but may be of importance in evaluating such programmes.

March *et al.* (1990) reported that the behaviour of laying hens immediately before and after dawn were similar under both 8L:4D:2L:10D and 14L:10D lighting. Sleep and rest during the 30 min before dawn was similar for both lighting treatments. Similar behaviour was also observed in both groups in the period prior to dusk, when intense feeding and drinking gave way to preening, and at dusk, when all birds were resting or asleep within 6-9 min of darkness. During the 10 h night there were no

significant behavioural differences between treatments. The only observable differences between the behaviour of the intermittent and conventionally lit hens occurred during the 4 h scotoperiod, which changed their active to a passive state.

These findings concur with those of Coenen *et al.* (1988), who observed a change to passive wakefulness during the 45 min scotoperiods of the 14 h biomittent programme. March *et al.* (1990) believed that the birds were waiting for the approaching 15 min illumination, in which they could continue eating and drinking. They also noted that the birds appeared to be more restless than when conventionally lit during the 10 h night, with sleep tending to be replaced by drowsiness.

Midgley (1984) reported that birds subjected to biomittent lighting compared to conventionally illuminated flocks were quieter, less cannibalistic, and had less stress during hot weather, whilst Kuit (1985) reported that a lower incidence of vice was found among hens subjected to intermittent lighting than among conventionally lighted controls.

2.4.3 Colour of lighting

Hammond and Titus (1941) painted the walls of darkened pens white, violet blue, black, yellowish green, red and dark green. Mortality was high in the black and red and dark green pens due to low light intensity, resulting in starvation, which led to the conclusion that the colour of light was less important than intensity because of the absence of differences observed between treatments. Bowlby (1957) used a 100,000 bird commercial broiler flock and found that red light reduced cannibalism and made feed more attractive. Birds under white light were more excitable, whereas birds under blue light were blind.

Smith and Phillips (1959) suspended fixtures containing red, orange, green and yellow neon tubes over feeders in one pen and showed greater feed consumption under green light. However, no differences in feed consumption occurred when the colours were placed in separate pens. Hurnick *et al.* (1971) used four hundred white leghorn laying hens to preference the test colour of feeders and the colour of the feed using blue, green, yellow and red. Both the variables and the interactions of feed colour and feeder colour revealed significant effects on feed consumption. The most preferred colour of feeders was red and for the feed it was blue, while the least preferred colour for feeders was yellow and for the feed it was red.

White light is sometimes replaced in an attempt to prevent feather pecking and cannibalism. However, Wells (1971) stated that in practice such a change is usually accompanied by a marked reduction in light intensity, and it is this and not colour that is thought to minimise these vices, although much work conflicts with this statement. Wells did note that dim red light may have have a subduing effect on the birds.

Schumaier *et al.* (1968) investigated the effects of coloured light on cannibalism and growth in Leghorn pullets during the rearing period. Body weight and mortality were not affected by light treatments. Cannibalism was most effectively controlled by the use of red light. Feather pecking up to 12 weeks of age occurred spontaneously without apparent cause and progressed until most of the birds in the green or white light had most of their tail feathers plus various amounts of feathers around the base of the tail removed. An estimated 70-90% of the pullets in the green or white light showed evidence of some feather pecking. Those under red light showed no signs of feather pecking.

Red light bulbs are often used to reduce cannibalism when the broiler house is light proof. Debeaking can usually be eliminated. But if the house has open sides or windows, the use of red lights during the morning and evening hours to supplement the hours of natural daylight is a disadvantage, as the birds cannot readily adjust to such an especially dim light after the bright, intense light of the daytime (North, 1978).

Based on the views above, it seems that there are some inconsistent results concerning the effects of colour of lighting on the behaviour of chickens. There is no satisfactory evidence to show how colour and intensity interact in the behavioural aspects. Perhaps with monochromatic light there would be no interaction; there might be no response to illumination outside a narrow waveband. But with commercial lamps there is a wide range of spectral emission so that blue light, for example, still gives some red radiation in part of the spectrum and if blue light requires a greater intensity than red to achieve an appropriate perceived intensity (McGinnis *et al.*, 1966), then blue light is not a main and pure factor affecting the reared birds. Hence, the responses observed may be mostly due to the red output of the blue lamp. To reduce and eliminate the biased result above, it can be resolved by the use of appropriate filters, to make sure that only certain colours are emitted to the test birds.

2.5. THE EFFECT OF LIGHT ON LEG ABNORMALITIES AND MORTALITY

2.5.1 Anatomy and physiology of bone

The skeleton of the bird evolved in relation to its power of flight and to walk and perch on its hind legs (Tayler, 1970). The individual bones combine lightness and strength. The skeleton is more than a rigid framework for attaching muscles, supporting the body and protecting the viscera (Figure 2.4). Bone is a dynamic tissue and its anatomical structure is primarily determined by the physical stresses to which it is subjected. Its chemical composition is also variable, allowing biochemical lability to occur, most noticeably in the utilisation of calcium from bone in the formation of the egg in the laying hen.

Bone contains a great deal of intercellular substance surrounding widely separated cells. Four types of cells are characteristic of bone tissue : oesteoprogenitor cells, oesteoclasts, oesteoblasts and oesteocytes. Oesteoprogenitor cells are found in the inner portion of the membrane (periosteum) around the bone, in the membrane that lines the medullary cavity and in the canals in the bone which contain blood vessels. Osteoblasts secrete organic components and mineral salts that are involved in bone formation and are found on the surface of the bone. Osteocytes are the principal cells of bone tissue, maintaining the cellular activities of bone tissue. Oesteoclasts develop from white blood cells and are found around the surfaces of the bone. They function in bone resorption, which is important in the development, maintenance and repair of bone.

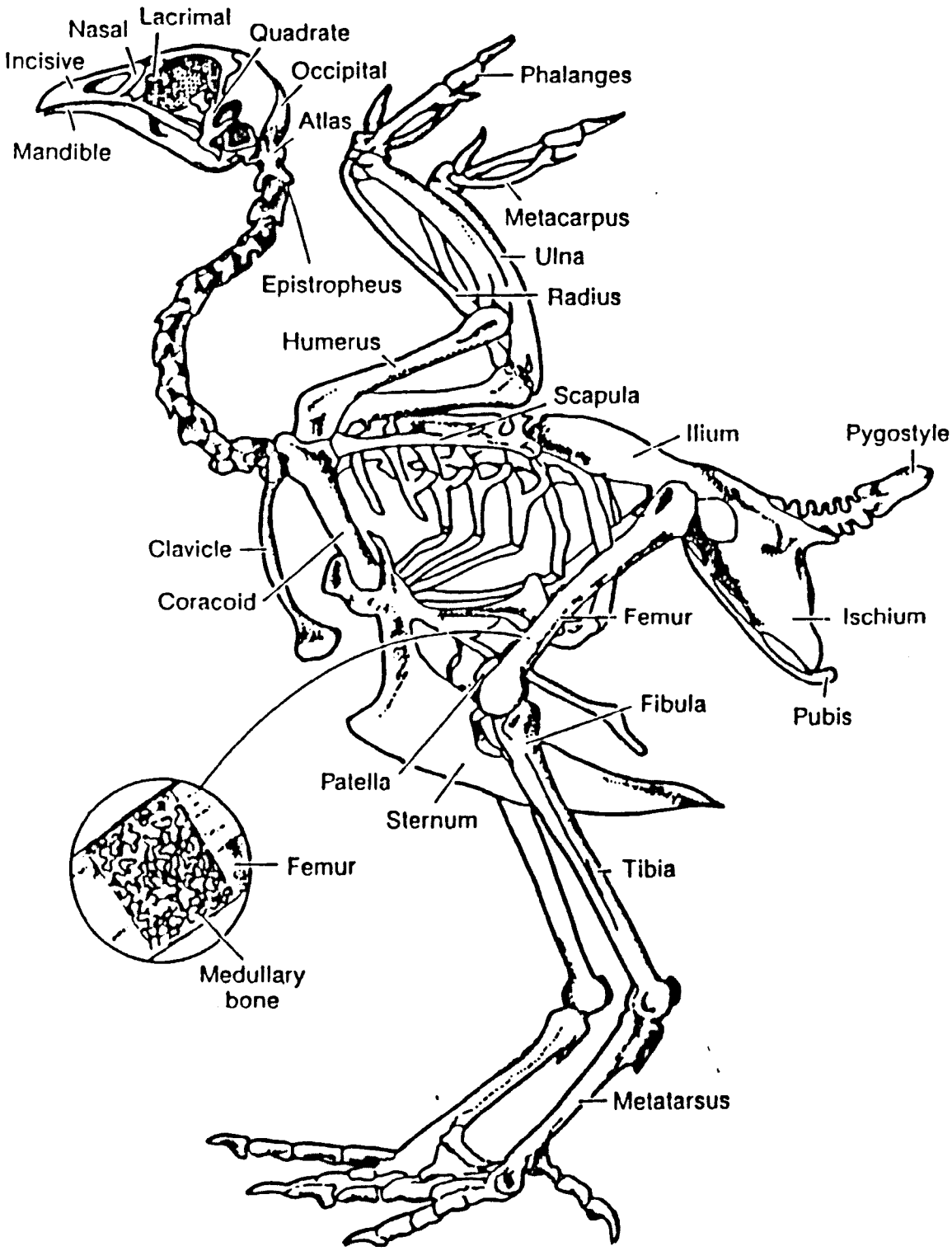


Figure 2.4. The chicken skeleton (Parkhurst and Mountney, 1988)

The microscopic structure of bone is not completely solid and all bone has spaces between its hard fraction which transmit the blood vessels that supply the bone cells with nutrients. The size of the spaces determines whether the bone is categorised as compact or spongy (Figure2.5).

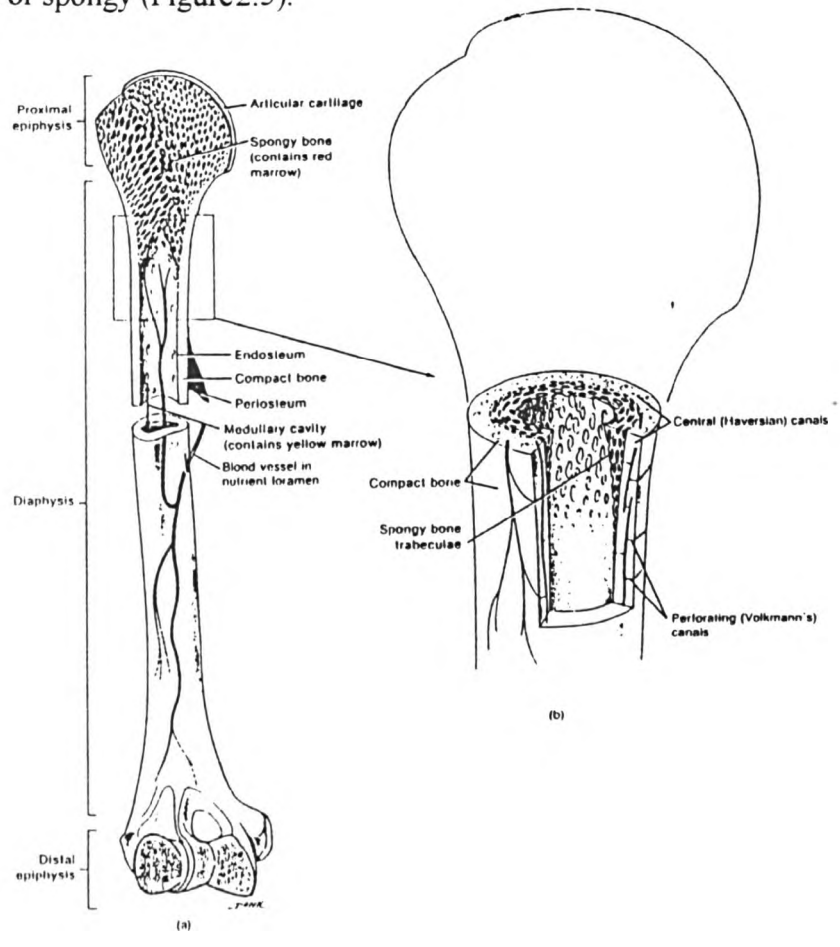


Figure 2.5 Macroscopic appearance of the tibia (Tortora and Anagnostakos, 1990)

Compact bone tissue contains few spaces and is found in a layer over the spongy bone tissue. The layer of compact bone is thicker in the diaphysis than the epiphysis. Compact bone tissue provides protection and support and helps the long bones resist the stress of weight placed on them. Spongy bone tissue contains many large spaces filled with red marrow. It makes up most of the bone tissue of the epiphysis of the long bones.

The process by which bone forms is called ossification. The skeleton of the avian embryo is composed of fibrous membrane and hyaline cartilage, both being shaped like bones and providing the medium for ossification. Two types of bone formation occur. Intra-membranous ossification refers to the formation of bone directly on or within the fibrous membranes. The second type of bone formation, which is known as endochondral ossification, refers to the bone in the cartilage, and is the replacement of cartilage by bone (Figure2.6).

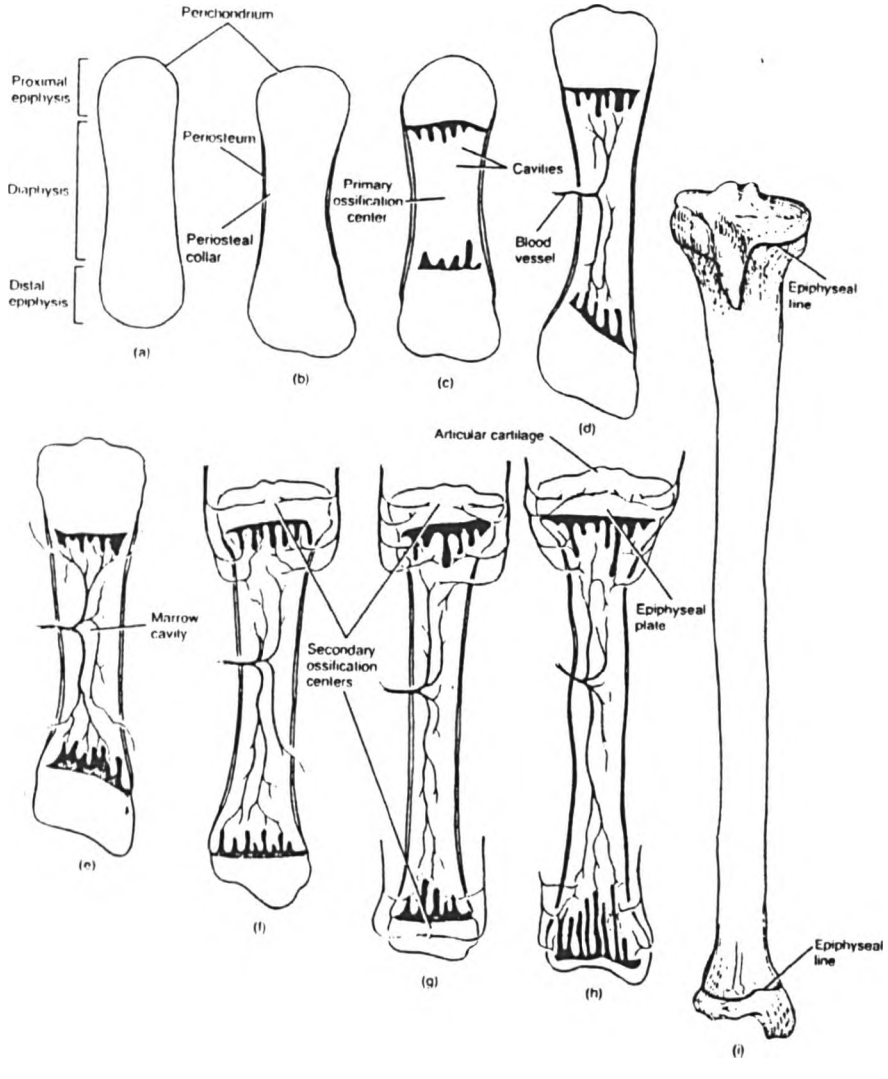


Figure 2.6 Endochondral ossification of the tibia (Tortora and Anagnostakos, 1990)

In young birds the limbs grow very quickly in length by a process involving the erosion of the narrow band of cartilage at the growing end of the bone and its replacement by long trabeculae of bone which are aligned along lines of stress to form spongy bone. This is achieved by the epiphyseal plate which consists of chondrocytes at different stages of development slowly calcifying to form new bone. The region between the diaphysis and epiphysis of a bone where this calcification occurs, turning calcified cartilage into bone, is called the metaphysis. The activity of the epiphyseal plate is the mechanism by which the diaphysis can increase in length.

As the bird grows, cartilage cells are produced by mitosis on the epiphyseal side of the plate. The cartilage cells are then destroyed and replaced by bone on the diaphyseal side of the plate, so that the thickness of the epiphyseal plate remains constant, but the bone on the diaphyseal side increases in length. Eventually the epiphyseal cartilage cells stop dividing and the cartilage is replaced by bone. The newly formed bony structure is called the epiphyseal line, a remnant of the once active epiphyseal plate. With the appearance of the epiphyseal line, bone growth in length stops (Tortora and Anagnostakos, 1990).

2.5.2 Leg abnormalities and mortalities caused by light

The incidence of weak or twisted legs demonstrated in commercial broilers has increased along with an increase in body weight and a decrease in light intensity. Birds grown under intermittent light show a lower incidence of leg abnormalities when compared to similar birds in continuous photoperiods, particularly in turkeys (Buckland, 1975). In general, birds grown under low light intensity and continuous illuminance are more docile and exercise less than chickens subjected to lighting

patterns (Wilson *et al.*, 1983). Haye and Simons (1978) suggested that the incidence of leg abnormalities increased as the birds exercised less. However, in previous experiments they had concluded that light intensity was not directly a determinant of leg abnormalities.

Riddell and Springer (1985) observed a trend of a lower incidence of leg disorders in flocks brooded under brighter light. If activity is higher under brighter light, then it would be expected that light intensity would be inversely correlated to the incidence of leg disorders. The influence of light intensity on activity and performance remains ambiguous (Newberry *et al.*, 1987). However, it is not clear whether light colour affects leg disorders.

Turkeys reared on a high protein diet at 8L:16D have no significant difference in leg disorders compared with 14L:10D. High mortality was found when feeding was restricted, but there were fewer leg disease problems (Dobrescu, 1986; Hocking, 1988).

Lewis *et al.* (1992) reviewed 36 sets of published mortality data and concluded that interrupted lighting generally improved bird survival. Lighting programmes which provided low total daily amounts of illumination gave the greatest improvement. Specific types of interrupted lighting were shown to reduce vices, obesity and heart stress.

Eye enlargement (buphthalmia) has been reported in chickens kept in continuous darkness (Whitley *et al.*, 1985). Oishi (1980) noted increased eye weight with both continuous illumination and continuous darkness, and concluded that the condition was caused by the abolition of a light-dark cycle. It is, therefore, possible that birds subjected to intermittent lighting regimes, which include small total amounts of

illumination, might have exhibited abnormalities similar to those reported in birds kept under continuous darkness condition, or that birds on 'free-running' symmetrical regimes might suffer from eye damage similar to that of birds kept under continuous illumination conditions. However, Lewis and Perry (1990a) reported that no ocular abnormalities were observed in laying hens after 12 months of asymmetrical intermittent lighting.

Chapter III

Experiment 1. Part 1

THE EFFECT OF COLOUR OF LIGHTING ON THE PERFORMANCE AND BEHAVIOUR OF BROILERS

3.1 ABSTRACT

Forty female and forty male Ross broiler chicks were group reared in cages with white (W), red (R), green (G) or blue (B) lights at 30 lux from one to four weeks of age to examine the effects of colour on growth and behaviour. There was no significant treatment effect on growth rate, carcase protein, fat, and ash content, but blue light increased the weight of skin, bone feathers and gut contents. Behavioural studies revealed that no significant differences were observed in time spent feeding. Feed intakes were also not affected by treatment. The incidence of aggression (W 1.25, R 1.71, G 0.05, B 0.94 incidence/bird/day, SED 0.31), wing stretching (W 11.0, R 16.6, G 10.2, B 8.5 incidence/bird/day, SED 0.95) and pecking at the floor (W 16.6, R 22.0, G 15.9, B 14.7 incidence/bird/day, SED 1.23) were all greatest for birds in the red light and least for birds in the blue or green lights, with birds in the white light intermediate. There was no significant difference in the time spent standing (W 8.1, R 7.9, G 8.4, B 8.6 min/h, SED 0.35), but the times spent sitting, dozing and sleeping were greatest for the green, blue and red treatments respectively (sitting : W 11.5, R 11.3, G 13.8, B 11.2 min/h, SED 0.40; dozing : W 15.9, R 14.4, G 14.4, B 16,7 min/h, SED 0.40; sleeping : W 11.0, R 13.7, G 10.3, B 10.6 min/h, SED 0.32). The sex of birds did not significantly affect the body weight and behaviour. However, carcase composition and most body components were considerably affected by sex. It is concluded that birds are more active in red light and less active in blue and green lights than white light. The greater activity under red light necessitated a longer sleeping time, whereas birds in the blue or green light were more inclined to sit passively and doze.

3.2 INTRODUCTION

There are many conflicting arguments about the effects of light colour on chickens. Levenick and Leighton (1988) reported that blue light, which is perceived by the birds as less bright than red or white, is preferable for stimulating growth, particularly in the first 16 to 18 weeks, while the birds are establishing dominance

order. However, once this order had been established white and red light act as a better photostimulant than blue light.

Cave (1990) indicated that a green fluorescent light was able to increase the growth rate of chickens. Previous studies by Lauber and McGinnis (1965) and Foss and Arnold (1969) found that yellow or green light tends to stimulate broiler growth, but red light tends to stimulate feed consumption. Wabeck and Skoglund (1974) investigated the effects on growth, feed conversion and mortality of broilers under white incandescent lamp and fluorescent light sources which emitted predominantly radiant energy representing the blue, green, yellow and red portions of the light spectrum. Based on four trials, 9-week-old broilers under either the blue or green fluorescent light were the heaviest, while the lightest were those under red lights. The white incandescent and yellow fluorescent groups were in between the two extremes with regard to weight. Neither food conversion nor mortality were influenced by light treatment.

Without considering light intensity, green light influenced broiler growth and feed consumption compared to white light or darkness (Foss *et al.*, 1972). Foss *et al.* (*loc cit*) observed the effects of narrow-band light at equal energy levels on the deveopment of cockerels. A total of 216 chicks were raised in conventional electrically heated starting batteries until 6 weeks of age. They were then allotted to environmental chambers and exposed to one of the following light treatments for 35 days : blue (450nm), green (545nm), red (650nm), far-red (750nm), dark or white. It was concluded that the chick growth was significantly ($P< 0.05$) stimulated by a green light environment compared with any other light environment. This was not accompanied by an increase in food consumption. Chicks grew approximately as well in complete darkness as under white lights. Furthermore, Smith and Phillips (1959) reported that

when the coloured lights were hung over the feeders in the same pen, feed consumption was higher in green light but this did not happened when the light was hung in another part of the pen.

Scheideler (1990) reports that broiler chicks require light for optimum growth and they respond differently to varying wavelengths of emitted light. Foss *et al.* (1972) and Osol *et al.* (1980) found that the growth of broilers is inhibited when they are exposed to certain wavelengths. Comparing six different wavelengths at peak transmission of 450, 545, 650 and 750nm, it was found that heavier and higher comb, testes, and gonadotrophic hormone levels were found under both red (650nm) and white light whilst weight gain was greatest at 545nm (green). In contrast, food consumption was not affected by light colour. However, this finding has been criticed by Wathes *et al.* (1982) who assumed that testosterone acts as a growth stimulant.

Besides considering the growth rate and body weight gain, since broilers are especially reared for meat, the body composition and behavioural aspects of the animals are important and should be considered. There are no reports of colour of light effects on the composition of the chickens. Colour of light might affect animal behaviour, body composition, and efficiency of feed consumption. At present, the colour of light and light intensity are becoming increasingly important because of their effects on behaviour.

In the commercial situation, Bowlby (1957) found that red light reduced cannibalism and made feed more attractive. Birds reared under white light were more excitable, while birds reared under blue lights were blind. White light is sometimes replaced in an attempt to prevent feather pecking and cannibalism. However, Wells (1971) stated that in practice such a change is usually accompanied by a marked

reduction in intensity, and it is this and not colour that is thought to minimise these vices, although much work conflicts with this statement. Wells (*loc cit*) noted that red light may have a subduing effect on the birds.

Although there are some conflicting results, from the reports above it is clear that light colour could influence broiler performance and behaviour and might affect the animal body composition. This chapter reports on the effects of the colour of lighting on body weight gain, food consumption, feed conversion ratio, body composition and dead weight of giblets, feathers, empty crops and gizzards, neck, left half, skin, muscle, bone and fat content of broilers after being reared for four weeks. The behavioural aspects such as time spent feeding, standing, sitting, dozing, sleeping, walking, drinking, pecking at the floor, wing stretching and in aggressive interactions are also described.

3.3 MATERIALS AND METHODS

3.3.1 Experimental animals, housing and management

Forty female and 40 male broiler chicks of commercial (Cymru Ross) breed were group-reared in cages supplied with white (W), red (R), green (G) or blue (B) light from one to four weeks of age. The chicks were reared in homogenous untreated conditions for one week before treatment. The cages for the experiment were placed in four rooms separated by a black curtain. Each room contained 2 cages, one above the other (156 x 60 x 57 cm per cage). The distance between the top and bottom cages was 60 cm. Three lights were placed in each cage at 57 cm from the cage floor and 52 cm distance from each other.

Trays were placed beneath each cage for the collection of droppings. Excreta were regularly removed from the trays every two days. Each cage contained 10 birds, 5 female and 5 male. The cages were made of wire mesh with steel frames and were equipped with a feeder containing 650 grams of feed and a drinker containing 600 ml of water (see Figure 3.1).

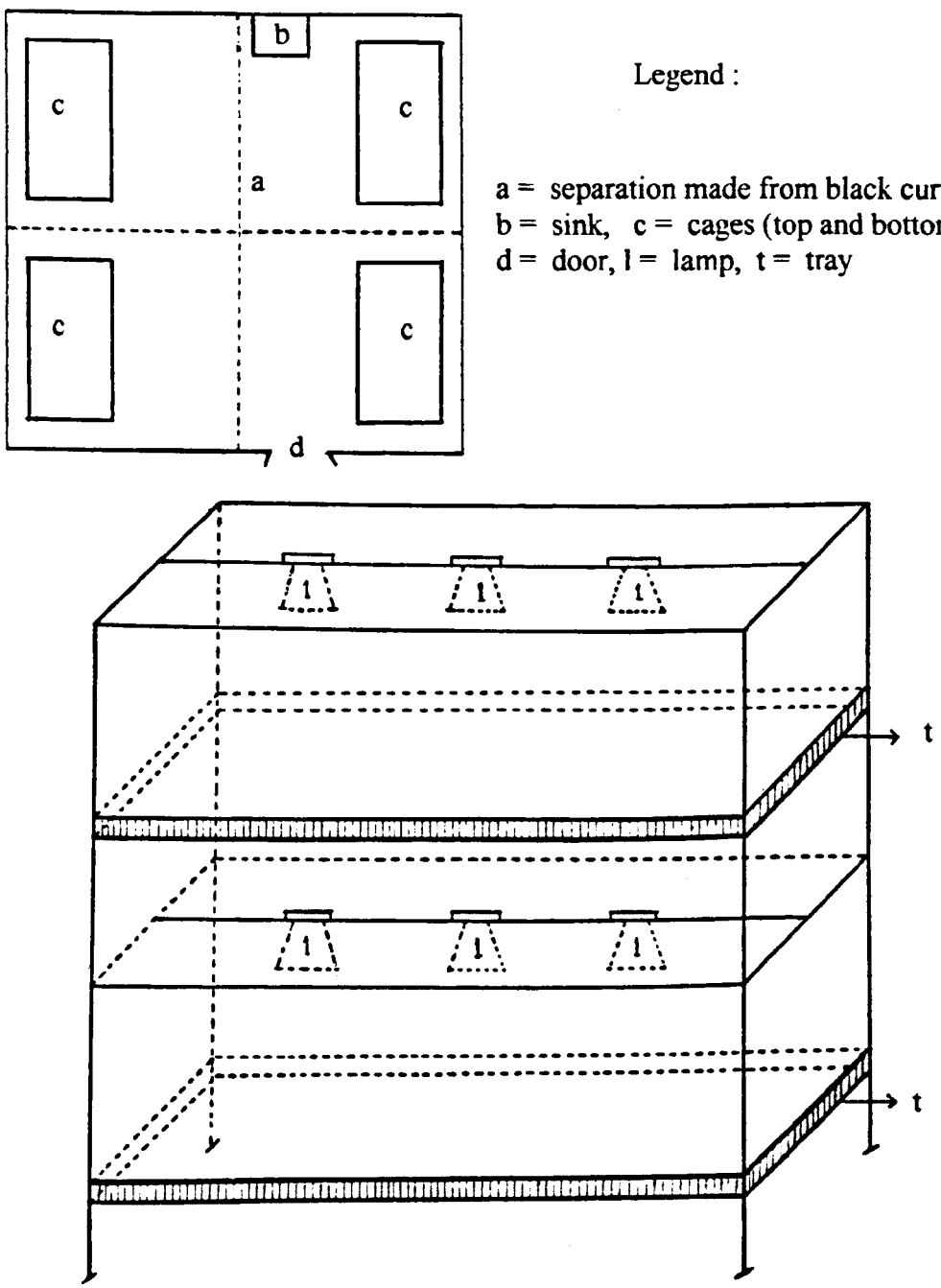


Figure 3.1. Plan of the chicken room and cage construction

The chicks were fed *ad lib* throughout. From one to 14 day-old chicks were fed with broiler starter crumbs, after which they were fed with 448 Gold Grow 15 pellet ACS from Dalgety Agriculture Ltd, 180 Aztec West, Almondsbury, Bristol, BS12 4TH (see Table 3.1). Fresh, clean water was made available to the chicks at all times.

Table 3.1 The composition of feeds used in this study

Composition	Starter	Grower
oil (%)	6	4.5
protein (%)	23	15.0
fibre (%)	3	5.25
ash (%)	5	8
ME (Mj/kg)	12.6	10.4
vitamin A (iu/kg)	8000	10,045
vitamin D3 (iu/kg)	3600	2700
vitamin E-alpha tocopherol (iu/kg)	35	30
sodium selenite-selenium (mg/kg)	0.3	0.2
sodium molybdate-molybdenum (mg/kg)	2	-
cupric sulphate-copper (mg/kg)	25	15
methionine (%)	-	0.22
acid insoluble (%)	-	1.6

Source : Dalgety Agriculture Ltd.

3.3.2. Experimental treatments and rearing procedure

Three 40 Watt tungsten light bulbs were installed at the top of each cage connected via variable resistors (dimmer switches) to the mains electricity. The different colours of light were produced through light filters mounted on a wire frame (LEE Filters Ltd., England); numbers 120, 106, and 139 for deep blue, primary red, and primary green respectively. There were chosen for the limited range of the spectrum that they allowed to be transmited and for the greatest distinction between peak wavelengths between the three filters. Y, light transmission was 1.26, 9.32 and 14.97% for blue, red and green respectively. The wavelengths of the lights ranged

from 350 to 500, 450-500, and 550 and above for blue, green and red respectively. Their peak wavelengths were 450, 550 and 650 for blue, green and red respectively (Figure3.2).

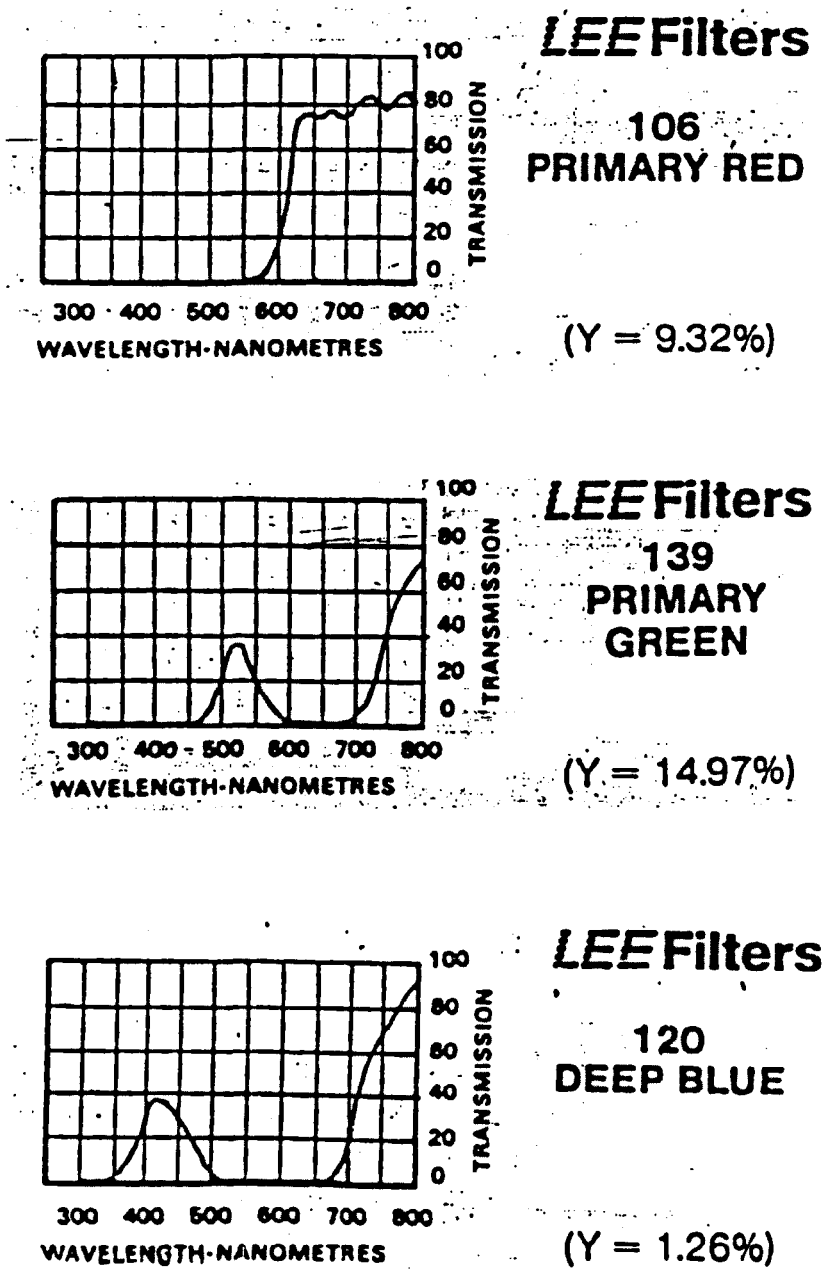


Figure 3.2 The graphs of transmission in each colour

The same intensity of 30 lux was used in blue green , red and white light. The mean light illuminance was measured from 15 points at 20cm above the floor of each cage using photometer model R102, Macam Photometric Ltd., Livingston, UK with a spectral sensitivity of between 420 and 700 nm at an average intensity of 30 lux, as shown in figure 3.3.

One day old Ross broiler chicks were first reared in a chicken room with an area of 20 square metres. This room is equipped with gas fired hot air central heating enabling a temperature of 29^0 C to be maintained for the first 7 days following the chicks' arrival. The room temperature was recorded daily at 08.00 and 16.00 using a thermometer. The brooding and growing temperatures applied were as recommended in the Farm Electric Handbook (1990)

Eighty chicks, 40 females and 40 males, were selected from one hundred initially purchased and were randomly divided into the four treatments of different coloured lights in the 4 cage rooms. The photoperiod used was 23 h of light and one hour of darkness between 14.00 and 15.00 (23L : 1D).

The experiment was started when the chicks reached 7 days old. Firstly, they were weighed and grouped to minimise body weight variation. The initial male body weight ranged from 172 - 205 g whilst the female ranged from 168 to 200 g. In each group of the same sex, 4 chicks were randomly selected and placed in cages with white, red, green and blue light. This was done 10 times so that each cage contained 10 animals consisting of 5 males and 5 females of similar weight.

During the course of the experiment, the chickens were individually weighed weekly, and temperature and food were continuously recorded daily.

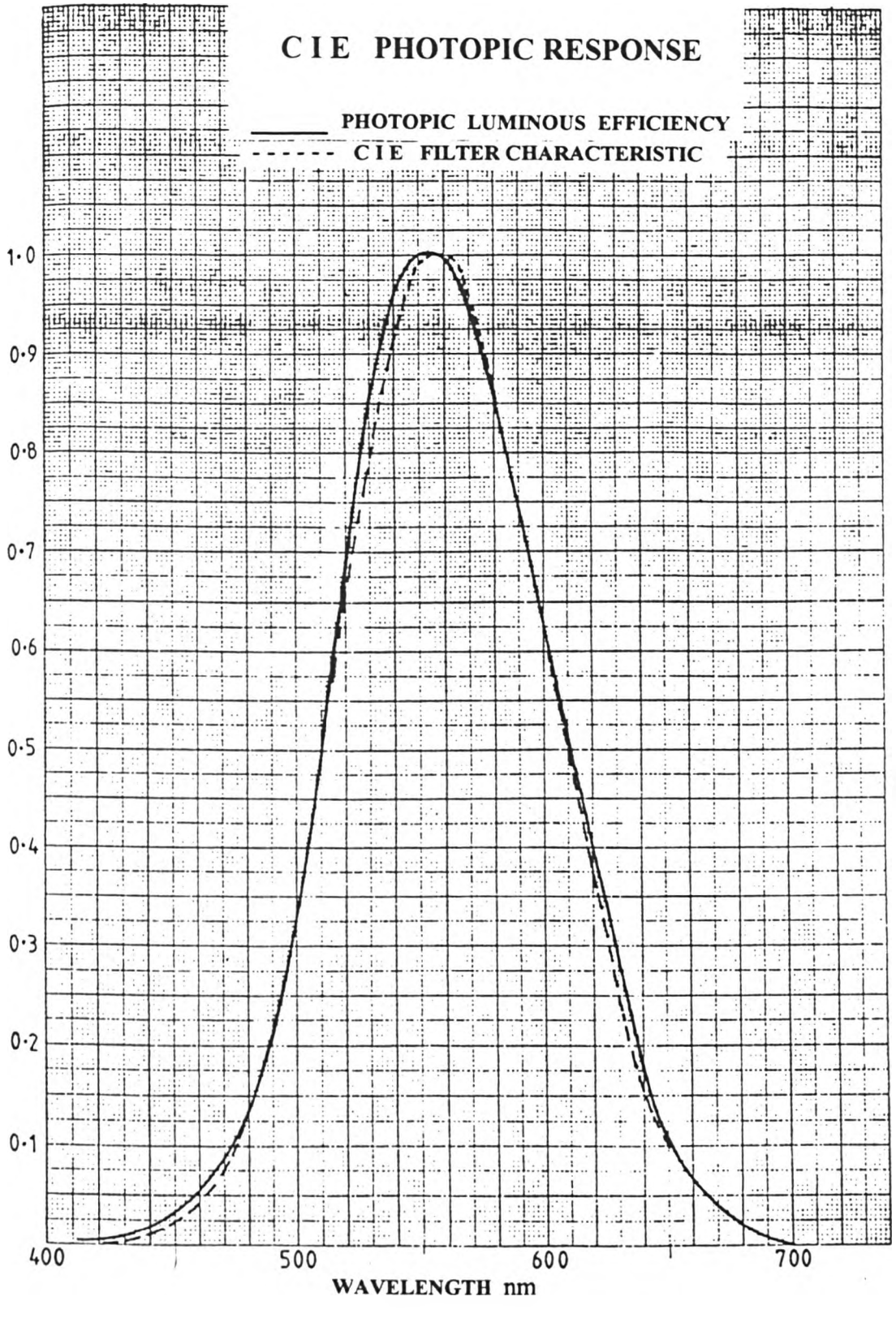


Figure 3.3 Spectral sensitivity curve of photometer

3.3.3. Performance parameters

3.3.3.1 Determination of the body composition

At the end of the experiment half of the birds in each treatment were slaughtered by the neck dislocation method (without bleeding). They were then cut into small pieces, homogenised in a food blender, and then labelled. Samples of known weight were dried in a hot-air oven at 90^0 C for 6 days. The dried samples were ground in a milling machine for fat, protein and ash content analysis.

3.3.3.2 Fat content

Two grams of each dried sample were placed in an extraction thimble. The samples were then extracted in a soxhlet extractor using petroleum ether of boiling range 40-60^0 C for six hours. At the end of the process, the petrol was evaporated from the extract; then the flask containing residual fat was dried in an oven at 100-105^0 C for approximately 1 hour. The percentage of crude fat was calculated as in the equation below :

$$\% \text{ crude fat} = \frac{\text{weight of crude fat}}{\text{weight of sample used}} \times 100\%$$

3.3.3.3 Ash content

Ash content was determined in a muffle furnace. A known weight of each sample was placed in porcelain crucibles. These were ignited in the Muffle furnace at 500^{0}C for 6 hours starting from cold. Ignition continued until all the carbon had been removed. The residues after ignition were taken to represent the inorganic components (minerals) in the chick bodies. The percentage of ash was calculated from :

$$\% \text{ ash} = \frac{\text{weight of ash}}{\text{weight of sample used}} \times 100\%$$

3.3.3.4 Protein content

Protein content was determined by the Kjeldahl method . One and a half grams of sample on small polythene sheets was placed in small tubes (in duplicate) and digested in the Kjeldahl digestion unit by adding 10 ml sulphuric acid and 1 tablet of Kjeltab or catalyst tablets (sodium sulphate containing 0.2% selenium or 0.4% SeO_2 and $CuSO_4$ $5H_20$) for 1.5-2.0 hours until the tube content cleared to a green colour. The solution was allowed to cool, then it was processed in the Kjeltec Auto Machine (1030 Analyser, Tecator) according to the manufacturer's manual. The percentage of crude protein was shown automatically by the machine.

3.3.3.5 Dead weight

The chickens were weighed after being slaughtered. First, the feathers were removed and weighed. Their was followed by the head, shank, crop and neck respectively. After that the intestines along with other internal organs were removed. The head, shank, intestines, liver, crop, gizzard and lungs were weighed together. They represented the giblets. The crop and the gizzard were then separated from the rest of the internal organs and weighed before and after removing their contents. Thus, it was possible to know the weights of the empty crop and gizzard and their contents.

The remains of the chick were subsequently divided into 2 equal halves (although the keel of the breast bone was always attached to the right half). The left half was weighed before being dissected into skin, muscle, bone and fat. As the sex of each chicken was noted and there were equal numbers of males and females in each treatment, sex was also taken into account to compare males and females.

3.3.4. Behavioural Parameters

The behaviour of the test birds was observed according to the procedures of Kruyt (1964); Blockhuis (1984a,b), and Coenen *et al.* (1988) with some modification. The behavioural parameters were divided into two types, main and incident behaviours.

The main behaviours observed were classified time spent feeding, standing, sitting, dozing, and sleeping. Dozing is a state where the chicken is sitting, the neck is withdrawn, the head is motionless and sometimes dropped, and the eyes are closed or are slowly opened and closed. Sleeping is the same as dozing but the eyes are totally closed while the head is recumbant. The incident behaviours included the occurrence of walking, drinking, pecking at the floor, wing stretching or aggression (fighting) by each bird during a certain period of time.

The behavioural data were collected manually (Figure 3.4). The main behaviours were collected every 5 minutes whilst the incident behaviours were recorded within 5 minute periods. These were recorded for 90 minutes per treatment per day for 16 days observation, hence each treatment produced 23 hours of behavioural data to be analysed which covered all the hours of the day except the one hour of darkness.

MAIN BEHAVIOUR

No.	5	10	15	20	25	30	35	40	45	50	55	60
T-1												
O 2												
P 3												
4												
5												
6												
7												
8												
9												
10												
B-1												
O 2												
T 3												
T 4												
O 5												
M 6												
7												
8												
9												
10												

INCIDENT BEHAVIOUR

No.	5	10	15	20	25	30	35	40	45	50	55	60
T-1												
O 2												
P 3												
4												
5												
6												
7												
8												
9												
10												
B-1												
O 2												
T 3												
T 4												
O 5												
M 6												
7												
8												
9												
10												

Figure 3.4 Behavioural record chart

3.3.5 Experimental design and statistical analysis

The experiment was designed using a Completely randomised design (Steel and Torrie, 1986). It was divided into two blocks of cages (top and bottom cages). The treatments were 4 colour of lighting and sex (male and female). Five replications were applied for each sex in each treatment. The significance of differences caused by treatment was examined by analysis of variance (ANOVA) using General Linear Model and Pearson coefficient correlation through the statistical package Minitab. The standard error difference (SED) was used to test the differences between treatment means and was calculated as follows :

$$SED = \sqrt{\frac{2s^2}{n}}$$, where s^2 denotes means square from ANOVA, and n denotes number of replications per treatment

3.4 RESULTS

3.4.1 Temperature

The average room temperature during the course of the experiment in comparison to the recommended temperatures is presented in table 3.2. In the pre-treatment the room temperatures were maintained between 28 and 30.5°C whilst during the experiment the temperature was from 23.0 to 26.5°C. In the four rooms (white, red, green and blue), the air temperatures throughout the experiment were very similar. From table 3.2 it can be seen that the bottom cages tended to be one degree colder than the top cages.

Table 3.2 Average room temperature during the course of the experiment*

Age of the chicks (days)	Recommended room temp. (°C)**	Recorded room temp (°C)							
		White		Red		Green		Blue	
		Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
1 and 2	32	30.5							
3 and 4	31	29							
5 and 6	30	28							
7 and 8	29	28							
9 and 10	28	26	24.5	25	24	25.5	24.5	26.5	24.5
11 and 12	27	25	23.5	24.5	23.5	25.5	23.5	25.5	24.5
13 and 14	26	24	23	23.5	23.5	24.5	23.5	26.5	25
15 and 16	25	25	24	24	23.5	24	22.5	26	25
17 and 18	24	24	23	23.5	23	23.5	23	25	24
19 and 20	23	24	23	24	24	23.5	23	25.5	25
21 and 22	22	23.5	23	24.5	24.5	25	24	25	24
23 and 24	21	24	23	22.5	23	24	23	24.5	24
25 and 26	21	23	22.5	23	23	23.5	23	25	24.5
27 and 28	21	23.5	23	23.5	24	24	23.5	24.5	24

* number means of duplicate; * * **source**, Farm Electric Handbook (May, 1990)

3.4.2 The performance of broilers reared in different colours of lighting

The growth in terms of body weight gain of broilers reared under white, red, green and blue light did not show any significant difference throughout the rearing period ($p>0.05$) (Table3.3a). Similar results were also gained for feed consumption, feed conversion ratio and carcass composition.

Table 3.3a The body weight (BW), cumulative feed consumption (FC), feed conversion ratio (FCR), carcass composition and the mean weight of body components of broilers reared under different coloured lights at 28 days of age

Parameters	Colour of lighting				SED	PROB
	white	red	green	blue		
BW (g)	1202	1183	1195	1224	29.1	0.58
FC (g)	2202	2123	2153	2219		
FCR	1.83	1.79	1.80	1.81		
Carcass composition						
Protein (%)	44.8.	44.9	44.6	44.8	1.02	0.99
Fat (%)	43.2	43.9	42.4	42.1	1.70	0.74
Ash (%)	7.4	7.5	7.6	7.7	0.29	0.73
Body components (g)						
Dead weight	1168	1181	1142	1221	30.44	0.17
Giblets	288.33	269.23	284.09	282.2	14.01	0.57
Feathers	51.93	59.49	52.41	63.09	4.61	0.06
Empty crop & gizzard	28.8	31.17	35.7	33.28	2.46	0.11
Full crop & gizzard	44.14	43.08	57.32	67.78	9.51	0.05
Gut contents	15.34	11.91	21.62	34.50	6.37	0.01
Neck	33.74	33.52	31.38	33.58	1.28	0.29
Left half	400.35	405.78	391.49	421.84	14.99	0.28
Skin	57.99	58.92	62.78	66.03	3.72	0.02
Muscle	215.97	217.7	206.23	215.06	9.07	0.60
Bone	73.74	73.67	78.60	82.78	3.96	0.09
Fat	46.60	46.74	40.88	49.89	5.88	0.51

Table 3.3b The precentage of body components of broilers reared under different coloured light at 28 days of age (%)

Parameters	Colour of lighting				SED	PROB
	white	red	green	blue		
Dead weight (g)	1168	1181	1142	1221	30.44	0.17
Giblets	24.68	22.80	24.88	23.11	0.54	0.71
Feathers	4.45	5.04	4.59	5.17	0.37	0.08
Empty crop and gizzard	2.47	2.64	3.13	2.73	0.41	0.87
Full crop and gizzard	3.78	3.65	5.02	5.55	0.17	0.02
Gut contents	1.31	1.01	1.89	2.82	0.21	0.00
Neck	2.89	2.84	2.75	2.75	0.12	0.21
Left half (g)	400.35	405.78	391.49	421.84	14.99	0.28
Skin	14.48	14.52	16.04	16.37	0.14	0.05
Muscle	53.94	53.65	52.68	51.02	0.63	0.43
Bone	18.42	18.15	20.08	20.20	0.16	0.02
Fat	11.64	11.12	10.44	11.63	0.43	0.54

The results showed that different colours of light (white, red, green and blue) generally did not have any effect on many body components of the chickens. The treatment only affected the weights of the skin, full crop+gizzard and gut contents $P<0.05$.

Broilers reared under blue or green light had significantly more skin and gut contents compared to broilers reared under white and red lights (Table3.3a and 3.3b). Broilers reared under white, red, green and blue lights did not significantly differ from each other in their muscle and fat content. However, the heaviest dead body weight, feather and bone tended to occur in birds under blue light.

The sex of the birds significantly affected body weight, fat, ash and most of the body components (Table3.4). The male bird has a higher body weight, ash and protein contents and most of its body components are heavier compared to the female. However, the male had a significantly lower fat content compared to the female. There were no significant differences in feather, empty crop + gizzard and fat weight caused by sex differences.

There were no interactions between sex and colour of light on the whole broiler performance (Table3.4).

3.4.3 The behaviour of broilers reared in different colours of lighting

Feeding time was not affected by colour (although there was an interaction between colour and sex in Table 3.6), but the incidence of aggression, wing stretching and pecking at the floor were all greatest for birds in the red light and least for birds in blue or green light, with birds in the white light intermediate. There was no significant difference in the time spent standing, but the time spent sitting, dozing and sleeping were greatest for the chickens reared under green, blue and red light respectively (Table 3.5). The birds reared in green light had the lowest incidence of walking followed by blue, white and red respectively.

There were significant interactions in terms of the time spent on feeding and drinking for both male and female broilers reared in white, red, green and blue light (Table3.6). The male birds had most drinks in the blue light but the female birds had most drinks in the white light. Male birds in green and blue lights spent more time feeding than those in white and red, with the opposite being true for the female birds.

Table 3.4. Body weight, carcass composition and body components of male and female broilers reared under different colours of lighting

	Male				Female				Colour		Sex		Interaction	
Parameters	**White**	**Red**	**Green**	**Blue**	**White**	**Red**	**Green**	**Blue**	**SED**	**PROB**	**SED**	**PROB**	**SED**	**PROB**
Body weight (g)	1227	1240	1268	1314	1136	1126	1122	1133	29.10	0.58	20.58	0.00	41.16	0.71
Carcass composition														
Protein (%)	45.20	45.39	44.79	56.51	44.34	44.33	44.42	43.12	1.02	0.99	0.72	0.06	1.44	0.50
Fat (%)	42.28	42.02	40.26	37.94	44.17	45.66	44.57	46.21	1.70	0.74	1.20	0.00	2.41	0.34
Ash (%)	7.61	7.77	7.68	8.29	7.16	7.30	7.58	7.12	0.29	0.72	0.20	0.01	0.41	0.36
Body components (g)														
Giblets	303.38	283.02	296.21	294.09	273.28	255.44	271.97	270.31	14.01	0.57	9.91	0.00	19.82	0.48
Feathers	52.94	60.05	52.96	63.19	50.92	58.93	51.86	62.99	4.61	0.06	3.26	0.20	6.52	0.87
Empty crop & gizzards	29.66	31.48	36.27	33.59	27.94	30.86	35.13	32.97	2.46	0.11	1.74	0.08	3.48	0.87
Full crop & gizzards	44.52	43.23	57.69	68.38	43.76	42.93	56.95	67.18	9.51	0.05	6.72	0.27	13.45	0.82
Gut contents	17.57	13.95	24.90	38.92	13.11	9.87	18.34	30.08	6.37	0.01	4.89	0.00	9.17	0.46
Neck	35.94	35.73	33.57	35.87	31.54	31.31	29.19	31.29	1.28	0.29	0.90	0.00	1.81	0.13
Left half	429.44	433.38	422.95	453.36	371.26	378.18	360.03	390.32	14.99	0.28	10.60	0.00	21.20	0.65
Skin	61.51	62.22	66.60	69.68	54.47	55.62	58.96	62.38	3.72	0.02	2.62	0.01	5.26	0.27
Muscle	240.96	242.63	223.11	239.99	190.98	192.77	189.35	190.13	9.07	0.60	6.41	0.00	12.83	0.39
Bone	76.57	77.05	81.78	85.53	70.91	70.29	75.42	80.03	3.96	0.10	2.80	0.01	5.59	0.97
Fat	46.87	47.50	39.91	50.84	46.33	45.90	41.85	48.94	5.88	0.51	4.16	0.82	8.32	0.38

Table 3.5 The time spent by broilers under different light colours in major behaviours

Behavioural parameters	Light colour				SED	PROB
	White	Red	Green	Blue		
Feeding (min/h)	13.54	12.66	13.08	12.98	0.37	0.13
Standing (min/h)	8.14	7.87	8.40	8.58	0.35	0.21
Sitting (min/h)	11.46	11.34	13.84	11.18	0.40	0.00
Dozing (min/h)	15.86	14.45	14.41	16.71	0.40	0.00
Sleeping (min/h)	13.01	13.72	10.31	10.59	0.32	0.00
Walking (no/bird/h)	1.18	1.04	0.83	1.03	0.05	0.00
Drinking (no/bird/h)	1.11	0.93	1.02	1.09	0.05	0.00
Pecking at floor (no/bird/h)	0.69	0.91	0.66	0.61	0.05	0.00
Wing stretching (no/b/h)	0.46	0.69	0.42	0.35	0.04	0.00
Aggressive interaction (no/b/h)	0.05	0.07	0.00	0.04	0.01	0.00

A correlation matrix with main and incidence behaviour shows that increases in the walking, drinking, stretching and aggression behaviours are positively correlated with feeding (Table3.7). Pecking at the floor also had a positive correlation with sitting. There was a negative correlation among the main behaviour parameters (feeding, standing, sitting, dozing and sleeping). There was a negative correlation between sleeping and feeding, walking, drinking or pecking at the floor.

3.5 DISCUSSION

Different colours of lighting at equal intensity (30 lux) as measured by the photometer did not significantly affect the growth, feed conversion ratio, food consumption, and carcass composition of broilers up to 4 weeks age. These results are in good agreement with previous studies conducted by Kondra (1961), Smith and Phillips (1959), Schumaier *et al.* (1968), Peterson and Espenshade (1971), and Wathes *et al.* (1982) who reported that the growth of broilers, turkeys, laying hens and chicks

Table 3.6. The behaviour of male and female broilers reared under White, Red, Green and Blue lights

Behavioural Parameters	Male				Female				Colour		Sex		Interaction	
	White	Red	Green	Blue	White	Red	Green	Blue	SED	PROB	SED	PROB	SED	PROB
Feeding (min/h)	13.07	12.04	13.72	13.67	14.02	13.28	12.44	12.28	0.37	0.13	0.26	0.66	0.53	0.00
Standing (min/h)	8.07	8.13	8.85	8.26	8.22	7.61	7.96	8.89	0.35	0.21	0.25	0.52	0.49	0.14
Sitting (min/h)	12.0	11.35	13.50	10.93	10.91	11.33	14.17	11.43	0.40	0.00	0.28	0.95	0.56	0.12
Dozing (min/h)	15.94	14.50	13.91	16.68	15.78	14.39	14.91	16.74	0.40	0.00	0.28	0.48	0.56	0.42
Sleeping (min/h)	10.96	14.02	10.11	10.50	11.07	13.41	10.52	10.67	0.32	0.00	0.23	0.92	0.46	0.43
Walking (no/b/h)	1.17	1.08	0.89	1.04	1.19	1.00	0.77	1.03	0.05	0.00	0.03	0.14	0.07	0.44
Drinking (no/b/h)	1.07	0.88	1.08	1.14	1.16	0.98	0.96	1.04	0.05	0.00	0.04	0.84	0.07	0.04
Pecking at the floor (no/b/h)	0.75	0.89	0.65	0.61	0.63	0.94	0.68	0.61	0.05	0.00	0.04	0.83	0.07	0.39
Wing stretching (no/b/h)	0.47	0.67	0.46	0.32	0.45	0.71	0.39	0.39	0.04	0.00	0.03	0.87	0.05	0.26
Aggressive inter-action (no/b/h)	0.06	0.09	0.00	0.04	0.05	0.06	0.00	0.03	0.01	0.00	0.00	0.23	0.02	0.59

no, numbers; b, birds; h, hour

Table 3.7 Correlation matrix between main behaviour and incident behaviour of broilers after being reared under different coloured light

	Feeding	Standing	Sitting	Dozing	Sleeping	Walking	Drinking	Pecking	Aggression
Standing	**- 0.253**								
Sitting	**- 0.260**	**- 0.227**							
Dozing	**- 0.228**	**- 0.233**	**- 0.268**						
Sleeping	**- 0.325**	**- 0.236**	**- 0.332**	**- 0.281**					
Walking	**0.145**	**0.187**	**- 0.109**	- 0.040	**- 0.111**				
Drinking	**0.184**	**0.188**	- 0.044	- 0.064	**- 0.179**	**0.094**			
Pecking	0.024	0.015	**0.098**	- 0.047	**- 0.082**	0.044	0.027		
Stretching	**0.076**	0.024	- 0.038	0.002	- 0.047	**0.082**	- 0.013	**0.084**	
Aggression	0.085	0.045	- 0.014	- 0.049	- 0.046	**0.121**	- 0.009	0.056	0.045

Bold numbers indicate significance by table of correlation coefficients at 5%
and degrees of freedom > 1000 { $T_{(>1000),5\%}$}-----> = 0.062 (Snedecor and Cochran, 1967).
The results of this correlation matrix should be considered with caution as it was performed on all birds **at all time periods**

were unaffected by the wavelength and spectral composition of light. In contrast, Woodard *et al.* (1969) and Foss *et al.* (1972) found that the growth of male Japanese quails and adult broilers respectively were significantly affected by the colour of light. Male Japanese quails grew better in red light compared to white, green and blue (Woodard *et al.*, 1969), whilst male broilers grew faster in green light compared to blue, red, and white light (Foss *et al.*, 1972). However, the combs and testes were heavier for broilers cultured in red and white light. Small differences in growth might be expected from the recorded differences in activity levels between treatments, but these would not be detectable with the numbers used in this experiment.

Broilers reared under blue light were less active compared to broilers under green and red lights. Similar trend highest in food consumption were reflected in the food conversion ratio. These results are in contrast to Lauber and McGinnis (1965), Woodard *et al.* (1969), and Foss *et al.* (1972) who stated that adult male broilers, Japanese quails, and laying hens reared under monochromatic red light tended to consume more food than in green, blue or white light. The high food consumption of birds in the blue light coupled with low forms of exercise such as walking, pecking of non-specific items, wing stretching, and aggressive interaction, might be the reason why they had significantly heavier crop and gizzard contents than other treatments.

Concerning the fat contents in both carcase composition and body components, there was a contradictory result, since fat in the carcase composition was affected by sex but it did not show in the body components. The difference might be due to the physical handling of the fat from the body component. It was very difficult to separate fat physically, since fat is situated in many parts of the chicken's bodies. There is intermuscular fat and fat situated in the skin. In fact there is more fat in the skin of a chicken than anywhere else and it is very difficult to separate the fat in the skin.

Different colours of lighting did not affect the overall body weight gains of broilers; however, they significantly affected some of the broilers' body components such as gut contents and skin. Although the mechanism is still unclear, this is the first demonstration of the effect of the colour of lighting on the body components of broilers. Broilers reared in red light have the lowest gut contents compared with broilers reared under white, green and blue light. Probably this is because of increased activity. The lightest body weight of birds under red light was in harmony with the findings of Wabeck and Skoglund (1974), but the fact that the heaviest birds were produced under blue light was in contrast with Foss *et al.* (1972) who stated that the chick growth was significantly stimulated by green light. Otherwise, the production of the heaviest birds under blue light is in good agreement with Wabeck and Skoglund (1974). The heaviest skin and feathers occurred in birds under blue light, followed by green, red and white. This may have been due to skin thickening caused by a constant friction against cage floor. This is not, however, reflected in the body fat content percentage, and further research is required.

Birds reared in red light were more active than birds reared in blue and green light. This effect may be due to the better visual sensitivity of chickens in red light, compared with the blue end of the visible spectrum; as a result of which the red light appears brighter. This result is in good agreement with Bowlby (1957) who stated that red light made the feed more attractive and significantly reduced cannibalism whilst birds reared under white light were more excitable, and birds under blue light were blind. This might be the reason why broilers reared under blue light are less active compared to other birds and the birds in blue might use their sense of taste more than their eyes to find the food. The greater sleeping time of birds in red light is of uncertain origin. Sleeping and activity are *negatively* correlated across treatments, so greater activity does not appear to be the cause. However, it should be noted that main behaviours are inherently inversely correlated ie. animals that sleep for longer spend

less time in active behaviours. This is a genetic influence. It is still possible that a treatment (environmental influence) that increases activity could increase sleep to compensate.

The ability of chickens to differentiate colours in the early studies have been the subject of controversy. Lashley (1916) stated that fowls were able to distinguish two colours regardless of the brightness of the stimuli, whilst Hamilton and Coleman (1933), cited by Bell and Freeman (1971), further stated that intensity has little effect on colour discrimination. The role of oil droplets in chickens' colour vision is still in controversial (Bell and Freeman, 1971). It is known that rod receptors serve for dim light reception whilst the cones serve for bright light (Sturkie, 1986); however, the mechanism by which the chicken's eye perception of different colours of lighting affects their behaviour is still unclear. A further study concerning the ability of chickens to distinguish between colour and apparent brightness on their behaviour and performance will be discussed in chapter VI.

3.6 CONCLUSION

In conclusion, broilers reared under different colours of lighting exhibited similar growth but more skin compared to broilers reared under white light. The heaviest gut contents were found in birds under blue light and the lightest were under red light.

The birds are more active in red and less active in blue and green light. Birds in white light were in between red and blue or green. The greater activity occurred under red light, while birds in the blue or green light seemed more inclined to sit passively and doze.

Chapter IV

Experiment 1. Part 2

THE INITIAL AND LONGTERM PREFERENCE OF BROILERS FOR RED, BLUE OR GREEN LIGHT AFTER BEING REARED IN RED, BLUE, GREEN OR WHITE LIGHT

4.1 ABSTRACT

Forty female and forty male Ross broiler chicks were group-reared in cages with white (W), red (R), green (G) or blue (B) lights at 30 lux from one to four weeks of age. In the fifth week one half of the birds in each treatment were given the choice of pens with red, blue or green lights and their preference monitored for the first three hours and for 24h after one week had elapsed. In the first three hours G and B birds preferred their original colour, spending there 47 and 32 min/h respectively; R birds preferred blue (39 min/h) and W birds preferred red (47 min/h) (SED 3.9, P=0). These preferences increased significantly from the first to the third hour. Sex did not affect the preference (P=1.0). After one week the preferences had changed and W, R and G birds all preferred the blue, spending there 47, 41 and 37 min/h respectively, with green as the second choice, spending there 8, 10 and 14 min/h respectively (SED 1.3, P=0). B birds preferred the green (35 min/h) then the blue (18 min/h). On average females spent 2.7 min/h longer in the preferred colour (P=0), and males were significantly more likely to prefer green (18 vs. 16 min/h) and less likely to prefer blue (37 vs. 34 min/h) than females (SED 0.96, P=0.002). Even though there was no significant difference in the body weight gain due to changing light ($P > 0.05$), there was a positive correlation between initial body weight and final body weight due to the treatment in W, G, and B birds but not in R birds (0.85, 0.98, 0.95 and 0.58 respectively, P=0.05). It is concluded that both male and female broilers show the greatest longterm preference for blue light, followed by green light, although their initial preference after a neutral colour is for red light. Birds reared in a coloured light show an initial preference to remain in that light but after one week they prefer a change to a different colour.

4.2 INTRODUCTION

Most birds, both domestic chicks and adult chickens, belong to the group of animals which have a relatively well developed mechanism for visual perception and discrimination (Hurnick *et al.*, 1971). Furthermore, this ability extends to a differentiation between certain areas of the colour spectrum. According to Bell and Freeman (1971) fowl can more easily be trained to distinguish colours than to distinguish light intensity.

Smith and Phillips (1959) suspended fixtures containing red, orange, green and yellow neon tubes over feeders in one pen and showed greater feed consumption under green light. However, no differences in feed consumption occurred when the colours were placed in separate pens. Hurnick *et al.* (1971) used four hundred white Leghorn laying hens to preference test for the colour of feeders and the colour of the feed using blue, green, yellow and red. Both the variables and interactions of feed colour and feeder colour revealed significant effects on feed consumption. The most preferred colour of feeder was red and for the feed it was blue, while the least preferred colour of feeder was yellow and for the feed it was red.

The present study was designed to investigate whether a response in the initial and longterm preference of broilers could be observed in different coloured lights (red, blue and green) after the birds had been reared in red, blue, green and white light.

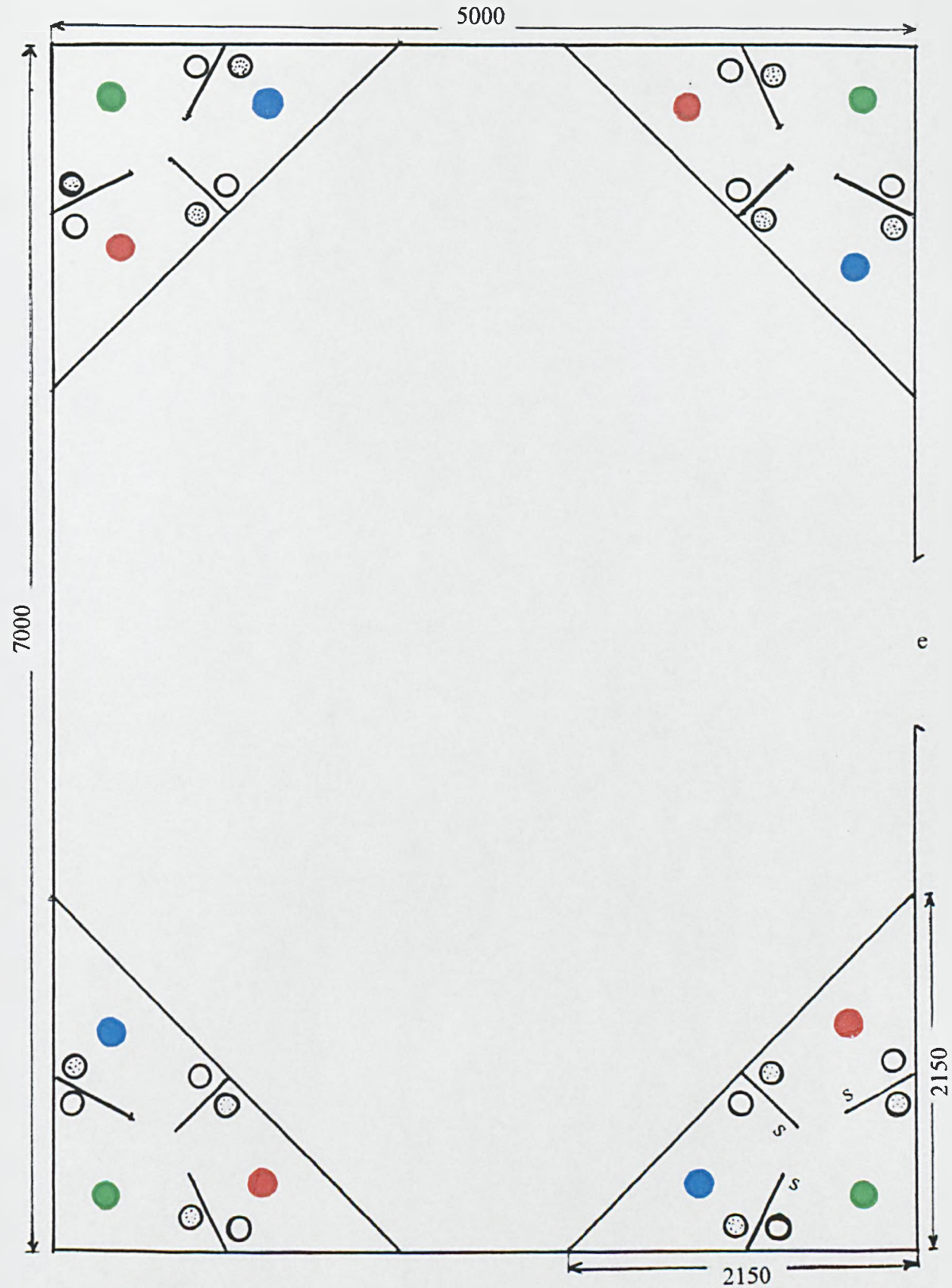
4.3 MATERIALS AND METHODS

4.3.1 Experimental animal housing and management

Forty female and forty male Ross broiler chicks were group-reared in cages with white (W), red (R), green (G) or blue (B) light at 30 lux (see Chapter III) from one to four weeks of age (Experiment 1 part 1). In the fifth week one half of the birds in each treatment were given the choice of pens with red, blue or green lights, using the same standard filters.

All the pens were placed in a room measuring 5m x 7m x 2.5m. The pens were made from hardboard shaped into equilateral triangles with about 2m-long sides which had a red, green or blue light hung at 60cm from the floor in each corner. Sawdust litter was used on the floor and changed twice a week . In order to give a space to the birds and to avoid interference between the coloured lights, separation boards were fitted in the middle of each side. In each corner a 30cm diameter drinker and a feeder were placed (Figure 4.1). Distances between the objects in the experimental pens of triangle were as follows ; lamp-corner : 75cm, lamp-drinker : 40cm, feeder-lamp : 40cm, lamp-pen centre : 75cm, feeder-drinker : 75cm, width of separation board : 50cm, separation board-separation board : 45cm, length of pen : 2.15cm, pen height : 120cm. Each pen contained 10 birds, 5 females and 5 males.

The birds were reared on a standard commercial *ad lib* diet of 448 Gold Grow Pellet ACS as used in experiment 1 part 1. The composition of the chicken diet is described in Table 3.1. The room temperature and humidity during the running of the experiment were recorded using a thermograph and a hygrograph. The photoperiod was 24L . All experimental birds remained in choice test area.



Note : = red, blue and green light respectively
s = separation, e = entrance, = drinker, = feeder

(all dimensions in mm)

Figure 4.1 Lay out of the chicken room

4.3.2 Experimental treatment and rearing procedure

Three 40 watt tungsten light bulbs (one bulb in each corner of the pen) were installed at 60cm over the floor in each triangular pen. The different colours of light were produced from the holder through light filters (LEE Filters Ltd., England); using number 120, 106 and 139 for deep blue, primary red and primary green respectively. Y, the light transmission was 1.26, 9.32 and 14.97% for blue, red and green respectively. The wavelength of the lights ranged from 350 to 500, 450 to 500 and 550 and above for blue, green and red respectively. Their peak wavelengths were 450, 550 and 650 for blue, green and red respectively (the same graphs as experiment 1 part 1). In the treatment was offering the red, green and blue lights were placed in each corner of the pens.

The same intensity of 30 lux was used in the blue, green and red lights as in experiment 1 part 1. The mean light illuminance was measured from 5 points at 25cm above the floor using photometer model R 102, Macam Photometric Ltd., Livingston, UK, with a spectral sensitivity of between 420 and 700nm at an intensity of 30 lux (the spectral sensitivity curve of the meter appeared in experiment 1 part 1). In order to achieve continuity and whilst preparing for further choice treatment, when the birds were transferred into the triangular pens they still received their previous colour of light for 5 days.

Starting with the pen containing of birds that had been reared in white light (W birds), the effects of the treatment were monitored by time lapse video for the first three hours after changing to the choice test. The video recording then continued in the pen of red reared birds (R birds), the pen of green reared birds (G birds) and the pen of blue reared birds (B birds). The video was hung on the ceiling above the centre of the pen at a 2.5m height from the floor. Afterwards, in the same way, video

recording was conducted for 24 hours after one week had elapsed. The schedule of video recording in each pen was therefore as follows :

Period 1 : the first three hours of treatment;

---------- : 3 hours recording in W bird pen

---------- : 3 hours recording in R bird pen

---------- : 3 hours recording in G bird pen

---------- : 3 hours recording in B bird pen

Period 2 : the 24 hours recording after one week had elapsed;

----------> : 24 hours recording in W bird pen

----------> : 24 hours recording in R bird pen

----------> : 24 hours recording in G bird pen

----------> : 24 hours recording in B bird pen

4.3.3 Parameters observed

4.3.3.1 Coloured light preference

The data were collected from the time-lapse video recording every 5 minutes for the first three hours and every 10 minutes for the 24 hours after one week had elapsed (Figure 4.2).

4.3.3.2 Body Weight Gain

The body weight was measured at the start and the end of the experiment to determine the effect of changing light on body weight gain.

Initial coloured light : **Date :** **Time :**

No.	5	10	15	20	25	30	35	40	45	50	55	60
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Initial coloured light : **Date :** **Time :**

No.	5	10	15	20	25	30	35	40	45	50	55	60
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Figure 4.2 Record chart of time spent by birds

4.3.4 Experimental design and statistical analysis

The experiment used a Randomised Block Design (Steel and Torrie, 1986). It was divided into four blocks of pens (W bird pen, R bird pen, G bird pen and B bird pen). The treatments used three colours of light (preference for red, green and blue) and both sexes (male and female). Five replications were applied for each sex in each treatment (the other half of the original birds being used for body composition analysis). The significance of differences caused by treatments was examined by analysis of variance (ANOVA) using GLM and the Pearson coefficient of correlation in the statistical package Minitab. The standard error of difference (SED) was used to test the differences between any two treatment means.

4.4 RESULTS

4.4.1 Temperature and Humidity

The average room temperature and humidity (Figure 4.3) during the course of experiment were 17 - 20^{0}C (mean =18.7^{0}C) and 71 - 97% (mean = 82.88%) respectively. Readings were taken from 26th May to 13rd June 1992. These conditions were similar to the recommendations used in commercial artificially controlled buildings (Farm Electric Handbook, 1990).

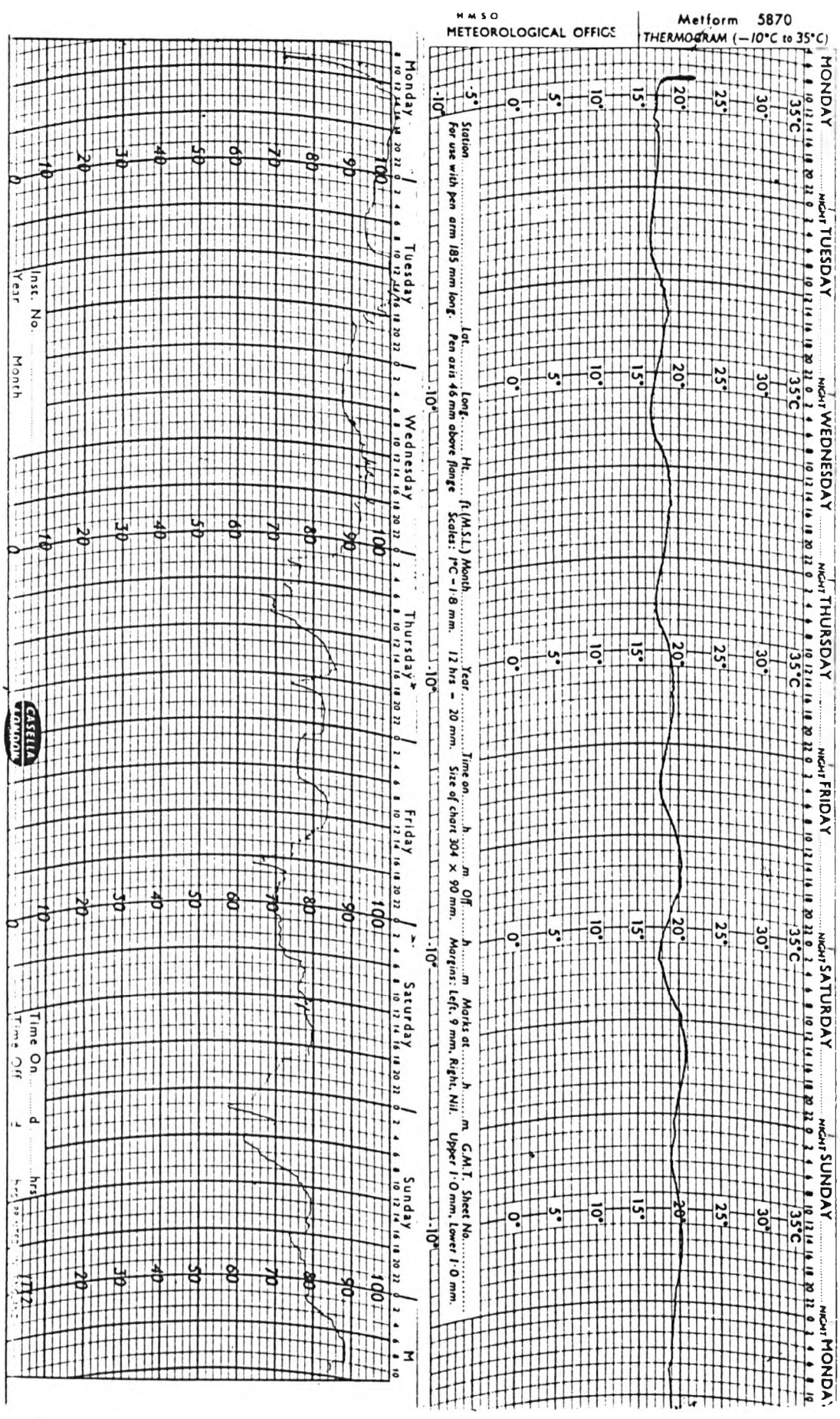


Figure 4.3 The graphs of daily room temperature and humidity

4.4.2 Coloured light preference in the first three hours of treatment

In the first three hours birds from green and blue lights preferred their original colour, spending 47 and 32 minutes/hour there respectively (Table 4.1), whereas 'red' birds preferred blue light (39 min/h) and 'white' birds preferred red (48 min/h). These preferences increased significantly from the first to the third hour (Table 4.2).

Table 4.1 Light preference of broilers in the first three hours post-treatment (min/hour)

Previous Colour	Time in each colour		
	Red	Green	Blue
Previous White	47.9	2.7	9.4
Previous Red	20.2	0.7	39.2
Previous Green	6.8	46.9	6.3
Previous Blue	19.5	8.3	32.3

Previous colour (Probability = 1.00 ; SED = 2.28)

Colour preference (Probability = 0.00 ; SED = 1.98)

Colour preference * previous colour (Probability = 0.00 ; SED = 3.95)

Table 4.2 Time spent in each colour in each of the first three hours of treatment (minutes/hour)

Hour	Red area occupation				Green area occupation				Blue area occupation			
	Previous				Previous				Previous			
	White	Red	Green	Blue	White	Red	Green	Blue	White	Red	Green	Blue
1	42.0	36.0	9.8	1.87	1.9	1.0	46.6	5.0	16.1	23.0	3.6	31.3
2	48.6	20.0	2.5	20.3	5.3	0.5	45.3	8.8	6.1	39.5	12.3	31.0
3	53.0	4.5	8.1	14.3	1.0	0.5	48.8	11.1	6.0	55.0	3.1	34.5

Time * previous colour (Probability = 1.00 ; SED = 3.95)
Time * colour preference (Probability = 0.06 ; SED = 3.42)
Time * previous colour * colour preference (Probability = 0.00 ; SED = 6.88)

There was no significant effect of sex on the preference (Table 4.3)

Table 4.3 The effect of previous light colour on the time spent in each colour by male and female birds in the first three hours of preference testing (minutes/hour)

Previous colour	Red area occupation		Green area occupation		Blue area occupation	
	Male	Female	Male	Female	Male	Female
Previous White	47.1	48.7	3.8	1.7	9.2	9.7
Previous Red	20.7	19.7	0.7	0.7	38.7	39.7
Previous Green	7.3	6.3	46.7	47.1	6.0	6.7
Previous Blue	17.9	21.0	7.9	8.7	34.2	30.3

Sex (Probability = 1.00 ; SED = 1.6)
Sex * previous colour (Probability = 1.00 ; SED = 3.23)
Sex * colour preference (Probability = 0.96 ; SED = 2.80)
Sex * previous colour * colour preference (Probability = 0.98 ; SED = 5.59)

4.4.3 Coloured light preference after one week had elapsed

After one week had elapsed, the preferences had changed significantly with all white, red and green reared birds preferring the blue light and spending 47, 41 and 37 minutes/hour there respectively. The green was their second choice, and they spent 8,10 and 14 minutes/hour there respectively. However, blue reared birds preferred green as their first choice (35 minutes/hour) and then blue as their second choice (18 minutes/hour)(Table 4.4). Female birds showed a significantly stronger preference for the blue than the males (Table 4.5).

Table 4.4 The light preference of broilers after one week of treatment (minutes/hour)

Previous	Time in each colour		
Colour	Red	Green	Blue
Previous White	5.4	7.6	47.1
Previous Red	8.9	9.9	41.3
Previous Green	8.5	14.9	36.7
Previous Blue	7.0	35.3	17.8

Previous colour (Probability = 1.00 ; SED = 0.79)
Colour preference (Probability = 0.00 ; SED = 0.68)
Previous colour * colour preference (Probability = 0.00 ; SED = 1.36)

Table 4.5 The effect of previous light colour on the time spent in each colour by male and female birds after one week of preference testing (minutes/hour)

Previous	Red area occupation		Green area occupation		Blue area occupation	
colour	Male	Female	Male	Female	Male	Female
Previous White	5.8	5.0	8.9	6.3	45.3	48.9
Previous Red	9.3	8.5	10.3	9.6	40.7	41.8
Previous Green	9.1	7.9	16.2	13.5	34.8	38.5
Previous Blue	6.9	7.2	36.5	34.1	16.7	18.8

Sex (Probability = 0.99 ; SED = 0.56)
Sex * previous colour (Probability = 1.00 ; SED = 1.11)
Sex * colour preference (Probability = 0.00 ; SED = 0.96)
Sex * previous colour * colour preference (Probability = 0.89 ; 1.93)

Table 4.6 shows the hourly preference of birds reared in the four colours of light. There was a tendency for the blue light to be preferred at night, suggesting that the birds were selecting a dimmer light. This of course would only be expected if the birds were entrained (in the egg) to a normal light dark pattern, because post hatching, the 23L:1D regime up to seven weeks gave 1h dark from 3 pm. Birds who had previously been exposed to the white treatment showed a greater tendency to prefer the blue light in the middle of the day, while birds who had been reared in green light showed little change of preference with the hour of the day.

4.4.4 The effect of changing light on body weight gain

Neither the initial colour of light nor the sex of the birds significantly affected the body weight gain (final body weight minus starting body weight) (Table 4.7). However, there was a significant interaction between the initial colour of light and the sex on body weight gain. The body weight gain of male birds after being reared in white and red light was greater than that of females, but after being reared in green and blue light, female birds were heavier than males.

Table 4.7 Effect of changing light on body weight gain of bird after being reared in different colour light and sex (gram/bird/49+ days)

Previous	Sex		Prev.colour		Sex		Interaction	
colour	Male	Female	P	SED	P	SED	P	SED
Previous White	1222.8	944.8						
Previous Red	1248.2	1189.3	0.26	73.31	0.90	51.84	0.02	103.6
Previous Green	1151.0	1270.0						
Previous Blue	1116.4	1307.0						

+ : Gain from 28 days to 49 days

Table 4.6 Time spent in each colour in each of the 24 hours by broilers after one week of treatments (minutes/hour)

Hour of the day	Red area occupation					Green area occupation					Blue area occupation				
	Previous					Previous					Previous				
	W	R	G	B	Mean	W	R	G	B	Mean	W	R	G	B	Mean
1	11	9	14	13	12	14	8	8	25	14	35	43	38	22	34
2	6	4	7	11	7	8	12	15	33	17	46	44	38	16	36
3	5	7	5	7	6	9	10	1	35	16	46	43	44	18	38
4	6	13	2	9	8	10	13	11	36	17	44	34	47	15	35
5	5	8	4	8	6	12	9	23	35	20	43	43	33	17	34
6	9	8	2	7	7	6	10	13	42	17	45	42	45	11	36
7	9	6	6	2	6	5	7	23	41	19	46	47	31	17	35
8	4	7	9	1	5	11	13	24	47	24	45	40	27	12	31
9	1	7	16	2	6	6	20	12	40	20	53	33	32	18	34
10	6	12	10	2	7	4	10	14	43	17	50	38	36	15	34
11	6	20	10	5	10	9	13	10	39	18	45	27	40	17	32
12	7	4	8	2	5	0	4	12	37	13	53	52	40	21	42
13	3	7	9	1	5	4	18	14	41	19	53	35	37	18	36
14	5	18	4	4	8	5	3	12	39	15	50	39	44	17	37
15	2	7	5	6	5	6	5	12	33	14	52	48	42	22	41
16	0	10	13	3	7	11	10	11	38	17	49	40	36	19	36
17	2	5	11	8	7	5	10	15	49	20	53	45	34	3	33
18	2	6	11	13	8	8	9	17	32	17	50	45	32	15	35
19	5	5	5	9	6	13	11	23	30	19	42	44	32	21	35
20	4	11	6	12	8	3	7	21	26	14	53	42	35	22	38
21	9	11	5	10	9	2	7	15	30	13	49	42	40	20	38
22	12	7	14	5	19	9	13	10	33	16	39	40	36	22	35
23	4	17	15	10	11	10	4	15	26	14	46	39	30	24	35
24	6	4	10	13	9	13	12	16	20	15	41	44	34	27	36

Note : W: white, R: red, G: green, B: blue

Time * previous colour (Probability = 1.00 ; SED = 3.85)

Time * colour preference(Probability = 0.02 ; SED = 3.34)

Time * previous colour * colour preference (Probability = 0.00 ; SED = 6.68)

There was a positive correlation between the initial body weight and final body weight due to the treatment in birds which had been reared in white, green and blue light. No correlation was observed between initial body weight and final body weight in birds that had been reared in red light ,with a probability of $P < 0.05$ (Table 4.8).

Table 4.8 The correlation of initial body weight and final body weight in birds after being reared in different coloured light due to the treatment

Initial colour	Correlation value
Previous white	0.845*
Previous red	0.582
Previous green	0.979*
Previous blue	0.954*

* indicates significant difference by Table of correlation coefficient at the 5% and degrees of freedom = 9 $\{T_{(9,5\%)}\}$-----> = 0.602 (Snedecor and Cochran, 1967)

4.5 DISCUSSIONS

The tendency of birds to go initially to the light that had been used during the rearing stage might be due to their residual memory during the first three hours of the test. The preference for red light of birds reared in a neutral colour (white) was reasonably to be expected because the most easily perceived part of the spectrum of white light is red.

After one week had elapsed, almost all the birds preferred blue light as the first choice and, secondly, green light. However, birds from the blue light preferred green as their first choice and then blue light as their second choice. However, blue and green light are most likely to be similarly perceived in term of brightness (they are dimmer compared to red). Clearly the birds did not like the red light, and it might be that the red light was merely brighter to them than the others. These results are supported by Hurnick *et al.* (1971), who stated that birds could differentiate between certain areas of the colour spectrum.

Even though there was no significant difference in the body weight gain after the tests, a positive correlation was shown significantly for birds reared in white, green and blue light, but not in red. It seems that birds reared under red light had less stability of live weight compared to the others if there was any change of light. This result is supported by the findings of Foster and Follet (1985) that red light (around 620nm) is more stimulatory than other colours for ducks and Japanese quail. They mentioned that this was because red light penetrates the skull and brain more efficiently than other colours.

Regarding the interaction between sex and the initial colour of light in their effect on growth rate, the indication is that male birds are more responsive to bright (white and red) light compared to the females. It may be partly testoterone that regulates this response. Sturkie (1986) stated that the intensity of light within the range of 2 to 50 lux does not appear to be critical for either testicular growth or maintenance (the intensity used for all of the colours in this experiment was 30 lux). He further stated that testicular growth in birds is stimulated to a greater extent by near-red visible light wavelengths than by shorter wavelengths such as blue and green.

4.6 CONCLUSION

It can be concluded that both male and female broilers showed the greatest longterm preference for blue light, followed by green light, although their initial preference after being reared in a neutral colour was for red light. Birds reared in a coloured light showed an initial preference for remaining in that light, but after one week they preferred a change to a different colour, usually blue. It is suggested that some of the differences in colour selection could have arisen in this experiment from the different perceived brightness of the colours.

Chapter V

AN INVESTIGATION INTO EQUATING BRIGHTNESS PERCEPTION OF BLUE AND RED LIGHTS AND LENGTH OF LINE DISCRIMINATION WITH HENS BY PSYCHOPHYSICAL TESTS

5.1 ABSTRACT

Ten pullets of the Warren Studler 128 breed, aged approximately 18 weeks, were used in three experiments using two identical chambers to determine the equivalent brightness perception of different colours (blue and red) in hens and their ability to compute a simple visual test. One half of the birds were initially trained to detect the brighter of two lights and the other half the dimmer. The first test studied the brightness perception of hens using bright blue (initially 24.14 x 10^{22} photons) and dim red (initially 0.66 x 10^{22} photons) lights; and the second test used bright red (initially 32.27 x 10^{22} photons) and dim blue (initially 0.84 x 10^{22} photons). In both tests the degree of brightness of the two colours of light were gradually brought together. The ability of hens to distinguish different levels of brightness in the two colours was recorded over a number of presentations as the correct response percentage (> 80% being taken as successful). In part 5.3.6 a visual test was conducted as a length of line discrimination. This was performed using equally bright red and blue lights (determined from part 1 of the experiment), initially using a short line (10cm) and a long line (30cm). The ability of hens to detect the longer or shorter line was decided by the correct response percentage (> 80%). In the first test the birds failed to distinguish the brightness of the two coloured lights at 11.20 x 10^{22} and 3.07 x 10^{22} photons for blue and red lights respectively (in a ratio of 3.6 : 1.0). In the second test the birds failed to distinguish the brightness of the two coloured lights at 2.53 x 10^{22} and 7.84 x 10^{22} photons for red and blue respectively (in a ratio of 1 : 3.1). On average, therefore the equivalent brightness of the red and blue lights occurred at a luminance of 1 : 3.37. At the mean ratio of 3.37 :1.0 for blue to red, birds failed to discriminate lines 24cm and 16cm long, and the same was those for both colours of light. It can be concluded that the chickens failed to differentiate the brightness of blue and red lights at a (photon) ratio 3.1 - 3.6 : 1.0. At this ratio chickens are not able to discriminate successfully a difference in the length of two lines of less than one third of their length.

5.2 INTRODUCTION

Morris (1968) and Cavalchini *et al.* (1984) stated that, despite some confusion between wavelength effects and light intensity effects, the avian species are known to be particularly sensitive to bands of light nearest red and orange .

Wathes *et al.* (1982) studied the response of male and female broiler chicks to blue (425nm peak), green (525nm peak), red (610nm peak) and white (560nm median) light. There was no significant effect on either growth rate or feed intake to 8 weeks of age for either sex. Although the authors kept the illuminance of the four different light sources as near equal as was practically possible, it could not be assumed that there were no intensity effects, as the findings of Benoit (1964) and Hartwig and van Veen (1979) had already shown that differences in cranial penetration of different wavelengths of light cause large variations in intensity at the hypothalamic extra retinal photoreceptor.

This experiment follows on from the conclusions of the first experiment in Chapter 1. In this experiment it was found that birds reared in red light were more active than birds reared in blue light. This effect may be due to the better visual sensitivity of chickens in red compared to blue light and the red light therefore appears brighter. This experiment aimed to determine the equivalent brightness perception of two different colours of light (blue and red) in hens and their relative ability to compute a simple visual test in these two colours (equated for brightness).

5.3 MATERIALS AND METHODS

5.3.1 Experimental design and research procedure

Ten pullets of Warren Studler 128 breed were used to distinguish between light of different wavelengths and intensities and to differentiate between of different length-lines. The birds, aged approximately 18 weeks, were placed in one white walled pen measuring 2 x1 m on sawdust litter, in a light-proofed room. The room temperature was kept close to the optimum (21°C) by suspending a 1000 watt infra red bulb 80 cm above the ground in the middle of the pen as a heater. A neon light of 100 watt was positioned in the ceiling of the room, otherwise the top of the pen was partially closed by hardboard to prevent over exposure whilst still providing the light required for the birds to lay.

Lighting was arranged as 23L:1D with L from 04.00-03.00 h and 1D from 03.00-04.00 h, using an automatic timer.

Water and pelleted feed were available *ad lib*. The birds were fed with 448 Gold Grow Pellet ACS at the beginning, gradually changing thereafter to 567 Spillers Home Range Layer Pells (Table 5.1).

Table 5.1 The composition of feeds used in this study

Composition	Grower	Layer
oil (%)	4.5	4
protein (%)	15.0	16
fibre (%)	5.25	5.5
ash (%)	8	15.5
ME (MJ/kg)	10.4	10.0
vitamin A (iu/kg)	10045	6000
vitamin D3 (iu/kg)	2700	2000
vitamin E-alpha tocopherol (iu/kg)	30	9
sodium selenite-selenium (mg/kg)	0.2	0.2
sodium molybdate-molybdenum (mg/kg)	-	-
cupric sulphate-copper (mg/kg)	15	15
methionine (%)	0.22	0.25
acid insoluble (%)	1.6	-

Source : Dalgety Agriculture Ltd.

The birds' wings were clipped to prevent flying and jumping from the pen and at approximately 19 weeks of age, the pullets were randomly numbered 1-10 on their heads and on both of their legs to make it easier to recognise them individually.

Two identical test chambers, separated by a light-proof partition (Figure 5.1), had been constructed from brown hardboard in the same room as the pen. The sawdust litter was not used on the floor since it disturbed the birds' concentration during the running of the experiment. Above each chamber was suspended a bulb attached to a dimmer switch. The maximum light intensity difference was obtained by setting one switch to the maximum (giving the bright light), and the other to the minimum. A feeder containing pellets was placed in each chamber, though one was covered by mesh at a level not visible to the birds from the starting point, thus preventing the possibility

of the sense of smell creating a bias in the birds' determination of the location of the feed reward.

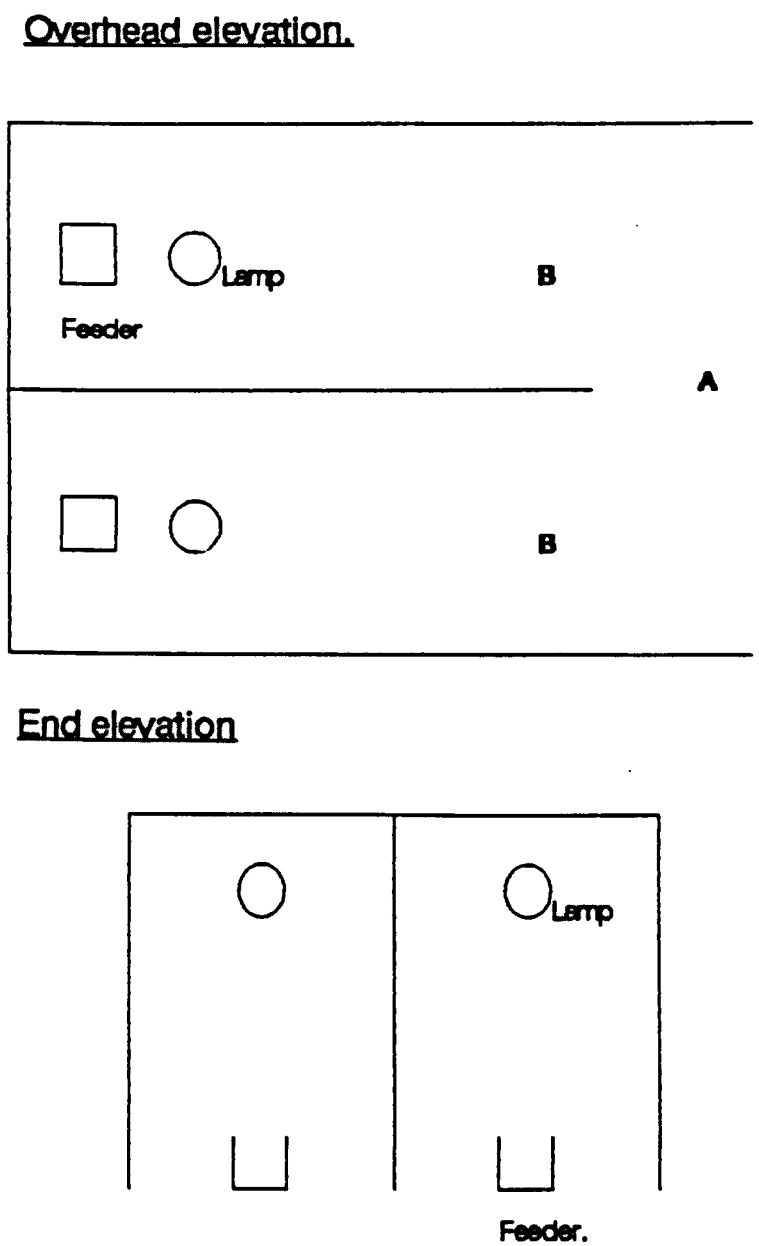


Figure 5.1 Test chambers

5.3.2 Training procedure

Before the tests were applied, training was done to accustom the birds to dim and bright lights using a 40 watt bulb of white or neutral light. Prior to each training session, the birds were fasted for two hours, but water was always available. Due to this fasting, training was limited to two hours per day. Birds 1-5 were trained to go to the bright light, and birds 6-10 to go to the dim. One by one, each bird in turn was placed at point A and was considered to have made its choice after passing point B (Figure 5.1). If the correct choice was made, a small feed reward of approximately 5g of pellets was obtained. Bias due to constant placement on one side was avoided by randomly varying the position of the light and feeder from left to right. Once all of the birds were consistently making the correct choice in every trial, they were deemed to be sufficiently trained to respond to particular intensities of light to begin the trial. A total of 20 trials were carried out for each bird, over a period of 5 days used to train the birds.

5.3.3 Brightness discrimination using white light (preliminary experiment)

This preliminary test was aimed at determining how well the birds could discriminate between two white lights of different intensities after being trained in minimum and maximum white lights; and how similar the intensities could become before the birds could no longer distinguish between them.

Before the beginning of this test, the dimmer switches attached to the lamps had to be calibrated using a light meter Quantum PAR sensor, Delta-T Devices Ltd. (Figure 5.2). The light output of the lamps on maximum and minimum settings, as well as at several approximately evenly spaced points that had been marked on the dimmer switches between the lamps, was measured and determined between two sides.

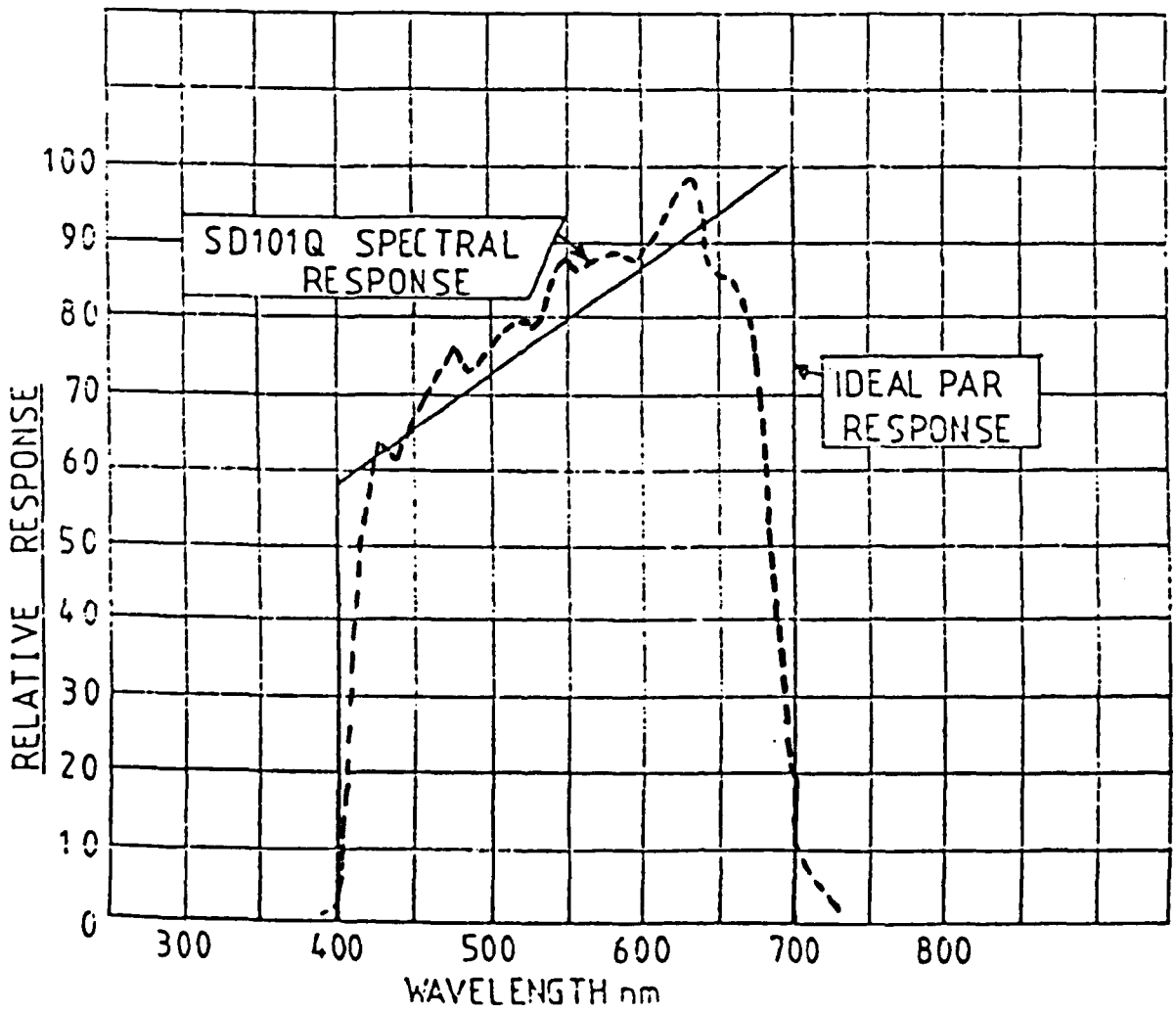


Figure 5.2 Spectral sensitivity curve of a quantum sensor
(the specification of the quantum sensor is shown in Appendix 1)

An average of five readings was taken on each side at a height of 40 cm from the floor and 20 cm from the bottom of the light lens, directly beneath the filter of the lamp holder. The light meter quantum sensor measured the light intensity in photons. As with all the tests carried out, the birds were fasted for two hours prior to each testing session but were allowed water at all times.

The trial began with a maximum intensity difference. Then by altering the light intensity from each lamp using calibrated points, the birds' discrimination ability at different lighting levels was tested. Each step involved a decreased intensity difference compared to the previous level. Ten trials for each bird were carried out at every level, with the birds expected to go to bright or dim light as they had been trained. The light and feeder locations were varied randomly and the correct response percentage for each test was recorded. Failure to discriminate between the intensities at any level was taken to have occurred when the group mean correct response over that set of tests was less than eighty percent. Tests were carried out on a total of eight levels.

Light intensity comparisons were conducted between the chickens in this trial and the findings of Phillips and Weiguo (1991), who studied the brightness discrimination abilities of calves relative to those of humans. A Luminance Contrast Index (LCI)(modified from Durrant, 1977) was used and determined as (B-D)/(B+D), where B was the bright and D the dim light intensity, in order that the chickens' ability to distinguish brightness at high and low light intensities could be compared.

5.3.4 Brightness discrimination using maximum blue and minimum red

Before the start of the test , the dimmer switches attached to the lamps had to be calibrated using the light meter (Quantum sensor Delta-T Devices Ltd). An average of five readings were taken throughout the pen at a height of 40 cm from the floor and 20

cm from the bottom of the light source, ie directly beneath the filter of the lamp holder. The quantum sensor available did not measure the intensity in lux as the meter used in Experiment 1 did, but it was connected into an integrator. From the reading of the integrator, this could be converted into photons. The red and blue lights were produced from LEE filter numbers 106 (primary red) and 120 (deep blue). The light output of the lamps on maximum and minimum settings, as well as at several approximately evenly spaced points that had been marked between these, was determined and equated between the two sides. As with all the tests carried out, the birds were fasted for two hours prior to each testing session but were allowed water at all times. Using the same procedure as above, the intensities were adjusted. Ten trials for each bird were carried out at every level, with the birds expected to go to bright or dim light as they had been trained. The light and feeder locations were varied as before, and the correct response percentage for each test was recorded. Failure to discriminate between the intensities at any level was taken to have occurred when the group mean correct response over that set of tests was less than eighty percent. Trials were carried out on a total of six levels, starting from a maximum intensity of blue (24.14 x 10^{22} photons) and a minimum intensity of red (0.66 x 10^{22} photons). The intensities were then brought closer to each other by reducing the blue intensity and increasing the red. The trial was stopped when the birds failed to discriminate both between different intensities and colours of light. The six levels used were as follows :

Level	Lamp intensity (x 10^{22} photons*) Bright blue	Dim red	The ratio Red : Blue
1	24.14	0.66	1 : 36.576
2	23.72	0.90	1 : 26.356
3	22.21	1.14	1 : 19.482
4	17.22	1.63	1 : 10.564
5	14.33	2.23	1 : 6.426
6	11.20	3.07	1 : 3.648

* per m^2/s

5.3.5 Brightness discrimination using maximum red and minimum blue

This test was carried out in a similar way to the test in part 5.3.4, but starting from the maximum intensity of red (32.37 x 10^{22} photons*) and the minimum intensity of blue (0.84 x 10^{22} photons). Before this test was applied, the birds were first reconditioned by 10 trials with white light as they had been during training. Secondly, they were exposed to 10 trials of alternating bright red and dim blue and this was followed by another 10 trials with bright blue and dim red. Both reconditioning and alternating treatments aimed to clear up any loss of brightness discrimination in the chickens' memories due to the previous test (see 5.3.4) or association with a aprticular colour. Up to and including level 6 a reward was offered by the same procedure as in test 5.3.4. From level 7 the reward was offered on both sides. Both tests in 5.3.4 and 5.3.5 consisted of 10 trials at each level. Again, failure to discriminate between the intensities at any level was taken to have occurred when the group mean correct response over that test was less than eighty percent. The nine levels used in this test were as follows :

Level	Lamp intensity (x 10^{22} photons*) Bright red	Dim blue	Ratio Red : Blue
1	32.27	0.84	1 : 0.026
2	29.32	0.96	1 : 0.032
3	20.71	1.26	1 : 0.061
4	15.05	1.99	1 : 0.132
5	10.23	2.89	1 : 0.282
6	6.38	3.97	1 : 0.622
7	4.52	5.60	1 : 1.239
8	3.07	7.10	1 : 2.313
9	2.53	7.84	1 : 3.098

* per m^2/s

5.3.6 Length of line discrimination

This test was designed to determine whether using different coloured lighting (starting with 30 cm as the Long and 10 cm as the Short line and white, blue or red in both chambers) had an effect on how well the birds could differentiate between the lengths of two lines. This test was carried out initially with white light in a similar way to test 1, but a piece of paper on which was drawn a line of predetermined length was hung vertically in the corner in front of the feeder (Figure 5.1), so that the birds could see the line easily. One half of the birds were trained to select the longer and the other half the shorter of the two lines. Tests were then carried out under red or blue light using the same procedure as in training, with a total of five levels, and 10 trials in each level.

5.3.7 Disrimination test using red and blue light of equal brightness to the chicken's eye perception

This test was designed in order to obtain confirmation of whether the birds perceived the red and blue light to be of equal brightness using the levels which were found to be of the same brightness as perceived by the birds in parts 5.3.4 and 5.3.5.

A blue light was placed in one chamber and a red in the other with the ratio, firstly, of 1 : 3.0 for red and blue respectively and, secondly, of 1 : 3.6 for red and blue respectively. The measurement of the brightness was the same as in the previous tests. Small rewards were placed on both sides and the preferences of the 'bright' and 'dim' groups of birds were recorded over a series of trials. As before, the positions of the two coloured lights were alternated, to reduce constant placement bias.

5.3.8 Statistical analysis

The data observed apparently for comparing between the bright and dim group to achieve the correct response percentage were examined by analysis of variance (ANOVA) and regression through the statistical package Minitab. For test 4 (Discrimination test using red and blue light of equal brightness in the chicken's eye perception) the data were tested by Chi-squared (Snedecor and Cochran, 1967).

5.4 RESULTS

5.4.1 Training results

After 6 trials, or 2 days' training, the group trained to go to the bright light, or group B, obtained a 100 percent correct response rate. The group trained to go to the dim light, or group D, achieved a 100 percent correct result on the 11^{th} trial, on the third day of training. However, for both groups to obtain a completely correct response together it took 14 trials and it occured on the 5^{th} day of training (Table 5.2). The bright selectors learnt significantly quicker than the dim selectors. There was also significant difference between trials. However, there was no interaction between the level and bright/dim selectors, which implies that the birds are more readily trained to go to bright light (Figure 5.3)

Table 5.2 Training results under maximum intensity (35.518×10^{22} photons*) and minimum intensity (0.132×10^{22} photons) of white light with 20 trials

	CRP			Bright/Dim		Trial		Interaction	
Trial	Bright	Dim	Mean	SED	PROB	SED	PROB	SED	PROB
1	20	0	10						
2	0	0	0						
3	20	20	20						
4	40	20	30						
5	60	20	40						
6	100	40	70						
7	100	60	80						
8	80	20	50						
9	100	60	80						
10	80	60	70	5.00	0.006	15.81	0.000	22.36	0.209
11	80	100	90						
12	80	80	80						
13	80	100	90						
14	100	100	100						
15	100	100	100						
16	100	100	100						
17	80	80	80						
18	80	80	80						
19	100	100	100						
20	100	100	100						
Means	75	62							

CRP = correct response percentage (%)

The use of ANOVA procedures to statistically test these differences is not proven to be justified. However the results are self evident and need little statistical proof.

* per m^2/s

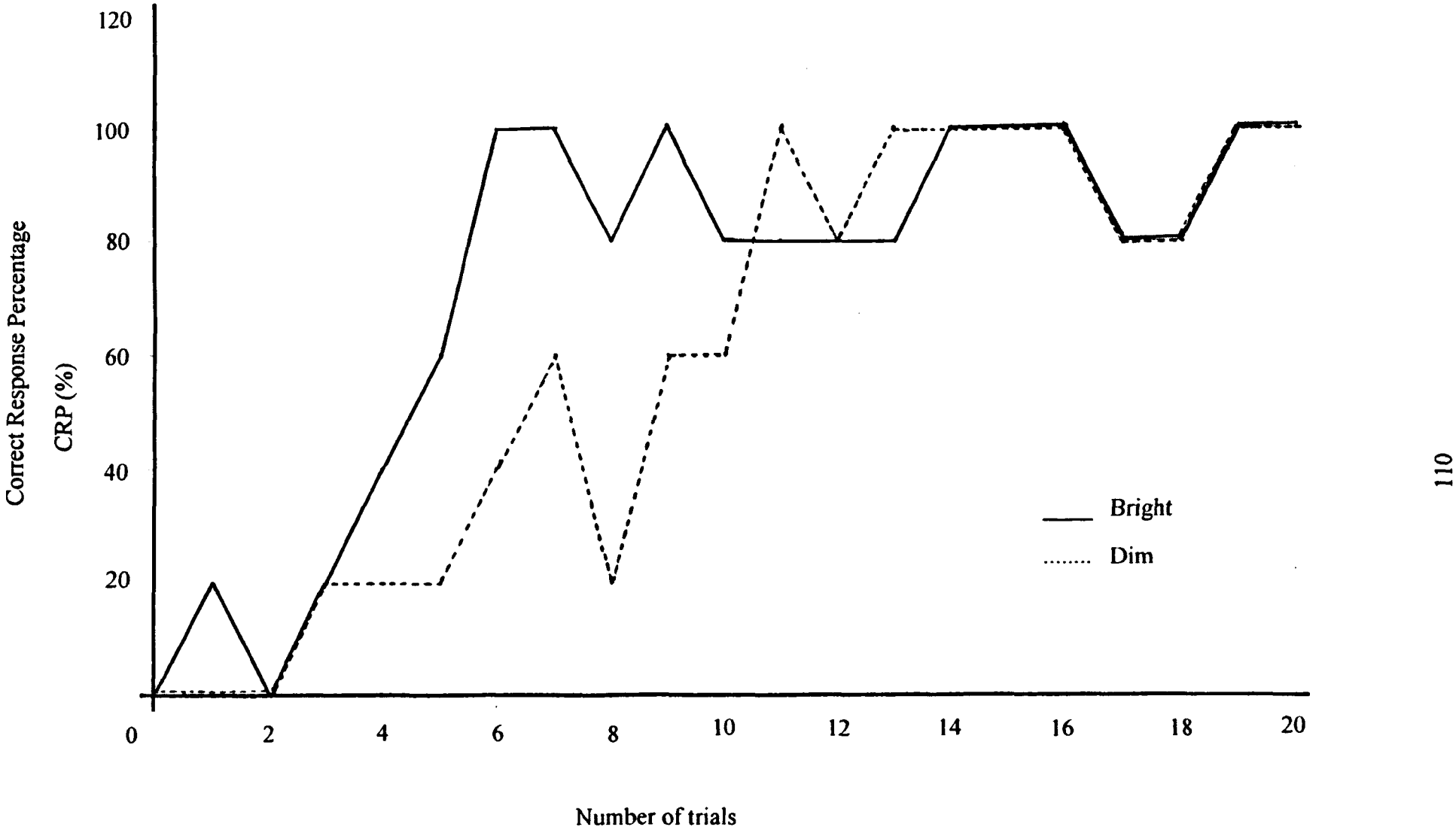


Figure 5.3 Correct response rate of broilers during the training period

5.4.2 Preliminary experiment using white light

From the results in Table 5.3 the birds as a group failed to successfully discriminate between two lights with an intensity difference of 1.99 x 10^{22} photons (level 7). The birds in group D failed at intensity differences of 4.16 x 10^{22} photons (level 6). However, the correct response rate of group B does not appear to fall below ninety percent until the intensity difference falls below 1.99 x 10^{22} photons (level 7). It is clear that bright selectors can distinguish the different intensity between two lights significantly better than dim selectors.

Table 5.3 Correct response percentage of hens under different intensities of white light

Level	Lamp intensity (x10^{22} photons*)		Int. Diff (x10^{22} photons*)	LCI	Correct Response Percentage		
	Bright	Dim			Group B	Group D	Overall
1	35.52	0.84	34.68	0.95	98	94	96
2	30.10	1.02	29.08	0.93	94	92	93
3	24.08	1.32	22.76	0.89	90	92	91
4	18.66	1.87	16.79	0.82	96	94	95
5	12.04	2.77	9.7	0.62	90	86	88
6	7.83	3.67	4.16	0.37	96	68	82
7	6.02	4.03	1.99	0.20	42	30	36
8	5.72	4.45	1.27	0.12	32	22	27
Mean					80	72	

Note : Int. Diff = intensity difference, LCI = luminance contrast index
Bright/Dim (SED = 3.01, P = 0.02)
Level (SED = 6.02, P = 0.00) * per m^2/s
Interaction bright/dim * level (SED = 8.52, P = 0.32)

In accordance with the Luminance Contrast Index, the final correct response percentage at each LCI level was significantly and consistently lower in the dim group compared to the bright group (figure 5.4). Failure to discriminate finally occurred at an LCI level of 0.20 for the bright group and 0.37 for the dim group.

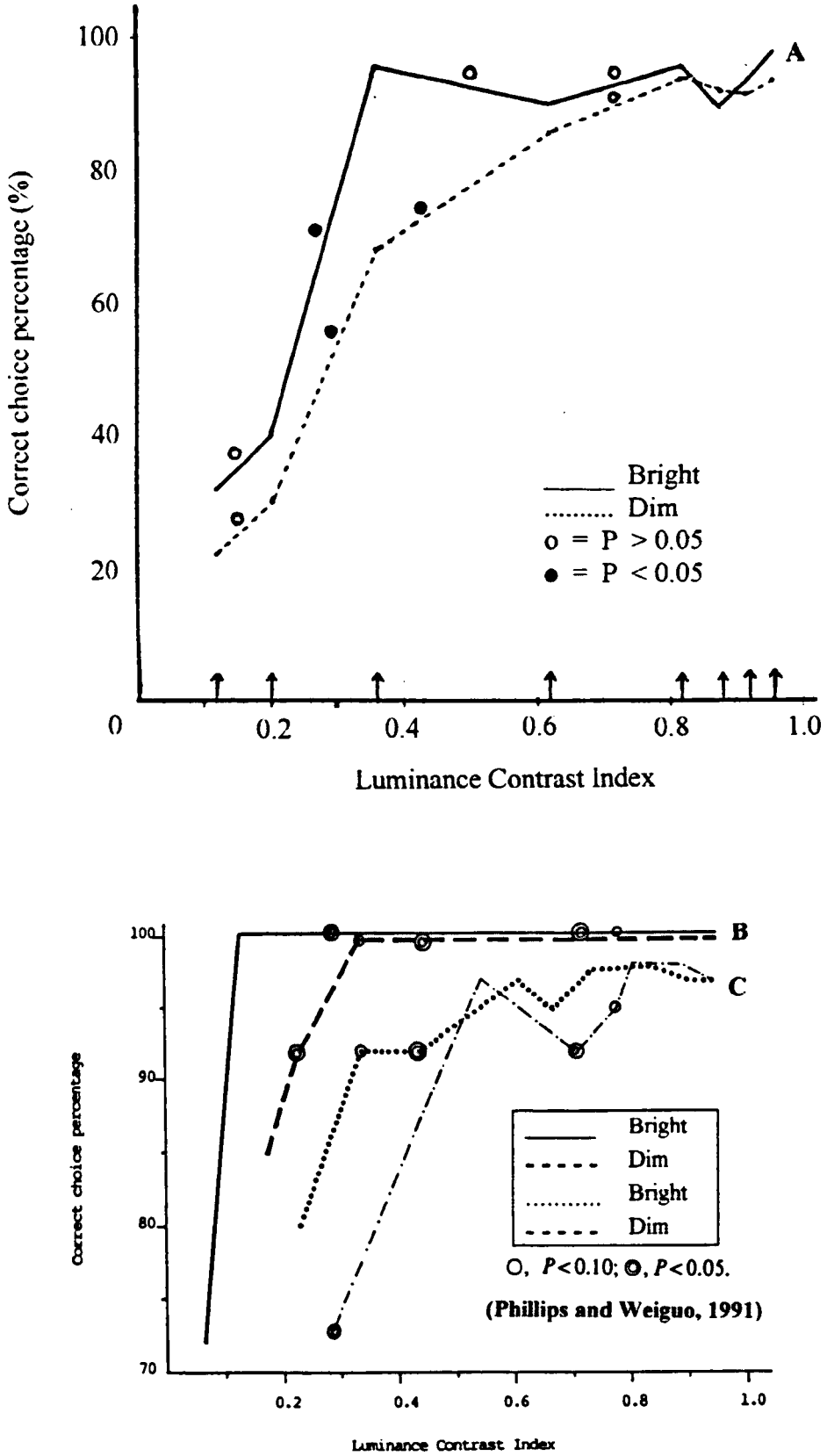


Figure 5.4 Relationship between Luminance Contrast Index and correct response percentage for chickens (A) compared to humans (B) and calves (C)

5.4.3 Brightness discrimination using maximum blue and minimum red

In the first test (Table 5.4), the birds for both bright and dim selectors failed significantly to distinguish the brightness of the two coloured lights at 11.20 x 10^{22} and 3.07 x 10^{22} photons for blue and red lights respectively (at ratio of 3.6 : 1.0).

Table 5.4 Correct response percentage starting from maximum blue and minimum red

Level	Lamp intensity (x 10^{22} photons)* Bright blue	Dim red	Ratio Red:Blue	Correct response percentage (%) Group B	Group D	Overall
1	24.14	0.66	1:36.576	92	92	92
2	23.72	0.90	1:26.356	96	96	96
3	22.21	1.14	1:19.482	88	92	90
4	17.22	1.63	1:10.564	92	88	90
5	14.33	2.23	1 : 6.426	84	82	83
6	11.20	3.07	1 : 3.648	60	54	57
Mean				85	84	

Note : Bright/Dim (SED = 3.95, P = 0.74) * per m^2/s
Level (SED = 6.84, P = 0.00)
Interaction bright/dim * level (SED = 9.68, P = 0.98)

5.4.4 Brightness discrimination using maximum red and minimum blue

In the second test of part 1 (table 5.5), the birds for both bright and dim selectors significantly failed to distinguish the brightness of the two coloured lights at 2.53 x 10^{22} and 7.84 x 10^{22} for red and blue respectively (at a ratio of 3.1 : 1.0).

Table 5.5 Correct response percentage starting from maximum red and minimum blue

Level	Lamp intensity (x 10^{22} photons)* Bright red	Dim Blue	Ratio Red:blue	Correct Response Percentage (%) Group B	Group D	Overall
1	32.27	0.84	1 : 0.026	96	96	96
2	29.32	0.96	1 : 0.032	92	92	92
3	20.71	1.26	1 : 0.061	92	98	95
4	15.05	1.99	1 : 0.132	96	96	96
5	10.23	2.89	0 : 0.282	96	88	92
6	6.38	3.97	1 : 0.622	92	92	92
7	4.52	5.60	1 : 1.239	86	86	86
8	3.07	7.10	1 : 2.313	88	86	87
9	2.53	7.84	1 : 3.098	60	58	59
Mean				89	88	

Note : Bright/Dim (SED = 2.75, P = 0.81)
Level (SED = 5.84, P = 0.00)
Interaction bright/dim * level (SED = 8.26, P = 0.99)

* per m^2/s

5.4.5 Length of line discrimination

5.4.5.1 Training results under white light

After 34 tests, or seven days' training, the group trained to go to the long or short line obtained a 70-80 % correct response rate. The hens, both group long (L) and group short (S) achieved > 80% correct response on the 40th test on the 9th day of training. However, the training was continued up to the 45th test, so it took 10 days to get a consistently successful correct response (Table 5.6). It was found that the Short selectors learned as quickly as the Long selectors (P = 0.565). There was no interaction between level and short/long selectors. However, the level itself was significantly deferent in the correct response percentage.

Table 5.6 Training results of length of line discrimination

Trial	CRP			Trial	CRP			Trial	CRP		
	S	L	M		S	L	M		S	L	M
1	20	20	20	16	60	60	60	31	80	60	70
2	40	20	30	17	60	40	50	32	60	80	70
3	20	20	20	18	40	60	50	33	80	80	80
4	20	20	20	19	60	60	60	34	80	80	80
5	40	40	40	20	60	60	60	35	80	80	80
6	40	20	30	21	40	80	60	36	80	80	80
7	40	40	40	22	80	40	60	37	80	60	70
8	20	40	30	23	60	60	60	38	80	80	80
9	20	20	20	24	40	60	50	39	80	80	70
10	40	20	30	25	80	60	70	40	80	80	80
11	40	40	40	26	60	60	60	41	80	80	80
12	60	40	50	27	80	60	70	42	80	100	90
13	40	20	30	28	60	60	60	43	100	80	90
14	40	40	40	29	80	60	70	44	80	100	90
15	60	40	50	30	60	80	70	45	100	80	90

Note : CRP = correct response percentage (%)
S = short selectors, L = long selectors, M = mean
Means (short selectors = 59% ; long selectors = 56%)
Short/Long (SED = 4.63, P = 0.56)
Trial (SED = 21.96, P = 0.00)
Interaction short/long * trial (SED = 1.00, P = 31.05)

Table 5.7 shows that the visual test was a length of line discrimination performed using equally bright red and blue lights (determined from the initial experiments), initially using a short line (10cm) and long line (30cm). At the mean ratio of 3.37 : 1.0 for blue to red, birds failed to discriminate between lines 24cm and 16cm long, and it was the same for both colours of light. It could be concluded that the ratio between blue and red has an equal brightness to the birds' eye perception.

Table 5.7 Correct response percentage under different lengths of line

Level	Length of line (cm)	Correct response percentage Under Red (%)	Under Blue (%)	Overall
1	30 vs. 10	88	86	87
2	28 vs. 12	86	88	87
3	26 vs. 14	86	84	85
4	24 vs. 16	14	18	16
5	22 vs. 18	16	12	14
Mean		58	57	

Note : Red/Blue (SED = 2.84, P = 0.401)
Level (SED = 6.36, P = 0.00)
Interaction red/blue * level (SED = 8.99, P = 0.928)

5.4.6 Confirmatory discrimination test using red and blue light of equal brightness according to the chicken's eye perception

Since the chickens' failure to discriminate the brightness of red and blue from the first and second tests (see 5.4.3 and 5.4.4) were 1 : 3.65 and 1 : 3.10 respectively, these tests were then continued using red and blue light in both chambers with a ratio of 1 : 3.0 at first for red and blue respectively. The second ratio used was 1 : 3.6 for red and blue respectively.

Probability suggests that without the influence filters on the two lamps, i.e. if the wavelength of the light emitted had no effect on how the intensity of the light was perceived, the birds would randomly choose a chamber for each trial, since no difference in intensity would be visible. This would result in each chamber being visited 50% of the time, thus the expected number of visits by either group of birds to the red or blue light should be 25 times out of the 50 possible (ten trials for each of the

five birds in each group). Using this expected figure and the results of how many times each group of birds selected the chamber containing the red light, the following calculation can be made:

Test for the ratio 1 : 3.0 for red and blue respectively

	OBSERVED (O)	EXPECTED (E)	O-E	$(O-E)^2/E$
GROUP B	28	25	3	0.36
GROUP D	21	25	-4	0.64
			X^2 =	1.00

Test for the ratio 1 : 3.6 for red and blue respectively

	OBSERVED (O)	EXPECTED (E)	O-E	$(O-E)^2/E$
GROUP B	24	25	-1	0.04
GROUP D	28	25	3	0.36
			X^2 =	0.40

$X^2 = 1.00$ (between P=0.50 and P=0.25) ; $X^2 = 0.40$ (between P=075 and P=0.50)
X^2 from table (d.f. 1 ; 0.05) = 3.84; thus, X^2 from both the above calculations gives $P > 0.05$

This result confirms that the birds perceive red light as being of the same brightness as blue light at somewhere between the ratios of 1 : 3.0 and 1 : 3.6 .

DISCUSSION

The training results showed that the birds were more readily trained to respond to bright light than dim light, and those trained to select bright light consistently achieved higher correct response percentage rates under white light than under blue and red lights. Tables 5.4 and 5.5, bright vs. dim, are not significantly different, and it is therefore suggested that the bright selectors initially learned to discriminate more quickly than dim selectors. This may be partly due to the novelty of the bright stimulus, the birds being kept for the rest of time under a light intensity more similar to the dim light.

It was found that the birds could distinguish successfully between white lights with a difference in their intensities of not less than 16.79×10^{22} photons. In terms of the Luminance Contrast Index (LCI), the chickens failed to differentiate at an LCI level of 0.20 for the bright group and an LCI level of 0.37 for the dim group. This is comparable with the findings of Phillips and Weiguo (1991), who found that the failure in the dim group to discriminate finally occurred at an LCI level of 0.23 for calves and an LCI level of 0.17 for humans. Furthermore, in their bright group the calves failed to discriminate at an LCI level of 0.29 and humans failed to discriminate at an LCI of 0.07. Thus, in an average between bright and dim light, chickens have a similar failure level of LCI to calves (0.285 and 0.260 for chickens and calves respectively).

In the first test it was found that the chickens failed to differentiate the brightness of blue and red light at a (photon) ratio 3.1-3.6:1.0. This indicates that birds have similar light perceptions for blue and red respectively at a ratio of 3.1-3.6:1.0. This would agree with the suggestion from Experiment One, Part 1 that chickens have

better visual sensitivity at the red end of the spectrum, causing red light to appear brighter than other lights of the same measured intensity.

This result also agrees with the calculation using the curves (figure 5.5) of the spectral response of the chicken's eye (Bowmaker and Knowles, 1977), the spectral response of the quantum sensor, and the blue filter and red filter. This shows that the relative light output of red (D+B area) is approximately 3.44 times the relative light output of blue (A+C area). However this assumes that the bird can perceive A,B,C and D, which is not apparent from the spectral response curve of the chicken's eye (Keele and Neil, 1971). From the results of the test 5.4.6, there was further evidence that the birds of both the bright and dim groups failed to distinguish the brightness of the two coloured lights at ratios of 1:3.0 and 1:3.6 for red and blue respectively. Furthermore, these results would help to explain the results of Experiment 1 (Chapter 3) by suggesting that the red light increases activity because the birds perceive it as being brighter than it actually is.

At the mean ratio of 3.37:1.0 for blue to red, birds failed to discriminate lines that were 24cm and 16cm long, and it was the same for both colours of light. This indicates that there is further evidence that at a mean ratio of 3.37:1.0 for blue and red respectively, the birds definitely perceive the same brightness.

Some of the unexpected peaks and dips in the results of training, the preliminary test, test 1 and test 2 could be due to the fact that at the time some of the tests were carried out one or two of the birds were preparing to lay, and their response to the tests was not as would have been expected.

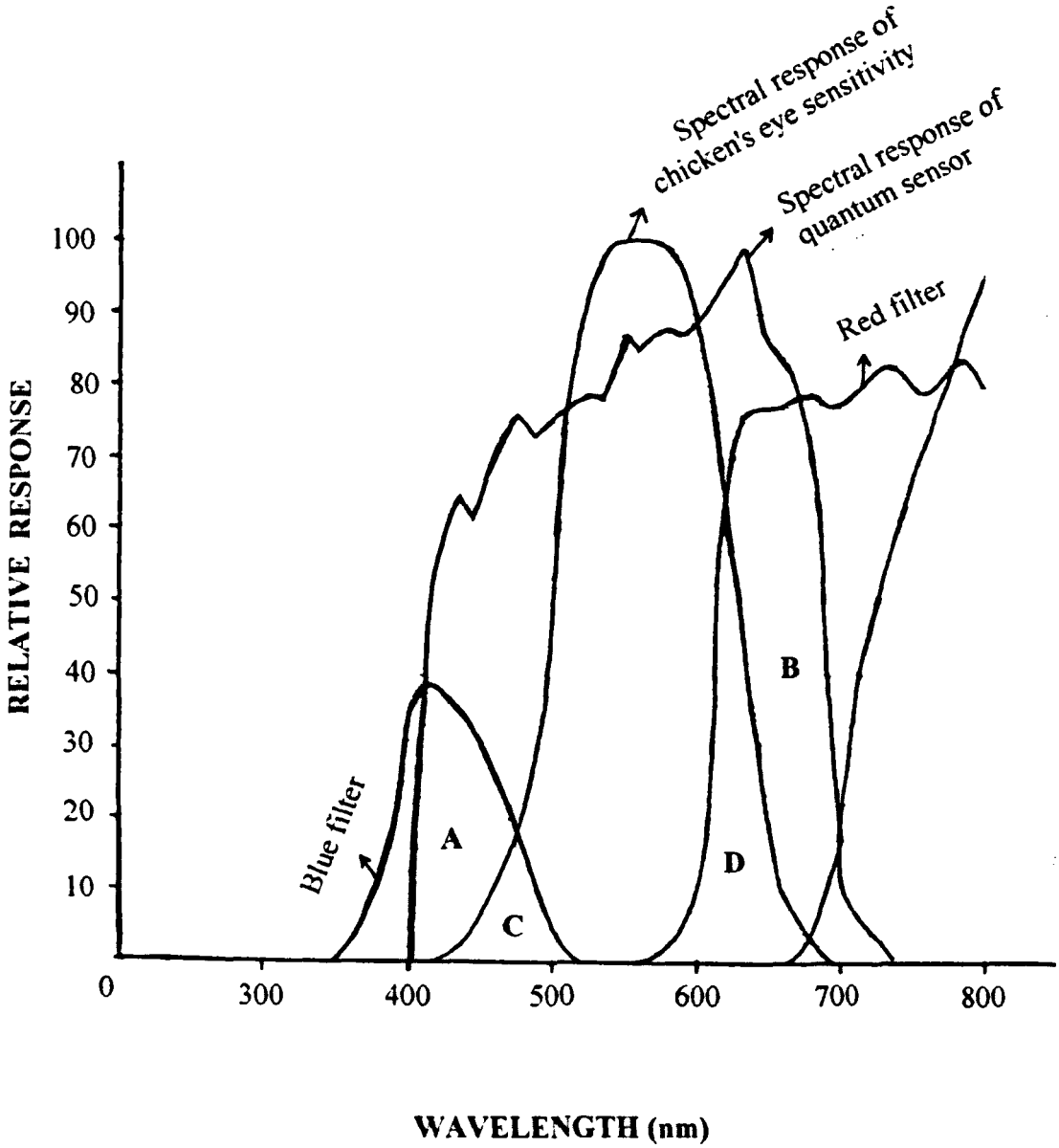


Figure 5.5 Spectral response curves of the chicken eye sensitivity (Keele and Neil, 1971), quantum sensor, and blue and red filters.

5.6 CONCLUSIONS

It can be concluded that the chickens failed to differentiate the brightness of blue and red lights at a (photons) ratio of 3.1 - 3.6 : 1.0. At this ratio chickens are not able to discriminate successfully a difference in the length of two lines of less than one third of it their length.

Chapter VI

Experiment 3

THE EFFECT OF COLOUR AND INTENSITY OF LIGHTS ON THE BEHAVIOUR AND PERFORMANCE OF BROILERS

6.1 ABSTRACT

An experiment was conducted in a controlled environment using 30 male and 24 female Ross broilers chicks. The birds were group reared in 6 cages with 5 males and 4 females/cage. The treatments applied were two different coloured lights, red and blue at three intensities, low (12 x 10^{20} photon, 36 x 10^{20} photon for red and blue light respectively), medium (18 x 10^{20}, 60 x 10^{20} photon for red and blue), and high (30 x 10^{20}, 108 x 10^{20}). The mean intensity ratio of red to blue was circa 1.0 : 3.3. Behaviour was monitored every 5 minutes for 23 hours/week/bird by time lapse video. Each bird was weighed weekly and feed consumption was recorded daily. It was found that birds reared under red light significantly increased ($P<0.05$) their time spent feeding, sleeping, the amount number of pecking, wing stretching and aggression whilst birds in blue light significantly increased their time spent standing, sitting and dozing. As light intensity increased, feeding, walking, wing stretching and aggression tended to increase, particularly for birds in red light. Interactions between colour of light and intensity were not significant for the time spent feeding and sitting ($P>0.05$) but they were for other behavioural parameters. The treatments did not affect the growth rate, feed consumption or food conversion ratio of the experimental broilers. It can be concluded that there are distinct effects of colour of lighting on broiler behaviour that increase activity in red light. Increased intensity also stimulated behavioural activity, particularly in red light.

6.2 INTRODUCTION

Newberry *et al.* (1985) found that chicken activity was greater when they were reared under bright light (12 lux) than under dim light (6 lux). Weaver and Siegel (1968) also found that feeding activity was increased by brighter light, whilst body weights and feed conversion were unaffected; thus the influence of light intensity on performance and activity appeared ambiguous. Newberry *et al.* (1986) found in their experiment using light intensity within a range of 0-100 lux that young chickens need more light and the light requirements are closely related to the chicken's age. However

some concern was expressed as to whether the presence of the observer may have affected the results.

Although there was no evidence that body weight was affected by light intensity, it was noted that in one of two experiments, the ratio between feed consumption and body weight gain was higher in birds under brighter light. In an attempt to clarify this, Newberry *et al.* (1988) carried out an experiment into the influence of two light intensities, 6 and 180 lux, on the chickens', behaviour over 24 hour periods, and on the performance of male and female chickens. The behavioural data was obtained by scan sampling video tape recordings of the birds, to eliminate any observer influence on the results, and it was found that although walking, standing and total activity were higher under 180 lux than 6 lux ($P<0.01$), feeding and drinking were not significantly affected by light intensity. In terms of performance, light intensity had no effect on feed conversion, body weight or feed and water consumption. There were also no significant light intensity and sex interactions. It was then concluded that brighter lighting had no adverse effects on performance, and there was some evidence that the welfare of the birds may have been improved by reducing bruising in the bright light.

Since many diurnal birds, including poultry, often have bright external colours, used by other members of the same species to induce the release of certain inbuilt behaviour patterns, for example in courtship, it has long been assumed that these birds can discriminate colour, as well as possessing good all-round vision. The earliest experiments attempting to show the existence of colour vision in poultry were, however, inconclusive, because it was not determined whether colour or brightness had been used as the distinguishing feature (Lashley, 1916).

Information about the effects of narrow bands of light energy on the performance, behaviour and physiological development of poultry is limited and often contradictory. Sexual maturation in pullets is advanced by an increase the hours of light hours, or delayed by a decreased intensity and, at a given photoperiod, greater light intensity also advances maturity. However, studies have found that the wavelength of light also has an influence on sexual maturation. Harrison *et al.* (1969b), reported early reproductive development in pullets and cockerels under blue and green light. Birds reared in red or white light matured later. In contrast, Scott and Payne (1937) and Woodard *et al.* (1969) reported that red light hastened maturation in Coturnix quail and in turkeys. These conflicting results might have been due to the intensity of the coloured light treatments rather than the wavelengths themselves, and the birds' perceptions of this intensity. Pyrzak *et al.* (1986) conducted a study of the effects of irradiation with narrow bands of visual light or with white light from several commercial sources, each with a specific spectrum, on the initiation of egg laying in juvenile and moulted adult hens. Light levels in each case were equalised on the basis of photon irradiance. Blue, green and red fluorescent bright light, white light, white light from cool white and sunlight-simulating fluorescent tubes and tungsten incandescent lamps were used, and the effect on the initiation of egg laying and renewal of egg laying after moulting was studied. At a given level of photon irradiation, the light quality or wavelength was found not to be a factor in the initiation of egg production. It was, however, reported to influence the renewal of egg laying following moulting in the domestic hens. In Experiment 1. part 1, the birds were least active under blue and green light and most active under red. It was shown that further research was necessary order to distinguish between the effects of apparent brightness and colour on the behaviour and performance of broilers.

Since it has been found that both wavelength and illuminance affect the behaviour and performance of poultry, some research has used a combination of these two factors. Cherry and Barwick (1962) carried out a series of tests on male and female chickens using white light and red light, which is often used at low intensities in poultry houses to reduce activity and cannibalism. In their first experiment red light and white light at different intensities (10 and 0.1 foot candles) were compared, but no significant difference was found in food consumption or body weight gain between either the colours or the intensities at any stage until the birds were 10 weeks of age. After this point the feed conversion ratio was significantly lower at 0.1 foot candles than at 10 foot candles. In their second experiment, four intensities of red light, 0.01, 0.1, 1.0 and 10 foot candles, were compared and it was found that body weights measured at 8 and 10 weeks of age increased with decreasing light intensity. Until week 5 the relationship between intensity and food consumption was a positive linear one , but after the sixth week birds at lower intensities had a higher food intake. By week ten, there were no significant differences in total food intake. It can be concluded from these results that red light has no significant effect compared to white light, but no comparison was made with other coloured lights, nor was the social behaviour of the birds studied, and the lights were not compared at equivalent brightness *as perceived by the birds.*

Wathes *et al.* (1982) studied the effects of wavelength and light illuminance on the growth of male and female broilers from one day old to 8 weeks of age. Several different coloured lights of peak wavelengths 425, 525 and 610 nm within the ranges of blue, green and red respectively and a broad spectrum white light of median wavelength 560 nm were used to treat groups of birds at equal illuminance levels (but not neccessarily equal to the birds). They found that various wavelengths tested at equal illumination had no significant effect on either the growth rate or cumulative

food intake of birds of either sex. In the case of the female birds, it was found that weight gain, when adjusted for food intake, was progressively depressed at illuminances above 3 lux. Performance in the male birds was, however, unaffected by different light illuminances, equal to 0.7, 3.0, 15.0 and 46.5 lux. This is contradictory to the findings of Foss *et al.* (1972), because wavelengths and spectral composition had no effect on bird growth in this experiment. Since there is some contradiction between the results of experiments studying wavelength and/or light intensity, it is possible that the discrepancies are not due to the wavelength and intensities themselves, but to how the birds perceive them.

Following on from the conclusions of Experiment 1 part 1 and Experiment 2 in chapters Three and Five respectively, this experiment attempts to study the behaviour patterns exhibited by birds in different light colours and intensities and in particular to distinguish colour and intensity effects. The effect on live weight gain, feed consumption and feed conversion ratio are also recorded.

6.3 MATERIALS AND METHODS

6.3.1 Experimental design and research procedure

An experiment was conducted in a controlled environment using 30 male and 24 female Ross broilers. The birds were placed randomly in three light-proof compartments, each compartment containing two cages, and each cage holding 9 day-old chicks (5 males and 4 females). Cages with wire floors and sides were equipped with a feeder containing 650 g of feed and a drinker containing 600 ml of water in the first two weeks. After the chicks had reached two weeks of age the feeder and drinker were changed to a size holding 3000 g of feed and 2500 ml of water respectively. Each

cage comprised a mesh floor (7x7 mm square holes) overlying a faeces catchment tray (Figure 6.1). The solid sides precluded visual contact among the groups. A floor space of 1530 x 765 mm allowed a stocking density of 20 kg/m2, considerably below the MAFF recommendation of 34 kg/m2. The birds were reared on a standard commercial *ad lib* diet of crumbs from day 1 - 14 and grower pellets from day 14 -35 as used in Experiment 1. part 1 and 2. The treatments applied were two different coloured lights, red and blue, at three different intensities, as follows ;

low intensity; 12 x 10^{20} and 36 x 10^{20} photon for red and blue light respectively

medium intensity; 18 x 10^{20} and 60 x10^{20} photon for red and blue light respectively

high intensity;30 x 10^{20} and 108 x 10^{20} photon for red and blue light respectively

The mean ratio of intensities, red to blue, was 1.0 : 3.3, since at this ratio it was found in Experiment 2 (Chapter V) that the chickens perceived these red and blue lights as being of equal brightness. The light intensity for red and blue light was measured using a Quantum sensor (Make Manufacturer) as a means of taking fifteen readings throughout the cage at a height of 20 cm above the floor. The specification of the lightmeter is shown in Appendix 1. The red and blue lights were produced from LEE filter numbers 106 (primary red) and 120 (deep blue) as in Experiments 1 and 2. The photoperiod used was 23 hours light and one dark between 14.00 - 15.00 (23L:1D).The maximum and minimum temperatures were recorded daily. This room was equipped with an electric fan heater and infra red light enabling a temperature of 29^0 C to be maintained for the first 7 days following the chicks' arrival.

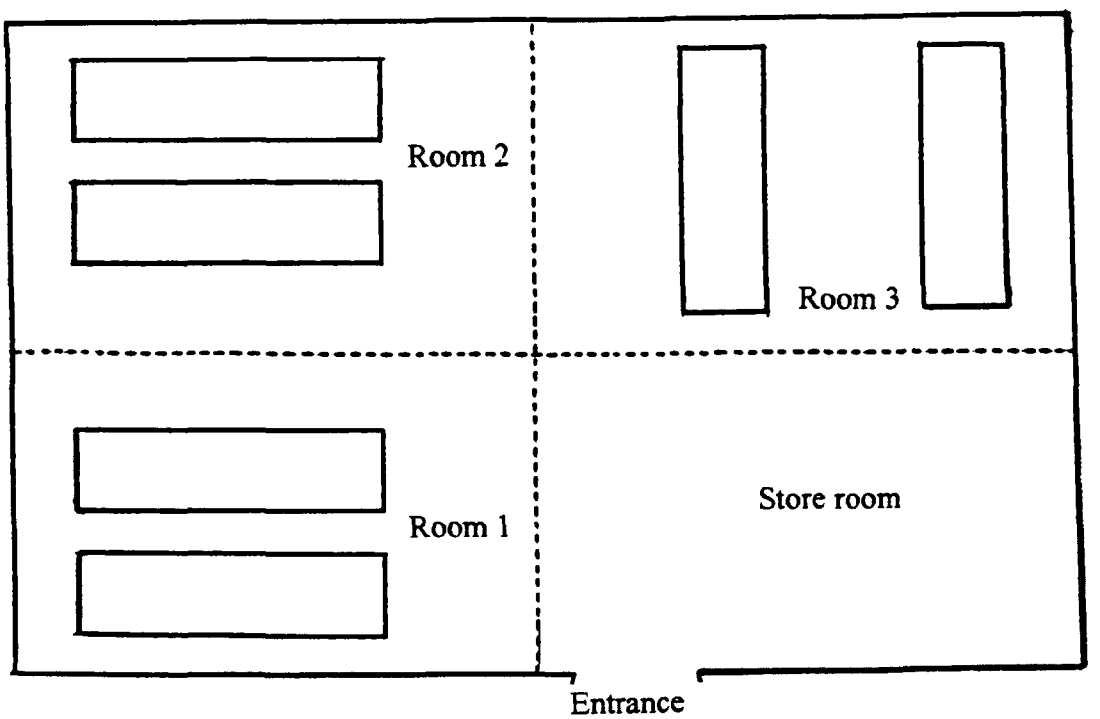


Figure 6.1a Plan of the chicken room

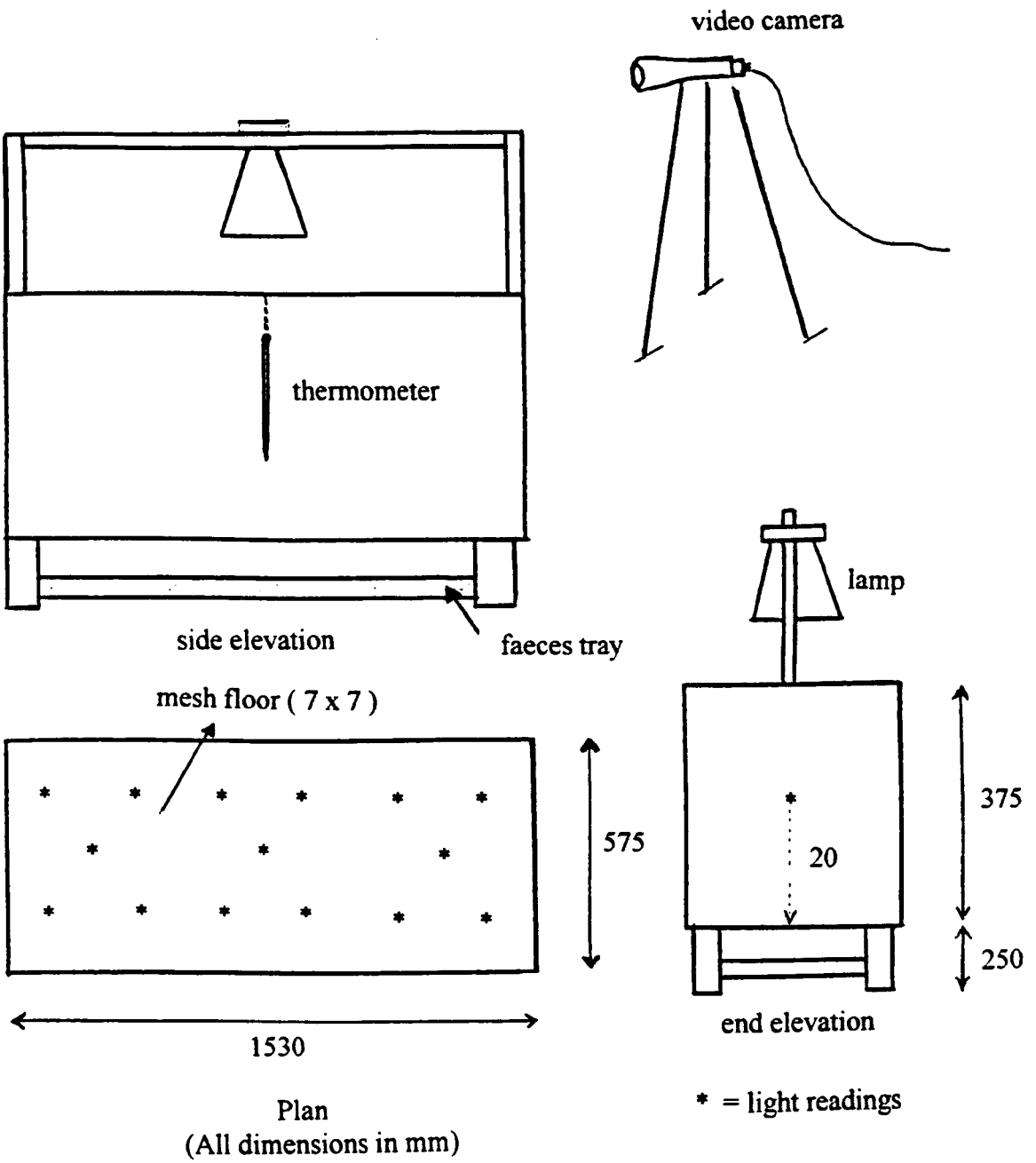


Figure 6.1b The cage construction

6.3.2 Behavioural parameters

The behavioural parameters consisted of main and incident behaviours, as was also the case in the first experiment. The main behaviours observed were time spent feeding, standing, sitting, dozing and sleeping. Dozing is defined as a state where the chicken is sitting, the neck is withdrawn, the head is motionless and sometimes dropped, and the eyes are closed or are slowly opened and closed. Sleeping is the same as dozing but the eyes are totally closed while the head is recumbent. The incidence behaviours were the occurrence of walking, drinking, pecking at the floor, wing stretching or aggression (pecking other birds) by each bird during a certain period of time.

The behavioural data were monitored every 5 minutes for 23 hours/week/bird by the time lapse video (Hitachi, VT-L30ED/VT-L3OED-UK), using a TV camera (Panasonic/Infra red camera, WV-1450/B) and the video-cassette(video recorder :3M, E180, professional extra high grade). Data on the main behaviours were collected every 5 minutes whilst the incidence behaviours were recorded within 5 minute periods (Figure 6.2). The video was run for 8 hours per cage for 6 days of observation per week. Hence, each treatment had 23 hours' behavioural data per week to be analysed.

6.3.3 Performance parameters

Each bird was weighed at days 1 and 35. The daily live weight gain was calculated by substracting initial body weight (day 1) from final body weight (day 35) and dividing the result by 35. Feed consumption was monitored for each replicate (9 birds) and an average feed consumption per treatment was calculated. A food conversion ratio for each treatment allowed an assessment to be made of the commercial viability of undertaking such a lighting pattern in practice, as any attempt

Colour : **Date :**

Intensity : **Time :**

MAIN BEHAVIOUR

No.	5	10	15	20	25	30	35	40	45	50	55	60
1												
2												
3												
4												
5												
6												
7												
8												
9												
INCIDENT BEHAVIOUR												
1												
2												
3												
4												
5												
6												
7												
8												
9												

Colour : **Date :**

Intensity : **Time :**

MAIN BEHAVIOUR

No.	5	10	15	20	25	30	35	40	45	50	55	60
1												
2												
3												
4												
5												
6												
7												
8												
9												
INCIDENT BEHAVIOUR												
1												
2												
3												
4												
5												
6												
7												
8												
9												

Figure 6.2 Behaviour record chart

to implement such a proposal would need to satisfy both welfare and economic considerations.

6.3.4 Experimental design and statistical analysis

The experiment was designed using a Factorial Block Design (Steel and Torrie, 1986). The experiment was divided into four time periods of 7 days each. The first period started with the one day old chick. The two main factors were colour and intensity of light, with red and blue for coloured light and low, medium and high levels of intensity in each coloured light. These treatments were each applied in two units, each containing 5 male and 4 female birds as replications. The significance of the differences caused by the treatment was examined by analysis of variance (ANOVA), coefficient of correlation and regression, using the statistical package Minitab version 7.2. The standard error of difference (SED) was used to test the differences between treatment means. This experiment was done twice .

6.4 RESULTS

6.4.1 Temperature

The daily minimum and maximum temperatures were recorded, and the average room temperature during the course of the experiment is presented in table 6.1. These room temperatures were similar to the recommendation from The Farm Electric Handbook (1990). The room temperature in the first week ranged from 27-32^{0}C and was gradually reduced to around 20-22^{0}C by the end of experiment.

Table 6.1 Average room temperature during the course of the experiment*

Age of the chicks (days)	Recommended room temperature (°C)**	Recorded room temperature (°C)		
		Room-1	Room-2	Room-3
1 and 2	32	31	31	31.5
3 and 4	32	29.5	29.5	30
5 and 6	30	28.5	28.5	29
7 and 8	29	28	28	28.5
9 and 10	28	27.5	27	28
11 and 12	27	26	25.5	26
13 and 14	26	25	25.5	25.5
15 and 16	25	24	23.5	24
17 and 18	24	23	22	23
19 and 20	23	22	22.5	22.5
21 and 22	22	23.5	23.5	23.5
23 and 24	21	21.5	21	21
25 and 26	21	21	21.5	21.5
27 and 28	21	21	21	21.5
29 and 30	21	21	21	21.75
31 and 32	21	21	21	21
33 and 34	21	21	21	21
35 and over	21	21	21	21.5

* the average of maximum and minimum temperatures
** **source**, Farm Electric Handbook (1990)

6.4.2 Behavioural pattern

There were significant interactions between colour and intensity of lights in all behavioural parameters except for time spent in feeding and sitting (table 6.2). An increase in intensity of the red light increased significantly time spent in standing, walking, drinking, stretching and aggression, whilst in the blue light the increase in intensity only slightly increased stretching and aggression.

A decrease in dozing, sleeping and pecking occurred with increased intensity in the red, but not the blue, light. Feeding times were longer and sitting time less in red than blue light. Feeding time also increased at high intensity in both colours.

Table 6.2 The time spent by broilers under different colours and intensities of light in major behaviours (mean of four times period observation)

Behavioural Parameters	Colour	Intensity			Colour		Intensity		Interaction	
		Low	Medium	High	PROB.	SED	PROB.	SED	PROB.	SED
Feeding (min/h)	Red	18.56	18.26	20.01	0.00	0.29	0.00	0.36	0.11	0.51
	Blue	16.42	15.12	18.38						
Standing (min/h)	Red	6.19	9.00	9.97	0.03	0.16	0.00	0.19	0.00	0.27
	Blue	7.67	7.08	7.42						
Sitting (min/h)	Red	10.15	9.74	10.68	0.00	0.18	0.00	0.22	0.23	0.32
	Blue	12.38	12.22	12.39						
Dozing (min/h)	Red	10.92	10.76	8.20	0.00	0.19	0.00	0.24	0.00	0.34
	Blue	13.40	14.13	14.20						
Sleeping (min/h)	Red	16.17	14.14	11.14	0.00	0.14	0.00	0.17	0.00	0.25
	Blue	8.12	9.45	7.59						
Walking (no/bird/h)	Red	3.73	4.47	4.80	0.00	0.05	0.00	0.06	0.00	0.08
	Blue	3.20	3.71	3.53						
Drinking (no/bird/h)	Red	1.57	1.61	1.62	0.07	0.03	0.67	0.04	0.05	0.06
	Blue	1.55	1.53	1.58						
Floor Pecking (no/bird/h)	Red	1.24	1.15	1.15	0.00	0.03	0.00	0.03	0.01	0.05
	Blue	0.98	0.97	0.98						
Wing stretching (no/bird/h)	Red	0.32	0.33	0.45	0.00	0.02	0.00	0.02	0.02	0.03
	Blue	0.18	0.18	0.26						
Aggression (no/bird/h)	Red	0.07	0.07	0.16	0.00	0.01	0.00	0.01	0.00	0.01
	Blue	0.03	0.03	0.05						

6.4.3 Performance

The growth in terms of final body weight gain and daily live weight gain of broilers reared under red and blue lights at different intensities did not show any significant treatment effect (P> 0.05), although there was a tendency for birds to have higher growth rates and daily live weight gains in blue than red light at all intensities. Similar results were also gained for the feed consumption and feed conversion ratio (Table 6.3).

Table 6.3 The mean of initial body weight (IBW), final body weight (FBW) at35 days of age, daily live weight gain (DLWG), feed consumption (FC) and feed conversion ratio (FCR) of broilers reared under different colours and intensities of light

Parameters	Colour	Intensity			Colour		Intensity		Interaction	
		Low	Medium	High	PROB	SED	PROB	SED	PROB	SED
IBW (g)	Red	48.89	48.78	48.89	1.00	0.77	1.00	0.94	0.98	1.33
	Blue	48.78	49.00	48.78						
FBW (g)	Red	1388	1366	1381	0.12	12.36	0.81	15.13	0.99	21.40
	Blue	1435	1445	1458						
DLWG (g)	Red	34.40	34.78	35.04	0.10	0.87	0.71	1.15	0.96	1.54
	Blue	35.52	36.56	36.55						
FC (g)	Red	3070	3039	3016						
	Blue	2985	3080	3173						
FCR	Red	2.21	2.22	2.18						
	Blue	2.08	2.13	2.18						

There was a positive correlation between daily live weight gain and initial body weight in both colours at high intensities (Table 6.4). This positive correlation also occurred in blue at low and medium intensities. No correlation was observed between final body weight and daily weight gain in red light at low and medium intensities.

Table 6.4 The regression equation, coefficient correlation and probability in each treatment between daily weight gain (y) and initial body weight (x)

Colour	Intensity	Regression equation	Coefficient correlation	Probability
Red	Low	y = 10.7 + 0.298 x	r = 0.564	P = 0.113
	Medium	y = 23.1 + 0.146 x	r = 0.443	P = 0.232
	High	y = - 5.6 + 0.507 x	**r = 0.832**	P = 0.005
Blue	Low	y = - 9.13 + 0.557 x	**r = 0.928**	P = 0.000
	Medium	y = 5.5 + 0.388 x	**r = 0.680**	P = 0.044
	High	y = - 1.8 + 0.479 x	**r = 0.812**	P = 0.008

Note : Bold numbers indicate that there is a significant difference by table of correlation coefficients at 5% and degrees of freedom = 9 $\{T_{(10,5\%)}\}$ -----> = 0.602 (Snedecor and Cochran, 1967).

6.5 DISCUSSION

Daily minimum and maximum temperatures were consistently comparable between rooms and followed the same temperature pattern used in commercial artificially controlled buildings. Throughout the experiment the ambient temperature was optimum for broiler growth .

The increase of intensity in the red light increased time spent in feeding, walking, drinking, stretching and aggression. These findings are in harmony with previous studies conducted by Cherry and Barwick (1962), who carried out an experiment on broilers using red light and white light at different intensities (0.1 and 10 foot candles). It appeared that the poorer grading found with lower intensities was due to an increase in breast blisters associated with reduced activity, although the data to establish this point are not available. Furthermore, Cherry and Barwick stated that it may be noted that bright lights are commonly supposed to be a contributory cause of cannibalism, although satisfactory evidence on this point is lacking. However, they found no significant difference in broiler performance due to the treatments. Besides that, Newberry *et al.* (1987) reported that increasing the light intensity caused an increase in the time spent walking, standing and in total activity. By contrast, in blue light the increase in intensity did not increase the time spent in walking and drinking, but stretching and aggression were increased. There was strong evidence that amounts of the time spent standing, sleeping, stretching, pecking and in aggression were greater in the red light at low, medium and high intensities than in the blue light. However, time spent in dozing was greater in the blue light than the red. The result is in conformity with that of Experiment 1 part 1 which found that a greater level of activity under red light necessitated a longer sleeping time, while birds in the blue light seem more inclined, to sit passively and doze. The increased time spent feeding and standing

at high intensity in this experiment can be compared with the results of part 1, Experiment 1 in which there were no significant differences. It is possible that using the time lapse video could give more accurate results than manual recording due to the disturbance caused by the observer.

The increase in the red to blue ratio in this experiment with intensity (1 : 3.0; 1 : 3.3 and 1 : 3.6 at low, medium and high intensities respectively) was considered with the results of test 1,2 and 4 in Experiment 5, where it is implied that the birds perceive red light as having the same brightness as blue light is a ratio of 1 : 3.0 - 3.6 for red : blue respectively. This slight variation is not expected to influence the results significantly because in Chapter V it is demonstrated that the birds could not discriminate between 1 : 3.0 and 1 : 3.6.

At low, medium and high intensities the body weight gain, feed consumption and food conversion ratio were similar in both red and blue light. These results are in harmony with those of Smith and Phillips (1959), Kondra (1961), Schumaier *et al.* (1968), Peterson and Espenshade (1971) and Wathes *et al.* (1982), who reported that the growth of broilers, turkeys, laying hens and chicks were unaffected by the wavelength and spectral composition of light. In contrast, Woodard *et al.* (1969) and Newberry *et al.* (1987) found respectively, that the growth of male Japanese quails and chickens, was significantly affected the by the colour of light and different intensities. Since there are some contradictions between the results of experiments studying wavelength and/or light intensity, it may be due to the different experimental designs. However, there was a tendency for less growth to occur in birds reared under red light compared to blue (P=0.10). This might be because the birds under red light were more active compared to birds in blue light. A similar effect was also obtained for FCR.

Proportionately the activity was more affected by the colour than the intensity of the light (Table 6.2).

The reason for the distinct effects of colour over and above the intensity effects could be the stimulatory effect of red light passing through the skull and being perceived separately from the eye. It may be that the equal luminescence measured in Chapter V was only applicable for light perceived by the eye.

6.6 CONCLUSION

It is concluded that there are distinct effects of colour of lighting on broiler behaviour, so that there is increased activity in red light. Increased intensity also stimulated behavioural activity, particularly in red light. This interaction may relate to the perception of red light that passes through the skull, rather than being perceived by the eye.

Chapter VII

Experiment 4

THE BEHAVIOURAL AND PHYSIOLOGICAL RESPONSES OF BROILERS TO STIMULATORY RED LIGHT

7.1 ABSTRACT

Twenty four male and twenty four female Ross broiler chicks were group reared in 12 cages with four birds/cage. During the rearing period three coloured light patterns were applied to examine the effects of treatments on behavioural and physiological responses of the broilers : 1) dim blue light from day 1 to 49 as a control (T0); 2) red light from day 1-16 followed by dim blue from day 17-49 (T1) and 3) dim blue from day 1-16 followed by red in days 17-32 and the dim blue from day 32-49 (T2). The red and blue light produced 860 x 10^{20} and 1.5 x 10^{20} photons respectively, and they were produced from white light covered by LEE filter numbers 106 and 120 for red and blue respectively.

The standing time during the life of the birds was not affected by the treatment, but using bright red light significantly increased the time spent walking (T0 3.7, T1 5.2, T2 4.6 min/h/b, SED=0.26), stretching (T0 1.3, T1 2.2, T2 2.3 min/h/b, SED=0.18) and feeding (T0 8.8, T1 9.9, T2 9.7 min/h/b, SED=0.34), particularly when applied in the first 16 days. The time spent sleeping (T0 17.6, T1 15.7, T2 16.2 min/h/b, SED=0.46) and sitting (T0 19.9, T1 17.8, T2 18.4 min/h/b, SED=0.49) were greatest for the control. The final body weight and FCR showed significant differences throughout the rearing period ($p<0.05$). The heaviest final body weight and the highest food efficiency were in T1 (BW=1683g, FCR=2.0) compared to T0 (BW=1545g, FCR=2.5) and T2 (BW=1476g, FCR=2.4), although there was a tendency for an increase in food consumption in T0. The sex of the bird did not significantly affect its behaviour or response to light. Sex and differences between left and right leg had no significant effect on tibia strength. However, the treatment did have an effect on bone strength, causing a significant reduction in the bone strength of birds in T2 (T0 257.7, T1 261.8, T2 235.0 Newtons, $P<0.05$, SED=11.09). Birds in the control treatment (T0) demonstrated the highest incidence of lameness problems, and 8 birds (50%) had at least an intermittently detectable abnormality in their gait, with four of these birds (25%) being crippled and unable to stand ,whilst two birds (12.5%) in T1 could not walk, had gone down on their legs and were slaughtered for welfare reasons. Birds in T2 were the least (6.25%) affected by lameness problems and by week 6 had only an intermittent abnormality in their gait (probability of lameness difference : 0.02).

It is concluded that exposing the birds to bright red light in early life increased the time spent walking, stretching, and feeding, which allowed the young chicks to exercise sufficiently. As a result it tended to increase bone strength and alleviated lameness problems. However, it reduced bone strength when applied later in life.

7.2 INTRODUCTION

By pushing the broiler chicken to its biological limit through years of selective breeding it is made to outgrow its strength, so that in the last 10-15 days of its 42-day life cycle it suffer from severe bone abnormalities that are known to be painful (Webster, 1993). We have not yet reached the limit for the efficient growth of bone (Broom, 1993). This problem can be rectified by slowing down the growth rate of the birds, particularly muscle growth, allowing bone growth to keep up. Alternatively, stocking density (particularly in the later stage of the growth cycle), lighting and nutrition can be reduced. However, production would thereby become more expensive and inevitably the consumer would be asked to pay more (Farquharson *et al.*, 1993; Whitehead *et al.*, 1993). For this reason, farmers and broilers are caught in a treadmill of faster and faster growth.

From the results of Experiment 1. part 1 in Chapter III it was demonstrated that birds are more active in red light and less active in blue light. In the light of a further experiment (Experiment 3) in Chapter VI, it is known that increased intensity also stimulated behavioural activity, particularly in red light. Similarly, low intensity lighting can also decrease activity and is commonly used for this purpose in commercial units because less active chickens usually produce better weight gains.

The hypothesis underlying experiment in this chapter is that an increase in locomotion might affect leg bone strength and gait abnormalities and thereby reduce limb disorders. Two limb disorders are common in the modern intensive poultry industry where rapid muscle growth frequently overtakes the bones' support mechanism. First, there is tibial dyschondroplasia, which is failure of the chondrocytes to adequately differentiate, with the result that bone is partially replaced by soft

cartilage (Lynch and Whitehead, 1992). Secondly, birds that grow rapidly may have soft weak bones that are more likely to break during the catching process. The aim of this experiment is to increase locomotion with bright red light in the early or middle part of the life of broilers.

This experiment will focus on the variables of light illuminance and spectral composition, keeping the photoperiod and cycle length constant at 23L : 1D in an attempt to determine whether the use of bright red light followed by dim light can increase activity and reduce leg abnormalities, increase bone strength, and affect feed consumption, feed conversion ratio and growth rate. An examination will be made of cartilages, tendons, joints and bones to assess the effect of increased locomotion or activity.

7.3 MATERIALS AND METHODS

7.3.1 Experimental design and research procedure

A controlled environment was used to house 48 Ross broiler chicks consisting of 24 females and 24 males. The temperature was set at 32^0 C and then gradually decreased by 1^0C every two days to 21^0 C, as recommended by the Farm Electric Handbook, according to the procedure used in the first experiment in Chapter III. Daily maximum and minimum temperature recordings were made in each room . The birds were placed in three light-proof compartment (the same size as the room used for the first experiment), each with four cages, and with each cage holding 4 seven-day-old chicks on day 1 of the experiment (2 female and 2 male). The cages were made of wire mesh and were equipped with a feeder containing up to 650 grams of feed and a

drinker containing up to 600 ml. of water (see figure 7.1). The birds were experimentally reared under different light treatments for seven weeks. The light treatments were as follows :

T0; Dim Blue (day 1 - 49), as a control .

T1; Red light (day 1-16), followed by dim blue (day 17- 49)

T2; Dim blue (day 1-16), followed by red (day 16-32), and then dim blue from day 33 to 49.

Each cage contained a mesh floor (7x7mm square holes), overlying a faeces catchment tray. The solid sides precluded any visual contact among the groups. The floor space measuring 575 x 765 mm allowed a stocking density of 20 kg/m^2 (MAFF recommendation is 34 kg/m^2)(Figure 7.2).

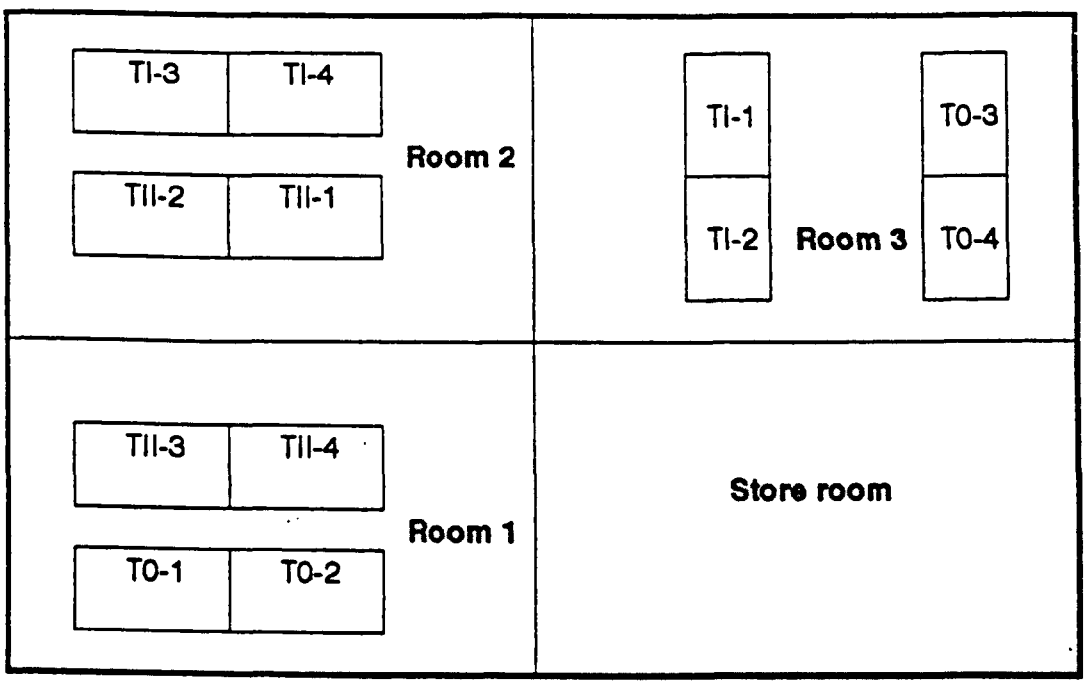


Figure 7.1 Plan of the chicken room

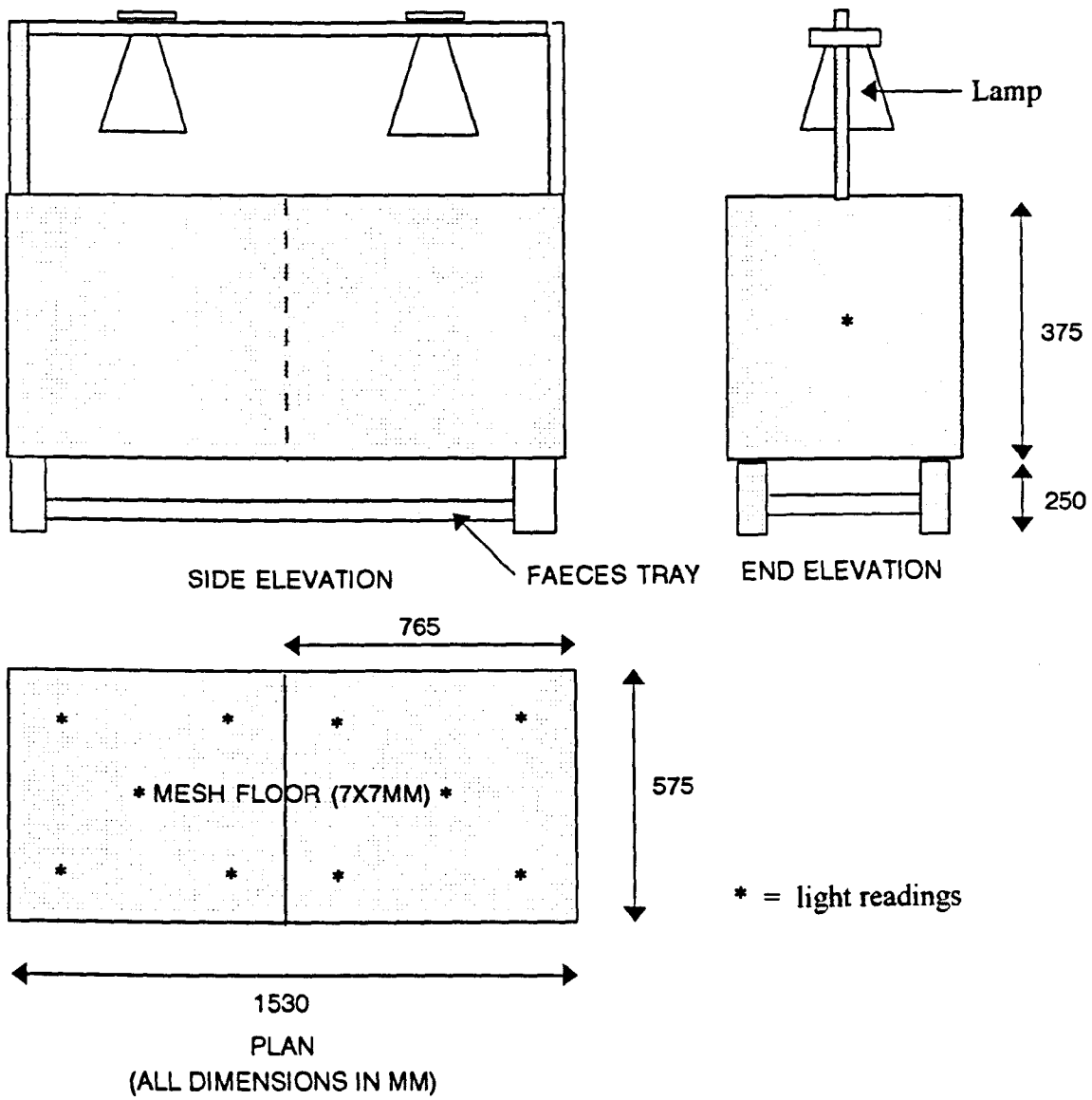


Figure 7.2 Pen construction

The birds were reared on a standard commercial ad-lib diet of 540 Broiler Starter Crumbs from day 1 - 14 and 448 Gold Grow pellet ACS from day 14 - 49 as used in Experiment1, parts 1 and 2. The composition of the chickens' diet is described in Chapter Three.

The light intensity for red and blue lights was recorded using a Quantum sensor. Five readings were taken per cage at a height of 20 cm from the ground and 30 cm from the bottom of the light source. The mean intensities were 0.07 mv (860 x 10^{20} photons) for red and 0.004 mv (1.5 x 10^{20} photons) for blue lights. The red and blue lights were produced using LEE filter numbers 106 primary for red and 120 for deep blue over a 40 Watt tungsten filament bulb.

7.3.2. Behavioural parameters

The behaviours observed were time spent in walking (W), feeding (F), standing (SD), wing and leg stretching (WS), sleeping (SL) and sitting (ST). In this experiment the dozing behaviour recorded in previous experiments was recorded as sleeping.

To measure the effect of the treatments, a visual assessment of activity was conducted throughout the experiment. Each change of light colour had an effect on the birds' activity and to establish the initial and long term reactions, each bird was individually head marked and recorded for a 24 hour period spread randomly throughout each of the three 16-day periods in one hour sessions, recording the parameters every 10 minutes for each bird (Figure 7.3). Overall, each bird was therefore monitored for a total of 72 hours over the 49 days (Figure 7.4). The time spent in each activity is reported in minutes of activity per hour. A visual assessment was also conducted of cannibalism and feather pecking behaviour following the same procedure as for the other behaviours.

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Treatment : **Date :** **Time :**

Bird No.	10	20	30	40	50	60
1						
2						
3						
4						

Note :

Figure 7.3 Behaviour record chart

Date	TIME							
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	21-24
Mon,26 July	DAV (123)		DWI (231)		DAV (312)		DWI (123)	
Tues,27July		DAV (231)		DWI (312)		DAV (123)		DWI (231)
Wed,28July	DAV (312)		DWI (123)		DAV (231)		DWI (312)	
Thur,29July		DAV (123)		DWI (231)		DAV (312)		DWI (123)
Fri,30July	DAV (231)		DWI (312)		DAV (123)		DWI (231)	
Sat,31July		DAV (312)		DWI (123)		DAV (231)		DWI (312)
Mon,2 Aug	DWI (123)		DAV (231)		DWI (312)		DAV (123)	
Tues,3Aug		DAV (231)		DWI (312)		DAV (123)		DWI (231)
Wed,4Aug	DWI (312)		DAV (123)		DWI (231)		DAV (312)	
Mon,9 Aug		DAV (123)		DWI (231)		DAV (312)		DWI (123)
Tues,10Aug	DWI (231)		DAV (312)		DWI (123)		DAV (231)	
Wed,11Aug		DAV (312)		DWI (123)		DAV (231)		DWI (312)
Mon,16 Aug	DAV (123)		DWI (231)		DAV (312)		DWI (123)	
Tues,17Aug		DWI (231)		DAV (312)		DWI (123)		DAV (231)
Wed,18Aug	DWI (312)		DAV (123)		DWI (231)		DAV (312)	
Mon,23 Aug		DWI (123)		DAV (231)		DWI (312)		DAV (123)
Tues,24Aug	DWI (231)		DAV (312)		DWI (123)		DAV (231)	
Wed,25Aug		DWI (312)		DAV (123)		DWI (231)		DAV (312)

Note : Observations taken over intervals of one hour/room according to the number in brackets,for example (123) means that the observation started in room 1 for an hour, then moved to room 2 for one hour, and then to room 3 for another hour. Two recorders were used (DAV and DWI).

Figure 7.4 Observation chart for behaviour analysis

7.3.3 Performance parameters

7.3.3.1 Weight gain, feed consumption, food conversion ratio,

Each bird was weighed on days 1,32 and 49. Feed consumption was monitored for each replicate (4 birds) and an average feed consumption per treatment was calculated. A food conversion ratio for each treatment allowed an assessment to be made of the commercial viability of undertaking such lighting patterns in practice, as any attempt to implement such a proposal would need to satisfy both welfare and economic considerations.

7.3.3.2 Bone characteristics

The bone length, bone weight and bone strength were measured at the end of the experiment after slaughter, ensuring minimal trauma and consequent leg damage. For bone strength examination, the right and left tibia were dissected and broken fresh within one hour of dissection. The bones were broken on an Instron 4301 tensiometer, using a three point bend with supports 60 mm apart and a load applied at 50 mm/minute to the mid point of the long axis of the bone, following the same procedure as Knowles (1991). The parts of the tensiometer which were in contact with the bone were covered in soft rubber tubing to avoid point stresses. The bones were always placed in the same orientation. The breaking strength was recorded as the peak load before the bone broke. Both right and left tibia breaking strengths were recorded.

Following guide-lines set out by Lynch and Whitehead (1992), a histopathological examination was made to assess the degree of tibiotarsal bowing in a venterodorsal plane by calculating the tibial plateau angle. The long axis of the bone was established by drawing a straight line from the proximal to the distal end of the tibia. A second line was drawn perpendicular to the long axis bisecting the proximal

extremity of the cnemial crest. The tibia plateau angle was measured between this perpendicular line and a line from the proximal crest across the surface of the condyles (Figure 7.5)

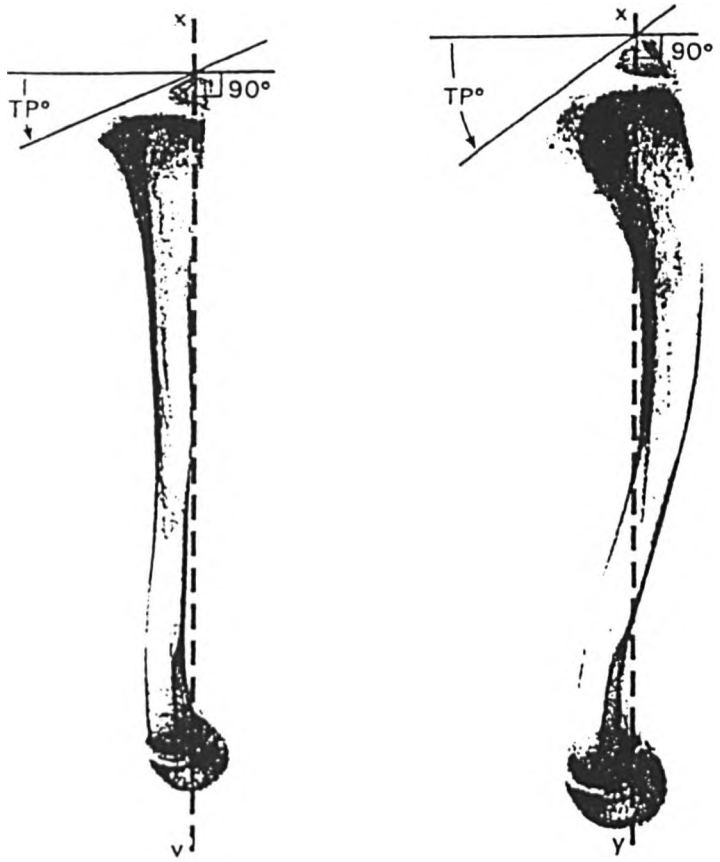


Figure 7.5 Technique for measuring the tibial plateau angle

Torsional measurements were made by comparing the transverse axes of the proximal and distal articular surfaces of each tibia, following the same procedure as described by Duff (1985). Torsional estimates were recorded as external or internal depending on the orientation of the distal relative to the proximal articular surface of the bone.

7.3.4 Lameness and gait abnormalities

A daily visual inspection was undertaken throughout the 44 day cycle for each bird, using a subjective assessment of lameness produced by MAFF (1992) for commercial flocks under the following criteria : 0, moves normally; 1, has intermittent detectable abnormality in its gait; 2, has permanent detectable abnormality in its gait; 3, has gait abnormality but can walk; 4, only one or two steps taken at a time; and 5, cannot walk at all.

7.3.5 Experimental design and statistical analysis

The experiment was designed using Randomised Block Design (Steel and Torrie, 1986). The experiment was divided into three blocks of time each of 16 days (periods). The three treatments of red and blue light patterns were applied with four cage replications with 2 male and 2 female birds in each unit. The significance of differences caused by the treatment was examined by Analysis of Variance (ANOVA), Pearson Coefficient of Correlation and Regression through the statistical package Minitab. The standard error of the difference between the two means (SED) is reported. Lameness and gait abnormalities were tested using Chi-squared (Snedecor and Cochran, 1967).

7.4 RESULTS

7.4.1 Temperature

Daily minimum and maximum temperatures were consistently comparable between rooms and followed the same temperature patterns used in commercial artificially controlled buildings (Table 7.1 and Figure 7.6). Throughout the experiment the ambient temperature was optimum for broiler growth.

Table 7.1 Average room temperature during the course of the experiment*

Age of the chicks (days)	Recommended room temperature (°C)**	Recorded room temperature (0C)		
		Room-1	Room-2	Room-3
1 and 2	32	29	28.5	28.5
3 and 4	32	27.5	26	26
5 and 6	30	26.5	25.5	25.5
7 and 8	29	26.5	25.5	26
9 and 10	28	25.5	26	25
11 and 12	27	25.5	25	26
13 and 14	26	25.5	25	25
15 and 16	25	25	24.5	24
17 and 18	24	24	23.5	23.5
19 and 20	23	23.5	23.5	23.5
21 and 22	22	23	22.5	22
23 and 24	21	22	21.5	21.5
25 and 26	21	22	22	21.5
27 and 28	21	21.5	21.5	22
29 and 30	21	21.5	21	21
31 and 32	21	21.5	19.5	20.5
33 and 34	21	21.5	19.5	20
35 and 36	21	21	19.5	20
37 and 38	21	21	19.5	20
39 and 40	21	21	20	20
41 and 42	21	21.5	19.5	20
43 and 44	21	21	19.5	20.5

* the average of maximum and minimum temperatures

** **source**, Farm Electric Handbook (1990)

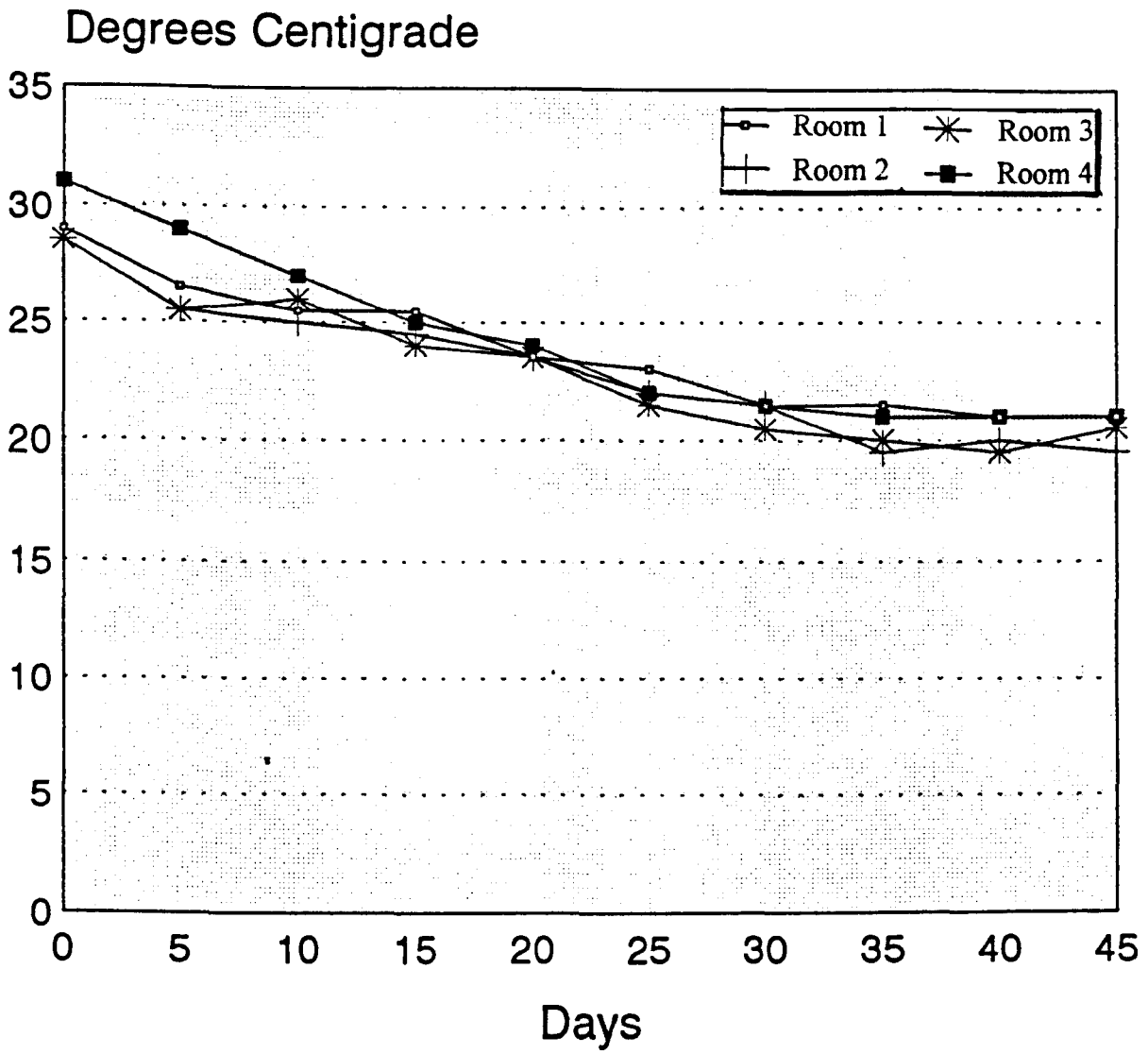


Figure 7.6 Daily room temperatures

7.4.2 Broiler behaviours

The standing time of the birds was not affected by the treatment overall but using bright red light significantly increased the time spent walking, stretching and feeding in T1 and T2 (Table 7.2). The increase in walking with red light was greater in T1 than T2. The amounts of time spent sleeping and sitting were greatest for birds reared by the control (Table 7.2).

Table 7.2 The time spent by broilers in different behaviours under different patterns of coloured light (minutes/hour/bird)*.

Behavioural parameters	T0	T1	T2	P	SED
walking	3.70	5.18	4.65	0.000	0.26
feeding	8.85	9.93	9.75	0.000	0.34
standing	8.60	9.10	8.73	0.359	0.37
stretching	1.34	2.25	2.26	0.000	0.18
sleeping	17.61	15.74	16.21	0.003	0.46
sitting	19.94	17.79	18.41	0.000	0.49

* mean of 3 observations

The sex of the birds did not significantly affect most behaviours or their response to light (Table 7.3). However, the male birds spent longer feeding and less time sleeping than the females. There were no significant interactions between sex and colour pattern in relation to the major behaviours of the birds (Table 7.3).

There was a tendency for feeding, standing and sleeping time to decline with the passage of time, and for stretching and sitting to increase (Table 7.4). The interactions showed that the changes in mean behaviour for the whole experiment were primarily due to changes in the treatment when light changes were made, but there were some residual effects, particularly in feeding and stretching. Comparing T0 and

Table 7.3 The behaviour of male and female broilers under different patterns of coloured light (min/h/bird)

Behavioural parameters	Male			Female			Sex		Treatment		Interaction	
	T0	T1	T2	T0	T1	T2	SED	PROB	SED	PROB	SED	PROB
walking	3.82	5.02	4.49	3.59	5.34	4.80	0.21	0.524	0.26	0.000	0.36	0.458
feeding	9.02	10.54	9.95	8.68	9.31	9.55	0.28	0.018	0.34	0.003	0.48	0.345
standing	8.59	9.58	8.91	8.61	8.62	8.55	0.30	0.147	0.37	0.359	0.52	0.406
stretching	1.45	2.05	2.34	1.23	2.46	2.19	0.15	0.902	0.18	0.000	0.26	0.158
sleeping	17.16	15.56	15.58	18.06	15.92	16.85	0.38	0.026	0.46	0.000	0.66	0.617
sitting	20.05	17.19	18.75	19.82	18.39	18.08	0.40	0.808	0.49	0.000	0.69	0.133

Table 7.4 The behavioural time spent by broilers under different patterns of coloured light (T) and period of time (P)

Behavioural parameters	T0			T1			T2			Treatment		Period		Interaction	
	P1	P2	P3	P1	P2	P3	P1	P2	P3	SED	PROB	SED	PROB	SED	PROB
walking	3.75	4.05	3.31	7.25	4.27	4.02	3.53	5.14	5.27	0.25	0.000	0.25	0.041	0.44	0.000
feeding	10.84	7.77	7.93	12.91	8.42	8.45	9.21	9.84	10.19	0.34	0.003	0.34	0.000	0.59	0.000
standing	9.37	9.21	7.20	9.35	9.48	8.48	7.85	9.24	9.10	0.37	0.359	0.37	0.016	0.63	0.005
stretching	1.14	1.30	1.58	2.69	2.28	1.79	1.09	3.12	2.58	0.18	0.000	0.18	0.004	0.31	0.000
sleeping	19.81	17.12	15.90	13.67	17.69	15.67	22.54	12.15	13.94	0.46	0.000	0.46	0.000	0.80	0.000
sitting	15.16	20.57	24.08	14.08	17.88	21.41	15.79	20.54	18.91	0.49	0.000	0.49	0.000	0.84	0.000

T1. the residual effects in P2 and P3 were 29 and 23% of the effect in P1 for feeding and 63 and 31% of the effect in P1 for stretching.

Birds in all treatments showed very little feather damage and most birds had their plumage in perfect condition. Periods of red and blue light made no difference to feather pecking. No signs of cannibalism were evident, although the data to establish this point are not available.

7.4.3 Performance

7.4.3.1 Weight gain, feed consumption and feed conversion ratio

By chance there were significant differences between initial body weights due the to treatment ($P<0.05$). The final body weights (adjusted by covariate) and feed conversion ratios of broilers reared under the different light patterns showed significant differences throughout the rearing period ($p<0.05$)(Table 7.5). The heaviest final body weight and the highest feed efficiency were observed in T1 compared with T0 and T2. However, the feed consumption did not show any significant difference ($p>0.05$), although there was a tendency for an increased feed consumption in the birds reared in T0. The equation of multiple regression between initial body weight (IBW) and final body weight (FBW) is as follows :

$$FBW = 711 + 6.91\ IBW\ (r^2 = 98.3\% ;\ P = 0.00)$$

Table 7.5 The growth rate of body weight, cumulative feed consumption and feed conversion ratio of broilers reared under different patterns of coloured light to 49 days of age

Parameter	T0	T1	T2	P	SED
Initial BW (g)	130	128	134	0.001	2.49
Final BW (g)	1536.6	1650.9	1508.1	0.172	78.49
Adj.Final BW (g)	1545.0	1682.7	1475.5	0.001	72.02
FC (g/bird)	3787.5	3387.5	3618.8	0.584	176.27
FCR	1 : 2.51	1 : 2.04	1 : 2.43	0.003	0.104

Legend :

BW = body weight, FC = feed consumption, FCR = feed conversion ratio
Adj.Final BW = adjusted final body weight, calculated by ANCOVA using initial body weight as a covariate.

7.4.3.2 Bone characteristics

Bone strength was significantly reduced in T2 (table 7.6). There were no major differences in bone weight or length, although the former tended to be reduced in T2.

Table 7.6 The bone length, bone weight, bone strength, TPA and torsion of broilers under different patterns of coloured light to 49 days age

Parameters	T0	T1	T2	P	SED
Bone length (mm)	104.94	106.38	106.22	0.64	1.68
Bone weight (g)	16.58	16.493	15.395	0.12	0.63
Bone strength (Newtons)	253.69	261.84	235.03	0.05	11.09
TPA (degrees)	27.22	25.84	25.34	0.41	1.45
Torsion (degrees)	5..41	7.09	6.12	0.62	1.73

TPA = tibia plateau angle

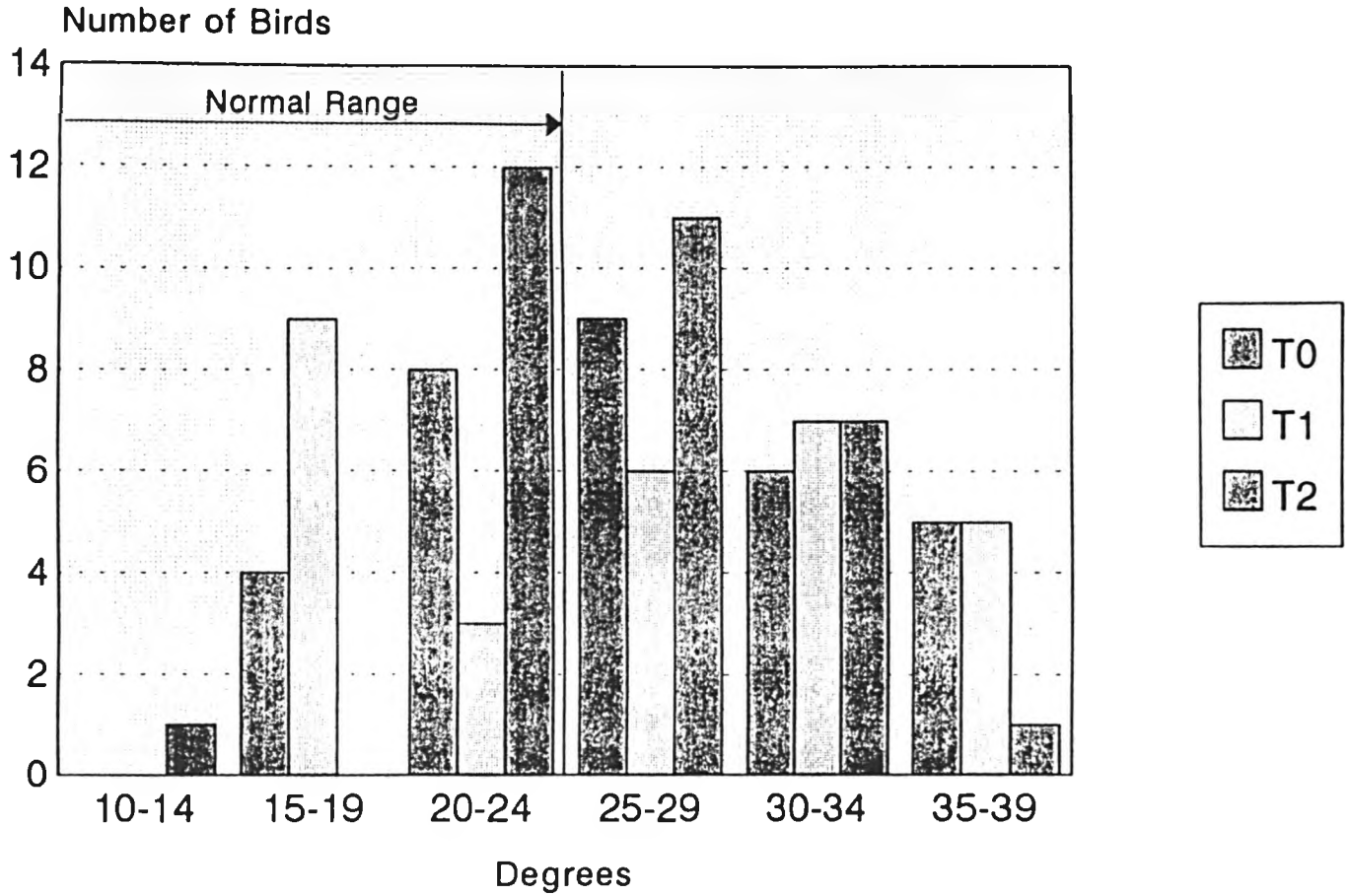
The effects of treatment effects on TPA were not significant and the results indicate that the number of bones (Table 7.6) above the normality threshold of 25 degrees was within birds between treatments. However, whilst the effects of red and blue lighting patterns did not differ, it should be noted that in all treatments sixty percent of birds had a tibia plateau angle over the 25 degree threshold (Figure 7.6).

There was no significant difference between treatments with regard to tibiotarsal torsion (Table 7.6), where the frequency of angles outside normal limits was consistently similar between treatment (Figure 7.7). Torsion was measured as an internal (i) or external bend (e), where external angles above 15 degrees and all internal angles were interpreted as abnormal (Table 7.7).

The interactions between treatments and sex on the bone length, bone weight, bone strength and tibiotarsal torsion were not significantly different, although the effect on bone strength of a reduction in T2 tended to be confined to females (Table 7.8). There was a tendency for shorter bones to occur in females. A significant interaction was observed with regard to the tibia plateau angle (P=0.008), which showed that females had more tibial bowing in T0 and T2; but male birds in T1 had greater tibial bowing than females. There was a tendency for greater torsion to occur also in T1 in males.

There was no significant difference between left and right legs in most leg characteristics ($p>0.05$) but the tibia plateau angle was greater in left than right legs (Table 7.9).

Fig. 7.7 Tibia Plateau Angle Results.



Figures over 25 Degrees represent abnormality

Table 7.7. Torsional measurements (degrees)

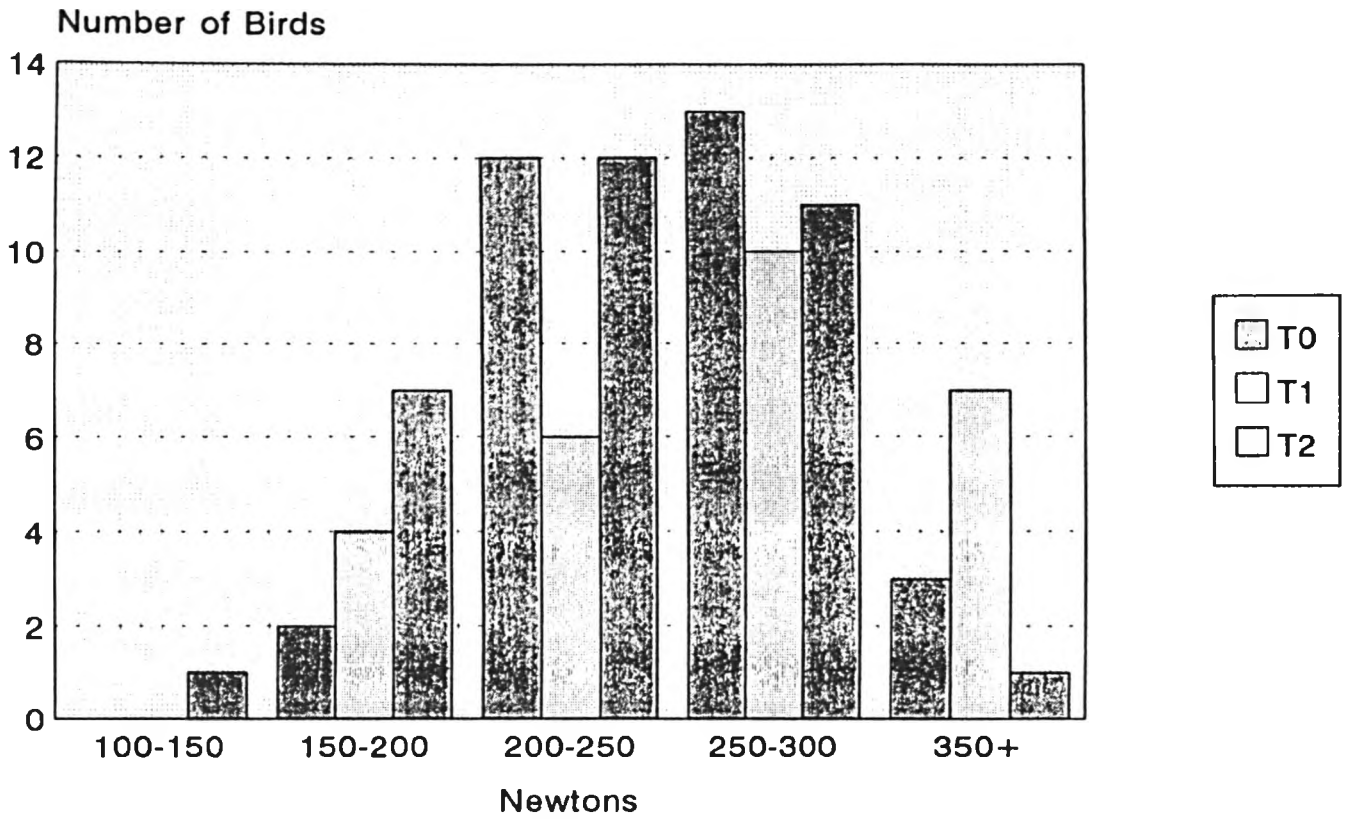
Bird	T0 1		T0 2		T0 3		T0 4	
No.	Right	Left	Right	Left	Right	Left	Right	Left
1	6i	16e	0	10e	14e	14e	13e	12e
2	6e	3i	0	0	15e	13e	1i	0
3	4i	0	4e	25e	8e	11e	0	2i
4	7e	2e	6i	14e	3e	6e	6e	4i

Bird	T1 1		T1 2		T1 3		T1 - 4	
No.	Right	Left	Right	Left	Right	Left	Right	Left
1	dead	dead	6e	8e	19e	18e	2e	8e
2	6e	0	17e	16e	20e	0	13e	11e
3	6i	0	12e	8e	dead	dead	12e	0
4	7i	2i	1i	8e	12e	13e	8e	0

Bird	T2 1		T2 - 2		T2 3		T2 4	
No.	Right	Left	Right	Left	Right	Left	Right	Left
1	20e	8e	4e	9e	7e	5e	6i	3i
2	3i	4e	2i	5e	7e	2e	13e	7e
3	8e	0	11e	3i	0	7e	5e	7e
4	10e	8e	16e	14e	15e	9e	7e	5e

Note : i : internal angle, e : external angle -----> refer to page 19
Torsion was measured as an **i** or **e** bend, where external angles above 15 degrees and all internal angles were interpreted as abnormal.

Fig.7.8 Tibia Peak Load Results



Averages. T0 = 253, T1 = 261, T2 = 235.

Table 7.8 The bone length, bone weight and bone strength, TPA and torsion of male and female of broilers under different patterns of coloured light

Parameters	Male			Female			Sex		Treatment		Interaction	
	T0	T1	T2	T0	T1	T2	SED	PROB	SED	PROB	SED	PROB
Bone length (mm)	106.19	108.75	105.94	103.69	104.00	106.50	1.36	0.11	1.68	0.64	2.37	0.29
Bone weight (g)	16.03	16.58	15.88	17.13	16.40	14.91	0.52	0.97	0.63	0.12	0.89	0.26
Bone strength (Newtons)	250.06	257.25	252.12	257.31	266.44	217.94	9.31	0.53	11.09	0.05	16.12	0.16
TPA (degrees)	26.06	28.25	24.75	29.37	24.44	25.94	1.18	0.85	1.45	0.41	2.04	0.01
Torsion (degrees)	6.44	9.75	4.81	4.37	4.44	7.44	1.42	0.27	1.73	0.62	2.45	0.08

Table 7.9 The bone length, bone weight, bone strength, TPA and torsion of left and right legs of broilers under different patterns of coloured light

Parameters	Left			Right			Left-Right		Treatment		Interaction	
	T0	T1	T2	T0	T1	T2	SED	PROB	SED	PROB	SED	PROB
Bone length (mm)	104.81	106.44	106.25	105.06	106.31	106.19	1.37	0.99	1.68	0.64	2.37	0.99
Bone weight (g)	16.62	16.49	15.35	16.54	16.50	15.43	0.52	0.99	0.63	0.12	0.89	0.99
Bone strength (Newtons)	251.94	253.66	233.50	255.44	270.13	236.56	9.30	0.41	11.09	0.05	16.12	0.80
TPA (degrees)	28.44	27.87	25.44	26.00	23.81	25.25	1.18	0.06	1.45	0.41	2.04	0.41
Torsion (degrees)	7.12	7.19	5.25	3.69	7.00	7.00	1.42	0.66	1.73	0.26	2.45	0.32

legend : TPA = tibia plateau angle

7.4.4 Lameness and gait abnormalities

The mean score of lameness problems and the total number of birds in each gait category indicating leg abnormalities (score 1 or above) in each treatment each week are presented in Table 7.10 and Figure 7.8 respectively.

A visual assessment of lameness and gait abnormalities of the birds showed little evidence of any problems in the initial 3 weeks of the experiment. The birds in the control treatment (T0) then demonstrated the highest incidence of lameness, where by week 6 eight birds (50%) had at least an intermittent detectable abnormality in their gait, with four of these birds (25%) being crippled and unable to stand. By the sixth week two birds (12.5%) in T1 could not walk and had gone down on their legs, and were slaughtered for welfare reasons. In T2 as a comparison only one bird (6.25%) suffered from lameness and gait abnormalities and by week 6 had begun to recover to only an intermittent abnormality in its gait (probability of lameness difference : 0.02).

Table 7.10 Mean score of lameness and abnormalities in each treatment each week

Treatment	week 1	week 2	week 3	week 4	week 5	week 6	week 7
T0	0	0	0	0	0.36	1.79	2.07
T1	0	0	0	0.07	0.57	0.64	0.50
T2	0	0	0	0.21	0.14	0.07	0.07

Note : 0 = moves normally, 1 = has intermittent detectable abnormalities in its gait
2 - 3 = has permanent detectable abnormality in its gait
total number of birds in each treatment = 14

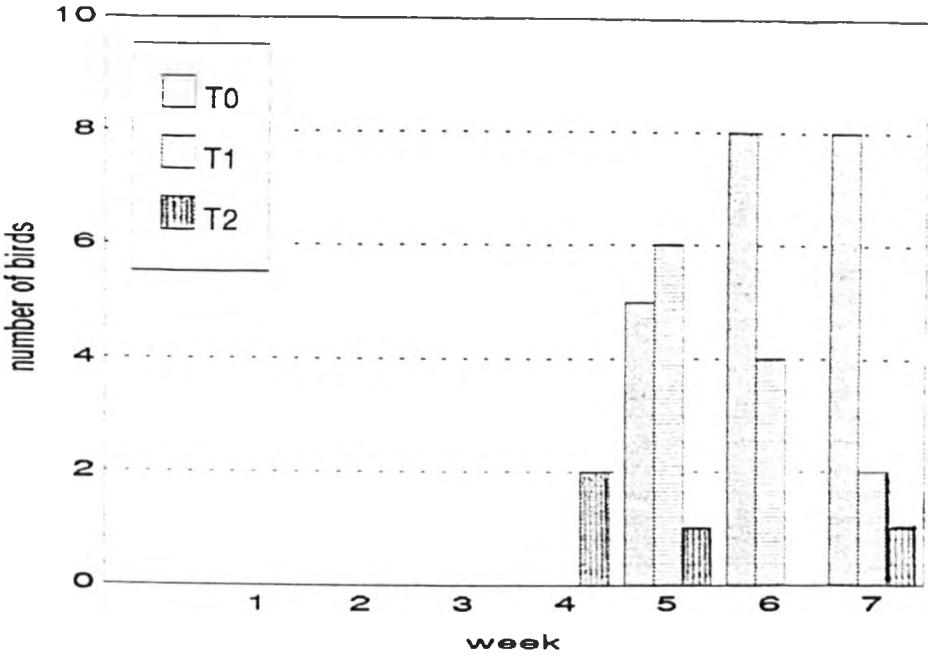


Figure 7.9 Total birds having incidence of lameness and abnormalities (score 1 or above) for each treatment each week

7.4.5 Correlation matrix between activities and performance of broilers

A correlation matrix between activities and performance shows that an increase in time spent walking is negatively correlated with the time spent sitting and sleeping (Table 7.11). Stretching also had a negative correlation with sitting, but it had a positive correlation with walking. No correlation was observed between bone strength and behaviours. There was a positive correlation between body weight and bone strength, length and weight; similar results were also obtained for the relationship between bone weight and bone strength or length.

Table 7.11 Correlation matrix between activities and performance

	Walking	Feeding	Standing	Stretching	Sleeping	Sitting	FBW	BLength	BWeight	BStrength	TPA
Feeding	0.048										
Standing	0.238	0.179									
Stretching	**0.300**	0.150	0.031								
Sleeping	**-0.405**	**-0.407**	**-0.328**	-0.194							
Sitting	**-0.430**	**-0.300**	**-0.320**	**-0.445**	-0.082						
FBW	0.280	-0.120	0.236	-0.089	-0.276	-0.011					
BLength	0.037	-0.114	0.233	0.007	-0.144	-0.158	**0.400**				
BWeight	0.154	-0.098	0.204	-0.093	-0.299	0.142	**0.430**	**0.356**			
BStrength	0.039	-0.206	-0.037	0.080	0.002	0.051	**0.424**	0.271	**0.500**		
TPA	-0.125	-0.014	-0.171	-0.018	0.107	-0.042	0.075	0.219	0.134	0.254	
Torsion	-0.086	-0.032	0.033	0.022	-0.035	0.092	0.132	-0.157	0.134	0.097	0.043

Legend : FBW = final body weight, B = bone, TPA = tibia plateau angle
Bold numbers indicate significance by table of correlation coefficients
at 5% and degrees of freedom = 48 { $T_{(50,5\%)}$} -----> = 0.273 (Snedecor and Cochran, 1967)
The regression aquation of FORCE of bones by stepwise analysis was as follows :

Force = 6.54 $\pm$ 1.64 bone weight + 0.0645 $\pm$ 0.01687 body weight + 1.65 $\pm$ 0.6109 TPA (r^2 = 31.5% , P = 0.000)

7.5 DISCUSSION

From the results it appeared that during period 1 red light had the effect of increasing walking and wing and leg stretching and this agrees with the findings of Experiment 1,part 1 (Chapter III), where a significant correlation was found between increased activity and red light in comparison with blue; it must, however, be noted that these were continual one-colour programmes and not mixed patterns. Red light during period 1 also enhanced the time spent in feeding which tended to result in better final body weight (the heaviest), although the food consumption tended to decrease in T1. It might be that exposing the birds to red light in the early period of their life can improve muscle growth and thereby result in a higher final body weight. Looking at the regression of growth rate, there was a significant relationship between the initial and final body weights (r^2 = 98.3% ; P = 0.00). This result was in good agreement with Bowlby (1957) who stated that red light made the feed more attractive. The reduced activity of the birds coupled with high food consumption usually resulted in better body weight gain. This phenomenon is in contrast with the findings of this experiment, in which the more active birds had a better food efficiency and lower food consumption. In this case a difference in the amount of uneaten food that spilled over the cage floor could have resulted in high food consumption records which could have affected the result. These results were in good agreement with Wathes *et al.* (1982), who stated that the birds' activity and growth were affected by the wavelength (colour) of light emitted by a 20 W. fluorescent tube.

The body weight was greatly affected by the difference in activity due to the treatment, and the difference between the group averages was clear. It is apparent that the initial body weight made a significant difference in terms of its effect in the final body weight gain. Therefore further analysis using analysis of covariance (ANCOVA)

was applied to eliminate another treatment factor influencing the differences. The differences between treatments in respect of the initial body weight was due to the error when the birds were taken for each treatment (the heaviest initial body weight was in T2 and the lightest in T1). This further strengthens the hypothesis that, when adjusted the final body weights from this study are representative of the three treatments and that the lighting patterns affected the final body weight and food efficiency. The result contrasts with the findings of Schumaier (1968), Wathes *et al.* (1982) and the first experiment in Chapter III, who/which found that different wavelengths had no significant effect on the growth of either male or female birds grown under blue or red light. There was a significant effect in terms of better efficiency and the heaviest final body weight in birds given bright red light in their early life. However, it should be noted that the use of red light in this experiment was not continuous as it was in Experiment 1, part 1 (Chapter III) and Experiment 3 (Chapter VI). In general, from all treatments the birds had a lower final body weight compared to the standard of the Farm Electric Handbook (1990) with averages of 1565g and 2000g respectively. It may be that the room conditions were not suitable for keeping the birds for more than five weeks, although the density was below the MAFF recommendation. The symptom typical in these experiments was that, when the birds approached 5 weeks old they started having respiratory problems. The ammonia concentration was not measured during the experiment, but it could have been one reason for the low growth rate. Another reason may be that during the first ten days of the birds' life, the room temperatures were below the standard used in commercial artificially controlled buildings.

Walking had a negative correlation with the time spent sitting ($r = -0.430$) and sleeping ($r = -0.405$). Stretching also had a negative relationship with sitting ($r = -0.440$). These findings tentatively point to the influence of the use of stimulatory bright

light in bringing about an increase in activity. Birds in continuously dim blue light were inclined to sit passively and sleep, and this caused the highest lameness problem.

The major result of this study is the high correlation which exists between bone strength, bone weight and body weight ($r > 0.4$), where birds given bright red light in the middle of their life had the lightest final body weight and the lightest average bone weight. The rate of change of bone strength with bone weight can be quantitatively described using the regression model as follows :

Bone strength = 56.20 + 6.46 Bone weight + 0.06 Final body weight

This association is entirely probable, being attributable to the increased mechanical loading on the bone and ossification of the bone over the lifetime of the bird (Knowles, 1993). In commercial application it states no more than the following : big birds have bigger heavier bones which are stronger than those of smaller birds, which could clearly be predicted by common sense.

The levels of leg abnormalities were comparable to those of birds of similar ages under commercial lighting programmes. However, significant improvements to torsional twisting and longitudinal bowing were not evident among those treatments which used lighting patterns and the continuous blue control. Although there were no differences between the sexes and left and right legs in terms of bone length, weight or strength or torsional twisting; the left leg tended to be longer than the right. The same tendency was also evident in the tibia plateau angle. There was a tendency for a stronger bone to be found in the right leg as compared to the left leg. These are the first, if somewhat inconclusive, reports of limb laterality in hens. There was a tendency for shorter bones to occur in females.

In terms of lameness and gait abnormalities, it is clear that giving bright red light in the first sixteen days can alleviate some of the lameness and gait abnormality problems, but it can also reduce bone strength when applied too late. This result contrasts with the findings of Wabeck and Skoglund (1974), Wathes *et al.* (1982), Zimmerman (1988) and Leighton and Hullet (1990), who have indicated that light wavelength and source have a relatively minor effect on the development of leg disorders. The difference in these findings may be because there were some differences between the design of the experiment, in particular the way in which this experiment imposed lighting conditions that doubled the walking time during the critical stages of life.

7.6 CONCLUSION

The present study has shown that giving bright red light in the first sixteen days significantly increased the time spent walking, stretching and feeding as well as the bone strength. Birds in continuously dim blue light were more inclined to sit passively and sleep and this caused the highest incidence of lameness. Bone strength was not affected by stimulatory red light in days 1 - 16 and the same red light in days 17 - 32 reduced bone strength. No adverse effects of stimulatory red light on weight gain were observed. It may be concluded that bright red light can alleviate some of the lameness problems in broilers, but that it can also reduce bone strength when applied too late.

Chapter VIII

GENERAL DISCUSSION

Hawryshyn (1982) emphasizes the importance of eliminating brightness as a discriminatory cue in animal colour vision studies. Without the control of brightness (intensity) the animals may not be using hue (wavelength) as a cue for discrimination. Hawrysyn concludes that spectral preference testing and other such innate responses have potential shortcomings for examining animals' colour vision. The innate behaviours are often confounded by a neutral mechanism other than the visual system and tend to distort the normal characteristics of the species' colour vision. Accurate descriptions of any species' colour vision depends, first, on a determination of spectral sensitivity or a brightness discrimination test to equate levels and, second, tests of wavelength discrimination.

Van Tienhoven and Planck (1973) stated that light intensity was important because it determined whether light of a given wavelength penetrated to the level of the bird's extra-retinal receptor. Foster and Follett (1985) subjected Japanese quail to 500 nm wavelength light, and calculated the absolute sensitivity of the bird's extra-retinal photoreceptors to be 1.71×10^{10} photons $m^{-2}.s^{-1}$.

Behavioural consideration.

This research has demonstrated that different colours and light intensities can influence the behaviour of broilers. Birds reared in red light were more active than birds reared in blue and green light. Birds in white light were in between red and blue or green. This effect may be due to the better visual sensitivity of chickens at the red compared with the blue end of the visible spectrum and as a result the red light appears brighter. This result is in good agreement with Bowlby (1957) who stated that red light

made the feed more attractive whilst birds reared under white light were more excitable, and birds under blue light were blind. Furthermore, Morris (1968) and Cavalchini *et al.* (1984) reported that despite some confusion between wavelength effects and light intensity effects, the avian species are known to be particularly sensitive to bands of light nearest red and orange.

Birds reared in a coloured light showed an initial preference to remain in that light but after one week had elapsed they preferred a change to a different colour, usually blue. The tendency of birds to go to the initial light used during the rearing stage might be due to the residual memory during the first three hours of the test. The preference for red light of birds that had been reared in neutral colour (white) was reasonable because the most easily perceived part of the spectrum of white light is red. After one week had elapsed, almost all the birds preferred blue light as the first choice and, secondly, green light. However, blue and green light are most likely to be similarly perceived in terms of brightness (they are dimmer compared to red). These results are in harmony with those of Hurnick *et al.* (1971) who stated that birds could differentiate between certain areas of the colour spectrum. Moreover, Foster and Follet (1985) who investigated duck and Japanese quail, found that red light (around 620 nm) was more stimulatory than other colours because red light penetrates the skull and brain more efficiently than other colours.

It was found that the birds could distinguish successfully between white lights with a difference in their intensities of not less than 16.79×10^{22} photons. In terms of the luminance contrast index (LCI) the chickens failed to differentiate at an LCI level of 0.20 for the bright group and a LCI level of 0.37 for the dim group. This is comparable with the findings of Phillips and Weiguo (1991) who found that failure in the dim group to discriminate finally occurred at an LCI level of 0.23 for calves and an

LCI level of 0.17 for humans. Furthermore, in the bright group calves failed to discriminate at an LCI level of 0.29 and humans failed to discriminate at an LCI of 0.07. Thus, on an average between bright and dim light, chickens have a similar failure level in terms of LCI to calves (0.285 and 0.260 for chickens and calves respectively). All of the bright selectors among chickens, calves and humans learn quicker and can discriminate better than dim selectors. It has been found that animals are better at detecting the presence of some additional light rather than the absence of some light. This may be partly due to the novelty of a bright stimulus, the birds being kept for the rest of the time under a light intensity more similar to the dim light. However, at least under scotopic conditions, these similar behavioural results for absolute sensitivity do concur with the concentrations of visual pigment in warm-blooded vertebrates (Munz, 1974). It is believed that the visual system, being similar for most vertebrates, evolved at an early period of time. The results of these experiments also suggest that the perception of brightness is relative rather than absolute, as has been demonstrated in preference tests with monkeys (Jacobs, 1977).

The chickens failed to differentiate the brightness of blue and red light at a (photon) ratio 3.1 - 3.6 : 1.0. This indicates that the birds have a similar light perception for blue and red in a ratio of 3.1 - 3.6 : 1.0. This result would help to explain the result of Experiment 1 (Chapter III) by suggesting that the red light increased activity because the birds perceived it as being brighter than it actually was. Based on this result, further experiments concentrated on red and blue using an equated brightness of blue to red at a (photon) ratio of circa 3.3 : 1.0.

An increase in the intensity of red light increased the time spent in feeding, walking, drinking, stretching and in aggression. These findings are in harmony with previous studies conducted by Newberry *et al.* (1988), who found that increasing the

light intensity caused the birds to spend increased time in walking, standing and in their total activity. By contrast, in blue light the increase in intensity did not increase the time spent in walking and drinking, but stretching and aggression were increased. There was strong evidence that the time spent standing, sleeping, stretching, pecking and in aggression were greater in the red light at low, medium and high intensities than in the blue light. On the other hand, the time spent in dozing was greater in the blue light than in red. This result is in confirmity with that of Experiment 1 (Chapter III) which found that birds were more active under red light compared to blue, whilst birds in the blue light seemed more inclined to sit passively and doze. The increased time spent feeding and standing at high intensity in this experiment can be compared with the results of Experiment 1 (Chapter III) in which there were no significant differences. It is possible that using the time-lapse video could have given more accurate results than manual recording due to the disturbance caused by the observer. The specific response to colour, apart from light intensity, may demonstrate specific effects of colour on photic stimulation in fowl. Thus, certain photoreceptors may transmit specific information which when decoded by the brain produces different responses by the bird.

Performance and physiological considerations

Different colours of lighting (White, Red, Green and Blue) did not affect the overall final body weight of the broilers. This result is in harmony with Smith and Phillips (1959), Kondra (1961), Schumaier *et al.* (1968), Peterson and Espenshade (1971) and Wathes *et al.* (1982) who reported that the growth of broilers, turkeys, laying hens and chicks was unaffected by the wavelength and spectral composition of light. In contrast, Woodard *et al.* (1969) and Newberry *et al.* (1987) found that the

growth of male Japanese quails and chickens respectively were significantly affected by different colours and intensities of light. Since there are some contradictions between the results of experiments to study wavelength and/or light intensity, these findings may be due to the different experimental designs and methods. However, this is the first demonstration of the effect of coloured light in equated brightness (as perceived by the bird) on the behaviour, performance and physiological responses of broilers.

Since the treatments were concentrated on red and blue light, it is evident that the final body weight, food consumption and food conversion ratios were similar in both red and blue lights at low, medium and high intensities. However, looking at the daily body weight gain under different colours and intensities of light, there is a tendency for less growth to occur in red light. This may be due to the greater activity of birds reared under red light compared to blue. This result is in harmony with Woodard *et al.* (1969) and Newberry *et al.* (1987) who found that the growth of male Japanese quails and chickens respectively were significantly affected by the colours and intensities of light. Since there are some contradictions between the results of experiments studying wavelength and/or light intensity, it may again be due to differences of experimental design and method.

Hence, the highest efficiency and heaviest final body weight were obtained in birds given bright red light in their early life. It should be noted that the red light was not used continuously throughout their lives as in the previous experiment (Chapters III and VI). Birds in continuous dim blue light were inclined to sit passively and sleep, and this caused the highest incidence oflameness problems. The major result of this experiment is the high correlation which exists between bone strength, bone weight and body weight ($r > 0.4$, $P = 0.00$) where birds given bright red light in the middle of their

life had the lightest final body weight and lightest average bone weight. The rate of change of bone strength with bone weight can be quantitatively described using the regression model as follows :

Bone strength = 56.20 + 6.46 Bone weight + 0.06 Final body weight

This association is entirely probable, being attributable to the increased mechanical loading on the bone over the lifetime of the bird and ossification of the bone (Knowles,1993). As regards the commercial application the conclusion to be drawn is merely that big birds have bigger, heavier bones which are stronger than those of smaller birds, and this could clearly be predicted by common sense. It was also found that :

Bone strength = 1.65 + 6.54 bone weight + 0.06 Final weight + 1.65 TPA

(TPA = tibia plateau angle; $r > 0.5$, $P = 0.0$)

Welfare considerations

Scientific evidence on the welfare of poultry is urgently required, so that an assessment can be made of intensive production systems (FAWC, 1992). However, it has become difficult for the academic hierarchy to agree on a single definition of welfare. It has recently been suggested that welfare is mainly (Dawkins, 1990) or solely (Duncan and Petherick, 1989) dependent on the animals' feelings, whilst Broom (1986) defines welfare as an individual's state as regards its attempts to cope with its environment.

Measures of poor welfare when animals encounter short term or long term problems may be physiological, behavioural or concerned with individual production or disease. Individuals vary in the way in which they cope, so that any one measure may indicate poor welfare and the absence of evidence from one measure does not mean that there is no welfare problem (Broom, 1988). However, how poor must the welfare become before it is humanely assessed as being intolerable, particularly when the incorporation of moral and ethical values makes it difficult to assess, given that individuals respond differently?.

In a utopian husbandry-systems the environment for a farm animal should not only minimise discomfort, stress, fear and frustration, but positively promote behavioural satisfaction (Lorenz, 1965). Progress towards this ideal depends on an improved understanding of the animal's own perception of its environment. Analysis of an animal's behaviour in terms of external and internal motivating forces requires a knowledge of physiology and ethology to design environments that are more in tune with those patterns of behaviour which the animal deems important (Spedding, 1988).

Spedding, in The Farm Animal Welfare Council (1992) states *"High priority should be given to the reduction of skeletal, muscular and tendon abnormalities in broilers. Research and development should be undertaken as a matter of urgency to determine the optimum light intensity and pattern for broiler chickens which minimise welfare problems".*

The Royal Society for the Protection and Cruelty to Animals state *"Research into leg problems in broilers with shorter and shorter growing periods is required to establish at what level stress and behavioural interactions occur with different light intensity and pattern"* (Potter, 1993).

Although there has been considerable research to date on lighting (including colour and intensity), it seems that work is still needed to establish the effect of light on broilers, particularly in relation to colour and intensity. Moreover, research findings about the optimum light patterns using different colours and intensities may have beneficial effects on bird welfare.

Form this study it has been concluded that, firstly, the birds are more active in red than in blue and green lights. Secondly, giving bright red light in early life increases the time spent walking, stretching, and feeding, which allows young chicks to exercise sufficiently. As a result, it tends to increase bone strength and alleviate lameness problems. However, it reduces bone strength when applied later in life. Broilers reared under different colours of lighting had more skin compared to broilers reared under white light. The heaviest gut contents were found in birds under blue light and the lightest were under red light. Thirdly, both male and female broilers show the greatest longterm preference for blue light , followed by green light, although their initial preference, after a neutral colour, is for red light. Birds reared in a coloured light show an initial preference to remain in that light but after one week they prefer a change to a different colour. Fourthly, in the equated brightness of red to blue at a ratio of circa 3.3 :1.0 there are distinct effects of colour of lighting on broiler behaviour with increased activity in red light. Increased intensity also stimulated behavioural activity, particularly in red light.

Future work

The heaviest skin and feathers occurred in birds under blue light followed by green, red and white. This may have been due to the more rapid onset of maturity in these birds compared with those reared under red light, which produced a greater bone percentage at slaughter. This was not, however, reflected in body fat percentage and needs further research.

In accordance with the chickens' preference, there was evidence that the birds did not like the red light. It might be that the red light was merely brighter to them than the others and caused stress. Thus, further fearfulness tests are needed and need to be reconciled with the reports of reduced bird cannibalism under red light.

The frequency of reports of lower feed intakes and improved feed conversion ratios among birds reared in red light suggests that these reflect real responses, even though they rarely achieve significant levels of probability. Small differences in food intake and conversion ratio, whether statistically significant or not, do contribute to profitability if they are real, especially in large operations. Research into food utilisation by broilers subjected to different light colours and intensities, using a large scale calorimeter and nutrient balances, would therefore seem very useful.

Practical implications

The equated brightness method in this experiment might be applicable in further experimental action relating to the colour and intensity of light. Giving bright red light in the first sixteen days for broilers may be of the greatest benefit on a commercial scale.

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APPENDIX 1. SPECIFICATIONS FOR QUANTUM SENSOR (TYPE QS)

SPECIFICATIONS :

Sensitivity	: 10.0 mV per mmole m^{-2} s^{-1}
Linearity	: $\pm$ 1% from 0 to 2 mmole m^{-2} s^{-1}
Absolute accuracy	: $\pm$ 5% traceable to NBS standards
Stability	: $\pm$ 2% per annum
Temperature coefficient	: - 0.1%/ ^{0}C
Azimuth error	: $\pm$ 1% over 360^0

DIMENSIONS :

Length	: 37.5 ($\pm$ 0.5) mm
Diameter	: 15.0 ($\pm$ 0.2) mm
Attachment	: via an M3 screw in base
Lead	: 5 m long unless otherwise specified
Connection	: Bare Wire Termination
Sensor Housing	: black anodised aluminium
Weatherproofing	: waterproof to 1m depth of water (10m versions available on request)

LIST OF PUBLICATIONS

British Poultry Science (1994) **35:** 161–187

1993 SPRING MEETING OF THE WPSA (UK BRANCH)

The abstracts which follow on pp. 161 to 187 are of communications presented at the Spring Meeting of the UK Branch of the World's Poultry Science Association, which was held at Scarborough on 17th and 18th March 1993. The Editors regret the delay in publishing these proceedings, due to circumstances beyond their control.

TABLE 1

Index of behaviours posing a potential damage risk to the bird

Behaviour	Score
Crouch (gripping cage floor)	1
Jump	2
Flap wings	3
Escape behaviour	3
Combined jump and flap	4

TABLE 2

Mean fear reaction scores of 5 test stimuli

Trial	1	2	3	4
Birds in cage	2	3	3	2
	Mean reaction score			
Stimulus				
Hands in cage (no gloves)	3·30	0·82	0·91	0·40
Grab leg	1·81	1·84	1·04	2·15
Novel stimulus	4·08	1·75	1·11	1·02
Grab legs and pull over	5·65*	4·08*	4·29*	5·41*
Depopulation	2·45	1·72	2·49	1·70

*$P < 0.001$.

TABLE 3

Contacts with cage on removal

Trial	1	2	3	4
Birds per cage	2	3	3	2
N	69	98	99	62
Total contacts	66	73	30	23
Strikes to trough (%)	47	47	13	8
Strikes to cage lip (%)	41	36	83	83
Birds with actual damage (%)	12	28	11	3

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GREGORY, N.G. & WILKINS, L.J. (1989) Broken bones in domestic fowl: handling and processing damage in end of lay battery hens. *British Poultry Science*, **30:** 555–562.

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EFFECT OF COLOUR OF LIGHTING ON THE PERFORMANCE AND BEHAVIOUR OF BROILERS

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Although there have been many studies which have examined the effect of coloured lights, they have shown inconsistent results. Previous studies conducted by Cherry and Barwick (1962), Wathes *et al.* (1981) and Levenick and Leighton (1988) showed that white, red, green and blue light had no significant effect on the body weight

gain, food consumption and food conversion ratio of broilers and turkeys. On the other hand it was demonstrated by Cave (1990) recently that green fluorescent light was able to increase growth rate of chickens. There is no satisfactory evidence as to how the colour of light affects the behaviour of chickens.

This paper reports on the effect of several colours of light on the body weight gain, food consumption, food conversion ratio and the carcase composition of broilers. The time spent feeding, standing, sitting, dozing, sleeping, walking, drinking, pecking at the cage, wing stretching and in aggressive interactions is also reported.

Eighty Ross broiler chickens consisting of 40 males and 40 females were group reared in cages with white (W), red (R), green (G), or blue (B) light at 30 lux from one to four weeks. The red, green and blue lights were produced with coloured filters (Lee Filters Ltd, Andover, UK; nos: 106, 139 and 120 respectively). The body weight gain, food consumption (FC) and food conversion ratio (FCR) were recorded weekly, whereas the diurnal behavioural aspects were observed hourly. Carcase composition was analysed at day 28.

The body weight gain of broilers reared under W, R, G and B light did not show any significant difference throughout the rearing period; results were similar for carcase composition, FC and FCR (Table 1).

TABLE 1

The body weight (BW), cumulative food consumption (FC), food conversion ratio (FCR) and proximate analysis of broilers reared under different coloured lights to 28 d of age

		Colour					
Age (d)	Variables	White	Red	Green	Blue	SED	PROB
28	BW (g)	1202	1183	1195	1224	29·1	0·58
	FC (g)	2202	2123	2153	2219		
	FCR	1·83	1·79	1·80	1·81		
28	Protein (%)	44·8	44·9	44·6	44·8	1·02	0·99
	Fat (%)	43·2	43·8	42·4	42·1	1·70	0·74
	Ash (%)	7·4	7·5	7·6	7·7	0·29	0·73

Feeding time was not affected by colour but the incidence of aggression, wing stretching and pecking at the cage were all greatest for birds under red light and least for birds under blue or green lights, with birds under white light being intermediate. There was no significant difference in the time spent standing, but the times spent sitting, dozing and sleeping were greatest for the green, blue and red treatments respectively. Sex of bird did not significantly affect the behaviour or response to light (Table 2).

TABLE 2

The time spent by broilers under different coloured lights in major behaviours

	Light colour					
Behaviour	White	Red	Green	Blue	SED	PROB
Feeding (min/h)	13·54	12·66	13·08	12·98	0·37	0·13
Standing (min/h)	8·14	7·87	8·40	8·58	0·35	0·21
Sitting (min/h)	11·46	11·34	13·84	11·18	0·40	0·00
Dozing (min/h)	15·86	14·45	14·41	16·71	0·40	0·00
Sleeping (min/h)	13·01	13·72	10·31	10·59	0·32	0·00
Walking (no/bird/d	1·18	1·04	0·83	1·03	0·05	0·00
Drinking (no/bird/d)	1·11	0·93	1·02	1·09	0·05	0·00
Pecking at cage (no/bird/d)	0·69	0·91	0·66	0·61	0·05	0·00
Wing stretching (no/bird/d)	0·46	0·69	0·42	0·35	0·04	0·00
Aggressive interaction (no/bird/d)	0·05	0·07	0·00	0·04	0·01	0·00

From the results it can be concluded that birds are more active in red and less active in blue and green light. Birds in white light were in between red and green or blue. The greater activity under red light necessitated a longer sleeping time while birds in the blue or green light were more inclined to sit passively and doze. However this effect may be due to better visual sensitivity in chickens at the red, compared with the blue end of the spectrum. This would cause the red light to appear brighter. Fuller research will distinguish between colour and apparent brightness in the effects on behaviour.

Colour of light did not affect growth rate, food consumption, food conversion ratio and carcase composition of the birds up to 4 weeks old.

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FACTORS AFFECTING THE SEX RATIO, HATCHING TIME AND ULTRASTRUCTURE OF THE YOLK-SAC MEMBRANE OF BROILER BREEDER CHICKS

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A study was carried out to observe the effect of strain, flock age and shell conductance (G_{H_2O}) on the sex and hatching time of 1800 broiler hatching eggs. A concomitant study investigated the development of the yolk-sac membrane.

Eggs from two commercial broiler strains (900 from each strain) were obtained from flocks aged 24, 35 and 50 weeks. The eggs were stored at an RH of 75% and a temperature of 15°C. Prior to setting, each egg was numbered and weighed. Following transfer, the hatcher was monitored every 8 h until the first chicks hatched at 431·1 h of incubation. Thereafter, the hatch was constantly monitored for 60 h. At hatch, each chick was identified from its shell number and was feather sexed. The time of hatch and sex was recorded.

The overall sex ratio of males to females was found to be 691:476, which is significantly different from the expected ratio of 1:1. However, the sex ratio of chicks from strain A obtained from a 51-week-old flock showed no significant deviation from unity. Chicks from strain A hatched significantly sooner than those of strain B ($P < 0{\cdot}001$). No significant differences between chick sex and hatching time were observed ($P > 0{\cdot}05$).

There was no correlation between shell conductance (measured as G_{H_2O}) and sex ratio or time of hatch.

Differences were not observed in the rate of development of the yolk sac membrane in chicks from differing present flock ages.

From this preliminary study, it can be concluded that the sex ratio of *Gallus gallus* may deviate from 1:1, but that sex differences in the rate of hatch do not exist.

RELATIONSHIP BETWEEN YOLK LIPID UTILISATION AND HATCHABILITY IN THE CHICK EMBRYO

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Yolk lipids are of particular importance during chick embryo development, providing over 90% of the embryo's energy needs as well as essential structural components. The utilisation of yolk lipid is characterised by a complex sequence of metabolic events involving the yolk sac membrane and the embryonic tissues. Given the embryo's predominant dependence on lipid metabolism, it would seem likely that defects in the lipid transfer process could severely impair development and lead to reduced hatchability. Recent work has shown this to be the case, because embryos derived from young parent stock, which typically exhibit hatchabilities as low as 50%, are clearly defective in their ability to utilise lipid. Major roles for enzyme systems and associated regulatory proteins involved in cholesterol esterification in the yolk sac membrane, and for lipoprotein lipase in the embryonic tissues, have been recently identified. In normal embryos, the concentrations of such enzymes are very high in comparison, for example, to the respective concentrations in mammalian tissues. Low hatchability may be causally linked to reductions in the activities of these enzymes. The efficient provision of essential fatty acids to the brain also appears to be a vital requirement for embryo survival.

THE INITIAL AND LONGTERM PREFERENCE OF BROILERS FOR RED, BLUE OR GREEN LIGHT AFTER BEING REARED IN RED, BLUE, GREEN OR WHITE LIGHT

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INTRODUCTION

Most birds,both domestic chicks and adult chickens,belong to the group of animals which have a relatively well developed mechanism for visual perception and discrimination (Hurnik et al , 1971). Furthermore, this ability extends to a differentiation between certain areas of the colour spectrum. According to Bell and Freeman (1971) fowls can more easily be trained to distinguish colours than to distinguish intensity.

The present study was designed to investigate whether a response in the initial and long-term preference of broilers could be achieved by using different colour light after being reared in red, blue, green and white light.

MATERIALS AND METHODS

Twenty female and Twenty male Ross broiler chicks were group reared in cages with white (W), red(R), green(G), or blue(B) lights at 30 lux from one to four weeks of age. In the fifth week the birds in each treatment were given the choice of pens with red , green or blue lights in each corner of a trianglular pen. Their preferences were monitored for the first three hours and for 24 hours after one week had lapsed. The position of each bird was recorded every 5 minutes for the first three hours and then after one week , every 10 minutes for 24 hours through a video camera recorder. Time spent in each coloured light was measured in minutes/hour.

RESULTS

Table-1 shows that in the first three hours birds from green and blue lights preferred their original colour, spending 47 and 32 minutes/hour there respectively , whereas red birds preferred blue light (39 min/hr) and white birds preferred red (48 min/hour). These preferences increased significantly from the first to the third hour (table-2) , while sex did not affect the preference (Table-3).

After one week had lapsed , the preferences had changed significantly with all white, red and green reared birds preferring the blue light,spending there 47, 41 and 37 min/hr respectively. The green was their second choice spending 8, 10 and 14 min/hour respectively. However, blue reared birds preferred green as their first choice (35 min/hr) and then blue as their second choice (18 min/hour)(Table-4). Female birds showed a significantly stronger preference for the blue than the males (Table-5)

CONCLUSION

It can be concluded that both male and female broilers showed the greatest longterm preference for blue light, followed by green light , although their initial preference after neutral colour was red light.

Birds reared in a coloured light show an initial preference to remain in that light but after one week preferred a change to a different colour,usually blue.

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TABLE-1 : LIGHT PREFERENCE OF BROILERS IN THE FIRST THREE HOURS POST TREATMENT (MIN/HOUR)

PREVIOUS COLOUR	PREFERENCE			SED	INTER. PROB.*
	RED	GREEN	BLUE		
WHITE	47.9	2.7	9.4	3.95	0.00
RED	20.2	0.7	39.2		
GREEN	6.8	46.9	6.3		
BLUE	19.5	8.3	32.3		

TABLE-4 : THE LIGHT PREFERENCE OF BROILERS AFTER ONE WEEK OF TREATMENT (MIN/HOUR)

PREV. COLOUR	PREFERENCE			SED	INTER. PROB.*
	RED	GREEN	BLUE		
WHITE	5.4	7.6	47.1	1.36	0.00
RED	8.9	9.9	41.3		
GREEN	8.5	14.9	36.7		
BLUE	7.0	35.3	17.8		

TABLE-2 : TIME SPENT IN EACH COLOUR IN THE FIRST THREE HOURS OF TREATMENT (MIN/HR)

HOUR	PREFERENCE RED				PREFERENCE GREEN				PREFERENCE BLUE			
	Previous				Previous				Previous			
	WHITE	RED	GREEN	BLUE	WHITE	RED	GREEN	BLUE	WHITE	RED	GREEN	BLUE
1	42.0	36.0	9.8	23.8	1.9	1.0	46.6	5.0	16.1	23.0	3.6	31.3
2	48.6	20.0	2.5	20.3	5.3	0.5	45.3	8.8	6.1	39.5	12.3	31.0
3	53.0	4.5	8.1	14.3	1.0	0.5	48.8	11.1	6.0	55.0	3.1	34.5
	SED				9.68							
	INTERACTION PROB.*				0.00							

TABLE-3 : THE EFFECT OF PREVIOUS LIGHT COLOUR ON TIME SPENT IN EACH COLOUR IN THE FIRST THREE HOURS OF PREFERENCE TESTING (MIN/HOUR)

PREV. COLOUR	PREF. RED		PREF. GREEN		PREF. BLUE		S E D	INTER. PROB.*
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE		
PW	47.1	48.7	3.8	1.7	9.2	9.7	5.93	1.00
PR	20.7	19.7	0.7	0.7	38.7	39.7		
PG	7.3	6.3	46.7	47.1	6.0	6.7		
PB	17.9	21.0	7.9	8.7	34.2	30.3		

PW = Previous white
PR = Previous red
PG = Previous green
PB = Previous blue

TABLE-5 : THE EFFECT OF PREVIOUS LIGHT COLOUR ON THE TIME SPENT IN EACH COLOUR AFTER ONE WEEK OF PREFERENCE TESTING (MIN/HOUR)

PREV. COLOUR	PREF. RED		PREF. GREEN		PREF. BLUE		S E D	INTER. PROB.*
	Male	Female	Male	Female	Male	Female		
PW	5.8	5.0	8.9	6.3	45.3	48.9	2.04	0.00
PR	9.3	8.5	10.3	9.6	40.7	41.8		
PG	9.1	7.9	16.2	13.5	34.8	38.5		
PB	6.9	7.2	36.5	34.1	16.7	18.8		

* Probability that the interaction between treatment is not significantly different

THE EFFECT OF COLOUR AND INTENSITY OF LIGHTS ON THE BEHAVIOUR AND PERFORMANCE OF BROILERS

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INTRODUCTION

Light of different illuminance and wavelength may influence the growth and behaviour of broiler chickens (Morris,1968) . Previous study of the ability of chickens to perceive red and blue light at different wavelengths and intensities (Prayitno et al, 1993) has shown that the chickens failed to differentiate the brightness of blue and red lights at ratio c. 3.3 : 1.0 in terms of blue light intensity to red light intensity.

The objective of this study was to study the behaviour pattern achieved by birds at different light colours and intensities and in particular to identify separate colour and intensity effects.. The effect on life weight gain, feed consumption and feed conversion ratio were also recorded.

MATERIALS AND METHODS

An experiment was conducted in a controlled environment using 26 male and 26 female Ross broilers chicks . The birds were group reared in 6 cages with 5 males and 4 females /cage . The treatments applied were two different coloured lights, red and blue and three intensities, low (12×10^{20} photon, 36×10^{20} photon for red and blue light respectively), medium (18×10^{20} ; 60×10^{20} photon for red and blue) ,and high (30×10^{20} , 108×10^{20} photon for red and blue) . Mean ratio of red to blue intensity was 1.0 : 3.3.

Behaviour was monitored 5 minutes for 23 hours/week/bird by the time lapse video . Each bird was weighed weekly and feed consumption was recorded daily.

RESULTS

Feeding, sleeping times, number of pecking, wing stretching and aggression were all increased in the red light (Table-1). Standing, sitting and dozing were all increased in blue light. As light intensity increased feeding, walking, wing stretching and aggression tended to be increase, particularly in the red light. This interaction was significant for most behaviours.

Table-1 : The time spent by broilers under different colour and intensity of lights in major behaviours (mean of four observations)

Behavioural Parameters	Colour	Intensity			Colour		Intensity		Interaction	
		Low	Medium	High	P	SED	P	SED	P	SED
Feeding (min/h)	Red	18.56	18.26	20.01	0.00	0.29	0.00	0.36	0.11	0.51
	Blue	16.42	15.12	18.38						
Standing (min/h)	Red	6.19	9.09	9.97	0.03	0.16	0.00	0.19	0.00	0.27
	Blue	7.67	7.08	7.42						
Sitting (min/h)	Red	10.15	9.74	10.68	0.00	0.18	0.00	0.22	0.23	0.32
	Blue	12.38	12.22	12.39						
Dozing (min/h)	Red	10.92	10.76	8.20	0.00	0.19	0.00	0.24	0.00	0.34
	Blue	13.40	14.13	14.20						
Sleeping (min/h)	Red	16.17	14.14	11.14	0.00	0.14	0.00	0.17	0.00	0.25
	Blue	8.12	9.45	7.59						
Walking (no/bird/h)	Red	3.73	4.47	4.80	0.00	0.05	0.00	0.06	0.00	0.08
	Blue	3.20	3.71	3.53						
Drinking (no/bird/h)	Red	1.57	1.61	1.62	0.07	0.03	0.67	0.04	0.05	0.06
	Blue	1.55	1.53	1.58						
Pecking (no/birds/h)	Red	1.24	1.15	1.15	0.00	0.03	0.00	0.03	0.01	0.05
	Blue	0.98	0.97	0.98						
Wing stretching (no/bird/h)	Red	0.32	0.33	0.45	0.00	0.02	0.00	0.02	0.02	0.03
	Blue	0.18	0.18	0.26						
Aggression (no/bird/h)	Red	0.07	0.07	0.16	0.00	0.01	0.00	0.01	0.00	0.01
	Blue	0.03	0.03	0.05						

There was no effect of treatment on growth rate of the broilers and feed consumption as well as feed conversion ratio were similar between treatments (Table-2).

Table-2 : The mean body weight (BW), feed consumption (FC) and feed conversion rate (FCR) of broilers reared under different colour and intensity of light up to 35 days of age

Parameters	Colour	Intensity			Colour		Intensity		Interaction	
		Low	Medium	High	P	SED	P	SED	P	SED
BW (g)	Red	1388	1366	1381	0.12	12.36	0.81	15.13	0.99	21.40
	Blue	1435	1445	1458						
FC (g)	Red	3070	3039	3016						
	Blue	2985	3080	3173						
FCR	Red	2.21	2.22	2.18						
	Blue	2.08	2.13	2.18						

CONCLUSIONS

It is concluded that there are distinct effects of colour of lighting on broiler behaviour that increase activity in red light. Increased intensity also stimulated behavioural activity, particularly in red light.

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THE BEHAVIOURAL AND PHYSIOLOGICAL RESPONSES OF BROILERS TO RED AND BLUE LIGHT PATTERNS

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INTRODUCTION

In any experiment on the effects of light on poultry, four characteristics of the light environment must be specified : the photoperiod, the cycle length, the spectral composition and the light illuminance (Wathes, 1981).

Previous experiments conducted by the University of North Wales, Prayitno et al (1993), have shown that under blue lights, birds were less active than birds reared in red light and this behaviour might affect the bone strength of broiler. Low intensity light is also believed to decrease activity and is commonly used for this purpose on commercial units.

This experiment will focus on the variables of light illuminance and spectral composition, keeping photoperiod and cycle length constant, in an attempt to determine whether the use of bright red light followed by dim light can increase activity and reduce leg abnormalities. Bone strength and the effect on feed comsumption, feed conversion ratio and growth rate were also recorded.

MATERIALS AND METHODS

Twenty four male and twenty four female Ross broiler chicks were group reared in 12 cages with four birds/cage and three treatments : T0 , the use of dim blue light (day 1-49) as a control; T1 , red light (day1-16) followed by dim blue (day 17-49) and T2 , dim blue (day 1-16), followed by red (day 17-32), followed by dim blue (day 33-49). The red and blue light were at 8.6×10^{22} and 0.015×10^{22} photons respectively and were produced from white light with covered LEE filters number 106 and 120 respectively.

The behavioural aspects were monitored in 3 periods every 10 minutes for 23 hours/ period/bird at day 11-15, day 27-31 and day 44-48. Each bird was weighed at day 1 and 49. Feed consumption was monitored for each replicate (4 birds, 2 males and 2 females) and an average feed consumption per treatment was calculated. Tibia bone strength was tested through an Instron 4301 tensiometer using a three point bend with supports 60 mm apart and a load applied at 50 mm/minute to the mid point of the long axis of the bone , following the same procedure as Knowles (1991). The breaking strength was recorded as the peak load before the bone broke. Right and left tibia breaking strengths were analysed separately. Lameness and gait abnormalities with daily visual inspection were recorded throughout the 49 day cycle for each bird.

RESULTS

Standing time during the life of the birds was not affected by the treatments but using bright red light significantly increased the time spent walking, stretching and feeding particularly when applied in the first 16 days. The time spent sleeping and sitting were greatest for the control treatment (Table-1).

Table-1 : The time spent by broilers under different patterns of colour lights in major behaviour (minutes/hour/bird, mean of 3 observations)

Behavioural parameter	To	T1	T2	P	SED
walking	3.70	5.18	4.65	0.000	0.26
sleeping	17.61	15.74	16.21	0.003	0.46
sitting	19.94	17.79	18.41	0.000	0.49
stretching	1.34	2.25	2.26	0.000	0.18
feeding	8.85	9.93	9.75	0.000	0.34
standing	8.60	9.10	8.73	0.359	0.37

The growth in terms of body weight gain of broilers reared under the different treatments did not show any significant difference throughout the rearing period ($p>0.05$) although there was a tendency for improvement in T1; similar results were also obtained for FC and FCR (Table-2). Sex of bird did not significantly affect the behaviour or response to light.

Table-2 : The body weight, cumulative feed consumption , feed conversion ratio and bone strength of broilers reared under different pattern of lights to 49 days of age

Age (days)	Parameter	T0	T1	T2	P	SED
49	BW (g)	1536.6	1650.9	1508.1	0.17	78.49
49	FC (g)	60.6	54.2	57.9		
49	FCR	1 : 2.4	1 : 2.0	1 : 2.4		
49	Tibia peak load (Newton's)	257.7	261.8	235.0	0.05	11.09

Sex and differences between left and right leg had no significant effect on tibia strength. However, treatment did have an effect on bone strength, causing a significant reduction in bone strength in T2 (Table-2).

Visual assessment of lameness and gait abnormalities of bird showed little evidence of any problems in the initial 3 weeks of the experiment. T0 then demonstrated the highest lameness problem, where by week 6, eight birds (50%) had at least an intermittent detectable abnormality in their gait, with four of these birds (25%) being crippled and unable to stand. By the sixth week two birds (12.5%) in T1 could not walk and had gone down on their legs, being destroyed for welfare reasons. In T2 only one bird (6.25%) suffered any problem and by week 6 had begun to recover to only an intermittent abnormality in its gait (probability of lameness difference : 0.02).

DISCUSSION AND CONCLUSION

The present study has shown that giving bright light in the first period increased the time spent walking, stretching, feeding as well as the bone strength. Birds in continuously dim blue light were more inclined to sit passively and sleeping and this caused the highest lameness problem. This result is contrary to those of Wabeck and Skoglund (1974) and Whates (1982), who have indicated that light wavelength has a relatively minor effect on the development of leg disorders.

Bone strength was not affected by a stimulatory red light in day 1-16 and the same red light in day 17-32 reduced bone strength. No adverse effects of stimulatory red light on weight gain were observed.

It is concluded that bright red light can alleviate some of the lameness problems in broilers, but that it can also reduce bone strength when applied too late.

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EQUATING BRIGHTNESS PERCEPTION OF BLUE AND RED LIGHTS AND LENGTH OF LINE DISCRIMINATION WITH HENS BY PSYCHOPHYSICAL TESTS

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Ten pullets of the Warren Studler 128 breed, aged approximately 18 weeks were used in three experiments using two identical chambers to determine the equivalent brightness perception of different colours (blue and red) in hens and their ability to compute a simple visual test. One half of the birds were initially trained to detect the brighter of two lights and the other half the dimmer. The first test, studied the brightness perception of hens using bright blue (24.140×10^{22} photons) and dim red (0.66×10^{22} photons); and the second test used bright red (32.37×10^{22} photons) and dim blue (0.84×10^{22} photons). In both tests, the brightness of the two colours of light were gradually brought together. The ability of hens to distinguish different brightness in the two colours was recorded over a number of presentations as percentage correct choice (>80% is taken as successful). The visual test was a length of line discrimination performed using equally bright red and blue lights (determined from the initial experiments), initially using a short line (10cm) and long line (30cm). The ability of hens to detect the longer or shorter line was decided by the percentage correct choice (>80%). In the first test the birds failed to distinguish the brightness of the two coloured lights at 11.20×10^{22} and 3.07×10^{22} photons for blue and red lights respectively (at ratio of 3.6 : 1.0). In the second test birds failed to distinguish the brightness of the two coloured lights at 2.53×10^{22} and 7.84×10^{22} photons for red and blue respectively (a ratio of 3.1). At the mean ratio of 3.37 : 1.0 for blue to red, birds failed to discriminate lines 24cm and 16cm long, the same for both colours of light. It can be concluded that the chickens failed to differentiate the brightness of blue and red lights at a (photon) ratio 3.1-3.6 : 1.0. At this ratio chickens are not able to discriminate successfully a difference in the length of two lines of less than one third of its length.

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