DOI: 10.1079/WPS200565

Nutrition and management of heat-stressed pullets and laying hens

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Maximum daily temperatures in excess of 30ºC are common in many table egg-producing regions of the world. Such temperatures require the application of specialized management and nutrition if laying hens are to produce eggs near their genetic potential. Environmentally-modified buildings have been shown to be especially advantageous for commercial layers that are housed in high density cage facilities. Directing air movement onto floor-housed birds has also been found to maximize heat loss and was beneficial as long as the air temperature did not exceed body temperature. This latter procedure was especially useful where sporadic incidences of heat stress were common.

Nutritional manipulation of the diet also offers advantages, especially in overcoming problems of reduced appetite. This principle has been shown to apply to both growing pullets and adult layers. Recent research has confirmed that optimum production during lay depends on the adult hen having an adequate gut capacity and sufficient nutrition during rearing. Egg production during moderate heat stress can be improved by increasing the intake of protein relative to energy but energy requirements will likely increase in severe heat stress. Dietary supplementation with ascorbic acid and vitamin E and a supply of cool drinking water have also been reported to improve production during lay but the response to the latter treatment varied with genotype.

Keywords: heat stress; growing pullets; laying hens; heat loss; dietary manipulation

Introduction

With the increasing concentration of poultry in semi-tropical and tropical countries has come the need to better appreciate the role of high ambient temperature and heat stress on the nutritional and management requirements of commercial egg laying stock during growth and lay. Nutritional management of laying stock in these environments may be characterized as still being largely based on nutritional specifications extrapolated from

World's Poultry Science Journal, Vol. 61, September 2005
Received for publication January 12, 2005
Accepted for publication January 23, 2005

data derived at thermoneutral temperatures although some attempts have been made to measure nutritional requirements directly under heat stress conditions. Furthermore, a major problem relates to the varied types of heat stress encountered in different regions of the world. In tropical countries, poultry can be exposed to high ambient temperatures for long periods of time and variations in relative humidity (RH) can alter the severity of heat stress. In contrast, the main problem in temperate countries typically relates to incidences of short, acute periods of heat stress.

When a bird that has been acclimatized to low ambient temperatures encounters rising temperatures, heat stress may be recognized when the ambient temperature increases above 25ºC. However, in many countries poultry experience temperatures of 32ºC and higher on a routine basis. To survive these conditions poultry must acclimate successfully. Limited research has indicated that the time required for complete acclimation varied from a few days to a few weeks depending on the extent of the change and the ability of the bird to respond (Shannon and Brown, 1969; Davis *et al.*, 1972). Furthermore, birds have been shown to be better able to withstand heat stress temperatures if they can dissipate body heat during a cool night period (Smith and Oliver, 1972). Wilson *et al.* (1972) demonstrated the benefits of cyclic versus constant temperatures for commercial layers and Smith and Oliver (1971) reviewed several studies that demonstrated similar effects. Therefore, in countries with high ambient temperatures it will probably be best to design poultry houses that either prevent excessive increases in body temperature during the day or facilitate optimum heat loss by the bird during the relatively cooler night periods.

Maximizing heat loss

Heat loss may be improved at all times of the day and night by increasing the rate of air movement over the bird to increase convective heat loss (Timmons and Hillman, 1993). This may be difficult to accomplish with caged layers as the cages may disrupt the air flow. In this situation it may be better to rely on environmental control of house temperatures. With floor-housed birds the wind speed factor ("wind chill") can also be important. For example, a wind speed of 2.55 meters per second at 35ºC has been calculated to be roughly equivalent to 29ºC in still air (Donald, 2001). This beneficial effect works relatively well irrespective of the environmental temperature as long as the air temperature does not exceed body temperature. Horizontally directed fans (Czarick, 1989) have been popular means of increasing air velocity but heat stress problems can be experienced as these may not provide good air velocity in the vicinity of all the birds and, therefore, do not maximize heat loss. In order to maximize the air movement on floor-housed birds, fans that are mounted within houses need to blow more directly onto the birds rather than just stir the air above the birds (Bottcher *et al.*, 1993b). Unfortunately, modern poultry houses are often designed to trap heat in order to improve feed efficiency. An example of the damaging effects of this practice can be seen with domestic turkeys grown in North Carolina during past summers (J. Brake, personal observations). Although turkeys raised in open fields were exposed to direct sunlight during daylight hours, they did not generally suffer high mortality from heat stress because they could lose body heat at night by radiating heat to the open sky. Their counterparts in the modern turkey house sometimes died from heat stress although they were never exposed to direct sunlight. This was probably due to the fact that the temperature in the house never decreased enough to allow sufficient body heat loss at night. Therefore, the logical conclusion was that it was necessary to emphasize air exchange between the outside and the inside of the house during the evening hours so as to maximize the night time temperature decrease within the house.

Much has been written about the positive effects of tunnel-ventilated poultry houses during extremely hot weather (Czarick and Tyson, 1989). Most of the benefits can be attributed to the high air speeds that maximize convective heat loss from the birds. This can be especially useful under conditions of high RH heat stress when the efficiency of respiratory and cutaneous evaporative heat loss may be reduced. Furthermore, by combining high air speeds with evaporative cooling systems (foggers or pad systems) to reduce the "effective" air temperature even greater convective cooling rates can be achieved. However, in many climates evaporative cooling may be needed for only very short periods of time each year. This can create an economic dilemma for the producer faced with the choice between sporadic heat stress mortality and the costs of advanced ventilation systems (Bottcher *et al.*, 1993b).

Lowering horizontally blowing fan thermostats by 10ºF (5ºC) below integrator standards for floor-housed birds during the night hours was found to improve performance enough to more than pay for the additional electricity required. Further studies have evaluated the use of downward directed high-speed fans. These fans produced high air speed over a large floor area. Combined with a fogger system, these fans were found to produce beneficial effects equal to those reported for tunnel-ventilated houses, at a lower cost (Bottcher *et al.*, 1991, 1993a).

Bird adjustment to heat stress

Body heat production interacts with ambient temperature to determine body temperature. As ambient temperatures increase within the thermoneutral range, birds initially utilize sensible heat loss mechanisms to control body temperature with little or no loss in egg production or growth. However, under moderate or severe heat stress birds minimize heat production since the major route of heat loss (in the absence of significant air movement), evaporation of water from the respiratory tract (panting), requires considerable energy expenditure (and, therefore, heat production from muscular activity). Birds respond by reducing their metabolizable energy (ME) and feed intake to reduce thermogenesis. Although ME intake has been shown to decline at an increasing rate with increasing ambient temperature it does so more rapidly than the corresponding decline in metabolic heat production. Therefore, less energy would be available for production processes, such as egg formation, as ambient temperature increased. This general principle was detailed by Smith and Oliver (1972) whose results are shown in *Table 1*.

Table 1 Effect of environmental temperature on metabolizable energy (ME) intake, heat production, and hen-day egg (HDP production) of a 1.7 kg hen (adapted from Smith and Oliver, 1972).

Ambient temperature	ME Intake	Heat production	ME for egg production	Possible HDP of 57 g eggs[1]
(ºC)	(kJ)	(kJ)	(kJ)	(%)
26.5	1216	906	310	82
29.5	1184	886	298	79
32.0	1083	821	262	70
35.0	911	711	200	53

[1] Assuming 376 kJ of ME per egg.

Nutritional management during growth

The problem of reduced appetite has often been observed with layer-type pullets where, under heat stress conditions, it has often been difficult to achieve satisfactory early growth rates. In such cases, it has been recommended that pullet starter diets containing approximately 12.00 MJ of ME and increased concentrations of protein and amino acids be fed beyond the normal starter period up to an age of 10 weeks (Daghir, 1995). It was suggested that such diets contain approximately 190 g crude protein (CP), 10 g lysine, 4.2 g methionine and 7.2 g total sulphur amino acids (TSAA)/kg. Alternatively, a broiler starter diet with approximately 12.75 MJ of ME/kg and 230 g CP/kg, with suitably scaled concentrations of lysine and the sulphur amino acids, could be fed for 3 weeks followed by a normal starter diet containing approximately 12.00 MJ of ME/kg (Daghir, 1995). If heat stress conditions exist throughout the growing period, there may be benefit in feeding grower diets with an ME of approximately 11.50 MJ of ME/ kg and slightly higher than normal protein and amino acid concentrations. In this regard, Jevne and Coon (1993) fed all combinations of 155 g and 175 g CP/kg and 11.53 MJ and 13.02 MJ of ME/kg to pullets at 32ºC from 8 to 18 weeks of age and obtained significantly improved 18-week body weight in birds fed the combination of 175 g CP and 13.02 MJ of ME/kg. Leeson and Summers (1989) also found that improved body weight gain of heat-stressed pullets resulted from increasing the dietary ME concentration. However, Njoya and Picard (1994) reported that similar 18-week body weights were obtained with layer pullets fed the same amounts of ME in temperate (20ºC, 60% RH), hot dry (32ºC, 40% RH) and hot humid (32ºC, 90% RH) environments.

Cumulative nutrient intakes during rearing of approximately 88 MJ of ME and 1200 g crude protein were necessary to maximize the growth to 20 weeks of age of Leghorn pullets in a daily 22-32ºC cyclic temperature regimen (Leeson and Summers, 1989). These cumulative intakes were similar to those reported by Cheng *et al.* (1991) in which the ambient temperature to which pullets were exposed declined from 32.8ºC during the first week to 21ºC at 6 weeks of age and subsequent weeks. These latter workers reported that providing a minimum cumulative ME intake of 84 MJ and a minimum total protein intake of 1140 g to White Leghorns to 20 weeks of age maximized subsequent laying performance. Cheng *et al.* (1991) also concluded that an increase in cumulative ME intake to 90 MJ exerted no adverse effect on subsequent laying performance. These protein intake data are strikingly similar to what have been determined to be minimum cumulative intakes to 20 weeks of age (photostimulation age) of approximately 1180-1192g crude protein for the maintenance of good fertility in broiler breeder females (Walsh and Brake, 1997, 1999).

Research data and practical experience with commercial layer pullets have suggested that an important aspect of rearing is to obtain satisfactory intakes of nutrients before photostimulation. This has obviously been more difficult to achieve with pullets reared at high ambient temperatures. Further, as feed efficiency may be improved in hot weather, the body weights of birds consuming adequate nutrients may be higher than published "standards" even with lower nutrient intakes. As rearing pullets to published standard body weights has become something of a paradigm, it may be difficult to make the necessary changes in management without some major changes in philosophy to accommodate this paradoxical situation. For many years broiler breeder pullets grown in warm weather, so-called "out of season" pullets, were allowed to gain additional body weight, *i.e.* consume the normal "in season" feed amounts, in order to be optimally productive layers.

Mineral and vitamin studies with heat-stressed growing pullets have been limited in number and most of the studies that have been conducted have been carried out with chickens that bear little resemblance to modern genetic stock. There is little justification for recommending dietary mineral specifications that differ from those used under thermoneutral conditions except that the potassium requirement of growing chickens may increase at high ambient temperatures if reduced blood concentrations under such conditions may be used as an indicator (Huston, 1978). Mills *et al.* (1947) observed that the thiamine requirement of chickens was increased approximately 3-fold (3 mg/kg) at 32ºC compared to 21ºC, whereas no changes were observed in the requirements for pyridoxine, nicotinic acid, folic acid, or choline.

It has been generally thought that acclimating hens to high ambient temperatures during growth will improve their productivity during lay. Although such acclimation can improve liveability during lay it does not necessarily improve subsequent egg production. Njoya and Picard (1994) reported no acclimation advantage during lay from rearing pullets at high ambient temperatures. In fact, Kyarisiima and Balnave (1996) found that rearing pullets in a cool, rather than a hot, environment not only allowed adequate nutrient intakes to be achieved prior to the onset of lay but also improved the capacity of the mature hen to consume feed when housed at high temperatures during lay. The resulting increase in appetite, presumably partially as a result of increased gut capacity, improved performance during lay. There was probably also a laying period benefit from the increased cumulative nutrient intake elicited at lower rearing temperatures.

Nutritional management during lay

It has been reported that fowl with a lighter feather cover were better able to withstand heat stress conditions than normally feathered fowl (Romijn and Lokhorst, 1961). However, the degree of feather cover can affect the rate of egg production (Peguri and Coon, 1993). This latter study examined the effects of removing half or all the feathers from laying hens at 34ºC. Results showed that feed intake increased with the degree of feather loss. Egg production improved when half the feathers were removed but then declined when the remaining feathers were removed, presumably because of the resulting higher maintenance energy requirement to maintain body temperature resulting in less energy being available for egg production.

Water intake has been shown to be a management factor of major importance to the heat-stressed hen. An adequate water supply has been shown to be needed by the bird to develop efficient heat loss mechanisms as well as to maintain adequate nutrient intakes. This was demonstrated by the fact that water:feed intake ratios increase from approximately 2:1 at thermoneutral temperatures to 5:1 at heat stress temperatures. In addition, cool drinking water temperature has a beneficial impact on hen performance at high ambient temperatures. This should be given careful consideration even though it may be difficult to control under practical conditions. Glatz (2001) reported that laying hens at 30ºC consumed more feed and produced eggs with better egg shell quality when the temperature of their drinking water was reduced to 15ºC in one case and 5ºC in another. However, cool drinking water also gave numerical improvements in egg production and significant improvements in egg weight with one strain, but not another, indicating that there was some genotype-associated effect involved.

The desire of the heat-stressed laying hen to control its body temperature, and improve its chances of survival, by reducing its ME intake often results in inferior performance due to reduced feed intake. It may be possible to improve egg output by stimulating the intake of nutrients other than ME. Reported improvements in performance under moderate heat stress conditions seem to have been associated primarily with increased intake of protein and amino acids. This was shown by De Andrade *et al.* (1977) who increased the dietary

ME and protein concentrations of a diet containing 12.20 MJ of ME and 150 g CP/kg by 10% and 25%, respectively. This procedure converted a 19% inferior egg production at 31ºC compared to 21ºC to a much smaller and statistically non-significant 3% deficit. Furthermore, in the self-selection studies reported by Scott and Balnave (1988, 1989), again under relatively moderate heat stress conditions (25ºC-35ºC), improvements in egg production were associated with increased intake of protein with little or no increased requirement for ME. In fact, the feeding of low ME, high protein diets at moderate heat stress temperatures (25-35ºC) has proved advantageous (Balnave and Murtisari Abdoellah, 1990) whereas at 30ºC high ME, high protein diets have not proved beneficial (Marsden *et al.*, 1987). The value of low ME, high protein diets was that they allowed increased intake of nutrients other than ME but they have not been normally recommended for commercial production.

Under the relatively moderate heat stress conditions mentioned above, hens showed little need for increased ME intake and ME concentrations between 12.0 and 13.0 MJ/kg should, therefore, prove satisfactory for complete diets. However, under more severe heat stress, ME requirements may increase due to the need for the bird to dissipate body heat by respiratory heat loss. Under these conditions it may prove beneficial to increase the dietary ME concentration of complete diets above 13.0 MJ of ME/ kg although this will restrict the intake of other nutrients. However, under severe heat stress the main problem will relate to survivability and production will be of minor significance. An increase in dietary fat content may be required to obtain high dietary ME concentrations. The inclusion of 5% tallow (Reid, 1981), or 4% soybean oil (Usayran *et al.*, 2001), in diets for young laying hens at high temperatures and the use of palm oil at heat stress temperatures (Njoku and Nwazota, 1989) have been shown to improve egg output although in older hens the major effect was to increase body weight or reduce body weight loss. This suggests that intervention strategies have to be applied early in the egg production cycle. In addition, the inclusion of feed ingredients containing greater than normal concentrations of fat and linoleic acid improved egg weight and the short-term egg weight response was manipulated by adjusting the concentrations of these nutrients in the diet of heat-stressed laying hens (Balnave, 1987). Unfortunately, shell quality was not measured in this study but shell quality was not observed to be a problem during the conduct of the experiment.

The increased panting associated with dissipating body heat during extreme heat stress can induce respiratory alkalosis and this may be exacerbated by high RH that makes respiratory heat loss less efficient. Cheng *et al.* (1990) exposed hens at 31ºC to an increase in RH from 40% to 60% for three months and observed symptoms of respiratory alkalosis as well as small but significant adverse effects on egg production, feed conversion, mortality, and egg quality. Hens housed at a higher, compared with a lower, cage density exhibited more detrimental effects on egg weight and shell quality, probably due to localized reductions in ventilation.

One means of alleviating the problem of respiratory alkalosis associated with panting has been to supplement the diet with sodium bicarbonate. This procedure has the additional merit of improving the shell quality of eggs from heat-stressed laying hens (Balnave and Muheereza, 1997). However, it has been reported that the dietary bicarbonate should be consumed during the period of egg shell formation by using suitable lighting patterns (Balnave and Muheereza, 1997, 1998). This, of course, requires the use of light-proof houses. The study by Balnave and Muheereza (1998) showed that when laying hens were exposed to 32ºC from 20 to 62 weeks of age and fed a diet containing 12.0 MJ of ME/kg, 199 g crude protein, 9.2 g lysine, 4.8 g methionine and 7.9 g TSAA/kg, the application of a repetitive intermittent lighting programme of 3h light:1h dark (3L:1D) rather than a daily 16L:8D schedule significantly increased feed intake, body weight gain, egg weight and egg shell quality. Although the sodium bicarbonate supplement in this study produced only a numerical improvement in egg shell breaking strength the effect was consistent and considerably greater in the 3L:1D regimen (7.1%) than in the 16L:8D regimen (3.1%). Furthermore, the 7.1% improvement occurred in addition to a significant 14% improvement resulting from the use of the 3L:1D regimen. The daily protein intake of the hens on the intermittent lighting schedule averaged 18.6 g compared with 17.4 g for hens on the 16L:8D schedule.

Finally, it should be noted that recent studies have indicated that the liveability and production of heat-stressed laying hens can be improved by supplementing their diet with ascorbic acid or vitamin E (Njoku and Nwazota, 1989; Cheng *et al.*, 1990; Bollengier-Lee *et al.*, 1999; Puthpongsiriporn *et al.*, 2001). Also, the lower concentrations of plasma calcium and inorganic phosphate in hens exposed to 30ºC compared to 18ºC (Usayran and Balnave, 1995) may provide some evidence of an increased requirement for these minerals in heat-stressed laying hens.

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