PRACTICAL NUTRITION OF THE LAYING HEN UNDER HIGH TEMPERATURE CONDITIONS

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Summary

The responses of the hen in terms of feed and energy intake under high temperature conditions are summarised. Effects on rate of lay, feed efficiency, egg weight and shell quality are similarly examined. Dietary means of minimising performance losses at high temperature are investigated. At extreme summer temperatures performance losses are inevitable in the absence of environmental control.

I. INTRODUCTION

Body heat of the hen, continuously generated by metabolic and muscular activity, is normally balanced by heat-loss to the environment. At moderate temperatures, heat losses by radiation, convection and conduction predominate, while as temperatures rise in summer, heat loss via water evaporation assumes increasing importance.

As the hen is characterised by efficient thermal insulation of the feathers and by lack of sweat glands, evaporative heat losses from the general body surface are low, the major route being evaporation from respiratory surfaces. When ambient temperature reaches extreme levels, such evaporative cooling becomes the major avenue for heat loss and is frequently unable to prevent some rise in body temperature. Defence against hyperthermia consists initially of this thermolysis by water loss, followed by a reduction in basal metabolic rate and in feed consumption (Smith & Oliver 1971).

Variation in breathing rate controls evaporative heat loss. Panting is normally initiated at an ambient temperature of approximately 30°C, the actual temperature being de-pendant on relative humidity. Thermal hyperventilation of the lungs results in respiratory alkalosis, with a rise in blood pH and a fall in blood CO_2 and bicarbonate ion concentrations. These factors lead to progressive shell quality problems as temperatures rise above 25°C.

This brief resume of the physiological responses of the hen to increasing temperature introduces the following consideration of the practical results of such increased temperatures.

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II. HEN RESPONSE TO INCREASING TEMPERATURE

(a) Voluntary feedintake and energy intake

Generally feed intake falls as temperature rises. Payne (1967) estimated this decline in feed intake as approximately 1.6%/° C temperature rise, after examining data from experiments covering temperatures up to 30°C. The fall off is not linear, becoming progressively greater with increasing temperature. Sukki *et al.* (1972) suggest that the reduction in intake is of the order of 1.5g/° C temperature rise between 26 and 32° C and 4.2g/° C between 32 and 36° C.

Similarly, energy intake declines at an increasing rate as temperature rises. Emmans (1974) assessed the effect of'temperature on energy intake as in Table 1.

TABLE 1: Effect of temperature on voluntary energy intake

Temperature or temperature range (°C)	Metabolisable energy(ME) intake (kJ/bird/day)	Change in energy intake (kJ/bird/day/°C)
15	1376	
15 to 29		- 16.44
29	1146	
29 to 37		- 53.55
37	720	

As temperatures rise, the decrease in energy intake becomes of progressively greater significance and a decrease in performance may result. At extreme temperatures, food intake and energy intake can be reduced below maintenance levels.

Sykes (1977) gave data relating ME intake and body heat production to environmental temperature. Figure 1 is abstracted from this data.

Line B, heat production of well feathered birds, shows heat production falling until around 30° C and thereafter rising, the hen being in the hyperthermal zone.

Sykes (1977) comments that sudden exposure to high temperature, 35°C, produces an immediate reduction in ME intake followed by a gradual 'increase to a new energy balance but still at a greatly reduced level of both ME intake and live weight, the period of adaption being three to four weeks. A feature of the response to increase in temperature was the use of body reserves to help meet an immediate negative energy balance.

(b) Rate of lay, feed efficiency, egg weight and shell quality

The range of temperatures within which rate of lay would be independant of temperature, given adequate nutrient supply, was estimated by Emmans (1974) to be between approximately 5 and 30°C for White Leghorns and probably between 5 and 25°C for heavier strains. Within these temperature ranges, increasing temperature will result in improved efficiency of feed utilisation. For egg weight, the upper temperatures of these ranges were estimated to be probably 3° C lower.

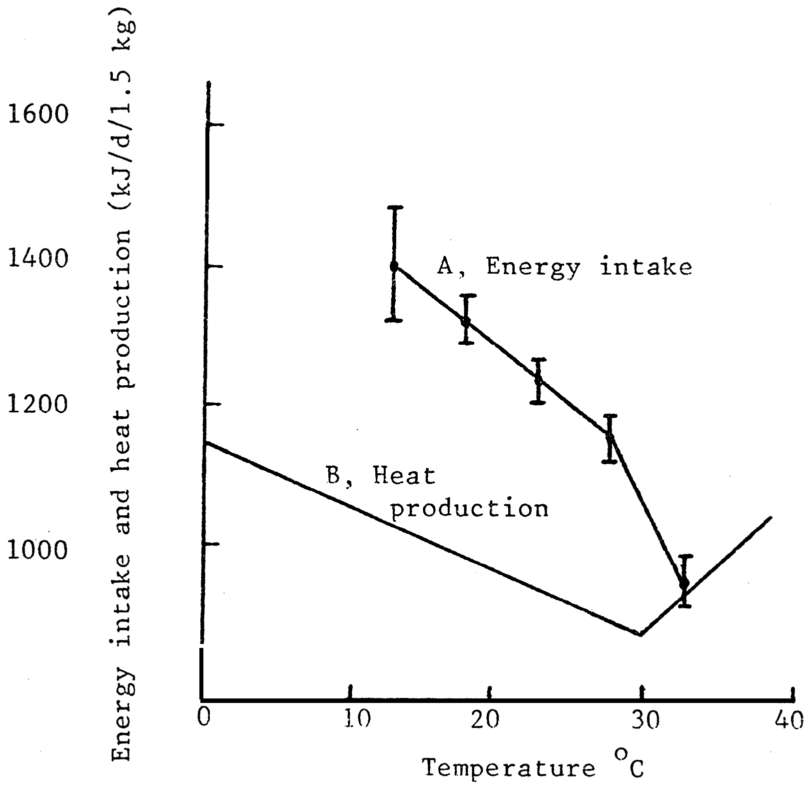

FIGURE 1 Intake of metabolisable energy and body heat production in relation to ambient temperature

The actual temperatures depend on numerous other factors including feather cover, comb size, number of birds per cage etc. He concludes that, as temperatures rise above these maxima, egg production and egg weight are depressed, whatever diet is fed.

It has been suggested (Payne 1967) that the depression in egg weight at higher temperature is due to a shortage of energy. He showed that birds at 30°C fed on very high energy diets increased energy intake sufficiently to overcome the depression in egg weight which occurred on diets of lower energy.

In practice, shell thickness and general shell quality are adversely affected by increased summer temperatures. Both gradual. and abrupt increases in temperature result in an immediate decline in shell rigidity, while gradual and abrupt decreases in temperature produced the opposite effect (Miller & Sunde 1975).

III. FACTORS INVOLVED IN MINIMISING PERFORMANCE LOSSES IN HIGH TEMPERATURE CONDITIONS

Requirements for nutrients other than energy remain substantially constant in absolute terms with increasing temperature. Therefore in order to minimise performance loss as temperature rises and voluntary feed intake falls, dietary nutrient concentrations must be increased.

Bray and Gessell (1961) were among the first to demonstrate that production could be maintained at 30°C provided a daily protein intake of about 15 g was ensured. Clearly, this satisfied amino acid requirements. At higher temperatures, energy intake may become limiting to performance. This explanation was offered by Reid & Weber (1973) who found that increasing daily protein intake by stages from 12.7 to 20.5 g did not improve performance at 35°C.

It is now generally accepted that nutrient allowances should be expressed as absolute intakes' per day for a given level of performance. Examples of such expression are given in Table 2.

TABLE 2: Estimates of absolute daily requirements for light-strain layers at peak production

	A.R.C. (1975)	A.E.C. (1972)	Summers & Leeson (1978)
Lysine (mg)	750	725	700
Methionine (mg)	350	365	320
Methionine + Cystine (mg)	471	660	590
Threonine (mg)	360	515	630
Tryptophan (mg)	170	165	150
Arginine (mg)	513	695	750
Isoleucine (mg)	550	N.A.	630
Protein (g)	16-18	17-18	17
Calcium	3.0-3.8g	3.2-3.5 (% ration)	3.25g
Available Phosphorus	0.39g	0.45-0.5 (% ration)	0.40g

Energy requirement is temperature dependant, decreasing as temperature is raised, at least up to 30°C. However, as temperatures increase, particularly to extreme summer levels, voluntary feed intake and energy intake can be reduced to below that required for maximum performance.

Attempts have been made to compensate for this energy deficit by increasing dietary energy level. Such an effect can be achieved because, while on an ad.lib. system, the hen reduces feed intake as dietary energy level is raised, this compensationmay not be sufficient to maintain a constant energy consumption. This is illustrated in Table 3, from Payne (1967), working at 30°C.

TABLE 3: Food and metabolisable energy intake in relation to dietary energy level and temperature

Dietary energy (MJ ME/kg)	Daily intake at 18°C		Daily intake at 30°C	
	Food (g)	M E (kJ)	Food (g)	M E (kJ)
11.97	127	1519	107	1280
12.80	118	1506	104	1330
13.60	112	1523	102	1389
14.43	106	1527	101	1452

At 18°C food intake adjusts to result in a virtually constant energy intake, while at 30°C, the feed intake reduction was small, with a consequent significant increase in energy intake.

'IV. CAN PERFORMANCE LOSSES UNDER SUMMER HEAT STRESS BE AVOIDED BY DIETARY MEANS?

A comprehensive investigation by de Andrade *et al*. (1977) into this question used White Leghorn layers in single-bird cages in environmentally controlled chambers. Environments imposed were: (1) 21°C constant (21°Co); (2) 31°C constant (31°Co); (3) 26.7 - 35.6°C cyclic, with a diurnal average of 31°C (31°Cy). This last environment is of particular interest because it has been suggested (Peterson *et al*. 1961) that fluctuating temperatures minimise the deleterious effects of high temperature. Two dietary treatments were imposed in each environment, referred to as Control and High Nutrient Density (H.N.D.). Diets were based on maize, soyabean meal and soy oil and had the following calculated specifications.

TABLE 4: Nutrient specifications of diets used (de Andrade *et al*. 1977)

	CONTROL	H.N.D.
M E (MJ/kg)	12.2	13.4
Lysine %	0.68	0.95
Methionine %	0.30	0.38
Methionine + Cystine %	0.54	0.67
Tryptophan %	0.16	0.21
Threonine %	0.50	0.62
Calcium %	2.8	3.5
Available Phosphorus %	0.57	0.71
Protein %	15	18.5

Results for egg production, feed consumption, feed efficiency and live weight change over the 12 week period are shown in Table 5.

A temperature of 31°C, whether constant or cyclic, significantly depressed egg production, feed consumption and live'weight. The H.N.D. diet almost completely overcame the detrimental effects of elevated temperature on egg production. Feed efficiency was improved significantly by the H.N.D. diet, and was better in the cyclic rather than the constant environment. Substantial live weight losses occurred with increased temperature on the control diet, while the H.N.D. diet partly alleviated this situation. It should be noted that even the Control diet, energy value 12.2 MJ ME/kg, would be of higher energy value than many Australian layer diets based on cereals of lower energy value than maize.

Egg weight was significantly reduced at increased temperature (55.33 g at 21°Co, 52.32 g at 31°Cy and 51.96 g at 31°Co). The use of the H.N.D. diet improved egg weight (54.14 g vs 52.25 g).

TABLE 5: Effects of temperature and diet on egg production, feed consumption and efficiency and live weight change

Environment (°C)	Diet		Diet	
	Control	H.N.D.	Control	H.N.D.
	% Egg production (hen/day)		Feed consumption (g/bird/day)	
21°Co	84.4	85.2	98.1	84.7
31°Cy	78.9	82.0	76.4	67.6
31°Co	67.8	82.5	72.3	73.3
	Feed Efficiency (kg feed/kg eggs)		Live weight change in grams	
21°Co	2.14	1.78	+ 96	+ 155
31°Cy	1.88	1.54	- 118	- 37
31°Co	2.14	1.66	- 152	+ 1

It is interesting to examine absolute nutrient intakes. These are calculated for energy, lysine, methionine + cystine and calcium in Table 6.

TABLE 6: Effect of temperature and diet on daily intakes of energy, lysine, methionine + cystine and calcium

Environment (°C)	Diet		Diet	
	Control	H.N.D.	Control	H.N.D.
	Daily energy intake (kjoules)		Daily lysine intake (mg)	
21°Co	1197	1135	667	805
31°Cy	932	906	520	642
31°Co	882	982	492	696
	Daily M + C intake (mg)		Daily calcium intake (g)	
21°Co	530	567	2.75	2.96
31°Cy	413	453	2.14	2.37
31°Co	390	491	2.02	2.57

Comparison with Table 2 shows that at the higher temperature intakes of these various nutrients on the Control diet fall below requirements for maximum performance and that increased nutrient intake on the H.N.D. diet significantly alleviates this situation.

High temperature resulted in decreases in the various measures of shell quality, e.g. shell thickness (0.320 mm at 21°Co, 0.293 mm at 31°Cy and 0.280 mm at 31°Co), specific gravity and % true shell. The use of the H.N.D. diet has no ameliorative effect on these factors, in spite of the increased calcium consumption achieved on this diet (see Table 6). It appears that deterioration in shell quality characteristics at high temperatures are influenced by physiological changes independant of calcium consumption.

Parameters measured to investigate further included:
(i) Plasma calcium, which decreased with increasing temperature and was increased by use of the H.N.D. diet. They conclude that this reduction in blood calcium with temperature may contribute to reduced shell quality, but it may not be the major cause. They suggest that at high temperature blood may be shunted to the periphery with a concomitant reduction in blood flow to the internal organs, e.g. the uterus and. shell gland.

(ii) Serum thyroxine levels, which decreased with increased temperature. They suggest that reduced thyroxine levels at high temperatures may contribute to the lower egg production and shell quality.

(iii) Partial pressure of CO$_2$ in blood (PCO$_2$) Higher temperatures caused lower PCO$_2$ readings, which may partly explain the reduction in shell quality. In order to maintain body temperature, respiration rate is increased and the resulting hyperventilation results in a change in blood pH and lower PCO$_2$ values. Mongin (1970) reported that respiratory alkalosis due to thermal hyperventilation reduced shell quality. .

At night, when most of the shell is formed, PCO$_2$ value for the cycling high temperature was significantly greater than for the constant high temperature. Shell quality was better in the cycling environment.

In certain circumstances, added dietary sodium bicarbonate can improve shell quality in hot conditions (Ernst et al. 1974). Levels of dietary chloride must be controlled before sodium bicarbonate additions will increase shell thickness (Mongin 1970). Variety of response in practice may be due to lack of control of chloride intake.

It has often been claimed that Vitamin C will prevent thinning of the eggshell under hot conditions. The evidence is conflicting, although there are controlled trials exhibiting well marked responses (Kechick & Sykes 1974). Ascorbate level in the tissues may be reduced under heat stress and responses could conceivably occur to dietary ascorbate supplementation.

(iv) Bone ash. High temperature significantly decreased % ash in bone (55.11% at 21°Co, 51.69% at 31°Cy and 51.96% at 31°Co). Diet had no effect on bone ash parameters. The data suggest that although calcium intake was theoretically sufficient to meet the demand for shell deposition, at high temperature the hens had to call upon their bone reserves to supply the calcium required for egg production.

In practice, insufficient daily energy intake at high temperature can be a significant factor. French workers (A.E.C. 1976) worked at 29/30°C with corn/soya based diets of two energy levels, 11.7 MJ/kg and 13.0 MJ/kg. Further dietary treatments included increased protein levels and supplementation with the essential amino-acids, lysine and methionine. Results showed significant improvements in performance, attributable to increased dietary energy level (Table 7).

TABLE 7: Effect of dietary energy level on % lay, egg weight and feed conversion (A.E.C. 1976)

Dietary energy (MJ ME/kg)	Feed Consumption (g/d)	Energy Consumption (kJ/d)	% Lay	Egg Weight (g/d)	Feed Conversion
11.7	104.9	1227	80.6	55.2	2.38
13.0	99.7	1296	83.6	57.0	2.11

The layers only partially adapted their feed consumption to dietary energy level, daily energy intake increasing by 69 kJ per hen.

Increased daily protein intake (15g to 18g), increased dietary lysine level (from 0.61 to 0.70%) and increased dietary methionine level (from 0.31 to 8.38%) gave no significant performance improvements, although at the higher energy level there was a tendency towards performance improvement with amino acid supplementation.

The conclusion was drawn that daily energy consumption may be the dominant problem of laying hen nutrition when temperatures are high. The practical technique of adjusting energy/protein ratio in hot weather by reducing energy level and increasing protein content appears completely erroneous.

V. SITUATIONS OF EXTREME SUMMER HEAT - EFFECTS ON PERFORMANCE

While it is possible to counteract the adverse effects of increasing temperature up to approximately 30/32°C, when temperatures rise above that point it becomes increasingly difficult to do so. The series of studies by Smith and Oliver (1972a) in Rhodesia covered temperatures of 21°C, 32°C and 38°C, using diets at energy levels of 12.2 and 13.5 MJ/kg.

At 21, 32 and 38°C temperatures, 79%, 72% and 41% of birds laid on any particular day. Eggs produced at 32°C or 38°C were 4.6% and 20.0% lighter than those produced at 21°C. Diet did not significantly alleviate these high temperature performance depressions.

Mean shell weight was reduced with feeding to appetite at 38°C but not when the same quantity of feed was fed at 21°C.

The experimental period was followed by a four week recovery period during which birds were fed to appetite at 21°C. During this recovery period, birds restricted by temperature or by rationing showed compensation associated with intake higher than that of the controls. Recovery of shell thickness at 21°C occurred immediately, but rate of production and egg weight took several weeks to fully recover.

In further work on the effect of prolonged exposure to high temperatures, Smith and Oliver (1972b) used very high energy diets, 14.2 MJ/kg and 16.2 MJ/kg (protein level 26.5%), at temperatures of 26°, 29.5°, 32° and 35°C. Over the initial 12 weeks, pullets took in an average of 1200 kJ, 1120 kJ, 1025 kJ and 807 kJ at the respective temperatures. Corresponding egg production was 81, 80, 77 and 63%, with egg weights of 59.6, 58.0, 55.6 and 52.8 g. Live weight decreased significantly at 35°C.

Results showed that egg production could be maintained at close to normal rates for at least 24 weeks at up to 32°C, but egg weight could not be maintained above 26°C. At higher temperatures, performances were depressed and high density diets were not effective in overcoming the depressing effects of such extreme temperatures.

In conclusion therefore, it can be said that where summer conditions include periods of extreme temperature (in excess of approximately 32°C), performance losses are inevitable. Below such temperatures, performance can be maintained at near normal rates, provided absolute daily nutrient requirements are ensured by use of diets of nutrient concentration appropriate to feed intake. In practice therefore, careful monitoring of feed intake is an important prerequisite in effectively determining dietary specifications to be used.

At extreme temperatures, feed and energy intakes are markedly reduced and liveweight losses are inevitable. While for short periods of time requirements for egg production may take precedence over maintenance of body tissue without performance loss, this effect must be of limited duration. Dietary energy level to be used will depend on economic considerations, including relative costs of energy-rich raw materials. However, in general terms, the use of higher energy, higher nutrient density diets is advantageous under summer conditions. The inevitable loss of body reserves during extreme conditions will be minimised and, in periods of reduced temperature, more effective compensatory nutrient intake will be achieved, with rebuilding of body reserves.

In restrict-reared flocks commencing lay in early summer, the effect on performance of further significant loss of body reserves due to heat stress and reduced nutrient intake, may be substantial.

In practise, many factors other than diet affect feed intake e.g. ration form and texture, cage stocking density and trough space, disease etc. Under summer conditions, where feed intake is so important, these factors assume-greater importance.

High temperatures cause losses of shell quality, normally not reversible simply by increased dietary calcium levels.

Where controlled environment shedding is used, there appear to be considerable advantages in the use of fluctuating temperature environments.

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