Dietary Energy Requirements of Broilers Reared in Low and Moderate Environmental Temperatures. 1. Adjusting Dietary Energy to Compensate for Abnormal Environmental Temperatures

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ABSTRACT Four trials were conducted to determine the feasibility of replacing fossil fuel energy with dietary energy to meet the 23- to 48-day-old broiler chicken's energy requirements during abnormal cold exposure. Sexed broilers were fed 3250 or 3500 kcal metabolizable energy (ME)/kg in a 10.0 C environment, 3250 or 3375 kcal ME/kg in a 15.6 C environment, 3250 kcal ME/kg in a 21.1 C environment (a normal management situation), and 3250 or 3125 kcal ME/kg in a 26.7 C environment.

Body weights and feed utilizations increased when broilers were exposed to a 15.6 C environmental temperature and fed 3375 kcal ME/kg dietary energy as compared to feeding a 3250 kcal ME/kg dietary energy in the same environment. When broilers were reared in a 10.0 C environment, maximum body weights were not obtained by increasing the dietary energy from 3250 to 3500 kcal/kg dietary energy. Broiler males, fed 3250 kcal ME/kg and reared in either a 21.1 or a 26.7 C environment, were larger than males reared in a 10.0 C environment. No significant differences were found in broiler female weights reared in a 10.0, 15.6, or 21.1 C environment and fed 3250 kcal ME/kg in each temperature regimen.

Feed utilizations were the same when broilers were reared in a 15.6 C environment and fed 3375 kcal ME/kg as compared to broilers reared in a 21.1 C environment and fed 3250 kcal ME/kg. These results indicate that maximum performance of 23- to 48-day-old broilers may be achieved in a 15.6 C environment by feeding a high energy diet (3375 kcal/kg). Results also showed that dietary energy may replace fossil fuel energy that would normally be supplied in a 21.1 C environment.

(*Key words:* energy requirements, broilers, environmental temperature, abdominal fat)

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INTRODUCTION

Growth of 3- to 7-week-old broiler chickens has been reported to be maximized at approximately 20 C (Kleiber and Dougherty, 1934; Barott and Pringle, 1949, 1950; Ota and Garver, 1954; Prince *et al.*, 1960; Howes *et al.*, 1962; Deaton *et al.*, 1978). Deaton *et al.* (1978) found that normal 4- to 7-week-old broiler body weights were attained when broilers were reared in a temperature range of 10 to 21.1 C or a simulated summer temperature regimen (23.9 to 35 to 23.9 C in a 24-hr cycle); however, feed utilization was reduced for the birds grown in the lower temperature regimen, due mainly to a higher feed consumption.

Adams *et al.* (1962) and Dale and Fuller (1980) found that increased dietary energy would offset, to some degree, the decreased body weights that growing broilers experienced in temperatures above 29 C. Mickelberry *et al.* (1966) also found that incorporation into the diet of either animal or vegetable fat, thus increasing dietary energy, would improve growth and feed utilization of broilers grown in both 21 and 29 C temperature environments.

Feed intake, an essential factor when considering nutritional requirements of chickens, is inversely related to environmental temperature and dietary energy (Hill and Dansky, 1954; Prince *et al.*, 1960; Lillie *et al.*, 1976; Byerly *et al.*, 1978; Dale and Fuller, 1980; Hurwitz *et al.*, 1980). Hurwitz *et al.* (1980) suggested that feed intake may decline due to the diminishing energy requirements for maintenance as temperatures increased up to 27 C. This is revealed when Hurwitz *et al.* (1980) measured the O_2 consumption or heat production under these conditions and is probably related to the

TABLE 1. *Beginning 23-day body weights*

Diet number[1]	Environmental temperature (C)	Dietary ME (kcal/kg	Mean 23-day body weight (g)		Mean[2]
			M	F	
3	10.0	3250	536	504	520
3	15.6	3250	541	499	520
3	21.1	3250	545	498	522
3	26.7	3250	548	494	521
Mean			543	499	
1	10.0	3500	536	501	519
2	15.6	3375	541	497	519
3	21.1	3250	545	498	522
4	26.7	3125	548	489	519
Mean			543	496	

[1] Each diet was fed in four trials to 120, 23- to 48-day-old broilers (15 males and 15 females for each of eight treatments.

[2] No significant differences (P<.05) were found in broiler 23-day body weights.

birds' ability to regulate the energy intake to meet their specific metabolic needs.

Hurwitz *et al.* (1980) also found in their studies that energy maintenance requirements decreased as the temperature increased from 12 to 24 C. The lowest energy requirement for maintenance was when environmental temperature was between 24 and 28 C. As the temperature was raised above 28 C, energy requirement increased. Studying the effect of environmental temperature and dietary energy on feed intake of broilers, Ahmad *et al.* (1974) found that the effect of the body's chemostatic mechanism was more pronounced than the thermostatic mechanism in controlling feed intake.

It is generally recognized that it is not always economically feasible to maintain optimum growing temperatures during all climatic seasons. Therefore, alternative means should be devised to assure maximum performance within the realm of profitability.

Feed energy may be one such alternative. The cost of feed accounts for more than 65% of the total cost of broiler production, and dietary cost increases as dietary energy increases. This suggests that a balance should be reached between attempts to attain optimum growing temperatures and the least expensive diet. Increasing dietary energy has been shown to have a beneficial effect on growth in hot summer conditions. The relationship between low environmental temperatures and dietary energy has not been fully explored. Thus, the purpose of this study was to determine the feasibility of substituting dietary energy for fossil fuel energy when maximum 23- to 48-day broiler growth and feed utilization and minimum abdominal fat is required.

EXPERIMENTAL PROCEDURE

Commercial broilers (Arbor Acre × Peterson) reared in floor pens were used in four experiments. One-day-old chicks were placed in an environmentally-controlled broiler house and temperatures were maintained at 29.4 C during the 1st week; 26.7 C during the 2nd week; and 23.9 C during the 3rd week.

At 23 days of age the chicks were transferred to controlled environmental chambers as described by Reece and Deaton (1969). Experiments were run successively. At the time each of the four experiments began the mean body weight of the experimental treatment groups did not differ significantly. A summary of the 23-day body weights is shown in Table 1.

The four temperature regimens employed when the broilers were 23 to 48 days of age were 10.0, 15.6, 21.1, and 26.7 C with a relative humidity of 70%. At each environmental temperature, broilers were fed either 3250 kcal metabolizable energy (ME)/kg of diet or dietary energy levels were adjusted in another group based on expected maintenance requirements to make a total of eight treatment regimens (4 temperatures × 2 dietary energy levels in each temperature). Diet compositions are shown in Table 2. Experimental diets met or exceeded the National Research's Council (NRC, 1977) nutrient requirements except for dietary energy. Expected energy requirements were calculated based on data by Deaton *et al.* (1978). Dietary energy levels included 3250 and 3500 kcal ME/kg in 10.0 C environment, 3250 and 3375 kcal ME/kg in a 15.6 C environment, 3250 kcal ME/kg (fed to two different groups) in a 21.1 C environment, and 3250 and 3125 kcal ME/kg in a 26.7 C environment. Southern US broiler diets for 23- to 48-day old broilers will normally contain 3250 kcal ME/kg of feed, and broiler house temperatures will usually be 21.1 C; therefore, this treatment regimen served as a control. In each experiment 15 males and 15 females were placed on each of the eight treatments. Each treatment was fed in four different experiments; therefore, each experiment served as a replicate. Birds were replaced with a bird of equal body weight throughout the experimental period as mortality occurred because bird density may have possibly altered environmental response.

In each experiment, birds were individually weighed, feed consumption determined, and abdominal fat removed (Kubena *et al.,* 1974) when broilers were 48 days of age. The fat removed surrounded the gizzard and lay between the abdominal muscles and the intestines. The layer of fat extended within the ischium and surrounded the bursa of Fabricius and cloaca where it was attached to the abdominal muscles. Abdominal fat was removed and immediately weighed from all broilers used in all experiments.

The abdominal fat data were subjected to the arcsin $\sqrt{\text{percentage}}$ transformation. Data were examined statistically by the analysis of variance (Steel and Torrie, 1960). Duncan's (1955) new multiple range test was used to determine significant differences among means. All statements of significance refer to 5% probability.

RESULTS AND DISCUSSION

The composite results of all four trials are presented in Tables 3 and 4. Male broilers fed

TABLE 2. *Experimental diets for 23- to 48-day-old broilers*

Ingredient	Diet number 1	2	3	4
Yellow corn	55.955	59.698	63.099	66.357
Soybean meal (49%)	28.445	27.788	27.373	27.121
Animal fat (7716 kcal/kg)	11.623	8.543	5.568	2.576
Dicalcium phosphate (18.5% P, 22% Ca)	1.868	1.857	1.844	1.831
Limestone	.978	.988	.998	1.008
Iodized salt	.486	.485	.484	.483
Broiler trace element premix[1]	.250	.250	.250	.250
MHA-Ca, 93%	.295	.291	.284	.274
Coban (.052 g/kg)	.100	.100	.100	.100
	100	100	100	100
Calculated analysis				
Crude protein, %	18.75	18.75	18.84	18.99
Metabolizable energy, kcal/kg	3500	3375	3250	3125
Lysine, %	1.00	1.00	1.00	1.00
Methionine + cystine, %	.85	.85	.85	.85
Calcium, %	.90	.90	.90	.90
Available phosphorus, %	.45	.45	.45	.45
Sodium, %	.20	.20	.20	.20

[1]The broiler premix furnished the following amounts of other ingredients per kilogram of feed: vitamin A palmitate, gelatin coated, 6614 IU; vitamin D_3, 1654 ICU; vitamin E, 2.2 IU; riboflavin, 4.4 mg; niacin 27.6 mg; d-pantothenic acid, 8.8 mg; folic acid, 275.6 μg; vitamin B_{12}, 8.8 μg; choline chloride, 551 mg; ethoxyquin, 55 mg; menadione sodium bisulfute complex, 2.8 mg or menadione sodium bisulfite, 1.7 mg; pyridoxine, .55 mg; manganese, 66.25 mg; zinc, 44 mg; iodine, 1.25 mg; iron (in sulfate form), 20 mg; copper (in sulfate form), 2 mg.

TABLE 3. *Effect of environmental temperature and dietary energy on body weight and abdominal fat*[1]

Diet number	Environmental temperature (C)	Dietary ME (kcal/kg)	Mean body weight (g)[2] M	Mean body weight (g)[2] F	Mean	Mean abdominal fat (%)[2] M	Mean abdominal fat (%)[2] F	Mean
3	10.0	3250	1958 ± 35^{c}	1738 ± 24^{b}	1848	1.74 ± .09^{d}	1.91 ± .04^{d}	1.83
3	15.6	3250	1999 ± 55^{bc}	1730 ± 22^{bc}	1860	1.87 ± .07^{cd}	2.02 ± .06^{cd}	1.95
3	21.1	3250	2075 ± 36^{ab}	1748 ± 28^{b}	1912	1.99 ± .06^{bc}	2.40 ± .08^{a}	2.20
3	26.7	3250	2070 ± 52^{ab}	1674 ± 24^{c}	1872	2.15 ± .07^{a}	2.50 ± .05^{a}	2.33
1	10.0	3500	1979 ± 38^{c}	1750 ± 25^{b}	1865	2.04 ± .08^{ab}	2.05 ± .09^{cd}	2.05
2	15.6	3375	2120 ± 44^{a}	1819 ± 47^{a}	1970	2.14 ± .10^{a}	2.44 ± .07^{a}	2.29
3	21.1	3250	2063 ± 30^{ab}	1735 ± 40^{c}	1899	1.83 ± .05^{cd}	2.37 ± .06^{a}	2.10
4	26.7	3125	1923 ± 55^{c}	1565 ± 32^{d}	1744	1.73 ± .06^{d}	2.11 ± .09^{c}	1.92

[a,b,c,d]Means within a criterion grouping and without a common superscript are significantly different (P<.05).

[1]Composite data of all four trials. Each mean represents an average of four replicates.

[2]Standard deviation (±).

3250 kcal ME/kg of diet had larger body weights when reared in either a 21.1 or 26.7 C environment as compared to a cold environment (10.0 C). No significant differences (P<.05) were found in female body weights fed 3250 kcal ME/kg of diet and reared in either 10.0, 15.6, or 21.1 C environments. When broilers were fed 3250 kcal ME/kg, abdominal fat of both male and female broilers increased as environmental temperatures increased. Deaton *et al.* (1978) also reported increased fat deposition in broilers grown under hot conditions, although they did not report the body weight changes associated with varying environmental temperatures that were noted in the present study.

Broiler females, but not males, accumulated abdominal fat more readily when reared in a 15.6 C environment and fed 3375 kcal ME/kg as compared to rearing broilers in a 10.0 C environment and feeding 3500 kcal ME/kg. Reducing dietary energy from 3250 to 3125 kcal ME/kg resulted in reduced abdominal fat when broilers were reared in a 26.7 C environment; however, body weights were also reduced.

Rearing either male or female broilers in a 15.6 C environment and feeding 3375 kcal ME/kg of diet resulted in significantly (P<.05) heavier body weights (Table 3) with an improved feed utilization (Table 4) as compared to broilers reared in the same environment and fed 3250 kcal ME/kg. These results compare very favorably to Adams *et al.* (1962), Mickelberry *et al.* (1966), and Dale and Fuller (1980) where it was found that dietary fat (or increased dietary energy) resulted in increased broiler performance when additional energy was needed for maintenance during heat stress. It appears the same phenomenon is true during cold stress.

The total mortality in all four experiments was nine. Therefore, mortality was considered to be of no consequence.

A significant (P<.05) improvement in feed utilization was found by feeding high energy diets as compared to low energy diets in both the 10 and 15.6 C environments. When broilers were reared in a 15.6 C environment, feed utilization (Table 4) was significantly improved (P<.05) by feeding 3375 kcal ME/kg as compared to feeding 3250 kcal ME/kg. Furthermore, broilers fed 3375 kcal ME/kg and reared in a 15.6 C environment produced equivalent feed efficiencies as those fed 3250 kcal ME/kg

TABLE 4. *Effect of environmental temperature and dietary energy on feed consumption and utilization*[1]

Diet number	Environmental temperature (C)	Dietary ME (kcal/kg)	23- to 48-day results[2]	
			Daily feed consumed (g)	Feed/gain
3	10.0	3250	120 ± 7[a]	2.325 ± .096[c]
3	15.6	3250	117 ± 6[ab]	2.247 ± .105[bc]
3	21.1	3250	113 ± 8[cd]	2.072 ± .076[a]
3	26.7	3250	111 ± 4[d]	2.085 ± .101[a]
1	10.0	3500	116 ± 7[bc]	2.209 ± .095[b]
2	15.6	3375	118 ± 5[ab]	2.086 ± .064[a]
3	21.1	3250	113 ± 6[cd]	2.098 ± .075[a]
4	26.7	3125	100 ± 5[e]	2.098 ± .072[a]

[a,b,c,d,e]Means within a column and without a common superscript are significantly different ($P<.05$).

[1] Composite data of all four trials. Each mean represents an average of four replicates.

[2] Standard deviation (±).

and reared in a 21.1 C environment. These data demonstrate that high energy diets may replace a portion of high cost fossil fuels required in optimum (21.1 C) environments. Hurwitz *et al.* (1980) found that dietary energy requirements increased when broilers have a high energy maintenance requirement. Presumably, high energy maintenance requirments will exist during both extreme hot and extreme cold environmental conditions.

As other researchers (Lillie *et al.*, 1976; Byerly *et al.*, 1978) have reported, broiler feed consumption (Table 4) increased when broilers were reared in lower than optimum environmental temperature. Unlike data published by Ahmad *et al.* (1974), a thermostatic mechanism (environmental temperature) was more pronounced in controlling feed intake than chemostatic mechanisms (dietary energy) in this study.

Our results indicate that broilers fed a high energy diet may be reared in a cooler than optimum environmental condition, i.e., 15.6 C rather than 21.1 C. Dietary energy was not consumed in adequate quantities to maximize performance when broilers were reared in a 10.0 C environmental temperature. Broiler producers should study their existing situation in evaluating the need to replace fossil fuel energy with dietary energy.

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