Fat Levels in Layer Feeds

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ABSTRACT

Supplemental fat, at levels up to 4-6% of the diet, has been shown to produce an "extra-caloric effect" beyond explanation, on the basis of metabolizable energy (ME) contribution to the diet. In addition, during periods of high-temperature stress (above 27 C mean daily temperature), consumption of ME above maintenance requirements decreases to an extent incompatible with economic production of eggs. The feeding of supplemental fat under these conditions to hens less than 50 weeks of age resulted in increased ME intakes and significant increases in egg production, egg weight, or both. This improved performance has been found to be associated with both the reduced heat increment of most diets when fat is added, and the effect on ME consumption. Fatty acid composition was not found to be related to improved performance.

INTRODUCTION

The use of supplemental fat in poultry diets has long been established as a means of providing higher caloric density and improvements in feed conversion (1-6). Thus, the successful utilization of fat for poultry is closely associated with energy utilization and voluntary feed consumption rates. Touchburn and Naber (7) have reported that substituting fat for carbohydrate in the diet of turkeys resulted in improvements in feed efficiency that could not be explained on the basis of increased dietary metabolizable energy (ME). This effect has been termed the "extra-caloric effect" of fat. Jensen and co-workers (8) have estimated that if the improvement in feed utilization due to the inclusion of fat in the diet was entirely attributed to the fat component, the ME of the fat would be 10.165 kcal/g. This value exceeds the gross energy (GE) value of the particular material employed in that study, and greatly exceeds the 7.7 kcal ME/g generally employed for fat in ration formulation. Horani and Sell (9) conducted a series of experiments evaluating the effects of supplemental fat for laying hens. When fat was included in rations based on corn, oats or barley, feed utilization was improved, and the improvements attributed to the fat supplementation were larger than anticipated from calculated changes in ME content of the diets. Horani and Sell (10) also showed that the most consistent effects of supplemental fat on ration ME occurred when the supplement was used at levels of 4-6% of the diet.

In general, the numerous reports available on fat supplementation for laying hens suggest three methods whereby fats exert beneficial effects on egg production: by increasing the caloric density of the diet; by increasing the bird's ability to obtain useful energy from the diet (extra-caloric effect); and by increasing the metabolic efficiency of energy utilization. The latter two effects of supplemental fat may be exploited to improve egg production in laying birds during periods of high-temperature stress.

The effects of high temperature on laying hen performance are well documented (11-13). The results of an experiment by de Andrade and co-workers (13) have shown that, during periods of high environmental temperature, laying hens reduce feed consumption, egg production rate, egg weight and shell thickness. This study was conducted with a constant temperature of 31 C and cyclic temperatures varying from 26.7-35.6 C, in comparison with a constant temperature control group at 21 C (Table I). The detrimental effects of high-temperature stress on laying hen production appear to be related to the physiological responses of poultry. The energy needs of chickens are intimately related to environmental temperature. As temperatures increase to 26-27 C, energy needs decrease linearly and consequently feed consumption will decline. As the environmental temperature exceeds 29 C, feed intake decreases more rapidly than at lower temperatures. Simultaneously, the additional stress placed on the birds due to their dependence on respiratory activity for heat elimination results in more energy consumption (14).

A number of energy terms are associated with feedstuff evaluation, as shown in Table II. The GE of the feed represents the maximum amount of potential energy available to the laying hen; it is reduced by losses occurring in fecal and urinary excretions to an energy term known as ME. Metabolizable energy represents the maximum utilizable energy that can be converted to either products or body weight

TABLE I

High Temperature Effects on Laying Hens (13)

Temperature	Egg production (%)	Feed intake (g/day)	Egg weight (g)	Shell thickness (mm)
21 C, constant	84.4	98.1	55.0	0.319
26.7 to 35.6 C, cyclic	78.9	76.4	51.5	0.292
31 C, constant	67.8	72.3	50.4	0.279

TABLE II

Energy Utilization—Poultry

Dietary gross energy

Fecal + urinary losses | Metabolizable energy

Heat increment | Net energy
a) Maintenance
b) Egg production
c) Body weight gain

gain. In the process of utilizing ME, an additional loss occurs in the form of heat increment, which represents the cost of utilizing and metabolizing energy for conversion to body weight or products. The remaining term, net energy (NE), is the amount of energy applied to maintenance, egg production or body weight gain. For many years, ME has been the measure used in poultry feed formulation for the evaluation of feedstuffs. Hathaway (15) has reviewed the effects of feed fat composition and digestibility in relation to ME content. He concluded that the feeding value of fats can vary considerably depending upon the fatty acid composition and structure, and that such factors as moisture, insoluble impurities and unsaponifiable matter should also be considered in evaluating fats for feed use. ME values have more recently been termed apparent metabolizable energy (AME). Within the last few years, a new technique has been developed by Sibbald in a series of papers for estimating true metabolizable energy (TME). Sibbald and Kramer (16) evaluated the TME values for a series of fat sources (Table III).

The efficiency with which laying hens utilize ME for body weight gain and egg production has become the subject of a number of studies in recent years. These measurements of energetic efficiency can be carried out quite rapidly and at the same time provide an accurate estimate of the effects of dietary formulation on laying hen performance. Studies in our laboratory have centered on the evaluation of environmental temperature effects in conjunction with dietary feed formulations and fat supplementation on energetic efficiency and laying hen performance.

Davis and co-workers (17) have evaluated energy balance (egg output and body weight gain) using a comparative slaughter procedure on groups of laying hens at ambient temperatures of 7.2, 15.6, 23.9, 29.4 and 35 C. These workers found that energy intake declined as the environmental temperature was increased and that heat production, measured as the difference between energy intake and energy retention, also declined with increasing ambient temperature. There was a linear relationship between heat production and ambient temperature; no thermal neutral zone was detectable. The energy available for egg production remained almost constant in these experiments at 50 kcal/kg physiological body weight per day, which was equivalent to an egg production rate of 82% at each of the ambient temperatures employed.

A study by Burlacu and Baltac (18) has also measured the efficiency of energy utilization of white Leghorn hens. The basal diet contained 4.469 kcal GE/g, 19.4% crude protein and 3.58 kcal ME/g. An energetic efficiency of 78.5% for the conversion of ME to NE was obtained in this study. The maintenance requirement for the white Leghorn hens weighing 1.7 kg was 125.8 kcal/kg physiological body weight. An additional measurement in this study involved estimating the energy costs per g of protein and fat synthesized by laying hens to be 7.2 kcal/g protein and 12.13 kcal/g of fat deposited.

There are three general methods available for estimating energy utilization in animals: direct calorimetry, indirect calorimetry, and slaughter techniques. The first two of these are usually of short-term duration and involve direct measures of heat production through sophisticated calorimetry techniques or indirect estimates of heat production by measuring oxygen consumption and carbon dioxide evolution. The carcass analyses techniques can be of long-term duration, and may be performed on a larger number of experimental animals than is usually possible with the measurements of heat production. In our studies the energy in eggs and in carcasses were measured by slaughter techniques, and we used regression analyses to predict energetic efficiencies of ME conversion to NE.

TABLE III

Metabolizable Energy of Fats (16)

Fat	AME (kcal/g)	TME (kcal/g)
Soybean oil	9.02	9.52
Corn oil	8.69	9.87
Lard	8.80	8.07
Beef tallow	7.11–7.70	8.07–7.00
Animal-veg. blend	8.14	9.34
Acidulated soapstock (soy)	7.77	9.05

TABLE IV

Energetic Efficiencies of Laying Hens (19)

Criteria	Maintenance and below	Above maintenance
Fasting heat production (kcal/PBW/day)	69.8	68.8
Maintenance ME (kcal/PBW/day)	112.7	109.5
Energetic efficiency (%)	61.9	62.8

TABLE V

Effect of Temperature on Laying Hens (20)

	21 C	32 C	% of 21 C
ME/day (kcal)	348.9	263.6	76.5
% production	86.3	85.0	98.5
Egg weight (g)	61.9	54.2	87.6
Maintenance (kcal/day)	209.8	172.1	82.0
Egg energy (kcal/day)	85.4	74.3	87.0
Energetic efficiency (%)	70.4	69.4	—
ME above maintenance (kcal)	139.1	91.5	65.8
Fasting heat prod. (kcal/day)	147.7	120.0	81.2

In one of the early experiments we measured the efficiency with which laying hens convert ME to energy for maintenance and for production (Table IV). This study showed that the energetic efficiency was virtually the same for these two functions–approximately 70%. The maintenance requirement of the hens employed in this study, housed under ambient conditions (16–26 C), was 100–112 kcal/kg physiological body weight per day (19).

In a subsequent experiment (20), the effects of housing temperature on energy utilization in laying hens were determined (Table V). The birds were housed at 21 and 32 C, and it was found that they consumed 24.5% less feed at the higher temperature. Egg production decreased only slightly by 1.5%; egg weight decreased by 12.4%. The maintenance energy required per hen per day decreased from 209.8 to 172 kcal when the birds were housed at 32 C, an 18% reduction. Egg energy production decreased by 13% due to losses in egg weight and egg production. The energetic efficiency with which the birds converted ME to NE was the same (70%) at the two temperatures, and in agreement with the results obtained in the first experiment. A striking effect of high temperature on laying hens is the reduction in the amount of energy available for production above maintenance. This reduction amounted to 34.2% and was not offset by the reduction in the maintenance requirements of the laying hen at the higher temperature (Table V).

The results of a number of experiments of this type are shown in Table VI. ME intake decreased significantly as housing temperature reached 27–29 C, and maintenance energy decreased linearly from 4–43 C. The difference between the maintenance requirement and the ME intake narrows at temperatures above 27 C, and results in decreased energy balance. These data indicate that housing temperatures for laying hens should be maintained below 27 C (average daily temperature) to provide optimum conditions for maximum performance.

A number of studies have shown significant differences in the energetic efficiency with which animals use the three major nutrients (carbohydrate, protein and fat). The energetic efficiency of fat is considerably higher than that of the other two major nutrients due to its low heat increment. In three experiments conducted at 13, 18 and 35 C we investigated the effects of incorporating 4% added fat in laying hen diets. The effects on energy balance are shown in Table VII. These studies demonstrate significant improvements in energy balance with added fat at 18 C or 35 C. Only a small increase was obtained at the lower temperature. The increase in energy balance, although significant at 35 C, was certainly not compatible with economic performance by laying hens. Energy balance was only 31 kcal when fat was fed at 35 C, in comparison with 131 kcal at 18 C.

Feeding fat during periods of high-temperature stress can be of substantial benefit in improving the performance of laying hens; however, at extremely high temperatures fat will not be sufficiently beneficial to offset the detrimental effects. In general, we have found that the incorporation of tallow into laying hen diets increases energy intake above that which would be obtained without the supplemental fat. This effect appears to be more pronounced at supplemental levels below 4% of the diet, and can result in substantial increases in egg production in younger birds. However, in birds above 50 weeks of age, adding tallow to the diet usually results in increases in body weight without any substantial increases in egg production. The summary of several other experiments conducted over a wider temperature range (13–35 C) (Table VIII) shows that feeding 2–4% added dietary tallow results in a 30 kcal increase in ME intake. These 30 kcal, if used for egg production, would amount to a 12% increase in egg production rate. A very small increase in energy intake per day can result in significant changes in egg production rate in laying hens.

Supplemental tallow at levels of 1, 3 and 5% were fed to hens housed at 18 and 35 C, as shown in Table IX. Maintenance energy was lower at 35 C, and was not affected by dietary fat level. Energy balance was significantly improved with the addition of 5% added tallow, in comparison with the basal diet containing 1%. Energetic efficiency was not significantly affected by either dietary tallow level or housing temperature in this experiment. However, the net energy of the diet was increased from 2.24 kcal/g to 2.46 kcal/g when 5% tallow was added. In a longer term experiment taking place over 12–28 day periods, dietary fats ranging from 12.5 to 57.9% linoleic acid were fed at a level of 3%. The metabolizable energy content of the diet varied from 2.73 to 2.94 kcal/g. Egg production was significantly increased from the 78.1% level of the basal diet to a range of 81.6–84.8% with three of the four fats tested in this experiment. One sample of fat (B) failed to produce a significant improvement in egg production or feed conversion rate (Table X).

We have also evaluated the effects of dietary protein intake on energy utilization and found that maximum energetic efficiency was obtained in the range of 17–21 g of protein intake per day in young laying hens. At lower protein intakes there was a significant increase in the heat increment of the diet; as the dietary protein intake increased above 21 g, there was also an increase in heat increment. Higher heat increments result in reduced energetic efficiencies; therefore, we should be cautious about overfeeding protein to laying hens.

The effects of dietary amino acid balance were studied in an experiment with laying hens housed at 16 and 32 C. Metabolizable energy intakes were considerably lower at the higher temperature. Since identical diets were fed in the two houses, sulfur amino acid intakes were also lower at the

TABLE VI

Effect of Temperature on Energy Utilization by Laying Hens

Temperature °C	ME intake (kcal/day)	Maintenance energy (kcal/day)	Energy balance (kcal/day)
4	368	288	20
16	358	243	80
21	333	221	83
27	300	205	74
32	250	186	58
38	186	160	29
43	131	131	-13

TABLE VII

Effect of Temperature on Energy Balance in Laying Hens

Temperature °C	Added fat	Energy balance/day		
		Eggs (kcal)	ΔBW (kcal)	Total (kcal)
13	0	71.5	30.5	102
	+	75.5	32.5	108
18	0	81.9	27.1	109
	+	88.3	42.7	131
35	0	46.0	-28.0	18.0
	+	50.8	-19.7	31.1

TABLE VIII

Effect of Added Tallow on ME Consumption Above Maintenance

Constant temperature °C	M.E. (kcal/day)		
	Without tallow	With tallow	Increase with tallow
13	135	169	34
18	136	168	32
24	139	159	20
29	87	127	40
35	5	34	29

TABLE IX

Temperature and Dietary Fat Effects on Energy Utilization by Laying Hens

	% Added fat					
	1		3		5	
Criteria	35 C	18 C	35 C	18 C	35 C	18 C
ME/day (kcal)	161^{a}	323^{d}	178^{b}	350^{e}	186^{c}	368^{f}
Maintenance ME (kcal/d)	102^{a}	129^{b}	106^{a}	127^{b}	104^{a}	135^{b}
Energy balance (kcal/d)	3.5^{a}	97.2^{c}	2.4^{a}	86.0^{c}	31.8^{b}	122.2^{d}
Energetic efficiency (%)	78.5	78.9	78.2	76.8	78.8	80.1
Diet NE (kcal/g)	2.23^{a}	2.24^{a}	2.35^{b}	2.31^{b}	2.45^{c}	2.47^{c}

[a]Means not having common letter superscripts are significantly different at the 0.05 level of probability.

TABLE X

Effect of Linoleic Acid Content of Feed Grade Fats on Laying Hen Performance

Dietary treatment				Feed
Fat source	% Linoleic acid	ME (kcal/g)	% Production	conversion (kg/doz)
Basal	---	2.73	78.1^{a}	1.78^{b}
Y.G., 3.0%	12.5	2.89	84.1^{b}	1.66^{a}
A, 3.0%	24.7	2.94	84.8^{b}	1.59^{c}
B, 3.0%	32.8	2.90	77.3^{a}	1.73^{b}
C, 3.0%	57.9	2.85	81.6^{b}	1.66^{a}

[a]Means not having common letter superscripts are significantly different at the 0.05 level of probability.

TABLE XI

Effect of Sulfur Amino Acid Level on Energy Utilization

	32 C		16 C	
Criteria	0.47	0.50	0.47	0.50
TSAA (mg/day)	449	465	517	598
ME (kcal/day)	281	279	330	359
ME above maintenance (kcal/day)	137	135	156	185
Energy balance (kcal/day)	81	90	107	133
Partial eff. of prod. (%)	59.1	66.7	68.6	71.9
Energetic efficiency (%)	53	62	58	64
Heat increment + activity (kcal/day)	132	106	139	129

higher temperature. The maximum energy balance obtained at 32 C was 90 kcal per day, while the maximum at 16 C was 133 kcal per day. Energetic efficiency was identical at the two temperatures with a maximum level of 61-64%. The feeding of diets deficient in methionine at the high environmental temperature resulted in an energetic efficiency of only 53%, whereas the lowest total sulfur amino acid intake at 16 C had 58% energetic efficiency (Table XI).

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Energy Levels for Broilers[1]

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ABSTRACT

One of the most important decisions to be made in feeding poultry is to determine the level of energy that will balance growth, carcass quality and efficiency of feed utilization with profitability of production. Strict adherence to measures of efficiency such as feed:gain ratios has caused many to overlook the potential benefits of modifying energy levels periodically to adjust to changes in price relationships among ingredients and in cost and quality of the finished product. It has been consistently shown that if an adequate quantity of essential nutrients is maintained in relationship to dietary energy, increasing levels of dietary energy for broilers results in a more rapid rate of gain and improvement in feed conversion efficiency. Controversy exists regarding the influence of dietary energy levels on carcass composition and quality, but in general, carcass fatness increases as dietary energy level increases. Selecting the optimum dietary energy level for broiler diets depends upon many factors, not all of which have been fully defined or quantitated. Higher energy levels may allow for more rapid gains or for a greater quantity of meat to be produced in a given time so that capital costs of housing, equipment and labor may be reduced. On the other hand, the ingredient and production costs of higher energy diets in contrast to diets of lower energy density may negate the benefits of improved performance.

INTRODUCTION

Energy is supplied to the chick by most feed ingredients, and modifications to the dietary energy level can be made

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