EFFECTS OF FAT LEVELS AND CAGE DENSITY ON ENERGY UTILIZATION BY LAYING HENS

by

Arturo Madrid Lopez

A Thesis Submitted to the Faculty of the

COMMITTEE ON NUTRITIONAL SCIENCES (GRADUATE)

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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SIGNED: R. Madrid S.

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

B. L. Reid
B. L. REID
Professor of Animal Science

2/22/80
Date

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to Dr. Bobby L. Reid, for his guidance, constructive criticism and helpful assistance during the planning, interpretation and writing of this thesis.

The author is sincerely grateful to Dr. F. D. Rollins and Dr. M. G. Vavich for their suggestions in editing this manuscript, and to Dr. Mauro Valencia for his encouragement and valuable assistance in the accomplishment of this research work.

I would like to thank Mrs. P. Maiorino, Mr. D. Parker, Mr. J. D. Ngou and staff of the poultry farm for their practical and technical assistance.

Sincere thanks are extended to the staff of the Nutrition Department of "Granjas Mezquital del Oro" for their practical help during the research period.

Grateful appreciation to Grace and my daughter Luz Elizabeth for their support and understanding throughout my academic program.

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ABSTRACT

Two experiments were conducted with laying hens to evaluate the effects of added fat levels and different cage densities on energy utilization. A typical layer ration was utilized in both experiments.

The first experiment was run during the summer months with ambient temperatures ranging from 16 to 37.5°C. The levels of added fat were 0, 4, 8 and 12%. These diets were fed to groups of 1, 2, 3 and 4 birds per cage (1350, 675, 450 and 337.5 cm^2/bird, respectively). The treatments with four birds/cage showed sub-optimal protein consumptions and this, in addition to crowding, resulted in consistently higher values for fasting heat production (FHP), maintenance metabolizable energy (ME) and maintenance feed, than the treatments with 3 or fewer birds per cage.

The treatments with 1 bird/cage had higher energetic efficiencies than the other treatments. The efficiency of tallow ME conversion to NE was 61.29% with calculated values of 7.554 kcal and 4.630 kcal/g of fat for ME and NE contents, respectively.

The second experiment was run during winter months with ambient temperatures ranging from 8 to 18.5°C. The levels of added tallow were 0, 4 and 8%. These diets were fed to groups of 3, 5 and 7 birds/cage (929, 557 and 412 cm^2/bird, respectively). All protein consumptions were optimal. The values for maintenance feed, maintenance ME and FHP per kg of PBW and energetic efficiencies were not significantly ($p <$ 0.05) affected by diet.

The treatments with 7 birds/cage had higher values for maintenance feed, maintenance ME and FHP per kg of PBW and energetic efficiencies for all diets, except maintenance feed in diet 1. The effect of cage density on energetic efficiency was not significant. The efficiency of tallow ME conversion to NE was 92.18% with calculated values of 7.686 kcal and 7.085 kcal/g of fat for ME and NE contents, respectively.

CHAPTER 1

INTRODUCTION AND REVIEW OF LITERATURE

Several studies have shown the usefulness of fat supplementation in poultry rations. Aside from improvements in feed efficiency, fats have been found to increase efficiency of energy utilization.

Sell and Horani (1977) reported a decrease in feed consumption and an improvement in feed efficiency with the addition of 2 and 4% fat to laying hen rations. They suggested that added fat had an "extra metabolic effect" whereby the change in ration ME caused by fat, as measured experimentally, exceeded that anticipated on the basis of calculated ME of the ration.

Animal fat has been used extensively in poultry diets and its effect on feed efficiency are very well defined. Improvements in energetic efficiency have been attributed to a lowered heat increment with the diets containing fat.

From a nutritional point of view, only linoleic acid is an essential nutrient for the chicken. All other lipids are important primarily as sources of energy, as "solvents" which aid in absorption of the fat-soluble vitamins, as materials which reduce the dustiness of feeds and perhaps improve palatability of some feeds. Of these properties, the energy value of lipids is by far the most important (Scott, Nesheim and Young, 1976).

Reid and Weber (1975) found that varying ME levels from 2.64 to 3.08 kcal/g with the supplementation of animal fat did not significantly alter egg production rate of laying hens housed in a conventional open-type colony cage house. Feed conversion was significantly improved with 10 and 15% fat additions. Another effect they observed in the same experiment was increased intake of ME in each of the houses resulting from the addition of fat. According to these data they suggested that the energy intake regulatory mechanisms are not adequately operative under high temperature conditions or more likely that the effects of heat increments are magnified by high temperature and can be offset by high fat levels.

The objectives of this work were the measurements of net energy of animal tallow and energetic efficiencies in laying ration as influenced by feeding different fat levels, cage density and ambient temperature.

Review of Literature

Animal Fat

Natural fats consist almost entirely of triglycerides, with very small amounts of phospholipids and sterols. Their physical properties depend on the nature of the constituent fatty acids. The factors that influence the digestibility of fats include the degree of saturation of the constituent fatty acids, the proportion of glycerides, chain length of the fatty acids, level of inclusion in the diet and age of the birds. The first three of these factors contribute to the synergistic effects of unsaturated fats on saturated fats (Annison, 1974).

In the gut lumen, the formation of a fat-bile salt micelle is an important prerequisite to fat absorption, since it is in this form that fatty acids are transported to the intestinal mucosal surface. Whereas unsaturated fatty acids readily form micelles with bile salts, saturated fatty acids which are non-polar, do not. Once micelles have formed however, they will themselves solubilize substantial amounts of non-polar, saturated fatty acids. This combining effects of fatty acids prior to absorption is often referred to as fatty acid synergism and account for the reason why fats that are predominantly saturated, can still provide substantial quantities of energy to the chicken. The balance of saturated to unsaturated fatty acids in a fat or oil can, therefore, have a marked influence on the overall digestibility of fat. The work of Sell, Horani and Johnson (1976) also confirms the hypothesis that fat ME values vary with the fatty acid content of the diet (Leeson and Summers, 1976).

Renner and Hill (1958) clearly demonstrated that palmitate and stearate per se did not provide energy when fed without unsaturated fatty acids in the diet of the chick.

Sell and Horani (1977) indicated a grain source by fat level interaction, showing that hens fed corn-based rations with added fat were able to metabolize more energy from the ration than from barley-based rations. In this study, fat increased the ME of corn-based rations per se and thus, the effect occurred prior to metabolizable energy utilization by the hen. The mechanism by which added fat may increase the ME of corn-based rations is not known. Apparently, fat acts in a synergistic manner with other ration components. Leeson and

Summers (1976) hypothesized that an interaction occurs between the fatty acid of the added fat which results in changes in the ME of the fat and, consequently, of the ration. The work of Sell and Horani (1977) lend some support to this hypothesis; they suggested the term "extra metabolic effect" to indicate an improvement in energy utilization related to increased absorption and/or increased metabolizability of ration energy, exclusive of changes in heat increments.

Jensen and Falen (1973) feeding 3 and 6% fat levels to growing turkeys found an extra caloric effect of added fat. Calculation of an adjusted ME value for fat showed that fat at the 3% level had 34% more adjusted ME in the mash diet and 55% more in pelleted diet than the energy value of the fat used to formulate the ration, 10.2 vs 7.7 kcal/gr of ME. The "extra caloric effect" of added fat was observed in both pelleted and unpelleted rations. At the 6% level of added fat, adjusted ME values were 20% higher for the unpelleted but no higher for the pelleted ration compared with the actual ME value.

Jackson, Kirkpatrick and Fulton (1969) reported that in laying hens the efficiency of ME utilization decreased with increasing dietary ME content at higher levels of fat addition (28.25%). The net utilization of ME was most satisfactory for production at 3.50 and 7.50% of the diet. There was a statistically significant dietary effect on mean egg weight, the trend being for egg weight to increase linearly with increasing dietary ME. The best results were achieved by feeding diets with a calorie protein ratio of 160 and 157. They also found that daily ME intake increased linearly with increasing ME from fat in the diet, contrary to literature reports suggesting that the laying hen adjusts her level of food intake on diets of widely different ME content.

Summers, Leeson and Griffiths (1977), working with broilers, fed 0, 3, 6 and 9% fat and found that corn oil and poultry grease produced significant ($p < 0.05$) increases in weight gain, compared with control birds. Since all diets were isocaloric and feed intake was equated, these results represent an "extra caloric effect" attributable to the fat source. The NE system of energy evaluation, as proposed by De Groote (1974a), is reported to account for the enhanced utilization of calories derived from dietary fat. So, diets containing the same quantities of fat, but formulated to be isocaloric with respect to NE would not be expected to show an "extra caloric effect" from fat.

Sibbald (1978) showed that the addition of soybean oil increased the true metabolizable energy (TME) value of the tallow but lard had little or no effect. Ninety-six percent of the lard energy was metabolized presumably because a high proportion of the saturated fatty acids were located in the 2 position on the glycerol molecule. Despite this positional advantage, lard failed to interact with the tallow to improve absorption. It is well known that unsaturated fatty acids, such as are present in soybean oil, aid in the absorption of saturated acids such as are present in tallow (Young, 1961). Sibbald (1978) showed that as little as 2% soybean oil increased the TME value of tallow. This adds weight to the hypothesis discussed by Leeson and Summers (1976) that small quantities of lipids found in some feed ingredients can profoundly affect the utilization of the fat added to poultry diets.

The degree of saturation was not the sole determinant of the TME content of fat. The positional distribution of fatty acids may explain the differences in the TME values for such fats as lard and tallow, which had similar fatty acid composition. Lard is known to contain high levels of saturated acids (16:0) in position 2, while tallow contains equal proportions of saturated in all 3 positions (Sibbald and Kramer, 1977).

The explanation for the high efficiency of utilization of certain fats when fed in dietary situations resulting in carcass fat deposition lies in the low energy cost of their digestion, absorption, transport and deposition relative to carbohydrates (Annison, 1974).

Energetic Efficiency

Few studies have evaluated the ME of a given feed at different temperatures. In those where it has been studied, it was found that temperature usually had no effect on the ME content of a diet when corrected for N-equilibrium, though it may be reduced in birds kept at such a high ambient temperature that mortality is high (Emmans, 1974). The efficiency with which ME is converted to egg or carcass energy does depend on the source of the dietary ME, i.e., whether it comes from carbohydrate, fat, protein and whether the energy is stored as fat or protein (Emmans, 1974).

There seems to be no reason to think that the net efficiency with which ME is converted to egg or carcass energy will vary with temperature. Actual determinations of this efficiency by feeding varying amounts of energy at each of several temperatures would be expected to show that the efficiency is greater at lower temperatures, as at such temperatures the heat released as a result of production should help the animal meet the environmental demand for heat. Weight gain and egg output in birds fed equal amounts of nutrients are virtually unaffected by temperature over a wide range (Emmans, 1974).

Fuller and Rendon (1977) fed different feed grade fats to broilers chicks and found that caloric efficiency (gross energy gained/ ME consumed) was greater with fat supplemented diets than with low fat controls, and was generally greater with 10% fat than with 20%. In the same test, energy and nutrient intake was influenced by heat increment of the diet as well as by energy levels. Reid, Valencia and Maiorino (1978) have indicated that the limiting factor for egg production during high temperature is energy intake. They reported a slight increase of feed intake for laying hens fed different fat levels at two housing temperatures, 18.3 and 35°C. They also indicated that the effect of supplemental dietary fat in increasing ME intake was more apparent at 35°C.

ME often seriously underestimates the true value of added fat and can seriously overestimate the value of using protein primarily as an energy source (Hathaway, 1977). For this reason, it seems logical that the feed industry will eventually move toward a NE system for formulating least cost poultry rations. However almost all rations are presently formulated on the basis of ME (Hathaway, 1977).

De Groote (1974b) reported a series of experiments in which the observed utilization efficiencies of ME for production with laying hens varied from 64% to 86%. It is mentioned that a problem in assessing the utilization efficiency of ME for egg production is that egg production is not uniquely determined by the energy supply in excess of maintenance requirements. Excess energy is either converted into eggs or used for body again. Furthermore body energy can also be used for egg production. Taking into account the age of the laying hens, it is reasonable to assume that the value of 80% is applicable for body fat gain. De Groote also concluded that compared with carbohydrates, proteins and fats are less efficient substrates in meeting maintenance requirements of energy; the same remains true for proteins in relation to fattening, but the ME from fats appears to be used more efficiently when compared with carbohydrates for fattening. Experiments using chicks from 2 to 4 weeks old, have shown that the net availability of the ME of fats for growth is considerably higher when compared with glucose (Carew and Hill, 1964) or carbohydrate-rich feedstuffs, such as yellow corn, milo, and wheat.

Farrell (1978) observed an increase in the amount of fat deposited by broilers with increasing ME concentration in the diet. There was no indication of a decrease in efficiency of ME utilization with high concentrations of fat and oil as had been previously observed by Farrell, Cumming and Hardaker (1973). Energy retention was greatest at the highest concentration of tallow (140 g/kg) in the diet; there was an indication that the availability of ME was greater for tallow than for oil at similar ME inclusion rates. Without any lipid in the diet, the partial efficiency was 77% and energy retention was lower than for diets with added fat (Farrell, 1978).

Gomez and Polin (1974) reported that the value obtained for fat absorption by birds fed different fat diets (purified-type diets) range from 90.4 to 94.8%. These values were improved significantly ($p < 0.05$) by 2.1% through the addition of 0.2% cholic acid. The improvement occurred in all treatments except when corn oil replaced 50% of the glucose ME. The addition of cholic acid also significantly increased ($p < 0.01$) the ME values of fat. Bile salts have proven efficacious in reversing to a major extent, the adverse effect of raw soybean meal on the apparent absorption of fat in young chicks.

Edwards (1962) also noted slightly improved absorption of fat by chicks fed practical-type diets containing cholic acid. Thus, the beneficial effect detected in these studies by Gomez and Polin (1974) and Edwards (1962) on fat absorption by exogenous bile salts suggest a practical need for bile salts in high fat diets fed to very young chicks.

Burlacu and Baltac (1971) obtained conversion efficiency of digestible energy to ME of 78.42 ± 2.9% with NE values of 76.6 ± 4.2% of the ME. In the same series of experiments they reported the following results: energy balance of hens was zero when the intake of ME was 117.6 kcal/kg$^{0.75}$/24 hr., laying hens synthetize protein energy with an efficiency of 77% and fat, energy with an efficiency of 77.5% of the ME for production.

Temperatures

Reid (1979) in a series of experiments reported the following conclusions: 1) The efficiency of conversion of ME consumed to net energy for maintenance and production is not affected by environmental temperatures. 2) A main effect of high environmental temperatures is a reduction in feed intake and consequently energy consumption levels above maintenance which are insufficient to maintain a high rate of egg production. 3) In the range of 19.5-29.5^{o}C optimum egg production rates can be expected from laying hens provided the diet is well balanced in other nutrients. 4) The feeding of added fat in the diet of laying hens during periods of high environmental temperature would be expected to result in increased levels of ME consumption as well as improvements in feed conversion and should partially alleviate the adverse effects of high environmental temperatures. 5) Management practices should be aimed to improve feed consumption.

There seems to be no reason to think that the net efficiency with which ME is converted to egg or carcass energy will vary with temperature. Actual determinations of the efficiency by feeding varying amounts of energy at each of several temperatures would be expected to show that the efficiency is greater at lower temperatures, as at such temperatures the heat released as a result of production should help the animal meet the environmental demand for heat (Emmans, 1974). It would seem that high temperatures can depress egg weight directly but that, excepting very high temperatures, the depression which occurs in birds with equal nutrient intake is mainly, if not entirely, due to reduction in energy intake (Emmans, 1974). Depending on the relative prices of the various cereals and fats it may be economic to try to overcome some of this depression by formulating diets with higher energies there by resulting in higher energy intakes (Emmans, 1974).

Emmans (1974) concludes that if the aim of research into the effects of temperature of laying hens is to increase the economic efficiency of egg production then future work should concentrate on the following areas: 1) The relationship between dietary energy level and temperature on energy intake of hens fed ad libitum. 2) The effect of varying controlled energy intakes on the performance of birds at different temperatures, fed equal quantities of other nutrients. 3) The relationship between constant and diurnally fluctuating temperatures of the same average temperature on performance.

The energy intake, expressed either per bird per day or per unit metabolic body weight per day showed a regular decrease with increasing ambient temperature. The daily energy production in the form of eggs followed the same pattern as egg mass, i.e., no significant differences but a tendency towards lower production at higher temperatures. Heat production showed a linear decrease with increasing temperature and there was no evidence of a critical temperature, a thermoneutral zone or a hyperthermal rise in metabolism. These are some of the conclusions reached by Davis, Hassan and Sykes (1973) based upon on experiments conducted with laying hens at temperatures of 7.2, 15.6, 23.9, 29.4 and 35^{o}C.

Davis, Hassan and Sykes (1972) in other experiments confirmed that production was maintained (88%) in the warm environment even though food intake was markedly reduced (95 and 63 g/day at 10 and 35°C, respectively) after two weeks of acclimatization. They observed that the first reaction of birds on exposure to a cold environment was to attempt to reduce heat loss by "huddling". These results therefore emphasize the need to allow adequate time for acclimatization to the environment in studies of energy metabolism.

CHAPTER 2

ANIMAL FAT STUDIES WITH LAYING HENS

Experiment I

Experimental Procedure

Six hundred white Leghorn laying hens (27 weeks old) were randomly allotted at cage densities of 1, 2, 3 and 4 birds per cage, in a house at ambient temperature for an experimental period of 14 days. The latter densities corresponded to 1350, 675, 450 and 337.5 cm^2/bird. The birds had been previously consuming the experimental diets for two weeks. These diets contained four levels of added animal tallow (0.0, 4.0, 8.0 and 12.0%). In order to provide a range of feed and metabolizable energy consumption for regression analysis, each diet was supplied at three feeding levels making a total of 12 treatments with five replicates per treatment at each cage density. The levels employed were as follows: diets 1 and 2 were fed *ad libitum*, 60 g and 40 g per bird per day; diets 3 and 4 were fed *ad libitum*, 50 g and 30 g per bird per day. The basal diet was formulated by linear programming techniques to meet the nutrient requirements of the laying hen (Table 1). Birds were fed once a day and feed consumption recorded. Water was supplied *ad libitum* and egg production and egg weights were recorded daily throughout the experimental period. Feed and fecal samples were collected and analyzed for gross energy using a Parr oxygen bomb calorimeter and for chromic oxide (Edwards and

Table 1. Basal diet composition for Experiment I.

Ingredient		Percent of diet
Milo		54.30
Soybean Meal		26.40
Meat Scraps		3.00
Dehydrated Alfalfa Meal		5.00
Animal Tallow (FESA)		1.00
Calcium Carbonate		7.80
Dicalcium Phosphate		1.20
Salt		.50
DL-Methionine		.10
Vitamins[1]		.25
Trace Minerals[2]		.25
Cr_2O_3		.20
	Total	100.00

[1]Supplied the following per kg of diet: 3250 I.U. vitamin A, 1000 I.C.U. vitamin D_3, 1.5 I.U. vitamin E, 2.25 mg vitamin K_3 Menadione Sodium Bisulfite, 1.50 mg Riboflavin, 1.75 mg d-Pantothenic acid, 6.25 mg Niacin, .125 mg Folic acid, 1.25 mcg vitamin B_{12}.

[2]Supplied the following in ppm: 50 Zn, 50 Mn, 50 Fe, 5 Cu, 1 I, 0.2 Co and 0.1 Se.

Gillis, 1959). Birds were weighed at the beginning and at the end of the experiment.

Regression analyses were performed for the three feeding levels of each experimental diet using g of feed per kg physiological body weight (Feed/$BW^{0.75}$) as the independent variable and energy retention per PBW (ER/$BW^{0.75}$) as the dependent variable (Farrell, 1974). The intercept on the x-axis was the maintenance feed requirement (g of feed/$BW^{0.75}$) and the intercept on the y-axis was the fasting heat production (FHP). The slope provided an estimate of NE in kcal/g feed. Regression analysis with ME per PBW (ME/$BW^{0.75}$) as the dependent variable gave the intercept on the x-axis as the maintenance energy expenditure expressed as ME and the intercept on the y-axis as fasting heat production. The slope of this line represented the efficiency of conversion of ME to NE.

Results and Discussion

The first experiment was run in "Granjas Mezquital del Oro: located in the northwest part of Mexico during the summer months. Temperatures ranging from an average minimum of 16°C (night) to an average maximum of 37.5°C (day). The ingredient composition of the basal diet, the fatty acid composition of the tallow used in this experiment, the nutrient composition of the basal diet and the analyzed values of the diets are shown in Tables 1, 2, 3 and 4, respectively.

Average protein consumptions per bird per day as affected by diet and cage density for the _ad libitum_ groups are shown in Table 5.

Table 2. Fatty acid composition of animal tallow (FESA) used in Experiment I.

Fatty acid	Percent of sample
Lauric (12:0)	2.44
Palmitic (16:0)	31.70
Palmitoleic (16:1)	3.97
Stearic (18:0)	16.28
Oleic (18:1)	38.17
Linoleic (18:2)	7.43

Table 3. Calculated composition of basal diet for Experiment I.

Nutrient	Amount
Crude Protein, %	20.29
ME, cal/g	2.698
Calcium, %	3.30
Total Phosphorus, %	0.65
Methionine + Cystine, %	0.74
Lysine, %	1.11
Arginine, %	1.33

Table 4. Comparison of analyzed and calculated values for diets used in Experiment I.

Factor	Diet 1	Diet 2	Diet 3	Diet 4
Metabolizable Energy kcal/g				
calculated	1.70	2.90	3.11	3.31
analyzed	2.69	2.89	3.08	3.27
Protein, %				
calculated	20.29	19.48	18.66	17.85
analyzed	21.71	18.80	18.53	16.25
Total Fat, %				
calculated	3.18	7.05	10.92	14.79
analyzed	3.36	7.14	11.17	14.87

Table 5. Average protein consumption for the *ad libitum* groups (g of CP/day) for Experiment I.

	Birds/cage (Sq cm^2/bird)				
Diet	1(1350)	2(675)	3(450)	4(337.5)	Means
D1	23.06	24.00	21.66	22.06	22.69
D2	18.80	17.79	18.93	18.06	18.39
D3	17.21	20.45	18.18	17.80	18.41
D4	14.74	14.54	15.05	13.82	14.54
Means	18.45	19.19	18.45	17.94	18.51

All consumption values were above the recommendations of the 1977 N.R.C. Poultry Requirements, except for the groups consuming Diet 4 (12% fat added) which had lower than the minimum specified protein intakes.

At this point, mention should be made of the low protein consumption figure of 14.54 g per bird observed for birds fed Diet 4, which had an estimated ME content of 3.31 kcal/g of feed. The fact that this group consumed less protein than the minimum required per day suggest a metabolic situation where the animal was forced to break down some body tissues in order to meet its requirements. Therefore, this may have influenced the values obtained for this group in regard to FHP and ME for maintenance.

Table 6 shows the separate effects of diet and cage density on maintenance feed, maintenance ME and FHP per PBW and energetic efficiency.

The data shown in Table 6 indicate that the maintenance feed requirements per PBW were not significantly different ($p < 0.05$) among the added fat diets and was higher for the group consuming Diet 1 (0% fat added). The average value in this experiment of 25.65 g of feed for maintenance is smaller than those obtained by Valencia (1978) and Reid et al. (1978) of 39.14 g and 40.54 g, respectively.

The average maintenance ME and the average FHP values of 76.06 kcal/PBW and 41.86 kcal/PBW (Table 6) were also lower than those reported by Reid et al. (1978) as 111.10 kcal and 69.28 kcal/PBW, respectively.

The lower values obtained are explainable in part by the higher ambient temperature prevailing during this experiment.

Table 6. Means comparison of diet and cage density effect on the following parameters; maintenance feed/PBW, maintenance ME/PBW, fasting heat production/PBW and energetic efficiencies (Experiment I).[1]

Factor	Diet Effect (0, 4, 8 and 12% added fat) Diet 1	Diet 2	Diet 3	Diet 4
Net Energy, kcal/g	1.42	1.62	1.69	1.82
Maintenance Feed/PBW, g	28.40[b]	25.92[ab]	23.25[a]	24.93[a]
Maintenance ME/PBW, kcal	76.34[ab]	74.78[ab]	71.56[a]	81.58[b]
Fasting Heat Production/PBW, kcal	40.48[ab]	42.05[abc]	39.45[a]	45.44[c]
Energetic Efficiency,[2] %	52.99[a]	56.27[b]	55.04[b]	55.73[b]
	Density Effect (1, 2, 3 and 4 birds/cage) 1	2	3	4
Cm^2/bird	1350	675	450	337.5
Maintenance Feed/PBW, g	27.84[b]	27.32[b]	22.60[a]	24.74[ab]
Maintenance ME/PBW, kcal	82.87[c]	81.08[bc]	67.28[a]	73.02[ab]
Fasting Heat Production/PBW, kcal	47.19[c]	43.76[bc]	36.85[a]	39.62[ab]
Energetic Efficiency,[2] %	56.99[b]	53.86[a]	54.78[ab]	54.39[ab]

[1]Means in the same line with different superscript are significantly different ($p < 0.05$).

[2]Metabolizable Energy converted to Net Energy for maintenance and production.

There were significant ($p < 0.05$) increases in energetic efficiency with added fat in comparison with the basal diet. It would seem that beyond the 4% level of added fat there was no additional improvement in energetic efficiency.

The effects of cage density, as shown in Table 6, indicate an almost linear relationship between maintenance feed, maintenance ME and FHP per PBW and number of birds per cage. There was a significant reduction in energetic efficiency for the 2 birds/cage groups with a value of 53.90% in comparison with 57.0% for the 1 bird/cage groups. Additional birds (3 or 4) also showed numerical decreases in energetic efficiencies (54.8 and 54.4%). FHP was decreased with 3 or 4 birds per cage in comparison with those groups with only 1 or 2 birds/cage. The reduced FHP values may reflect the effects of heat load on the birds undercrowded conditions. It would seem that a greater temperature effect would be apparent in crowded birds than when more space is available for movement. The same effects were noted in the maintenance values; lower maintenance energy and feed requirements were found with 3 or 4 birds per cage.

Earlier observations by Hughes and Black (1974) and recently by Reid (1979) indicates that in caged birds, activity is increased by putting more birds in a group since the movement of a dominant individual may cause all the other birds to shift position. So, as space becomes more restricted and birds move less the amount of time spent standing increases.

The NE content of the fat used in this experiment was 4.63 kcal/g calculated by regression of NE content of the diet (Table 6) on fat level. The ME of the fat was 7.554 kcal/g. The above figures give us an efficiency of conversion of ME of fat to NE of 61.29%.

Tables 7 and 8 show the effect of diet and cage density, respectively, on laying hen performance. Percent egg production and egg output (g egg/bird/day) decreased linearly as level of fat was increased. Both parameters were significantly ($p < 0.05$) lower for the 12% added-fat than the rest of the diets. Although no significant differences were found in energy retention per PBW, a tendency for lower energy retention values was observed as energy of the diet increased from 2.70 to 3.31 kcal of ME/g of feed. In comparing separately the values for ME consumed per bird/PBW and per day were very similar for all diets, suggesting the ability of the hens to adjust their daily feed consumption according to the energetic density of the diet.

Egg production as affected by cage density did not show any significant differences. Egg production data, either by diet or cage density did not allow valid conclusions due to the short duration (14 days) of the experiment. Egg output and energy retention values had significant differences among the four cage densities. The energy retention values per day and per PBW were significantly decreasing as number of birds/cage increased. The similarity among the values of ME consumed per bird/PBW and per day, again indicates the ability of hens to regulate feed intake in accordance to the energy content of the diet.

Table 7. Effect of added fat levels on laying hens performance for the *ad libitum* fed groups (Experiment I).[1]

Factor	% Fat Added			
	0	4	8	12
Egg Production, %	85.09[b]	82.35[b]	81.93[ab]	73.90[a]
Egg Output, g/bird/day	44.74[b]	44.15[b]	43.14[ab]	38.08[a]
ER/bird/day, kcal	67.71[a]	61.09[a]	64.16[a]	67.75[a]
ER/bird/PBW, kcal	74.44[a]	73.91[a]	69.93[a]	66.77[a]
ME/bird/day, kcal	286.94	282.35	305.85	292.73
ME/bird/PBW, kcal	220.26	216.92	227.34	223.89

[1]Values in the same line with different superscript are significantly different ($p < 0.05$).

Table 8. Effect of cage density on laying hen performance for the *ad libitum* fed groups (Experiment I).[1]

Factor	Birds/cage[2]			
	1	2	3	4
Egg Production, %	81.78[a]	83.04[a]	81.54[a]	76.90[a]
Egg Output, g/bird/day	43.00[b]	43.94[b]	43.25[b]	39.91[a]
ER/bird/day, kcal	70.37[a]	65.35[ab]	65.06[ab]	59.92[b]
ER/bird/PBW, kcal	76.82	71.42	71.33	65.47
ME/bird/day, kcal	295.10	300.70	290.96	281.10
ME/bird/PBW, kcal	225.12	228.09	220.35	214.85

[1]Values in the same line with different superscript are significantly different ($p < 0.05$).

[2]1, 2, 3 and 4 birds/cage corresponds to 1350, 675, 450 and 337.5 cm^2/bird, respectively.

Summary

An experiment was run with 600 laying hens to measure the effect of 0%, 4%, 8% and 12% added tallow levels in combination with 1, 2, 3 and 4 birds/cage on energy utilization during summer months with temperatures ranging from 16°C to 37.5°C.

The average protein consumption for the 4 birds/cage group of 14.54 g/bird was below the minimum of 16.5 g specified by the N.R.C. Poultry Requirements of 1977. Low protein consumption appeared to influence the values obtained for maintenance requirements.

<u>Effect of Diet</u>. The maintenance feed requirements per PBW were not significantly different among the added-fat diets and was higher for the group consuming Diet 1 (0% fat added). The average maintenance ME and FHP/PBW values of 76.06 kcal and 41.86 kcal/PBW were smaller than those reported by Reid et al. (1978) as 111.10 kcal and 69.28 kcal/PBW, respectively. Smaller values here obtained might reflect the hot ambient temperature effect.

Energetic efficiency was increased significantly ($p < 0.05$) for the added-fat groups in comparison with those fed the basal diet. This would suggest that beyond a 4% supplemental level of fat no additional gain in energetic efficiency occurred.

<u>Effect of Cage Density</u>. Maintenance feed, Maintenance ME and FHP values were decreased as number of birds went from 1 to 3 birds/cage (i.e., from 1350 cm^2 to 450 cm^2/bird). The values for the 4 birds/cage group were consistently higher ($p < 0.05$) than the 3 birds/

cage. Suggesting the latter, a crowding effect when putting more than 3 birds/cage or giving a space allowance less than 350 cm^2/bird.

There was a significant reduction in energetic efficiency for the 2 birds/cage groups with a value of 53.9% in comparison with 57.0% for the 1 bird/cage group. Additional birds (3 or 4) also showed numerical decreases in energetic efficiencies (54.8 and 54.4%).

The reduction in FHP values for the 3 or 4 birds/cage group in comparison with those with only 1 or 2 birds/cage, may reflect the effects of heat load on birds under crowded conditions.

The similarity between the ME consumption figures per bird/day shows the ability of the hens to adjust daily feed consumption according to the energy density of the feed.

As percentage egg production concerns, either affected by diet or cage density, no valid conclusion could be attained because of the short duration of the experiment (14 days).

The NE calculated content of the fat of 7.554 kcal/g vs its calculated ME content of 4.63 gave us an efficiency of converting ME to NE of 61.29%.

Experiment II

Experimental Procedure

A second experiment, carried out at the University of Arizona Poultry Research Center, was designed in a similar manner to Experiment I using three hundred and sixty laying hens (U of A stock) randomly allotted at cage densities of 3, 5 and 7 birds per cage.

Corresponding 929, 557 and 412 sq cm per bird respectively. Birds were housed at ambient temperature for an experimental period of 14 days. The birds had been previously consuming the experimental diets for two weeks. The diets were formulated with 0, 4 and 8% added animal tallow. Each of the three diets was supplied at four feeding levels making a total of 12 treatments with two replicates per treatment at each cage density. The following levels were used: ad libitum, 80 g, 60 g and 40 g per bird per day. Egg production, feed consumption, body weights and feed and feces analysis were all handled as in Experiment I.

Results and Discussion

A second experiment was run at the University of Arizona Poultry Research Center during the winter months with temperatures ranging from an average minimum of 8°C to an average maximum of 18.5°C. The basal diet (Table 9) used was essentially the same as in Experiment I. The differences in vitamins and minerals levels among the basal diets were considered as not having influenced the final results. The tallow used in the second experiment was different from that of the first experiment mainly in its linoleic acid content (Tables 2 and 10). Proximal analyses of both diets were very similar (Tables 11 and 12).

Average protein consumption values for the ad libitum fed groups are shown in Table 13. All consumption figures were above the minimum levels specified by the N.R.C. (1977) for Poultry (16.5 g of protein per day).

Table 14 shows the separate effects of diet and cage density on maintenance, feed maintenance ME and FHP per PBW and energetic efficiency.

Table 9. Basal diet composition for Experiment II.

Ingredient		Percent of Diet
Milo		54.15
Soybean meal		26.25
Meat scraps		3.00
Dehydrated alfalfa meal		5.00
Animal fat		1.00
Calcium carbonate		7.00
Dicalcium phosphate		0.75
Salt		.50
Vit. Pr - 9[1]		2.00
Trace mineral mix[2]		.10
DL - Methionine		.05
$Cr_2 0_3$		.20
	Total	100.00

[1]Supplied the following per kg of diet: 8019 I.U. vitamin A, 1353 I.C.U. vitamin D_3, 3.85 mg Riboflavin, 24.2 mg Niacin, 9.68 mg Calcium-Pantothenate, 11.66 g vitamin B_{12}, 4.84 I.U. -2 Tocopheryl acetate, 1.98 g Menadione Sodium Disolfite, 385 mg choline chloride and 110 mg Ethoxyquin.

[2]Supplied the following per kg of diet in ppm: 10 Fe, 30 Zn, 30 Mn, 2 Cu and .05 Mo.

Table 10. Fatty acid composition of animal tallow used in Experiment II.

Fatty Acid	Percent of Sample
Lauric (12:0)	3.80
Palmitic (16:0)	31.49
Palmitoleic (16:1)	4.34
Stearic (18:0)	11.46
Oleic (18:1)	46.29
Linoleic (18:2)	1.54

Table 11. Calculated composition of basal diet for Experiment II.

Nutrient	Amount
Crude Protein, %	20.44
ME, kcal/g	2.662
Calcium, %	3.30
Total Phosphorus, %	0.65
Methionine + Cystine	0.73
Lysine, %	1.18
Arginine, %	1.45

Table 12. Comparison of analyzed and calculated values for diets used in Experiment II.

Factor	Diet 1	Diet 2	Diet 3
Metabolizable Energy kcal/g			
calculated	2.66	2.86	3.07
analyzed	2.84	3.02	3.23
Protein, %			
calculated	20.44	19.62	18.80
analyzed	20.22	19.58	18.70

Table 13. Average protein consumption for the *ad libitum* groups (g of CP/day) for Experiment II.

Diet	Birds/cage (Sq cm^2/bird) 3 (929)	5 (557)	7 (412)	Means
D1	24.59	23.11	23.86	23.85
D2	20.64	23.92	21.64	22.06
D3	20.22	20.68	19.64	20.18
Means	21.82	22.57	21.71	22.03

Table 14. Means comparison of diet and cage density effect on the following parameters: maintenance feed/PBW, maintenance ME/PBW, fasting heat production/PBW and energetic efficiencies (Experiment II).[1]

Factor	Diet Effect (0, 4 and 8% added fat)		
	Diet 1	Diet 2	Diet 3
Net Energy, kcal/g	1.60	1.82	2.04
Maintenance Feed/PBW, g	26.47[a]	24.77[a]	24.94[a]
Maintenance ME/PBW, kcal	75.18[a]	72.91[a]	77.28[a]
Fasting Heat Production/PBW, kcal	43.46[a]	41.83[a]	48.78[a]
Energetic Efficiency,[2] %	57.80[a]	56.08[a]	62.78[a]
	Density Effect (3, 5 and 7 birds/cage)		
	3	5	7
Cm^2/bird	929	557	412
Maintenance Feed/PBW, g	21.21[a]	24.26[ab]	30.71[b]
Maintenance ME/PBW, kcal	63.02[a]	71.23[ab]	91.13[b]
Fasting Heat Production/PBW, kcal	36.61[a]	40.16[ab]	57.30[b]
Energetic Efficiency,[2] %	57.74[a]	56.20[a]	62.72[b]

[1]Means in the same line with different superscript are significantly different ($p < 0.05$).

[2]Metabolizable Energy converted to Net Energy for maintenance and production.

The values for maintenance feed/PBW were 26.47, 24.77 and 24.94 g for the 0, 4 and 8% added-fat diets, respectively and indicate no diet effects on this parameter. The average values for maintenance feed/PBW for Experiment I and II were 25.62 and 25.39 g, respectively. It would seem that the similarity between the above two values suggest that ambient temperature had no influence on this parameter. Experiment I was run in summer months vs. Experiment II carried out during winter months.

The maintenance ME/PBW also showed no significant effects ($p < 0.05$) of diet. Average values for maintenance ME/PBW were 76.06 and 75.12 kcal in Experiments I and II, respectively are almost identical and lower than the value of 111.10 kcal obtained by Reid et al. (1978). The energetic efficiency values were 57.80, 56.08 and 62.78% for diets 1, 2 and 3, respectively.

The effects of having 929, 557 and 412 cm^2/bird (3, 5 and 7 birds/cage, respectively) on maintenance feed, maintenance ME and FHP per PBW showed no significant difference ($p < 0.05$), between the first two groups, although numerical differences were observed. But the difference was significant between the first and the third group. The values for maintenance feed, maintenance ME, FHP per PBW and energetic efficiencies were consistently higher for 7 birds/cage (412 cm^2/bird) for all diets except for maintenance feed in Diet 1.

In the first experiment (summer months) maintenance feed and ME/PBW values were decreased as number of birds/cage was increased from 1 to 3; contrary to the tendency observed in the second Experiment (winter months) where the same parameters were increased as number of birds moved from 3 to 7. We did not find a logical explanation for these differences. It would seem that the maintenance energy requirements fo the birds under hot conditions should be reduced by crowding. However, putting 4 birds/cage, appeared to work in the other way, i.e.; caloric requirements of the animals were increased in order to dissipate the extra heat load produced by the crowded contions.

During the second experiment, one would think that maintenance requirements of feed and ME should be increased because of the lower temperature, but here the extra heat load of crowding increased the maintenance requirements for feed and ME, with the number of birds per cage. FHP was increased significantly for the 7 birds/cage group, from 36.61 (for 3 birds/cage) to 57.30 kcal. Again, as in maintenance requirements the effect of crowding resulted in greater values for FHP.

The energetic efficiencies, as affected by the different bird densities in this experiment, showed that the highest energetic efficiency obtained was 62.72% and corresponded to the 7 birds/cage group.

The calculated NE content for the tallow used in this study was 7.085 kcal/g, obtained by regressing NE of diets (Table 14) vs. percentage of fat levels added. The ME was 7.686 kcal/g, calculated by the same method but using this time the analyzed ME values of the diets (Table 12). From above figures an efficiency of conversion of ME to NE of 92.18%; higher than the value of 61.29% calculated in the first experiment.

Tables 15 and 16 show the effect of diet and cage density, respectively, on laying hen performance. Egg production and egg output (g/bird/day) were very similar for the 3 diets, meaning no diet effect under the present conditions.

Energy retention per day and per PBW showed a reduction with 4 and 8% added-fat diets compared with the 0% added-fat diet. ME consumed per bird per day or per PBW were very constant, due to the ability of the hen to adjust feed intake with different dietary energy levels.

Egg production and egg output decreased linearly as number of birds/cage increased from 3 to 7. However, only the egg output values were significant.

The data for density and energy retention per bird and per PBW showed a significant greater retention values with 3 birds/cage than the rest of the groups.

Summary

A second experiment was carried out with 360 laying hens to measure the effect of 0, 4 and 8% added tallow levels in combination with 3, 5 and 7 birds/cage on energy utilization during winter months with temperatures ranging from 8^{o}C to 18.5^{o}C.

The average protein consumptions were 23.85 g, 22.06 g and 20.18 g/bird/day for Diets 1, 2 and 3, respectively. It is obvious from these data that there was adequate protein available for all birds.

Table 15. Effect of added fat levels on laying hens performance (Experiment II).[1]

Factor	% Fat Added		
	0	4	8
Egg Production, %	76.98[a]	76.68[a]	75.54[a]
Egg Output, g/bird/day	46.56[a]	43.03[a]	43.06[a]
ER/bird/day, kcal	96.05[a]	81.64[a]	86.79[a]
ER/bird/dayPBW, kcal	106.68[a]	91.37[a]	98.19[a]
ME/bird/day, kcal	327.53	334.58	330.17
ME/bird/PBW, kcal	237.50	237.14	227.73

[1]Values in the same line with different superscript are significantly different ($p < 0.05$).

Table 16. Effect of cage density on laying hens performance (Experiment II).[1]

Factor	Birds/cage[2] 3	5	7
Egg Production, %	80.16[a]	77.62[a]	71.43[a]
Egg Output, g/bird/day	45.50[a]	43.50[ab]	40.67[b]
ER/bird, day, kcal	102.87[a]	84.34[b]	77.27[b]
ER/bird/day/PBW, kcal	114.08[a]	95.20[b]	86.95[b]
ME/bird/day, kcal	323.46	339.17	329.66
ME/bird,PBW, kcal	235.96	235.00	231.41

[1]Values in the same line with different superscript are significantly different ($p < 0.05$).

[2]3, 5 and 7 birds/cage corresponds to 929, 557 and 412 cm^2/bird respectively.

Effect of Diet. The values for maintenance feed, maintenance ME and FHP per kg PBW, and for energetic efficiencies as affected by diet (0, 8 and 12% added-fat) showed no significant differences. Average values for maintenance feed/PBW for Experiments I and II were 25.62 g and 25.39 g, respectively; suggesting no influence on this parameter by temperature.

The maintenance ME/PBW as affected by diet were also similar in Experiments I and II (76.06 and 75.12 kcal, respectively). The values for energetic efficiencies were 57.80, 56.08 and 62.78% for Diet 1, 2 and 3, respectively. Indicating a higher efficiency at the highest fat level.

Effect of Cage Density. The maintenance feed, maintenance ME and FHP per PBW showed no significant difference between the first two groups, however the differences were significant between the first and the third groups. All the latter parameter were consistently higher for the 7 birds/cage group for all Diets except for the maintenance feed of Diet 1.

Contrary to the tendency observed during the first Experiment; in this study maintenance feed and ME per PBW were increased as the number of birds/cage increased from 3 to 7. In this experiment, the requirements for maintenance feed and ME were increased by crowding.

As with maintenance requirements, FHP was increased significantly from 36.61 to 57.30 kcal for the 3 and 7 birds/cage groups, respectively.

The NE calculated content of the fat of 7.085 kcal/g vs its calculated ME content of 7.686 kcal/g gave us a conversion efficiency of 92.18%.

APPENDIX A

SUMMARIZED DATA OF THE TWO EXPERIMENTS

Table A.1. Summarized data for the *ad libitum* groups of each diet at different cage densities for Experiment I.

	Diet 1				Diet 2			
Birds per Cage	1	2	3	4	1	2	3	4
Sq. cm per bird	1350	675	450	337.5	1350	675	450	337.5
<u>Consumption</u>								
Feed/bird/day, g	115.00	110.55	99.76	101.61	100.00	94.64	100.73	96.10
Feed/bird/day, g[1]	89.91	82.34	76.84	78.62	72.75	75.56	76.71	75.73
ME/bird/day, kcal	309.17	297.22	268.19	273.18	288.50	273.05	290.60	277.25
ME/bird/day, kcal[1]	241.72	221.38	206.59	211.36	209.89	217.98	221.32	218.48
<u>Performance</u>								
Egg production, %	90.00	89.29	79.52	81.55	84.29	79.29	87.62	78.19
Egg weight, %	52.89	53.18	52.84	51.40	54.33	52.62	56.04	51.22
Δ BW/bird/day, g	7.57	3.92	1.62	3.68	5.57	6.24	5.36	5.71
<u>Energy Factors</u>								
ER/bird/day	80.78	63.59	52.87	59.39	64.82	71.08	69.01	66.08
ER/bird/day[1]	87.60	70.00	57.44	64.68	72.08	76.55	75.48	71.53
HP/bird/day	197.24	203.72	194.53	189.56	189.28	177.33	191.72	186.44
HP/bird/day[1]	154.12	151.37	149.15	146.66	137.80	141.42	145.84	146.96

Table A.1., Continued.

Birds per Cage	Diet 3				Diet 4			
	1	2	3	4	1	2	3	4
Sq. cm per bird	1350	675	450	337.5	1350	675	450	337.5
Consumption								
Feed/bird/day, g	92.86	110.37	98.10	93.08	90.71	89.47	92.61	85.01
Feed/bird/day, g[1]	79.54	80.46	72.70	71.69	70.80	68.85	70.19	63.82
ME/bird/day, kcal	285.85	339.77	301.99	295.78	296.86	292.80	303.07	278.20
ME/bird/day, kcal[1]	217.18	247.68	223.80	220.69	231.69	225.32	229.70	208.86
Performance								
Egg production, %	74.29	87.14	83.80	82.50	78.57	76.43	75.24	65.36
Egg weight, g	51.28	54.16	51.66	53.28	51.54	51.57	51.30	51.71
Δ BW/bird/day, g	9.28	4.10	7.86	4.73	4.50	5.89	7.50	4.64
Energy Factors								
ER/bird/day	74.10	62.92	71.25	62.59	61.80	63.80	67.12	51.63
ER/bird/day[1]	80.63	69.49	78.76	68.90	66.99	69.66	73.65	56.78
HP/bird/day	180.34	245.94	195.48	203.84	211.34	201.85	205.75	202.60
HP/bird/day[1]	136.54	178.18	145.04	151.78	164.70	155.66	156.06	152.08

[1]Expressed per kg of Physiological Body Weight (BW 0.75).

Table A.2. Summarized date for the *ad libitum* groups of each diet at different cage densities for Experiment II.

	Diets								
	Diet 1			Diet 2			Diet 3		
Birds per cage	3	5	7	3	5	7	3	5	7
cm^2/bird	929	557	412	929	557	412	929	557	412
Consumption									
Feed/bird/day, g	113.50	114.31	118.02	105.40	122.13	110.48	108.09	106.52	105.04
Feed/bird/day, g[1]	84.70	82.05	84.00	79.12	81.22	79.30	75.03	74.46	70.99
ME/bird/day, kcal	322.45	324.75	335.40	312.98	362.68	328.09	334.94	330.08	325.49
ME/bird/day, kcal[1]	240.63	233.11	238.75	234.75	241.18	235.50	232.50	230.71	219.98
Performance									
Egg Production,	84.53	82.15	64.28	80.95	73.58	75.51	75.00	77.14	74.49
Egg Weight, g	58.88	55.12	55.38	54.16	57.60	56.85	57.26	55.44	58.44
Δ BW/bird/day, g	21.62	12.16	12.16	12.16	12.16	11.58	16.21	16.21	11.58
Egg Output, g/bird/day	49.77	45.28	35.95	43.84	42.38	42.93	42.94	42.77	43.53
Energy Factors									
ER/bird/day	127.64	85.65	74.86	89.02	74.56	81.34	91.94	92.82	75.62
ER/bird/day[1]	140.53	95.66	83.84	97.89	85.38	90.85	103.84	104.57	86.16
HP/bird/day	134.83	191.48	217.61	182.29	234.42	201.53	185.35	180.55	198.00
HP/bird/day[1]	100.09	137.45	154.90	137.06	155.80	144.65	128.65	126.15	133.82

[1]Expressed per kg of physiological body weight (BW 0.75).

LITERATURE CITED

Annison, E. F. 1974. Dietary sources of energy. In: Energy Requirements of Poultry. Ed. T. R. Morris and B. M. Freeman, British Poultry Science Ltd., Edinburgh, pp. 135-149.

Burlacu, G. and M. Baltac. 1971. Efficiency of the utilization of the energy of food in laying hens. J. Agric. Sci., Camb. 77: 405.

Carew, L. B. and F. W. Hill. 1964. Effect of corn oil on metabolic efficiency of energy utilization by chicks. J. Nutr. 83: 293-299.

Davis, R. H., O. E. M. Hassan and A. H. Sykes. 1972. The adaptation of energy utilization in the laying to warm and cool ambient temperatures. J. Agric. Sci., Camb. 79: 363-369.

Davis, R. H., O. E. M. Hassan and A. H. Sykes. 1973. Energy utilization in the laying hen in relation to ambient temperature. J. Agric. Sci. Camb. 80: 173-177.

De Groote, G. 1974a. A comparison of a new net energy system with the metabolizable energy system in broiler diet formulation, performance and profitability. Br. Poult. Sci. 15: 75-95.

De Groote, G. 1974b. Utilization of metabolizable energy. In: Energy Requirements of Poultry. Ed. T. R. Morris and B. M. Freeman, British Poultry Science Ltd., Edinburgh, pp. 113-133.

Edwards, H. M. 1962. Observations on feeding cholic acid to broilers. Poultry Sci. 41: 340-341.

Edwards, H. M. and M. B. Gillis. 1959. A chromic oxide balance method for determining phosphate. Poultry Sci. 38: 569-574.

Emmans, G. C. 1974. The effects of temperature on the performance of laying hens. In: Energy Requirements of Poultry. Ed. T. R. Morris and B. M. Freeman, British Poultry Science Ltd., Edinburgh. pp. 79-90.

Farrell, D. J. 1974. Calorimetric measurements on chickens given diets with a range of energy concentrations. British Poultry Science Ltd., Edinburgh. 15: 341.

Farrell, D. J. 1978. Efficiency of utilization by growing chickens of the energy of dietary fat and oil. British Poultry Science Ltd., Edinburgh. 19: 105-109.

Farrell, D. J., R. B. Cumming and J. B. Hardaker. 1973. The effects of dietary energy concentration on growth rate and conversion of dietary energy to weight gain in broiler chickens. British Poultry Science Ltd., Edinburgh. 14: 329-340.

Fuller, H. L. and M. Rendon. 1977. Energetic efficiency of different dietary fats for growth of young chicks. Poultry Sci. 56: 549-557.

Gomez, M. X. and D. Polin. 1974. Influence of cholic acid on the utilization of fats in the growing chicken. Poultry Sci. 53: 773-781.

Hathaway, H. D. 1977. The composition of feed fats as related to digestibility and metabolizable energy. Proceedings 37th Annual Meeting, Nutrition Council. Published by American Feed Manufacturers Association, Arlington, Va. pp. 19-22.

Hughes, B. O. and J. Black. 1974. The effect of environmental factors on activity, selected behavior patterns and fear of fowls in cages and pens. British Poultry Science Ltd., Edinburgh. 15: 375-380.

Jackson, N., H. R. Kirkpatrick and R. B. Fulton. 1969. An experimental study of the utilization, by the laying hen, of dietary energy partially supplied as animal fat. British Poultry Science Ltd., Edinburgh. 10: 115-126.

Jensen, L. S. and L. Falen. 1973. Effect of pelleting on the "extra caloric" effect of dietary fat for developing turkeys. Poultry Sci. 52: 2342-2344.

Leeson, S. and J. D. Summers. 1976. Fat ME values: The effect of fatty acid saturation. Feedstuffs, November 8.

Nutrient Requirements of Domestic Animals. 1977. Nutrient Requirements of Poultry. Seventh revised edition. National Academy of Sciences, Washington, D.C.

Reid, B. L. 1979. Feeding and management practices for improving performance in hot weather. Selected Topics Concerning Feeding and Management of Poultry in Hot Weather. Poultry Science Department, University of Florida, Gainesville. pp. 71-88.

Reid, B. L., M. E. Valencia and P. M. Maiorino. 1978. Energy utilization by laying hens. I. Energetic efficiencies of maintenance and production. Poultry Sci. 57: 461-465.

Reid, B. L. and W. C. Weber. 1975. Supplemental dietary fat and laying hen performance. Poultry Sci. 54: 422-428.

Renner, R. and F. W. Hill. 1958. Metabolizable energy values of fats and fatty acids for chicken. Proc. Cornell Nutrition Conf. pp. 95-100.

Scott, M. L., M. C. Nesheim and R. J. Young. 1976. Nutrition of the chicken. 2nd ed. by M. L. Scott and Associates, Ithaca, New York.

Sell, J. L. and F. Horani. 1977. Effect of feed grade animal fat on laying hen performance and on metabolizable energy rations. Poultry Sci. 56: 1972-1980.

Sell, F. Horani and R. L. Johnson. 1976. The "extra-caloric" effect of fat in laying hen rations. Feedstuffs. 48(27): 28-29.

Sibbald, I. R. 1978. The true metabolizable energy values of mixtures of tallow with either soybean oil or lard. Poultry Sci. 57: 473-477.

Sibbald, I. R. and J. K. G. Kramer. 1977. The true metabolizable energy values of fats and fat mixtures. Poultry Sci. 56: 2079-2086.

Summers, J. D., S. Lesson and L. Griffiths. 1977. Influence of energy system and level of various fat sources on performance and carcass composition of broilers. Poultry Sci. 56: 1018-1026.

Valencia, M. E. 1978. Energy utilization in laying hens. Ph. D. Dissertation, University of Arizona.

Young, R. J. 1961. The energy value of fats and fatty acids for chicks. I. Metabolizable Energy. Poultry Science, 40: 1225-1233.

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